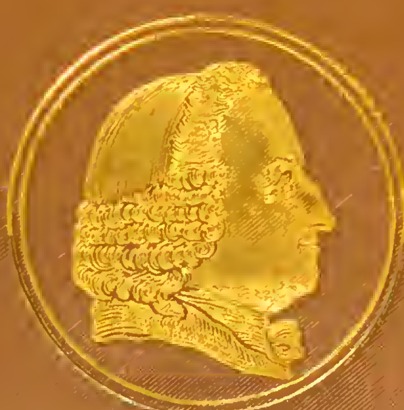

THE BRAIN

THE BRAIN

Considered Anatomically, Physiologically and Philosophically

BY

EMANUEL SWEDENBORG

EDITED, TRANSLATED, AND ANNOTATED

BY R. L. TAFEL, A.M., PH.D.

VOLUME II

THE PITUITARY GLAND, THE CEREBELLUM AND THE MEDULLA OBLONGATA

JAMES SPEIRS
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EDITOR'S PREFACE.

As several years have elapsed since the appearance of the first volume of the present work, an explanation is due to our respected readers for the delay which has occurred in the publication of the remaining volumes. So far as the original manuscript of Swedenborg is concerned, that was translated and ready for the printer when the publication of the work was first announced. But, as explained in the Editor's Preface of Vol. I., it was thought that the usefulness of the work would be enhanced, by presenting the analyses it contains in the combined light of modern science; and thus by testing Swedenborg's theory of the Brain by all the facts that science has accumulated since his time; namely, since the middle of 1744, when he put the last touches to his work.

The Editor at first supposed that testing Swedenborg's work by the anatomy and physiology of the Brain as taught by the most approved text-books of England, France, and Germany, would be all that was required. But he very soon became convinced, that facts concerning the Brain and the Nervous System generally had been discovered and described in the periodical literature of the medical sciences, and in the Transactions of learned bodies, which failed to find their way into our text-books. The number of such facts is by no means inconsiderable.

The Editor thus, in the pursuance of his work, at last became persuaded that in order to do justice to Swedenborg's work, it would be necessary to digest the whole of the Brain-literature published during the last one hundred and forty years; that, consequently, it was incumbent upon him to collect and classify all books and papers published, during this period, on the anatomy and physiology of the nervous system, in all languages. By no means a small task. Thanks to the resources at his disposal at the British Museum, he was able to compile such a classified catalogue for his special purposes. In this work the Editor engaged after finishing Vol. I., and before entering upon the preparation for the press of Vol. II.

Naturally enough, perhaps, the current text-books were found chiefly deficient in the presentation of those parts of the Brain which, so far as their functions are concerned, are still a *terra incognita, e.g.* the pituitary gland with the sinuses of the sella turcica; even as nearly all facts have been ignored by which the motion of the Brain is substantiated. And again the English text-books proved woefully deficient in the treatment of the "Cerebro-spinal Liquid."

The Editor believes that in the present volume the function of the pituitary gland, as determined by Swedenborg, has been definitely proved and established in the combined light of the facts of the last one hundred and forty years; as well as Swedenborg's theory of the "Cerebro-spinal Liquid," to which two subjects upwards of 220 pages are devoted in the appendix.

In thus surveying the literature of the Brain and the Nervous System in connection with the Pituitary Gland and the Cerebro-spinal Liquid, the Editor was very much struck with one feature which seemed to be characteristic of modern science; namely, that important facts, well known more than a hundred years ago, had been completely lost by modern science, and have had to be newly discovered. Thus *Santorini* discovered and described in 1724 the "carotid sinus," that is, a venous sinus, by which the carotid artery is encompassed during its passage through the bone of the cranium,—which sinus was forgotten, until it was re-discovered by Rektorzick, who brought it to the notice of the learned in 1858. See below, p. 520, *et seq.* Again, *Tabarrani*, in 1743, described a canal or sinus underneath the inferior petrosal sinus, on the lower surface of the cranium, which Trolard, in 1870, denominated the "lower petro-occipital sinus." The attention of the learned was directed to this canal by Haller, in his "Elementa Physiologiæ," in 1762; but since his time this canal was forgotten, until it was re-discovered by Dr. Englisch, who described it in 1863 in precisely the same language as Tabarrani in 1743. See below, p. 503, *et seq.* In 1786 *Vieq d'Azyr* called the attention of the learned to the fact, that the "inferior petrosal sinus discharges its contents through the intermediation of a vein which is found at the base of the cranium before the internal jugular vein." This fact is only now beginning to find its way into the text-books. See below, p. 537. Another illustrious instance is the case of the "Cerebro-spinal Liquid." This liquid was most minutely described by *Cotugno* in 1764; his work was republished in Rotterdam in 1769, in Vienna in 1770, in Naples in 1775, and it was published in English in 1776, and yet soon after this information was forgotten or overlooked, and this liquid had to be re-discovered by Magendie in 1825. Key and Retzius demonstrated in 1875 that the honour of this discovery belongs to Cotugno, and in Vol. I. of their grand work on the Nervous System, they give copious extracts from Cotugno's book; and yet these same observers overlooked the fact that Cotugno in his little work demonstrated also the existence of lymph-tracks in the peripheral nerves; and that he likewise proved the fact, that the subarachnoid space is continued into the peripheral nerves beyond the spinal ganglia, and that the Cerebro-spinal Liquid circulates there (see below, p. 356, *et seq.*), which discovery the Swedish observers consider to be of a much more recent date.

Still, the priority of a discovery is a matter of small consequence; if only science would not disregard and forget so many facts after they have once been discovered. Swedenborg, as we have shown in the Preface to Vol. I., has noticed and foreshadowed in his work on the Brain so many facts which are attributed to modern times, that it would be tedious to continue their enumeration here. Yet his object was not so much to discover new facts, as to elicit and establish the true causes of facts discovered by others; and the purpose of his present work is to assign their true functions to the various organs of the Brain; which includes also a determination of the functions of those enigmatical and mystical organs, namely, the pineal gland, the infundibulum, the pituitary gland, and also of the cerebellum. No one, indeed, has poured such floods of light on the functions of the human body, and especially on those of the Nervous System, as Swedenborg has done; and yet how little he is still understood and appreciated.

Upon the whole, we cannot feel dissatisfied with the reception of the first volume of this work by the profession. Not many notices and reviews appeared, but those that did appear were in the main satisfactory. We owe our thanks to Dr. Rabagliati for the fair and considerate way in which he introduced the work to the notice of the learned in the neurological quarterly "Brain." Dr. David Goyder of Bradford also read a very thoughtful paper on the Motion of the Brain, before the Bradford Medical Society, in which he called the attention of his colleagues to this work. In America a most able review, from the pen of the late Dr. Farringdon, appeared in the pages of "Words for the New Church." Twenty-two medical schools also accepted the offer of a medical gentleman to place the volume in their library; although one of the London medical schools, with a spirit that reminds one more of the bigoted ages of the past, than of the latter part of the Nineteenth Century, returned the work as undesirable for their library.

A similar spirit is evinced by Dr. Maudsley, the author of "Natural Causes and Supernatural Seemings" (London, 1886), who asserts that Emanuel Swedenborg, in 1743 and 1744, thus at the time he was engaged upon his work on the "Brain," was "subject to seizures which were closely akin to, if they were not actually, epilepsy;" and for the facts on which he bases this extraordinary assertion, he points us to an essay on Swedenborg which he published in the second edition of "Body and Mind," in 1873.[1] In his work on "The Pathology of the Human Mind," published in 1879, the author, after first repeating the above statement, in another part of his work asserts that in 1743 Swedenborg had "an attack of acute mania;" and that "when the acute attack passed away, a monomania was left behind which was the morbid evolution of his self-sufficient character." He says, also, that "until the evidence of Swedenborg's Diary [for 1744] be proved false, he could not alter his opinion." In "Body and Mind" he fixes the date of the alleged occurrence a year later, that is, in 1744; for he says that "if Swedenborg was not at this time [1744] fast gliding into madness, he imitated exceedingly well the character of its *incipient* stages" (p. 230). He also admits in the same place that the inferences which he drew from Swedenborg's Diary of 1744 are "conjectures." For, in speaking of the use which he made of the contents of this Diary, he continues, "But there is no need of *conjecture* where something like certainty is attainable" (*Ibid.*). What he means by "something like certainty" will be seen below.

The learned author thus declared in "Body and Mind" that Swedenborg showed "the *incipient* stages of madness" in 1744; while in his "Pathology of the Mind" he maintains that Swedenborg had "an acute attack of mania" in 1743, which left him a "monomaniac" ever afterwards. This latter date, however, he abandoned again in his work on "Natural Causes and Supernatural Seemings," where he endorsed anew the whole of his essay on Swedenborg which appeared in "Body and Mind." From this it would appear that the learned Doctor is quite uncertain as to the time when this alleged "attack of acute mania" took place.

Again, in his "Pathology of the Mind," in endeavouring to prove his charge of madness against Swedenborg, the author adduces as evidence the Diary of the former during 1744; but in "Body and Mind" he declared those inferences which he drew from Swedenborg's Diary to be "conjectures." *Conjectures*, however, are evidently out of place in a scientific text-book, and therefore in 1886 the learned Doctor preferred to base his assertions about Swedenborg again on "something

[1] This essay, which was originally published in the "Journal of Mental Science," for 1869, seems to be looked upon as authoritative by the profession, from the manner in which it is referred to by Dr. Ireland, in his recent work, "The Blot upon the Brain," 1885, p. 47.

like certainty," or on what he further styles "a well-authenticated narrative of an outbreak of acute insanity." But why did the learned Doctor in his treatise on the "Pathology of the Mind" not appeal again to his "well-authenticated narrative"? His attention may probably have been drawn to the second volume of the "Documents concerning the Life and Character of Emanuel Swedenborg," which appeared in 1877. In this work two versions of the Doctor's "well-authenticated narrative," both emanating from the Rev. Aron Mathesius, the author of this "narrative," are compared in parallel columns. One of these versions Mathesius gave to Wesley in 1781, by whom it was published in the "Arminian Magazine;" the other version, which is published in White's "Life of Swedenborg," Mathesius wrote down in 1796; this last version constitutes the "well-authenticated narrative," quoted by the author of "Body and Mind."

On comparing these two versions, it appears that a number of particulars with which Mathesius was not acquainted in 1781, emerged quite fresh from his memory in 1796; besides, the two versions are contradictory in a number of important particulars; so that Mathesius' testimony, when examined in its own light, breaks down completely, and is shown to be a web of falsehoods. But this is not all. Mathesius quotes as his authority for the statements he makes, a certain "Brockmer.' This man "Brockmer," as is shown in "Documents," etc. (Vol. II., pp. 601–604), when interrogated as to the truth of the "narrative," as published by Wesley in 1781, denied the truth of almost all the statements which Mathesius made on his authority.

This, then, is the documentary value of the facts on which the learned Doctor based his assertion that Swedenborg at the time when he was engaged on his work on the "Brain" was an "epileptic;" that he had an "attack of acute mania;" and that ever afterwards he was insane, and a "monomaniac."

When Swedenborg returned to his native country in 1745, no one noticed anything of the "monomania" with which the author of "Body and Mind" charges this truly eminent man. From August 1745 to July 1747 he again attended to his duties as Assessor at the College of Mines; where he acted both in the character of a public Administrator of Mines, and as a Judge in disputed mining cases. In the spring of 1747 the College unanimously recommended him for a vacant Councillorship of Mines, which Swedenborg declined; but soon after he applied to the king for a release from his office. On accepting Swedenborg's resignation, the king used the following language: "Although we would gladly see the Assessor continue at home the faithful services he has hitherto rendered to us and his country, still we can so much the less oppose his wish, as we feel sufficiently assured that the work on which he is engaged will in time contribute to the general use and benefit, no less than the other valuable works written and published by him have contributed to the use and honour of his country, as well as of himself. We therefore decree and, by this open letter, release Emanuel Swedenborg from the office of Assessor in our and our country's College of Mines, which he has hitherto filled with renown; and as a token of the satisfaction with which we look upon his long and faithful services, we also most graciously permit him to retain for the rest of his life one-half of his salary as Assessor."

In the Minutes of the College of Mines, under the date of June 15, 1747, we read: "Assessor Emanuel Swedenborg handed in to the College of Mines the Royal Decree, by which he was released from his duties here in the Royal College, retaining during his life one-half of his salary as an Assessor. All the members of the Royal College regretted losing so worthy a colleague, and they asked the Assessor to kindly attend the sessions of the College, until all those cases should be adjudicated that had been commenced during his attendance at the College; to which the Assessor kindly assented."

Under the date of July 17 we read: "Assessor Swedenborg, who intends as soon as possible to commence his new journeys abroad, came up for the purpose of taking leave of the Royal College. He thanked all those at the Royal College for the favour and kindness he had received from them during his connection with the College, and commended himself to their further friendly remembrances. The Royal College thanked the Assessor for *the minute care and fidelity with which he had attended to the duties of his office as an Assessor* UP TO THE PRESENT TIME; they wished him a prosperous journey and a happy return; after which he left." See "Documents," etc., Vol. I., p. 466.

Such is the testimony, contained in the approved Minutes of the Royal College of Mines, of a highly intelligent board of gentlemen, who met Swedenborg almost daily for two years after the time when, as the learned author of "Body and Mind," and of "The Pathology of the Mind" asserts, Swedenborg had an "attack of acute mania," and when, according to him, he was in a state of insanity or "monomania." Persons of a diseased mind, and in a state of "monomania," are not usually able to perform in a highly creditable manner the functions of a judge; nor are their services usually considered so important that their colleagues request them to continue in office for a month longer after their resignation has been accepted; nor are they usually commended by their colleagues, in an official record, for the "care and fidelity with which they have attended to the duties of their office, up to the very last."

Again, the learned author of "Body and Mind" withholds from his readers the fact that Swedenborg in 1745 returned to his duties as an Assessor, and continued to attend to these duties until the end of July 1747. He says instead: "In the years 1744 and 1745 Swedenborg suddenly abandoned all his former pursuits and interests," and "was writing what an unprejudiced person [! ! ?] must affirm to be the product of madness" (p. 235). If we can suppose that Swedenborg's theological Writings, to which the learned Doctor here alludes, are "the products of madness;" that Swedenborg, consequently, was "mad" or insane, while writing these works, we must also suppose that he kept his "madness" a profound secret from everybody in his native country for *thirteen years;* for, as appears from a letter of Baron Tilas, dated March 16, 1760 (See "Documents," etc., Vol. II., p. 395), no one in Sweden, up to that time, was aware that Swedenborg was the author of those remarkable works which appeared in London between 1749 and 1758; nor had any one the least suspicion that in respect to the transcendental world of spirit he was differently situated from other people.

For the present we have no more to say to the author of "The Pathology of the Mind;" but in Part IV. of the present work, where Swedenborg treats of "the Affections and Diseases of the Brain," we shall have occasion to examine and criticize some of the learned Doctor's theories on the same subject.

We regret that the Doctor, by re-asserting in 1886 the position which in 1869 he took up in respect to Emanuel Swedenborg, should have compelled us to introduce into a purely scientific work, questions concerning revelation and the spiritual world, which questions require a different treatment altogether from scientific subjects.

In conclusion, we venture to express a hope that the case of the learned author of "Body and Mind," on which we found it necessary to animadvert in our Preface, is an isolated one among the representative men of Medical Science in Great Britain; and that in future, before making any new utterance respecting Emanuel Swedenborg, the Doctor will consider more carefully the facts on which he intends to base his theories.

R. L. TAFEL.

LONDON, *April* 10, 1887.

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EDITORIAL NOTES.

CHAPTER XVI.

THE PINEAL GLAND.

532. The pineal gland, formerly called the conarium, and also the conoid, is a little body which in adults generally equals the size of a pea. It is irregularly round, and of the shape of a little pine cone. It is placed immediately before the " nates," the anterior tubercles of the corpora quadrigemina, under the posterior part of the fornix, which forms there an expanse, to which, however, it does not adhere continuously. It is situated besides between the optic thalami and at the extreme end of the third ventricle over the foramen, called " anus." By its middle portion, it closes and bounds on the one hand that blind gap or canal which is formed by the corpora quadrigemina, on the other it keeps guard over the third ventricle, which, or at least the door of which, it seems to open from the lateral ventricles and the aqueduct of Sylvius. In order to receive their gland the " nates " inflect themselves obliquely downwards under the optic thalami, forming a certain bosom drawn apart, and thus a comfortable seat. Into this bosom on high they invite the gland, and on withdrawing from one another, or on being compelled to leave their position by the subsidence of the thalami, they divide it as it were between them ; yet on regaining their natural position, they at once urge the gland back into its original place, as may be seen in Vieussens' Plate. On changing their position they also draw apart the sides of the passage underneath, and thus the gland opens the approaches, over which it acts as a custodian. For this purpose fibrils pass out from the stria pinealis situated between the thalami ; which fibrils pass around and cover the edges of the foramen

called "anus." Other fibrils also depart thence, which, if they do not enfold the gland, at least approach the same; and then they bend backwards encircling the margins of the cavity under the "nates," at the entrance into the third ventricle. This remarkable gland or gem, like its remaining corpuscles or satellites [*i.e.*, the corpora quadrigemina], rests upon a substance which is placed under it like a cushion, and which on its surface is medullary, but a little further down cineritious. This intervening substance separates the pineal gland from the aqueduct of Sylvius, and also from the lateral ventricles. Through its mediation the gland also is approached on the sides by the optic thalami; and from below by the grey substance of the striated plane, which verges thither by a moderate bent. The gland also is most directly approached as by binding cords, by two medullary processes, *i.e.*, by peduncles which run out from the optic thalami, and likewise by two processes extending from the "nates." By these cords or peduncles, the optic thalami, as well as the "nates," are adjoined and bound to the gland, for the purpose of performing harmoniously the work common to them all. The gland is compelled there to incline its vertical point towards the cerebellum in a right angle in respect to its base. Thus engirded and suspended, the gland is covered with a thin membrane, an offshoot of the pia mater, as is thought, while numerous little arteries, which are extreme capillaries of the vertebral arteries, and likewise little veins which in close ranks run down towards the straight sinus, creep through it in every direction. The twin veins of Galen also, which form the root of the straight sinus, press against it, offering their protection; while the extreme and first web-work of the choroid plexuses is incumbent upon it, to which it seems to serve in the place of a support. Thus when the falx, the pia mater or the textile fabric of the choroid plexuses are incautiously removed, or again when the cerebrum has collapsed, or is distended by the ventricles, the gland is torn out of its native soil, and its proper seat is concealed from the observers. The pineal gland thus acts as a root to the straight sinus, in no other sense, than is done by that kind of vegetables which spread themselves underground, and send out widely in every direction, plexiform little roots which are ingrafted in them. Its interior substance is more evidently cineritious than that of the "nates," because it is also saturated with copious blood, and irradiated by so many concentrated striæ, on account of the extreme subtlety of which it is generally somewhat soft. In dropsical persons it sometimes swells to triple its size, and is translucent from a gelatinous lymph, which is stagnant interiorly. Upon being exposed to the air it is easily attenuated, it shrinks, and is rarefied into a spongy substance. By some who have scanned its organism with the armed eye, it is said to be composed of small glandules; by others to be divided into little compartments; and by one it is reported to be hollow, as in the brains of stags. More frequently in its interior recess is found a little body, which is hard, rough, friable and yellow. In one gland again three little stones or little bones were found, as reported by Ruysch, to whom the specimen was given. In others it is said to have shrivelled up into a sort of dead flesh, and in others to have disappeared altogether.

533. WILLIS.[1]—"Not far from the corpora quadrigemina—namely, between them and that opening which is called 'anus,' is placed the pineal gland. It is situated in that valley-like depression which lies between the anterior tubercles of the corpora quadrigemina, and the optic thalami. This gland is fastened there to the part underneath only by a few slender fibres, and sometimes by two more conspicuous roots. It is, besides, enclosed as in a capsule by a membrane which is a portion of the pia mater; and as this membrane is interwoven by many arteries and veins, some slender vessels also enter this gland (p. 19) . . . From the ridges of the optic thalami, whence the optic nerves derive their origin, certain medullary processes also arise, and after being brought down on both sides to the margin of the second foramen [the posterior foramen called

[1] "Cerebri Anatome," Cap. II.

'anus'] they meet around the root of the pineal gland. These processes, it seems, are those parts which the most illustrious Des Cartes supposed to be nerves belonging to that gland; while I am rather of the opinion that they are simply productions with which the optic nerves, also near their origins, communicate" (p. 16). See also Plates III., IV., V., in his "Cerebri Anatome," and Plates V., VI., VIII., in his "Anima Brutorum."

534. VIEUSSENS.[1]—"That gland, which on account of some likeness of its form is called 'pineal,' nay, and sometimes is styled 'conarium,' is a greyish body, in adults of the size of a pea, consisting of a soft and spongy substance, and covered with a very thin membrane. This little gland, in which I have often found a hard, yellowish body, sometimes a little rough, is appended to the back part of the fornix, and is placed on a cineritious substance between the anterior tubercles of the corpora quadrigemina, with which it is united near the foramen called 'anus.' Sometimes, however, a very little medullary tract derived from that tract, mentioned above, which is interposed between the thalami optici [the stria pinealis], and which bears a likeness to a little bow and also to a little nerve, coalesces with it. . . . This gland is irrigated by small arteries, sent out from branches of the basilar artery, and small veins are derived from it, which terminate in the straight sinus" (p. 71).

535. RIDLEY.[2]—"The gland, called 'pineal,' from its figure is about the size of an ordinary pea, prefixed to the anterior tubercles of the corpora quadrigemina, called 'nates,' at the extremity of the third ventricle, immediately under the broad and hinder part of the fornix, with which, nevertheless, it has no connection, contrary to Vieussens' assertion, and over that part of the rima or opening in the third ventricle, called 'anus.' It is joined to the 'nates' by several fibrous roots, and becomes a support to that part of the choroid plexus which is situated there. In the dropsical brain of a scrofulous boy, I have seen it swollen to three times its ordinary size, and by reason of the abundance of stag-

[1] "Neurographia," etc., Cap. XI.
[2] "Anatomy of the Brain," etc., Cap x.

nate gelatinous lymph contained in it, perfectly transparent. . . . It is true that there are two considerable medullary tracts—the stria pinealis—arising seemingly from the two roots of the fornix, stretching lengthways over the thalami optici as far back as this gland, which tract by Vieussens is called 'the medullary tract interposed between the thalami optici,' as though it were only one, but in reality it is double, one on either side. These tracts turn about near this place, and are united by a kind of transverse bending of the tract, called by Vieussens, the medullary tract placed before the 'nates' [the posterior commissure], as has been accurately observed by him. This, as Willis truly thought, and also Vieussens, no doubt gave rise to the error of Des Cartes, whose sublime and most deservedly admired philosophy had doubtless been much more useful had he conversed more with dissections, and less with things invisible. For upon a more accurate inspection it will be found that no part of the aforesaid process, however near it comes to this gland, does in any wise become continuous to it. . . . This gland has arteries and veins in common with other glands, the veins ending in the straight sinus, as may be the case with the lympheducts also when they are visible." (Pp. 83-86). See also his Figure VII.

536. WINSLOW.[1]—"The pineal gland is a small, soft, greyish body, about the size of an ordinary pea, irregularly round, and sometimes of the figure of a pine cone, situated behind the thalami optici, above the corpora quadrigemina. It is fixed to the lower part of the thalami by two very white medullary peduncles, which at the gland are very near each other, but separate almost transversely toward the thalami. It seems to be mostly of a cortical substance, except near the above-mentioned peduncles, where it appears a little medullary. These peduncles are sometimes double, as if they belonged also to the two anterior tubercles. This body adheres very closely to the choroid plexus by which it is covered; and it requires therefore some dexterity to remove it from the gland, without altering its

[1] "Anatomical Exposition," Sect. x.

situation or breaking the peduncles. Sometimes a jelly has been found contained in it. Under the pineal gland, in the substance of the thalami, there is a medullary transverse cord, called the 'posterior commissure' of the hemispheres of the cerebrum." (Sect. x., nos. 82, 83.)

537. MANGET.[1]—"In stags the pineal gland arises by a double crus from the parts underneath it, and is hollow; it also arises from its own peduncle, and the afore-named crura. It is worthy of being mentioned that it is composed of many very minute glandules. Some time ago it was seen in a petrified condition by Fred. Schuyl. Ruysch found in it three calculi. But it is still more wonderful what Drelincourt observed in a virgin about twenty years old, who, after having suffered for six months excruciating pains in the head, finally had become blind, and was deprived gradually of her remaining senses, and died amid grievous shrieks. In her the pineal gland had not only become petrified, but had also attained the size of a hen's egg, and with its weight pressed not only upon the optic thalami, but in the course of time also bore down in a deadly manner upon the remaining nerves."

538. MORGAGNI.[2]—"Last year I examined a woman's brain in which the pineal gland was uniformly larger and firmer; it was also very much whiter than the cortical substance of the brain; although I have very often seen it of the same colour. In that gland I discovered, as it were, several little compartments (*loculi*), its substance, however, appeared manifestly glandulous. . . . This is certain, and worthy of being noted: namely, that within this gland, a hard, yellowish, and frequently a somewhat rough little body is found, as has been observed by Vieussens, and as I also have several times observed. I noticed besides in a man from Bologna that his pineal gland consisted almost altogether of a yellow, somewhat hard and friable substance. But, on the other hand, I have not often seen it

[1] "Theatrum Anatomicum," Vol. ii., Geneva, 1716, folio.—Vol. ii., p. 309, footnote.

[2] "Adversaria Anatomica," vi., Lugduni Batavorum, 1760.

swollen with water. In my dissecting room at Padua, however, I have sometimes demonstrated that it differed in no particular from the nearest glands of the choroid plexus, with which I compared it, and which in the same brains were in a like manner distended with water. To this may be added that this gland has a very close connection with that same choroid plexus, so that on raising the plexus the pineal gland is generally raised at the same time. . . . As to the rest I am fully aware that there must be a peculiar reason why the pineal gland is continued chiefly into that medullary tract [the posterior commissure] which is carried across before the anterior tubercles called 'nates.' I therefore believe that further investigations have yet to be made into its nature, and, consequently, into its office." (*Animadversio* ix. pp. 10, 11.)

539. Lancisi.[1]—"That portion which occupies a central place in the cerebrum, and has not a double or twin nature, besides the pineal gland, consists of the corpus callosum with the fornix and the septum lucidum. . . . And although there are also some other parts, which run across the middle of the cerebrum in other directions, for instance, the adhesions to the corpora quadragemina, the centre of the pons Varolii, and especially a certain medullary cord which binds together and conjoins the bases of both hemispheres above the sphenoid bone, and transversely under the connection of the optic nerves [*i.e.*, the anterior commissure], still this kind of small parts in the interior of the cerebrum, besides being very little, are destitute of that symmetrical structure, which seems necessary to me in order that the soul may deliberate therein, concerning what it intends to carry out (Vol. II. *Dissertatio* VII., *de Sede cogitantis Animæ*, p. 304.) . . . . Although the pineal gland is of various size, nevertheless, we have noticed, that in man, as well as in all animals, it always occupies its proper seat. . . For if it be stated by some, that it was missing altogether, this was due either to its extremely small size, which sometimes is the case, or it was cut off during the dissection, or, finally, they passed it by with neglect.

[1] Opera, quæ hactenus prodierunt. Geneva, 1718; Vol. II.

I noticed also that the pineal gland is covered with pia mater, which so teems with thick and copious sanguineous and lymphatic vessels, that, if you carefully relieve the gland of this coating, you will find that you have removed from it almost one third of its size (*Ibid.* p. 308). . . . I noticed, besides, that this gland on its surface is reddish, and that it is variegated with sanguineous dots in a wonderful manner; and that when examined under the microscope, it exhibits its least glandular follicles, which do not merely secrete a lymph, but also a liquid peculiar to the nerves; so that they seem indeed to constitute a peculiar cortex of a diminutive little brain. For if you cut through the pineal gland either longitudinally or transversely, you will notice that it does not by any means exhibit the white colour [of conglobate glands], but that it is of a slightly reddish colour. You will perceive in addition that from its basis on either side, there proceed two considerable nerves [striæ pineales] which some have called medullary processes. But if you cut them across near the base of the gland, you will see a beautiful sight; for you will notice, as it were, two little eyes encompassed with a reddish cortex, which have a whitish sparkle. But upon dividing the beginning of these processes through its little branches in the interior of the pineal gland, there has been offered sometimes to the eye of the observer something not unlike the ramification of the medulla in the cerebellum; whence it is that without doing any injustice we may call the pineal gland the cerebellum of the cerebrum itself. I noticed, further, that these nervous processes which take their departure from the pineal gland in an oblique direction, pass over the optic thalami, to which they adhere very closely, and that they chiefly spread over those places, which in the thalami are the extreme ends of the cortical and medullary parts, of which they themselves are composed; or in other words, the division of the substances is bounded by those processes which retain a medium nature between the white and the cineritious substances. There, at last, they penetrate into the interior of the thalami optici, and escape the keenness of vision, even when armed by the microscope. It is also worthy of observation that while in respect to the remaining parts of the brain, there is a great likeness between various persons; in respect to the corpus callosum and the pineal gland there is generally a great difference. For in some persons the texture of the corpus callosum is so compressed and worn off that no fibres can be distinctly noticed in its framework; in others the longitudinal striæ are almost invisible, while in some they are most elegant, and relieved to the sight; in many their direction is irregular. The pineal gland at one time is large, then again so small, that it scarcely exceeds the size of a grain of millet; generally it is conical, sometimes spherical; and lastly, it is more or less resisting to the touch, and more or less reddish (*Ibid.*, pp. 309, 310). . . . Moreover, I am not willing to pass over in silence, what I observed in dissecting the brain of one who, during life, stammered and was a simpleton. In his case, who was not over thirty-six years old, the whole substance of the cerebrum was more compact than usual, and it appeared whiter, so that it was very much like that coagulated milk which is commonly called *ricotta* (curds). For the blood-vessels did not penetrate very deeply through the cortex, nor did they seem to be sufficiently filled with blood and spirit. The corpus callosum was likewise a little hard; the longitudinal striæ were, indeed, visible in it, but they were not parallel with one another, as usually; the transverse striæ, however, were quite invisible. The pineal gland, finally, I found so very small, that it scarcely equalled the size of a hemp-seed" (*Ibid.* p. 311).

540. STENO.[1]—"Cartesius in his philosophy laid stress particularly on the following points:—'The surface of the pineal gland has respect to the interior surface of the brain; 2. In the concavity of the brain the pores are directly opposite to those of the small gland; 3. The spirits run from all sides of the gland into the concavities of the brain; 4. The

[1] "A Dissertation on the Anatomy of the Brain," read at the Assembly held at M. Thevenot's House in 1668. In Winslow's "Anatomical Exposition," etc., Section x. § 10; Douglas' English Translation, pp. 56-73.

gland can perform its functions, though it be inclined sometimes to one side, sometimes to the other; 5. The small tubes on the surface of the concavities are always turned to the gland, and may easily be turned toward the different points of this gland; 6. The gland is situated at the entry to the cavities of the brain.' . . . It is, however, very certain that the basis of this gland touches immediately the place of transit from the third to the fourth ventricles; but the posterior part, *i.e.*, one half of the gland, may evidently be perceived to be altogether outside of the cavities, by only removing the cerebellum, and one or both of the anterior tubercles of the corpora quadrigemina; upon which the posterior part of the gland will be brought into view, and yet no passage will appear, by which any air or any other fluid may enter [into the ventricles]. . . . The anterior part of the gland is not in the lateral ventricles; for the substance of the brain will always be found to lie between these lateral cavities and the gland; so that it can have no manner of relation to them, being hindered by the insertions by which this part is fixed to the basis. . . . When the sides of the ventricles are raised, only the anterior surface of the gland can be turned towards these cavities; but never the posterior surface. . . . I own that behind the fissure or the third ventricle, and immediately behind the posterior foramen, that is, the 'anus,' there is a cavity lined on both sides by the choroid plexus, which rises to the straight sinus; this cavity on the back part is closed by the pineal gland, and the anterior part of it is entirely continuous with it; and when the roof of the fornix is taken out, this small passage represents the form of an inverted little horn. . . . The pineal gland does not incline its point forward towards the cerebrum, as other anatomists believed; but its point is always turned towards the cerebellum, and describes nearly a half right angle with the basis. . . . The whole basis of the gland adheres to the cerebrum, or rather, the substance of the gland is continuous with that of the cerebrum. . . . In respect to the vessels of this gland, they are a collection of veins from the corpus callosum, the interior substance of the cerebrum, the choroid plexus, and the gland itself (*Ibid.*, Engl. edit., pp. 60-62). . . . The pineal gland adheres to the straight sinus, so that the dura mater cannot be raised at that place without affecting the gland. (*Ibid.*, p. 68.)

541. NUCK.[1]—"In respect to the pineal gland, as it is commonly called, I have not always found it in the shape of a pear; for, sometimes it is more oblong, not seldom oval, and often it appears in a spherical form. Sometimes, without doubt, this gland is found shrivelled up, and almost consumed; and sometimes firmly attached to the lateral parts. It is gifted with very small nerves, or such as are so slender as to escape generally the eyesight. I shall not speak of the viscus and tough matter, which not unfrequently covers the surface of this gland; nor of the calculi which have just as often been observed in it, by which the gland was deprived of its mobility, if it has ever been moveable. You cannot have forgotten, how once I found it full of gravel, and numbered as many as fourteen little stones of various sizes and forms, which were quite hard, and which I shewed to many curious persons; even as at the present day I am willing to shew them to any one who is desirous of examining them. I make only one observation here, at which you will perhaps wonder—namely, that as far as I could see, those who suffered from this gravel, during their life-time were not any less wise, than those with whom their gland was in its natural order. We are therefore quite justified in singing the funeral service of this gland in this wise, etc." (pp. 150-152.)

[MODERN AUTHORS.

541*a*. MEYNERT.[2]—"The pineal gland has often, but improperly been compared to the hypophysis cerebri—the pituitary gland. Luys regards it as a prolongation of the grey substance

[1] "Epistola ad Amicum de Inventis Novis," in his "Adenographia," etc., Lugduni Batavorum, 1692.

[2] MEYNERT (T.). "The Brain of Mammals," translated by J. Putnam, in Stricker's "Manual of Histology." New York, 1872.

of the third ventricle. Arnold very properly declared it to be separated by its medullary substance from that grey substance. It should in truth be considered as a ganglion, and, like the ganglionic mass of its pedicle, which is similarly constructed, it is connected on the one hand with the medullary substance of the cerebral lobes, and on the other by means of the posterior commissure with the crus cerebri. It may then be reckoned among the *ganglia of origin of the tegmentum.* It contains cells of two different sizes, the one 15μ in thickness, the others very small only 6μ in thickness, and its structure only differs from that of the other cerebral ganglia in that the cells are crowded very closely together. In the habenula, layers of cells often alternate with layers of nerve-fibres, a formation which calls to mind the alternating layers of granules and fibres in the bulbus olfactorius. The neighbourhood of the medullary substance, as well as the universal presence of processes, characterizes the cells described as nervous elements. The crowded arrangement of these cells is like that of the cells in the stratum corporum arctorum of the cornu ammonis, and this peculiar mode of arrangement and minute size is found also among the cells of the olfactory lobe, the cortex cerebelli, and certain cell-masses in the corpus striatum. The latter ganglion contains also collections of larger nerve cells" (p. 700 *et seq.*)

541*b*. HAGEMANN[1]—"The pineal gland, or conarium, this enigmatical formation of the brain, the investigation of which has kept busy the most renowned anatomists since the time of Des Cartes, and which so far as its function is concerned has given rise to the most diverse hypotheses—this same organ, by the researches of Henle and Bizzozero, has lately created an increased interest, wherefore on the basis of their labours I undertook a most minute examination of said organ (p. 429).

"As regards the nervous fibres wherewith the conarium is provided, they arise from the commissure of its peduncles which

[1] Hagemann (Dr.). "Ueber den Bau des Conarium." In "Archiv für Anatomie, Physiologie und wissenschaftliche Medizin," herausgegeben von Dr. C. B. Reichert and Dr. E. Bois-Reymond. Berlin, 1872.

is situated at the anterior edge of this organ. The nerves are most abundant immediately behind the anterior edge, where in dense strands, and closely pressed, they enter the gland. Among the fibres there are those with double contours and numerous varicose swellings, and there are also clear nervous tubes, which are likewise not altogether destitute of varicose enlargements. Their thickness is 0.004—0.007mm., and the thickest fibres are chiefly in the anterior portion of the gland. In the middle third of the gland I discovered repeatedly little nervous stems, 0.002 to 0.003mm, in thickness, which consisted some of 5, and others of upwards of ten fibres. In the posterior section of the gland there were only here and there a few delicate fibres. Whether the above-mentioned numerous homogeneous fibres with frequent varicose enlargements, ought to be classed among nervous fibres, we cannot decide with certainty, because at the present time we have no reagent, by which this question can be settled beyond a doubt.

"The order and arrangement of the nerve-cells differs from that of the nervous fibres; since they occur in all parts of the gland of the same size and the same in quantity. They were mostly 0.039mm., in length, and 0.021mm., in width and, in a bright granulous substance, they exhibit a large roundish nucleus 0.014 mm. in diameter with distinct nucleoli 0.0023mm. in size. I noticed both bipolar and multipolar cells with long productions greater or smaller in number; these productions, however, could not be traced to the point where they divided. I succeeded in observing nervous fibres attached to nerve-cells not only in a human pineal gland hardened in osmic acid, but also in a fresh pineal gland of a guinea-pig (p. 438 *et seq.*).

"According to *Henle* the nervous strand which has coalesced with the anterior point of the pineal gland, does not give out any fibres which enter into the organ; he also holds, that the exceedingly scanty nervous fibres which are contained in the parenchyma, are furnished to it by the blood-vessels. In the preliminary account which *Bizzozero* gives of his observations, he does not mention the nervous elements of the pineal gland. *Kölliker* discovered in the gland a scanty number of nervous fibres, from 0·0022 to 0·0045mm. in thickness, as well as multipolar nerve-cells. *Hyrtl* maintains that in the interior of the pineal gland which consists for the most part of grey substance, there are white, medullary striæ, which pass over into the peduncles of the gland" (p. 440).

"With respect to the function of the pineal gland, for the present it will have to be classed among the enigmatical organs; since it has not been possible in the least to start any hypothesis which meets the facts and is at all tenable—unless we choose to put it into the category of those formations whose function, like that of the thymus-gland, has been superseded. Des Cartes placed the soul in the pineal gland, as Galen had done before him. The great abundance of nerve-cells and nervous fibres in the pineal gland disposes one to entertain favourably the idea that it belongs to the nervous centres; but this idea is refuted by the consideration, that even in those cases where the gland was entirely degenerated or destroyed, it could not be discovered that any function in the body suffered in consequence, or that it ceased altogether. It is equally doubtful whether the roundish cells may not perhaps serve in a secretory capacity, since no excretory passage can be found, and since the fact of the function of said organ having ceased by degeneracy is not productive of any visible disadvantage to the human system" (p. 446).

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The bearing of the modern facts and theories, respecting the pineal gland, on the theory propounded by Swedenborg in the following pages, is discussed in Vol. I., Editor's Note iii., Nos. 42, 43, 45, 47, pp. 762-767.]

ANALYSIS.

542. Between the globose bodies of the cerebrum and cerebellum, and the medulla oblongata which extends underneath, there is a kind of triangular, medullary space thrust in between, which embraces the corpora quadrigemina, the pineal gland, the passages underneath, and some striated medulla. This space by the Ancients was called "isthmus." It is in a certain sense the uniting medium between those three bodies; above it thrones the cerebrum with its two hemispheres; below it rests the cerebellum, and around it, at the sides as well as behind, extends the medulla oblongata. Immediately opposite to it is the pons Varolii. Nor does it belong to either of the above bodies as an appendage, for it has its own tubercles, and consequently its own cortex and fibre. The cerebrum touches it only lightly; for the column of the corpus callosum, as well as the posterior part of the fornix, are not attached to it; the cerebrum, therefore, only licks its surface. The optic thalami, indeed, apply themselves to the angle of its upper side; yet they do not send fibres into it, but, on the contrary, receive within themselves the anterior tubercles or nates. From the posterior part of the medulla oblongata it is also separated by the interposition of a barrier, *i.e.*, the valve of Vieussens, where a certain medullary septum and band [frænulum] is led across in front of the fourth ventricle and immediately behind the posterior tubercles or "testes." The cerebellum reaches up from below, and sends out towards the isthmus its first process, the "crura ad testes," whence some fibres seem to extend upwards, and at last, after applying themselves to the fibres proper to the isthmus, they run out towards the neighbouring optic thalami. This small, medullary space or "isthmus"

is thus in a certain sense placed rather under the jurisdiction of the cerebellum, than under that of the cerebrum, although it is not wholly subjected to the former.

543. In what respect, however, this part is thus placed under the jurisdiction of the cerebellum, appears more evidently from the influx of the arteries, veins and filaments, which congregate around the isthmus. The vertebral artery which belongs to the cerebellum, sends thither its offshoots; nay, it even forms here a second choroid plexus, which is the middle one of the three. The carotid artery which belongs to the cerebrum, indeed, also sends a few twigs thither, but only indirectly as it were, and not professedly; for the carotid artery, at an acute angle from its trunk, throws off a branch, which it sends into the vertebral artery, and into the shoots of which it also enters obliquely on the way, whence there arises this little choroid plexus. Veins belonging to the cerebrum, as well as to the cerebellum and the medulla oblongata, meet here from every quarter with interior blood; those of the cerebrum, however, do not become affixed to the isthmus, but enter the straight sinus on the side. The straight sinus which carries off almost all the blood from the interior recesses of the cerebrum, the cerebellum, and the medulla oblongata, plants its roots here. This sinus, however, is incumbent on the cerebellum, and not on the cerebrum, and therefore obeys chiefly the motions of the former, and not that of the latter body. In like manner the falx, as well as the tentorium, which when taken collectively form but one process, together with the straight sinus, dispatch thither their middle axis, and thus the part common to them all; consequently also the inferior lamina of the dura mater, which accompanies its processes thither, as into a certain centre. The pia mater, especially that of the cerebellum, crosses over this place, as over a bridge, on its way into the lateral, as well as into the third or middle ventricles, and it penetrates thence still further into the infundibulum and the pituitary gland, where it meets with the anterior pia mater, or with that of the anterior part of the brain. The four ventricles, that

is, all of them, enclose this isthmus as it were in the middle; the larger ones at the sides, the lesser or third one in front, and the fourth at the back; and thus they form the isthmus; they hollow out its whole expanse, and perforate it by three clefts or passages, which terminate in a common cavity or cave. The alternate motions of the passages of this isthmus are directly the reverse of those of the remaining cavities of the encephalon; for here they all concentrate, and thither they press from all sides. Here therefore is collected all that spirit or liquor which is poured into the organs of the laboratory from the lateral cisterns. It appears hence that this intervening neck of land or isthmus, or this small peloponesus, which is excited into a state of motion by its five tubercles, acts under the rule of the cerebellum, and not under that of the cerebrum. The cerebrum simply pours in the spirit, the cerebellum, chiefly through the choroid plexuses, sprinkles in the serum, and the former, *i.e.*, the cerebrum by means of the corpora striata or the upper beginnings of the medulla oblongata, imparts to the isthmus general and alternate motions, yet only under the direction of the cerebellum. The cerebellum, consequently, takes charge of, and superintends the chymical operations much more than the cerebrum. Without such a government and such a communication of offices, this most noble and universal laboratory of the kingdom, which purveys spirit and life to the whole mass of the blood, would be subject, not to the rule of nature, which acts according to order and law, but to the power of man's will, which almost in every instant runs counter to order and law; for the will destroys what nature builds up, and hence, we contract diseases, and are again restored to health, but in time we grow old and die.

544. The pineal gland is placed over this intervening space or isthmus, and, as it were, sways the sceptre here. It is also situated at the root of the straight sinus, and likewise of the falx and tentorium, and of the choroid plexus of this region; and it guards the approach and threshold, through which there is an access to the organs of the laboratory. It is placed over this entrance door; with some of its middle portion it is exposed immediately

to the third ventricle, and also partly to the meeting-place of the foramina and the aqueduct. It closes and opens in particular this door; the same is also effected in a general way by the optic thalami, and in a most particular way by the fibres of the cerebrum which emerge from the tract of the fornix. All the active powers in the neighbourhood thus concur in this one object, and lend their friendly help; but it is the special office of the pineal gland to be the custodian and regulator of this one particular foramen, and thereby to act as the dispenser of the inflowing lymph. So while the optic thalami raise their backs and close up the ventricles, they at the same time consign the reins and the helm into the keeping of this gland; wherefore on receiving this power, the gland rises, and from its own principles of motion, or from its own cineritious substances, it begins to swell and to close thereby in particular that door, which the optic thalami have closed in a general way. On the other hand, the door is opened when the optic thalami subside, and when the gland contracts. An opposite effect, however, is exerted upon the foramina at the sides and upon the aqueduct of Sylvius which is the common passage or cavity of the foramina.[1]

545. The pineal gland is situated in the meeting-place of the axes; namely, of the longitudinal and of the transverse axes. The longitudinal axis runs out from the septum lucidum, and under the base of the fornix, through the third ventricle, the passage under the corpora quadrigemina, and the fourth ventricle, until finally it reaches the spinal marrow; the transverse axis, however, passes from the meeting ground of the sinuses and processes—the torcular Herophili—through the straight sinus, the foramen under the pineal gland, and thence through the infundibulum to the pituitary gland or the sella turcica; and thus it passes to the opposite meeting ground of the sinuses at the base of the cranium, and of the lateral processes of the tentorium. In the middle of this intersection or of this meeting of the axes, the pineal gland has its position; thus from a certain centre it has respect to the rest, as to circumferences. It thus

[1] Consult on this subject the Editorial Note in Vol. I. from p. 751 to 759.

resides in a tranquil station, and is inflected neither forwards nor backwards, neither to the right nor to the left. It hence expands and contracts in its own centre, and from its own centre. The third ventricle bears upon it in front, the aqueduct of Sylvius behind, and the two larger ventricles at the sides. Three cavities thus urge it backwards, and three forwards; whence there results an equilibrium, and its permanence in its own place. When the foramina and the aqueduct are opened, the third ventricle and the two lateral ventricles are closed. The action of all centres in the place where the pineal gland is, and which thus is in a state of perfect tranquillity. The corpora quadrigemina are in the circumferences of the isthmus; they also, together with the optic thalami, poise the body of the gland, as a pair of scales poise the tongue in the middle.

546. The straight sinus which carries off the interior blood of the cerebrum and cerebellum, the falx and tentorium, and likewise the choroid plexus, plant their final roots in the place above the pineal gland; so that this gland is, as it were, in the place of a fulcrum, and sustains forces, which are exceedingly small in the centre, but increase towards the circumference; therefore also it is pointed like a cone, and with its apex is kept in the direction of that straight line which is described by the straight sinus, the processes of the dura mater, the choroid plexus and the transverse axis. On this account also it is called the conoid, and turns towards the cerebellum. The posterior wing of the fornix by its slight contact, the optic thalami, as well as the corpora quadrigemina, that is, the whole of the isthmus, conspire for the same purpose, wherefore also they incline the gland in that direction.

547. In this wise the pineal gland is at liberty to turn, whither the axis and the vortex carry it, and also to expand as is required by its work. Two bands only whereby it is connected with the optic thalami, and two others which conjoin it with the anterior tubercles of the corpora quadrigemina, as well as its peduncle, act as a restraint upon it, and limit its expansile motion; as to the rest it is under its own jurisdiction. The gland,

like the cerebellum, and like the cerebrum in its convolutions, is interlarded with cortical and also with medullary substance. It also throws out fibres, and collects them into peduncles or processes, and dispatches them into the optic thalami. As the gland has the faculty of expanding freely when the optic thalami relax the cords or peduncles of the same; therefore it sometimes swells beyond its normal size, and gives rise to gaps, follicles or cavities, so that it has the appearance of a genuine gland. But when the lateral ventricles, because distended by too much serum, are unable to contract their cavities, and thus to relax the peduncles of the pineal gland, then the serum in its follicles stagnates, and hardens into a calculus, into gravel, or into any other solid little body; or again, according to some observations made, it swells into a considerable mass. Then the corpora quadrigemina succeed to the government; for so long as the pineal gland is a living power, those bodies act as its satellites and assistants; but when the nearest circumferences succeed to the office which had been administered by the centre, then the action becomes obtuse and indistinct, and the organism gradually verges towards death.

548. When the pineal gland is regarded in itself, and in respect to its texture, as I remarked above, it is not unlike the remaining bodies of the cerebrum, nay, it is even like the cerebellum; for it is encircled by its pia mater, which is irrigated with vessels; it is also furnished with its own cineritious substance, and its own medulla, which is ramified like a tree. It also sends out peduncles, one into the right, and the other into the left thalamus opticus; the same it does in respect to the corpora quadrigemina. The fibre of the peduncles is thus the proper fibre of the gland, and does not belong to the optic thalami; for when the peduncles are cut off at their roots they appear like two little eyes, which are rooted in the inmost structure of the gland. But as the gland attaches its peduncles to the optic thalami, it cannot expand, unless these peduncles are relaxed, which takes place at the time when the optic thalami themselves, that is, the cerebrum and the

cerebellum, are expanded. Whither the fibres of the peduncles which are propagated through the optic thalami finally tend, must be conjectured. It is probable, that in company with the fibres of the cerebellum they enter the optic nerves, and hence the eye itself;[1] for the organs of sense derive their origin both from the fibre of the cerebrum, and from that of the cerebellum, since there is more of a spontaneous and natural, than of a voluntary element in them. If the fibre of the cerebellum flows likewise into the eye, there is no other way by which it can do so except through the isthmus, and thence through the optic thalami into the optic nerves; or by that way whither the fibres of the corpora quadrigemina and of the pineal gland tend.

549. We may conclude thence what the pineal gland contributes to sensation and motion. In respect to sensation, it sends no fibre from its body towards any of the organs of sense except what it delegates to the eye;[1] for towards the organs of hearing and taste the fibre is sent out from the medulla oblongata; and the sense of touch also derives its fibre from the spinal marrow, and indeed from that region of it, where the fibre of the cerebrum and of the cerebellum is conjoined with the fibres of the medulla oblongata. The modes of the sensations also, when they are about to distribute themselves over the whole cortical substance of the cerebrum and the cerebellum, burst out through the fibres both of the posterior and the anterior parts of the medulla oblongata [that is, through the tegmentum and the crusta of the crura cerebri]. Those fibres which burst out through the posterior part of the medulla oblongata emerge into the cortical expanse of the cerebrum through the upper

[1] This seems corroborated by the "median eye in Vertebrates," concerning which Mr. W. B. Spenser reported in the "Zoologist" for June, 1886, that "he discovered the nerve by means of which the 'median interparietal eye'—first noticed by Dr. Graaf in the Slow worm—is connected with the brain, and finds that it is a portion of the epiphysis cerebri, (pineal gland). The eye does not reach the surface, is surrounded with connective-tissue, has a distinct lens, and is on 'the invertebrate type;' that is to say, the rods are turned towards, and not away from, the light, as they are in the lateral eyes of the Vertebrates."—Editor.

beginnings of the medulla, and not through the pineal gland except in a merely perfunctory manner. Those, on the other hand, which are carried through the anterior part of the medulla oblongata, do not touch the pineal gland, but by the pons Varolii are poured forth into the whole cortical cerebrum through the basal striated plane [*i.e.*, the crusta or pes of the crura cerebri], and thus through the corpora striata, or again through the optic thalami, in the direction towards the base of the fornix. The very medullary substance of the cerebrum is not continued into the substance of the pineal gland, so that there is no communication between them, except obliquely through the optic thalami. The gland, however, with its corpora quadrigemina, and with the whole of its isthmus, seems to perform this function, namely, that those visual rays, which from the eye through the optic nerves, flow into the thalami, are by this way also transmitted into the cerebellum, and into the whole of its cortical or cineritious substance; for the superior peduncles of the cerebellum, or the processus ad testes which flows proximately into the cerebellum, receives these rays presently.[1] Any fibre which tends from the cerebellum into the eye, emerges likewise from this process.

550. In respect to motions, both in respect to those which are natural and those which are voluntary: Neither the cerebellum nor the cerebrum communicate their actions to the pineal gland. For the cerebrum acts from its surface, where its substance, and thus where the origin of its fibres is conglomerated, but it does not act from the centre. The cerebrum also does not determine any fibres towards this, its centre; but it leads them forth by other ways altogether; likewise the cerebellum. Wherefore this gland is a centre of the actions of the cerebrum, the cerebellum, and the medulla oblongata, only in respect to their chymical functions, and not in respect to sensations and motions.

[1] Consult on this subject the Editor's note. Vol. I. p. 767.

CHAPTER XVII.

THE THIRD VENTRICLE.

551. The third venticle, also called the common cavity and the rima, arises by an opening in the middle, between the thalami optici. It is separated on either side from the lateral ventricles by a medullary substance. On top it is bounded by its own proper ceiling, which is double, [" velum interpositum " and " soft commissure "], each of which reaches to either side. This " ceiling " is yielding, and easily broken, and it then gaps open along the edges of the thalami. Below, or at the bottom, it is bounded by the common striated plane [crusta of crura cerebri], and there it approaches more nearly to the anterior portion of the cerebrum. Two *umbilici* close its two extremities; the pineal gland on the one side, and the base of the fornix on the other. From one end of it to the other there runs a large vein [vein of Galen] united in the middle, but on either side divided into two vessels. Shoots of little veins enter into it in sufficient numbers, and on one side they unfold or ramify over the pineal gland and the anterior tubercles of the corpora quadrigemina, and through the edges and sides of the aqueduct of Sylvius underneath. This ventricle with its venous blood is enclosed by the optic thalami. It extends between the two lateral ventricles, vertically under the middle portion of the falx major, or under the middle of the longitudinal sinus of the dura mater, and in the same line with the clefts which divide the crura cerebri and the medulla oblongata into two halves, from the septum lucidum to the spinal marrow. Some add to the third ventricle the superior and inferior fissures [*i.e.*, the portion above the soft commissure], including the foramina, and they thus extend its limits beyond the poles.

552. WILLIS.[1]—Under the prominences which we have described above, a narrow cavity or ventricle extends for a considerable length; which seems indeed to perform important uses, although it appears to be only of secondary importance, and to owe its existence merely to a certain chance, namely, so far as the processes of both prominences [*i.e.*, of the corpora quadrigemina] had to be conjoined with one another, and to be distinguished from the medullary caudex underneath. Two foramina open into this ventricle, one of which is situated at its beginning, and the other at its end; and through the middle of the cavity a declivitous opening tends towards the infundibulum; so that the serous liquid which enters either of these foramina, descends without delay to the infundibulum. Further, another transit opens into the same opening of the infundibulum; namely, through the first foramen, which is situated near the roots of the fornix; so that from every quarter of the cerebrum, serosities are conveyed into this sewer, namely, through the first foramen from the lateral ventricles; through the second foramen, however, those humours descend, which collect around the corpora quadrigemina; and through the third foramen, those humours find an exit, which are deposited near the confines of the cerebellum (p. 19). . . . The position and structure of the infundibulum seem to indicate that some humour out of the ventricles of the cerebrum is carried into the pituitary gland. For that part is so constituted, that a discharge of humours is effected into its aperture from every angle and recess of the interior cerebrum, and its appendage; and while in the various animals the shape and the situation of the ventricles differ, nevertheless in every one of them all the ventricles, of whatever kind they may be, have apertures opening in the direction of the infundibulum" (pp. 77, 78).

553. VIEUSSENS.[2]—"The third ventricle is a cavity very much like a long cleft, interposed between the thalami optici. A cineritious and soft substance covers its upper part like a

[1] "Cerebri Anatome," Cap. II., XII.

[2] "Neurographia," Cap. XI.

ceiling wherefore I call it the "lacunar," [the middle or soft commissure.] On this cineritious substance reposes, and to the same is united the above-mentioned medullary tract [stria pinealis.] When the thalami optici which by the mediation of this lacunar are united, are drawn apart, on account of its uncommon softness it is very easily torn; and its torn particles on both sides of the third ventricle shrink up to such a degree that they scarcely appear. After the 'lacunar' of the third ventricle, [the soft commissure] has been examined and torn, so that its lateral portions are a little drawn apart from each other, nothing solid remains interposed between the vulva, [the foramen Monroi] and the anus, [the posterior foramen]. It appears manifestly that this ventricle is excavated within the medulla oblongata, and is situated between its two crura, the optic thalami. At the same time also the orifice of the infundibulum becomes visible which is appended to the middle of its base, and also the opening of its gaping cavity. Nay, the two roots or pillars of the fornix are also laid bare, before which is placed the medullary body which has the appearance of a thick nerve [the anterior commissure], and which is situated transversely before it, and united with it; the 'centrum semicirculare' [the inner capsule], also on both sides around its anterior portion enters most intimately into this medullary body, and thereby joins the two together; on this account we call it the commissure which has the appearance of a thick nerve [the anterior commissure]. This commissure, however, is formed by the coalition of certain white tracts which are the first which are brought forth in the anterior region of the cerebrum from the medulla of both hemispheres. In the posterior part of the third ventricle the orifice of a duct [aqueduct of Sylvius] shows itself, which is intermediate between the third and fourth ventricles, just as through the 'vulva' and 'anus' the third ventricle seems to communicate with the lateral ventricles" (pp. 64, 65).

554. RIDLEY.[1]—" The three ventricles, by cutting asunder the

[1] "Anatomy of the Brain," chap. xiii.

fornix near to its roots, and folding it backwards over the corpora quadrigemina and the pineal gland, appear to be but one; those on either side of the fornix being called the lateral ventricles, in which are the corpora striata; that rima or cleft, however, so far as it is covered by the fornix, and divides the thalami optici, being the third ventricle" (p. 117).

555. WINSLOW.[1]—"Below, at the thicker parts of the optic thalami, and directly under their union, lies a particular natural canal, called the third ventricle of the cerebrum. I call it a natural canal, that we may not mistake for it an accidental fissure lying between the thalami in brains taken out of the cranium. This ventricle opens forward into the infundibulum under the foramen commune anterius [*vulva*] by which it likewise communicates with the lateral ventricles. It has an opening backward under the foramen commune posterius [*anus*] between the thalami and the corpora quadrigemina, opposite to the small middle canal, leading towards the cerebellum" (Sect. X., nos. 85, 86).

556. MORGAGNI.[2]—"Willis says, 'The optic thalami in man are here altogether separated and apart from one another, leaving a declivitous opening which is the passage to the infundibulum,' [see no. 488 above]. Vieussens, however, says on this subject, 'The ridges of the optic thalami in man are always conjoined by the interposition of an intermediate medullary tract, and the ceiling of the third ventricle [soft commissure]; and I maintain this in the face of Dr. Willis, who says that for the most part they are apart from each other, and altogether separated,' [see above no. 489]. If now Ridley in this matter sides with Vieussens in opposition to Dr. Willis [see above no. 490], it is necessary that he should acknowledge that these parts are conjoined by the interposition of a medullary tract [the stria pinealis with the velum interpositum] and of the ceiling (lacunar) of the third ventricle [soft commissure], or by the interposition of one of the two. In another passage, however,

[1] "Anatomical Exposition" etc., Sect. X.

[2] "Adversaria Anatomica," vi., Animadversio x.

Ridley says, 'Vieussens speaks of the medullary tract interposed between the thalami optici [stria pinealis], as though it were only one, but in reality it is double, one on each side' [see above no. 535]. There, however, he does not seem to acknowledge any ceiling [lacunar] at all of the third ventricle, for he does not describe it; and of that very place where Vieussens declares a little before that it is, he says, 'the rima or cleft which is covered by the fornix, and divides the thalami optici, is the third ventricle,' [see above no. 554]. Now as there is so great a discrepancy in this matter between Vieussens, Willis, and Ridley, I thought it necessary to enquire anatomically what the real status of the matter is, and unless I have been deceived in everything, it seems to me the result of the case is, that nature in this matter is not consistent with herself. . . . That ceiling of which Vieussens writes that 'it constitutes the upper part of the third ventricle,' I have frequently seen, on the top of the sides of the thalami optici which it conjoins, bending downwards a little. Nay, sometimes I have seen two, of which one was underneath the other; the higher one of which I would say was that 'medullary tract' [mentioned by Vieussens], if he had not said that it was lying upon and was united to that underneath, [viz., to the soft commissure]. But while I declare that I have seen the former ceiling or lacunar, [viz., the velum interpositum], and indeed several times, and sometimes double, I have to state also, that in some brains I have scarcely seen the transverse cineritious lamina [soft commissure] which is much shorter than the ceiling [proper]—the velum interpositum—and which does not join the sides of the thalami optici on the top, but according to the height of the third ventricle, the middle portion of the thalami; and this, so far as I am aware, no one has as yet mentioned. In some brains, however, I was utterly unable to discover the least trace or vestige either of the 'velum,' or of the 'lacunar,' that is, of the 'transverse lamina' that has been described. But lest any one, on account of what Vieussens says about the parts of the lacunar, being very easily torn, and about their shrinking together afterwards, so as scarcely to appear—lest any one, I say, might suppose that on account of the uncommon softness of the parts, and on account of their melting because of their looseness; that thus, whilst I was revolving all these things in my mind, I tore the lacunar before I succeeded in examining it, it will not be out of place here to remind the reader, that this happened to me in such brains, as in themselves were most excellently formed, and as were of sufficient consistency, while with a slow and raised up hand the necessary incisions were made, the parts themselves remaining in their original place within the cranium itself" (p. 11-13).

557. STENO.[1]—"The ancients knew very well that the fornix is not continuous with the basis of the cerebrum, but that it supports a substance with a fold, and in this way forms a third cavity or ventricle. It is true that by forcing in air through the foramen of the passage between the posterior tubercles—*testes*—the fornix is raised, and thus by breaking the filaments which connect it to the basis, a large cavity is formed; whence some have imagined that when the spirits swell the cavities, the fornix rises, and that the surface of the pineal gland on all sides looks towards the surface of the cavities. Yet only the anterior surface of the pineal gland can be turned towards the lateral ventricles; but no contrivance whatever can turn its posterior surface towards the ventricles. But if no air is forced into the cavity of the third ventricle, which is very narrow in the middle, nothing else will be found in it, except the great vein [the vein of Galen] which runs into the straight sinus, and the glandular bodies [the choroid plexuses] which accompany that vein. I own that behind this fissure or rima, and immediately below the foramen posterius—*anus*—there is a cavity lined by a part of the choroid plexus, and which at the back-part is closed by the pineal gland, a part of which is perfectly continuous with it; and when the fornix is removed, this cavity

[1] "A Dissertation on the Anatomy of the Brain," 1668; in Winslow's "Anatomical Exposition" etc., Sect. X. English Edition by Douglas, pp. 56-71.

remains entire under the pineal gland, and sometimes is in the shape of an inverted horn (p. 61). . . . The third ventricle is a very equivocal term. The ancients understood by this word a cavity under the fornix which they represented as it were with three legs, that it might support the cerebrum which lies upon it. Sylvius calls the third ventricle, a canal found in the substance of the base of the cerebrum, between the infundibulum and the passage which goes under the corpora quadrigemina towards the fourth ventricle. Some anatomists having separated the posterior tubercles—*testes*—, take the space between them, which is owing to their manner of dissection, for the third ventricle, which consequently sometimes is the fissure above and sometimes the canal below, and some will have it to be the space between the aqueduct and the ventricle proper, which is likewise owing to the rupture of the parts already mentioned. We have therefore three third ventricles, the second of which alone is the true one. To these a fourth third ventricle may be added, if the small fissure under the body of the fornix would be looked upon as a passage between the two anterior ventricles and the fourth. Yet this is so small and so full of the vessels and glands of the choroid plexus, that I doubt very much whether there can be any communication that way, between the anterior [lateral], and posterior [fourth] ventricles, especially since Sylvius' third ventricle is sufficient for this purpose, and likewise answers the design so well, that whatever goes from the lateral to the posterior ventricle, must first fill the infundibulum and this canal" (p. 64).

558. Consult also Willis' Plates V. and VIII. in his "Anima Brutorum," in the last of which two openings are drawn, of which one leads into the infundibulum, and the other to the passage under the pineal gland and the anterior tubercles. Likewise Vieussens' Plates VIII. and IX., where the third ventricle appears with the optic thalami very much spread apart, whence appear the openings into the infundibulum near the base of the fornix, and into the canal under the anterior tubercles and the pineal gland; the third ventricle is also exhibited very much

distended in Plates XI., XII., XIII. Further, Ridley's Plate V., where two large veins [the veins of Galen] are exhibited coming down from the apex of the upper part of the plexus to the other branch of the plexus, for the whole length of the third ventricle—which veins terminate in the straight sinus. There are also represented the two parts of the choroid plexus, of which "one is formed of the second branch of the basilar artery, joined with the first by a communicant branch, becoming glandulous near the 'isthmus,' and especially under the pineal gland covered here with the fornix."

ANALYSIS.

559. The third ventricle is like an alembic or helmet over the infundibulum, or the receiver below. It is also armed or lined by a thin bladder, or in other words by a membrane which is a continuation of the pia mater,[1] which through this ventricle is continued to the the pia mater on the other side, that thus it may conjoin the inmost to the outermost.

560. This cavern extends from the base of the fornix to the pineal gland, or it is intermediate between the two centres; one of which belongs to the cerebrum, and the other is common to the cerebrum and cerebellum. Thus protected at its extremities it stretches out in the most secure region of the encephalon; and so far as the dimension of its upper portion, or of its top-line is concerned, where its cleft or rima is closed, it never contracts, and thus is never shortened, but preserves its length, no matter how much the circumferences around it may be stretched apart, and no matter how much they may be moved, or may impinge against this ventricle. This also contributes very much to the welfare of the whole kingdom; for thereupon depends the stability of life.

[1] According to modern investigations the inner lining of the ventricles, and thus of the third ventricle, does not consist of pia mater, but of an integument peculiar to the ventricular spaces of the brain and spinal marrow, called *ependyma*. The definition of the *ependyma*, as given by VIRCHOW is as follows: "The ependyma consists of a stratum of connective tissue lined with epithelium; and although this stratum may be removed from the surface without any great difficulty, still it does not constitute any isolated skin in the proper sense of that word, but is simply that portion of the intermediate, connective substance of the brain, called *neuroglia*—a kind of cement in which the nervous elements of the brain-substance are lodged—which has reached the surface and extends over it." (Gesammelte Abhandlungen der wissenschaftlichen Medicin." Frankfurt, 1856; p. 890. See also Virchow's "Archiv," etc., Vol. vi., p. 318.)—EDITOR.

561. The optic thalami, however, recline against the ventricle on either side, and make up its ample walls. When these thalami swell or raise up their backs, they contract closely the whole of the intermediate space or belly, so that there is presented to the eye a mere fissure, extending from the ceiling to the bottom, as in the case of collapsed and defunct brains. But presently, when the optic thalami subside, or constrict their swelling bodies, then the squeezed-up cavity is dilated on either side, and from a rima or cleft it is enlarged into a sufficiently wide and capacious trough. In order, therefore, to explore correctly the uses of the members of the brain, as well as those of the members of the body, we must not look upon, and contemplate, them as dead, but as living, and thus as set in motion as it were. The action, however, of the optic thalami upon this cavity increases in the middle from the top downward to the bottom. And there the ventricle becomes ampler, and receives the liquid; for the top edges of the cavity which extend between the two "umbilici"—the base of the fornix and the pineal gland—cannot be easily dilated, even as they do not suffer themselves to be elongated, since the "umbilici" constantly preserve their original positions. That, nevertheless, in this direction also a certain force of action is exerted, appears from the medullary tract, that is, the topmost ceiling which appears double by a folding back [viz., the velum interpositum]; and especially because sometimes another ceiling is superadded, still under the fornix, with an interval between the two; and this second ceiling [viz., the soft commissure] is furnished lengthways with its own grey substance, or with an auxiliary force of expansion and contraction.[1]

[1] Swedenborg's statement concerning the expansile character of the soft commissure—*commissura mollis*—which at his time was not supposed to be of regular occurrence, is confirmed by the following observations of KOELLIKER:—"The *commissura mollis* carries smaller cells with 1, 2, 3, and even more processes, and with their contents slightly pigmented; and at the same time it has very many fine fibres of 0,0012—0,0016''' which are arranged in a reticular fashion, and run in a vertical and horizontal direction. It has also still finer fibres which are under 0,001,''' and a few thicker ones of 0,004.''' " (HANDBUCH DER GEWEBELEHRE," Leipzig, 1854; p. 297, § 117).—EDITOR.

562. Through the common aperture over which the pineal gland presides, the lymph enriched with spirit, that is, prepared for purification in the subsequent organs, pours in from the two reservoirs, the lateral ventricles, through the two posterior foramina, and also from the passage under the anterior tubercles containing the reserve lymph [*i.e.*, the aqueduct of Sylvius]. And this lymph pours in at such moments when the optic thalami on either side draw away or dilate the walls of this cavern or bladder, and indeed it pours in, in a like manner, in which it would rush into the empty space of an air-pump, or of a water-pump where the piston is drawn up, and where there is very little on top pressing against it; for such a force of attraction prevails in every cavity of the brain, even in its tubes and blood-vessels. There is nowhere any violent intrusion; but everything goes on spontaneously, with nature sending out its invitations; the active force being just as great as the passive force. For whatever is exacted by the condition of the body is furnished by the blood; and what the blood requires is given by the brain, what the brain gives being furnished by its plexuses, fibres and cortex. Thus the want in the extremities imparts to the first principles the power of acting and willing in a suitable manner.

563. The first mixture of essences, namely, that of the spirituous essence with the fresh and purer serum of the blood, as said above, is conveyed to the posterior foramen—*anus*, and is introduced into the alembic or third ventricle by the meeting place of the three passages under the pineal gland, and is conveyed thence into that cucurbit which is called infundibulum. Whatever the latter does not receive or sip in with its mouth, it cannot, however, as it seems, regurgitate or throw back by the posterior foramen, wherefore it casts it out by the anterior foramen—*vulva*—which is excavated under the medullary tripod or the fimbriated appendage of the fornix. Where there is a confluence of lymph or serum, there is a reception, and besides an exit or a discharge of the residuum. That the anterior foramen grants a passage to the residuous or super-

fluous liquid, appears first from the more elevated situation of this foramen in respect to the bottom of the lateral ventricles, near the base of the fornix where the ventricles meet together; *secondly*, from its proximity to the orifice leading into the infundibulum; *thirdly*, from the vein [vein of Galen] which sometimes is double, and from the extremity of the choroid plexus, which runs through the ventricle: for when the ventricle is dilated, the above vein pulls the foramen in a different direction, and draws it open more in an inward than an outward direction; *fourthly*, it appears also from the infantile thalami, as it were, which are attached to the larger thalami, [the "tuberculum" or "genu anterius," see Meynert above, No. 492*j*], and which extend their fibres into this direction; which cannot be done by the larger thalami: for the general force acts upon the general, and the particular upon the particular, which in the present case acts upon the little foramen, by stretching out or extending its fibres, and thus by relaxing the connection of the parts. The optic thalami do not send any fibre thither; for the edges of the thalami on the sides of the third ventricle are but thinly lined with the medulla of the cerebrum.

564. The superfluous lymph of the third ventricle, which is cast out by the anterior foramen, flows back again into that very focus which is the common mart or emporium of each lateral ventricle. Thence, as it were, by a circle it returns to its first threshold or its first prison under the "nates" and the pineal gland; and again and again it flows and reflows from foramen to foramen by a kind of chymical circulation, lest the third ventricle should ever lack its supply of liquid—even though the fibres and the blood-vessels of the cerebrum should not be constant in their supply of contributions; and lest anything of this hidden quintessence of the brain, destined for the uses of life, should be lost. Perhaps also a circulation of the same lymph is instituted by the isthmus through the interstice of the double ceiling.

565. The serum of the smaller choroid plexus or of that of

the isthmus is sprinkled into the same ventricle; for this plexus spreads out its webs in the three foramina, and also in the aqueduct of Sylvius, in order that in this terminus it may meet with the serum of the lateral ventricles which is impregnated with spirit. Besides, the vein [of Galen] together with the extremity of the larger plexus, namely, of that of the lateral ventricles, is reflected backwards, and passes through the third ventricle, in order that it may be joined to the smaller plexus, or to that of the isthmus. Thus the two run back from focus to focus, from centre to centre, in order that from the same point under the pineal gland the blood may be determined upwards through the straight sinus, but the spirit of the blood downwards through the infundibulum; each thus hastens to its own extremity of the transverse axis, and thence beyond, in order that both may meet again in the receptacles of the sinuses, that is, in the fossæ of the jugular veins. It appears hence sufficiently clear, what sublime use nature carries on here for the universal body; for the large gland, that is, the laboratory of the brain cares for universal things, but the glands or laboratories of the body for individual or singular things.

CHAPTER XVIII.

THE INFUNDIBULUM.

566. In the bottom of the third ventricle is an opening into an empty vessel, on account of its shape and use called *infundibulum* (funnel), and thence into the pituitary gland. At first this organ swells out and assumes ampler dimensions, but gradually it tapers off into a beak, or contracts like the neck of a bottle, through which there is a passage into the pituitary gland by an invisible opening. The infundibulum, however, is united with the gland in the middle through an isthmus or process of medullary substance furnished with insensible pores; while both anteriorly and laterally it sends out membranous productions which are continued from its surface, and which embrace the gland. For that part of the infundibulum which is inserted in the middle of the gland, and which is almost round in shape, so far as its outer covering is concerned, passes off into a membrane in the direction of the posterior appendage of the sphenoid bone [viz., the posterior clinoid process], to which it is attached together with the gland.[1] Another part of this membranous covering is continued inwards, and passing under the gland spreads out under it. The pituitary gland is thus united with the infundibulum both in respect to its surface and to its substance. If, therefore, alcohol dyed with saffron or any

[1] According to more recent observations, the outer covering of the infundibulum which consists of pia water, passes through the dura mater which is stretched over the sella turcica—and is continued into the integument or capsule of the pituitary gland. Besides, the sub-arachnoid liquid, according to Key and Retzius, passes through the dura mater at the same time, and bathes the surface of the pituitary gland, which, so far as this upper surface is concerned, is attached to the dura mater only around its edges.—EDITOR.

other substance be injected into the third ventricle with a syringe, the dye passes through the infundibulum, and on its way downwards is poured around the upper and lateral portions of the gland;[1] the interior substance of the gland, however is not dyed, according to Vieussens' experiment. The thin membrane which is continued through the ventricles and their passages, is led down as far as the opening leading to the infundibulum, which it invests. Below, the infundibulum receives, or there approaches towards it [from without], a meningeal production from the bottom of the cerebrum. This affords a passage to the infundibulum, and at the same time it is added to the former membrane, and tightens the neck. This membrane is also attended by the arachnoid membrane. This permeable chymical vessel, namely, the infundibulum, is encircled below by the vertebral artery, where its branches depart from the common trunk towards the choroid plexuses. At the sides it is enfolded by the carotid arteries, which being united to the former through the communicant branch, form at the same time an embrace around it. It is also irrigated by twigs which are sent out thence. Higher up this same chymical vessel is encompassed by the chiasma of the optic nerves; so that it rests securely, as it were, in a safe port, when the cerebrum is agitated and in a state of commotion. In most animals two foramina lead into the infundibulum; one, before the chiasma of the optic nerves, and the other near the same, according to Dr. Willis. In the dog, the infundibulum is wider, but shorter, and rests upon and is united with the pituitary gland like an undivided organ; that very thin membrane, also, by which it is covered, after it is extended still more, embraces proximately the gland underneath. In the sheep, the anterior surface of the infundibulum, through the mediation of the pia mater is loosely connected with the dura mater; because a wide and roundish foramen is in that part of the dura mater, which covers

[1] That is, it percolates from the infundibulum into the pituitary gland immediately under its integument which is derived from the pia mater.—EDITOR.

the upper surface of the sella turcica. It is different in man, and also in the calf. In animals the medullary substance of the infundibulum passes visibly into the gland itself, where it is lost to the sight. If in a calf the infundibulum be inflated by inserting a tube into it, its further course is swelled out a little; the quantity of the injected liquor, according to Vieussens, regurgitating out of the gland. Near the extremity of the infundibulum, further down, there are situated two mamillary, roundish tubercles, of a white colour, lined with pia mater, and interiorly either medullous or cineritious [corpora albicantia].

567. WILLIS.[1]—"In the base of the medulla oblongata, besides the ends of the vessels which are torn off, and which have been described above, the situation and structure of the infundibulum deserve to engage our attention; for near the chiasma of the two optic nerves, between the optic thalami which are here spread apart, a receptacle is sent out in the shape of a tube, which is covered exteriorly by a thin membrane derived from the pia mater and interiorly is lined by a medullary membrane. Its upper orifice is situated between the optic thalami, and it receives their declivitous cleft; a short tube sent out thence lodges in the pituitary gland. I saw this tube in the brain of a horse of the size of a quill-pen, transparent and filled with limpid water; so that there was no room for doubting, that serous liquids descend by this way from the cerebrum into the pituitary gland. . . . Near the lower margin of the infundibulum, there are in man two shining white little glands [corpora albicantia]; but in animals there is found only one which, however, is much larger, (p. 20). . . . If any one takes but a cursory view of the parts which are situated around the ventricles, and if he examines their structure but lightly, he will easily agree with the Ancients, that the excrements of the cerebrum are discharged partly through the infundibulum into the palate underneath, or that in an anterior direction they are cast out through the olfactory bulbs into the nares. . . . But in order to meet an objection made to the idea that the

[1] "Cerebri Anatome," Cap. ii., xii.

cerebrum is purged in some measure through these emunctory organs, we may state, that in living beings liquids easily percolate through places which seem impervious; for when the pores and passages which exist in every part of the animal body are dilated by spirit and heat, they transmit a shower of serum with the same ease as the loose texture of a woollen cloth. This is very plain from arthritic affections, during which a serous fluid gradually creeps through the nervous bodies, and passing through the least spaces, sometimes makes these, and sometimes other parts, the recipients of the deposits of the humours; it is also obvious, that membranes and nervous processes, like sponges, imbibe these serous humours; for on a slight pressure, they again give them out *en masse*. . . . In reality, the transit of humours in the living animal body is not effected simply through ducts and open canals; but a watery and more attenuated liquid makes its way through the solid and compact bodies of the nerves as through bits of a sieve, and likewise through fibres and membranes, so that it penetrates from place to place, through imperceptible narrows or straits. . . . This is the case, very plainly, with the infundibulum," (p. 77). See also his Plates I., II., V. in the "Anatome Cerebri," and Plate VI. in his "Anima Brutorum."

568. VIEUSSENS.[1]—"The infundibulum is a vessel covered with pia mater, soft, greyish-white, and short. It opens into the third ventricle, is situated immediately before the chiasma of the optic nerves, and rests upon the pituitary gland. Nature has appointed for it the duty of receiving a certain aqueous humour emanating from the brain, and of transmitting the same to the pituitary gland. Although I described the infundibulum as a vessel, and although I do not deem it quite unworthy of that name, because that part of it which opens into the third ventricle, is evidently hollow; yet its structure differs from the texture of the remaining vessels of the body in this respect, that it is not merely membranous, and that throughout the whole of its extent it does not seem furnished

[1] "Neurographia," Cap. VIII., XIII.

with a sensible passage, as is the case with the remaining vessels. Still by ocular inspection it is patent that its lower part, which is inserted in the pituitary gland, consists merely of insensible pores; and this is also proved by an experiment, namely, by introducing alcohol dyed of a saffron or any other colour, by means of a syringe into the third ventricle of the cerebrum, after this has been opened on the top. For if this experiment be tried, it will be seen that only the most subtle particles of the spirit of wine, not quickly, but very slowly, flow past (*præterlabuntur*) the infundibulum, and alight upon the pituitary gland. When this gland, after the experiment has been accomplished, is cut into sections, it appears manifestly that the liquid has touched only its upper and lateral parts; for its interior substance appears nowhere affected by the colour of the injected liquid. Although therefore the lowest part of the infundibulum is not provided with a sensible perforation, as I just said above, still it nevertheless appears to me partly hollow, and partly spongy, and consequently to be furnished with loose pores, and to consist of a substance which is highly fitted for the reception of a certain aqueous humour, and for excreting the same again. But lest the mode by which this excretion is carried on should remain unknown, I have to note first, that that part of the above excretory vessel which presses immediately upon the pituitary gland, is divided into two branches; and that one of these which rests upon the upper and middle region of the aforesaid gland and is attached to it, at first preserves a somewhat round shape, but by-and-by passes off into a membrane, and tends towards the posterior process of the sphenoid bone, to which, as well as to the gland below, it is attached.[1] The other branch, however, tending forwards, is at first spread out a little like a membrane, and passes under the anterior portion of the pituitary gland, as may easily be seen in a sheep's skull, where the exterior surface of the infundibulum, by means of the pia mater, is loosely conjoined with the dura mater; because in sheep, according to nature,

[1] See footnote 1 on p. 37.

an ample and roundish foramen is left in that part of the dura mater which covers the upper portion of the sella turcica; which is differently arranged in man, in the calf, and in most other animals. For in the latter the outer surface of the infundibulum touches more nearly the margin of this foramen, and coheres with it, by the intervention of pia mater. In the second place, it must be noted, that in the dog the excretory vessel under consideration is more ample, but shorter, than in man; since the perforation of the vessel appears there manifestly produced as far as the pituitary gland. Besides, in the dog, differently from what is the case in man, the calf, the sheep, and in most other animals, the infundibulum rests upon the gland as a single undivided organ; it is united with it, and covered with a thin membrane, which, by being extended farther, embraces proximately the gland underneath. After the structure and the situation of the infundibulum have been examined, and after the reasons of its connection and association with the cerebrum and the pituitary gland have been weighed with an equally balanced mind, we cannot help acknowledging that its only use consists in its receiving in the capacity of a larger lymphatic vessel, a certain aqueous or lymphatic humour, which rains down from the brain, and which by degrees it transmits towards the pituitary gland . . . and, further, that in its downward passage this moisture penetrates through the infundibulum, since it cannot be discharged in any other direction . . . or that it flows underneath that membrane, by which the upper portion of the pituitary gland is covered, and where by flowing under it gently, it is carried as far as the anterior and lateral parts of the same pituitary gland, where by degrees it flows through the insensible pores of the most delicate membrane by which these parts are invested, so that at last it falls into the two receptacles [cavernous sinuses] which are placed near the sides of the sella turcica (pp. 48-51). . . . As to the 'corpora albicantia,' they are two roundish bodies covered with pia mater, and outwardly, and also inwardly, of a white colour; they are placed near the infundibulum, and terminate in the 'commissura crassioris nervi æmula' [the anterior commissure]" (p. 82). Consult also Vieussens' Plates IV., V., VI.; in one of which is represented the portion of the pia mater which covers the base of the cerebrum [Plate XI. H. H.], where the hiatus left for the infundibulum is exhibited to the sight, together with the two prominences of the infundibulum [the corpora albicantia g. g.]. In Plates XIV., XV., the corpora albicantia [G. G.] are seen drawn apart, and terminating in the 'anterior commissure,' or the 'commissura crassioris nervi æmula [F. F.]; likewise in Plate XVII.

569. RIDLEY.[1]—"The pituitary gland is covered on all sides with pia and dura mater, except that part on its upper surface in which there is a little round hole, through which the infundibulum descends slopingly into it, being at its entrance surrounded with a production of pia mater, for its firmer connection with that part (p. 71) . . . If we consider the gland together with the appended infundibulum, we shall certainly find a conformation far different from any other part in the whole body of man, inasmuch as that which this gland receives from the infundibulum, or which is the same thing, what this infundibulum conveys to it, is not separated from the mass of fluids by any visible secretory duct, which in its ordinary method nature, according to observation, constantly makes use of, whenever it parts with any part of the blood, whether excrementitious or of a nature to be received again into the system, throughout the whole compages of the body (pp. 73-74) . . . Being therefore very inquisitive after the true use of this part, and despairing of ever attaining to such a knowledge without first knowing the exact structure thereof, in addition to all the other means commonly made use of in all anatomical inquiries, I made use of all sorts of injections serviceable to such an end, as of dyed liquors, wax and mercury; but all with little, if any success according to my expectation; the wax not penetrating its texture at all, the dyed liquors but very superficially, and the mercury, on which I had placed my chief hope, by its weight always—do what I could

[1] "Anatomy of the Brain," Chaps. IX. XV.

to the contrary—either breaking through the sides of the infundibulum, where it leaves the brain, or else falling down in greater globuli than the extremely narrow passages were capable of admitting, and by this means becoming altogether useless (pp. 75, 76) . . . The infundibulum is a thin medullary duct covered with pia mater, descending from the internal concave surface of the cerebrum, to which, by reason of its ampleness towards one end, and its narrowness towards the other, in resemblance to a funnel, as well by reason also of the purity of its uses, the Ancients gave the name of infundibulum. In man it is closely invested with pia mater at its very entrance into the gland, and from that place has no manifest cavity which I could discover by blast or probe, but it is altogether of a medullary substance, contrary to what it is in sheep or calves; in the last of which, where the parts are larger, by the insertion of a blowpipe into that part of the infundibulum, next to the gland, I have seen its further tract or passage on its upper side, a little puffed up and a considerable quantity of water regurgitate, as though it had lain contained either in some pipe or porulous substance of that gland. This difference is not taken notice of by Vieussens, and therefore what he says of this part seems chiefly, in this respect if not altogether, applicable to the structure it has in men. Those two divisions or ramifications of this part which the said author mentions, one in an anterior, and the other in a posterior direction, in sheep, calves, etc., I have always found in agreement with the descriptions he there gives of them; but I have my doubts whether the first reaches out and terminates after the manner he there describes, seeing I have always observed the extremity of that part in animals, towards the anterior part of the gland, sinking as it were into its very substance, and afterwards becoming presently altogether imperceptible; and in man its termination just after the same manner, save only that in the latter case it happens forthwith upon its approach to the gland, without reaching out either in a posterior or in an anterior direction (pp. 77-79) . . . Consequently, all I can say is that I look upon the infundibulum to be no more than a large lympheduct variously ramified through the pituitary gland, discharging its moisture by those many small branches into the veins which are dispersed through that part; in order that after the manner in which this is done in all secretory glands, it may afterwards be carried back again into the blood (p. 80) . . . That this lymph, however, is only the result of the condensed vapours arising from the arteries of the choroid plexuses, I am the more readily inclined to believe, because I never saw water in that part of any sound brain, nor unsound neither, where the choroid plexus was firm; and there was no reasonable ground, by the extravasation of serum in some other remote parts of the brain, to believe it had its rise from thence (p. 82) . . . We must also notice two fair white bodies [corpora albicantia] on this side of the infundibulum, in that depressed part of the brain, where the pia mater is so remarkably double" (p. 140) . . . See also his Plates I. II.

570. WINSLOW.[1]—"Between the base of the anterior pillar of the fornix, and the anterior part of the union or coalition of the thalami optici, there lies a cavity or a little fossa called infundibulum. It runs downwards towards the base of the cerebrum, contracting gradually, and terminates in a straight course, by a small membranous canal, in a softish body situated in the sella turcica, and named pituitary gland. The infundibulum opens above, immediately before the thalami optici, by an oval orifice, named foramen commune anterius [*vulva*], and consequently communicates with the lateral ventricles (Sect. x. no. 84). . . . The beak or tube of the infundibulum is a very thin production from the sides of that body, and is strengthened by a particular coat given to it by the pia mater. It is bent a little from behind forward, towards the gland, and afterwards expands again around this gland (*Ibid.*, no. 115). . . . The tubercula mamillaria [corpora albicantia] which are situated near the beak or production of the infundibulum, have been taken for glands, probably because of their greyish inner substance, which however does not seem to be at all different from

[1] "Anatomical Exposition," etc., Sect. x.

that of several other eminences of the medulla oblongata. . . . These tubercles seem to have some immediate relation to the roots or bases of the anterior pillar of the fornix, so that they might be named, as Santorini has done, the bulbs of these roots, though they appear likewise partly a continuation of other portions of the cortical and medullary substance, of a particular texture" (*Ibid.*, nos. 113, 114).

571. See in addition *Bidloo's* Plate, xcvi. fig, 3, in Manget's Theatrum Anatomicum, where he says that the infundibulum is nothing else, than a certain overhanging portion composed of looser and softer fibres, situated between the optic thalami, but not inserted in the pituitary gland, and only attached to it by the aid of membranes; a globous, not very hard little body, very much like two little glands, is situated near it. *Ruysch* represents the infundibulum as furnished with little arteries, under which, as he says, are two protuberances of the optic thalami, which are wrongly called glands, near the infundibulum. (Epistola xii, Amsterdam, 1738, Plate xiii., R).

[MODERN AUTHORS.

571*a*. VIRCHOW.[1]—"On the outside of the infundibulum there is an integument of pia mater which is relatively very richly furnished with vessels of considerable size. This covering consists of the well-known loose fascicles and trabeculæ of connective tissue, and very frequently it is furnished with small villi and blunt appendages, as is often the case with the pia mater in other parts of the brain. Occasionally the extremities of those appendages are swollen and filled with calcareous deposits, and also here and there the pia mater is studded with grains of sand (brain-sand, *acervuli cerebri*). The vessels are almost always very ample, and in aged persons frequently wound in spirals, with vesicular enlargements. The ependyma of the

[1] Virchow (R.). "Untersuchungen über die Entwickelung des Schädelgrundes," etc. Berlin, 1857, 4to.

third ventricle is very decidedly continued into the interior of the infundibulum, where it generally forms a soft and very frail mass rich in nuclei. This mass, on its exterior surface, almost always gives evidence of a very scanty presence of nervous elements. Among these there are occasionally dark-bordered nerve-tubes, which accompany the infundibulum from above downwards. Nevertheless, I could not observe nervous fibres in all cases. There is in addition in the infundibulum the same grey substance which occurs also in the *tuber cinereum*; with the only difference that in the latter organ numerous corpora amylacea are scattered through this substance, which are almost entirely wanting in the infundibulum. Ganglionic cells I have never observed in the infundibulum" (p. 92).

571*b*. LUSCHKA.[1]—On the basis of the investigations which I have thus far made, I feel compelled to declare that as a rule in the adult male and female the infundibulum has an aperture only in its upper extremity and in that portion which communicates with the tuberculum cinereum; further, that its interior cavity presents a fissure which terminates in a point below; and that beyond this cavity it is filled up by a loose, reddish-grey mass. Only in exceptional cases the cavity of the infundibulum can really be traced into the pituitary gland. . . . In respect to the composition of the infundibulum, there must be distinguished in it, its membranous cover, and the whitish-grey or reddish-yellow substance which is enclosed by this membrane. The membranous integument of the infundibulum for the most part is a continuation of the pia mater, in which vessels of a considerable size are visible to the naked eye; and chiefly exteriorly in a longitudinal direction there are always attached to this membrane remnants of the arachnoidea which sometimes present the appearance of villi. This membranous cover at the beginning of the infundibulum is extremely thin and easily torn. . . . Further down, the pia mater of the infundibulum grows thicker and becomes very much firmer, it

[1] Luschka (H. v.), "Der Hirnanhang und die Steissdrüse des Menschen." Berlin, 1860; 4to.

also clings more closely to the proper substance of the organ. In most cases, in the adult, the inner side of the pia mater, in this part of the infundibulum, presents various inequalities. Here and there the vessels bulge out, and in the form of loops which are arranged in various ways, they make their way into the interior of the infundibulum, and sometimes their number is so great, that they alone constitute a loose, red substance in the interior. . . . By these vascular loops and the productions which result thence, not only the cavity of the infundibulum is obstructed, but also the proper substance of this organ is crowded out and broken up. . . . A very noticeable ingredient in the tissue of the pia mater of the lower portion of the infundibulum are glandular vesicles or glandular sacs, which are identical with those contained in the anterior lobe of the pituitary gland, and which, in a way to be explained hereafter, originate from the gland. The greater thickness and solidity of the pia mater in the lower end of the infundibulum is chiefly due to these glandular sacs. They are usually most abundant in the anterior surface of the organ, and are mostly found in the immediate neighbourhood of the blood-vessels which run in a longitudinal direction, and which not unfrequently are enlarged in the fashion of aneurisms. A portion of the cellular substance and of the blood-vessels of the pia mater of the infundibulum, which is a direct continuation of the cerebral pia mater, passes over and is lost in the corresponding integument of the pituitary gland, from which there enter always a certain number of little vessels into the substance of the anterior and posterior lobes of the gland. The fundamental substance of the infundibulum is really a soft, reddish grey mass which on the one hand is continued into the tuber cinereum, and on the other into the posterior lobe of the gland. . . . But it must be well observed that the nervous substance properly constitutes neither the infundibulum nor the posterior lobe of the gland, to any great extent; and that the substance of said lobe consists essentially of a growth of connective-tissue ingredients and of epithelial elements. These ingredients gain the upper hand more and more, and the nervous elements grow less and less, the nearer the infundibulum approaches the pituitary gland. Before the infundibulum passes over into the posterior lobe of the gland, there are noticed in it only a most subordinate number of fine nervous tubes, and only very few, mostly bipolar ganglion-cells; which besides are undergoing a peculiar process of degeneracy. What is met with there chiefly is another kind of cells which are imbedded in a molecular substance. These cells are partly fusiform, partly pear-shaped, and partly they are formations of another kind which are ramified in various ways, and which contain nuclei more or less clearly defined. Again, there are in addition a considerable number of formations which mostly prove to be degenerate epithelial cells, deprived of their cilia, with very long productions. The sharply marked and dark-bordered stems or productions of these cells are sometimes continuous with the ramified processes of the above-mentioned cells. These epithelial cells are thoroughly identical with the better preserved epithelial forms which Gerlach has shown to exist in the aqueduct of Sylvius. To a substance of this description the human infundibulum chiefly owes its solidity, and by this substance its original cavity was filled up in a similar manner, as by the development of the ingredients of the ependyma, the central canal of the spinal marrow is not unfrequently obliterated in part" (p. 16, *et seq.*).

571*c*. Mueller.[1]—"The basis of the mesocephale in man is continued at a right angle into the cerebral stems or protrusions which are situated under the mesocephale . . . . namely, into the anterior protrusion the *tuberculum* or *trigonum cinereum*, and into the posterior, the *infundibulum*. . . . The tuberculum cinereum, as well as the infundibulum are hollow; the cavity of both is connected with that of the third ventricle. Where the anterior wall of the infundibulum meets with its lateral and posterior walls, its cavity ends in a point; and thence

[1] Müller (Wilhelm). "Ueber Entwickelung und Bau der Hypophysis und des processus infundibuli." (Jenaische Zeitschrift für Medicin und Naturwissenschaft. Bd. vi. Leipzig, 1871; pp. 334-425).

it is prolonged into a production, the processus infundibuli, which follows a downward course, a little in an anterior direction, and at its extremity it is thickened into a club. This process is attached to the posterior surface of the pituitary gland, and in man it is embraced in the form of a horse-shoe, by comparatively short, but in the dog by long, lateral productions. In all animals at the time of their birth it is solid ; and only in exceptional cases there extends between the anterior and posterior walls a delicate cleft which is visible even to the naked eye. This process has a yellowish colour; it passes over into the anterior wall of the infundibulum without any sharply marked boundary; into the posterior wall it is continued for a short distance, gradually assuming a wedge-like form from above downwards. That place where the posterior wall of the infundibulum is formed exclusively by nervous substance, is visible for the naked eye by a shallow horizontal furrow, and a change in the colour. Numerous finely stretched vessels extend along the posterior wall of the processus infundibuli, imparting to it an appearance different from that of the remaining walls. . . .

"The bottom of the tuberculum cinereum and the anterior wall of the infundibulum exhibit the same structure. Both organs on their surface which is turned towards the cavity are invested with short cylindrical epithelium furnished with cilia; this is succeeded by a thin layer of a finely granulated substance with a small number of round and elliptical nuclei, which are partly provided with reticular areolæ of protoplasm. After this, in the direction of the circumference, there follows an extensive layer formed of a fine tissue of protoplastic threads which anastomose in many ways; this layer carries nuclei of 0,004 to 0,006mm., which are partly round, and partly elliptical. The two inner layers may also be distinguished in the lateral walls. Besides, the layer which is nearer to the outer circumference, is also much more voluminous, and in a substance carrying nuclei, which partly is finely granulated, and partly formed of fine fibrils which are ramified in a reticular fashion, it contains ganglionic cells of various sizes, which are mostly furnished with three productions; this same substance also is finely striated by fine protoplastic productions, which run out in the form of rays. The posterior wall of the infundibulum which at the same time forms its bottom, is peculiar in so far that only at some distance from the pointed end of the cavity, the layer containing the ganglionic cells is continued from the lateral walls into the bottom, and indeed in a gently declining line which runs in an antero-posterior direction, and from above downwards. This is caused by this circumstance that the bottom [and thus the posterior wall] of the infundibulum, for some distance from the place where it is joined by the processus infundibuli, has a structure similar to that of the processus, and this modified structure, the farther it extends backwards, the more it is limited to the lowest layers of the posterior wall. The structure of this portion of the infundibulum, like that of the processus, is of a peculiar character. Its chief substance in man, as well as in the pig and the dog, is a fibrillous connective tissue which abounds in round and fusiform cells, and partly also in ramified cells, which are strewn in between. This connective tissue is gathered in bundles, which decussate in various directions, just as in sarcomas formed of fusiform cells. In man there are in addition numerous, pretty large, round or fusiform, and partly also pear-shaped cells, which in their protoplasm carry yellow pigmental nuclei, in a larger or smaller number. They are like the cells which impart a brownish tinge to the tissue in the choroidea, and like those in the pia mater which encloses the medulla oblongata. In those rare cases, where remnants of the original cavity of the processus infundibuli are preserved, they are found invested with short ciliated, cylindrical epithelium. Thus are explained the observations of Luschka, who states that ciliated epithelium furnishes one of the constituents of the processus infundibuli. From the pia mater by which this processus is invested, it derives vessels, which form in its substance a net of irregular rhomboid meshes."]

ANALYSIS.

572. If a line or diameter, almost straight, be drawn from the middle of the occipital bone, from the meeting-place of the sinuses—the torcular Herophili— ; if this line passes through the straight sinus, afterwards through the apex of the conical pineal gland, and thus through the gland itself to the mouth of the infundibulum ; and if it is continued through the infundibulum itself and its process into the pituitary gland, *i. e.*, into the middle of the sphenoid bone, or of its sella turcica, where the sinuses of the base of the cranium meet—we then obtain the transverse axis of the brain. For the sake of preserving the proper direction [of this axis], the pineal gland itself, like the tongue of a pair of scales, is provided with a certain apex, wherewith it looks towards the straight sinus, while with its basal surface which is directly opposite to this vessel, it regards the mouth of the infundibulum. The infundibulum itself also extends obliquely forwards, and its processus, in a like direction, extends to the pituitary gland, into the middle or anterior part of which it is inserted, lest it deviate from the straight line.

573. The opening (*orificium*) of the infundibulum is expanded and dilated, when the third ventricle is constricted in its upper part, or when it is reduced into a cleft; which coincides with those moments when the optic thalami rise or elevate themselves. Then also this middle interstice, the third ventricle, is compressed and closed up. The bottom of this ventricle, however, is distended by the moisture which has but recently been injected into it; consequently the opening which from the bottom of the ventricle gaps into the infundibulum, is also drawn apart. The very fibre and membrane of the

ventricle co-operates in bringing about this effect; and likewise the pia mater [on the outside], which is encountered here, and offers a transit. For this membrane, because it is expanded with the cerebrum, draws out the margins of the orifice, and pulls it open in various directions, thus affording a passage to the inflowing liquid.

574. The very infundibulum, or its cavity, at the same time when its opening is drawn apart, becomes likewise more swollen, wider, more globose and capacious, yet at the same time also shorter. For the inflowing moisture distends its sides, which are densely medullary, soft and expansile, and yield easily. Towards the production of this effect the bottom of the third ventricle, the pia mater of the cerebrum, and the fibre itself of the infundibulum conspire; for the *bottom of the ventricle* is then compressed in a downward direction, and bears upon the cavity of the infundibulum from above; the *pia mater* of the cerebrum does so in a like manner, which being attached to the same orifice [on the outside] is brought nearer to the pituitary gland and the sella turcica whenever the cerebrum is expanded, which coincides with the time of expansion here: the *fibre of the infundibulum*, however, is then constricted. It follows thence that the process of the infundibulum, and at the same time the membranous productions, are then relaxed, and rest flaccidly on the pituitary gland. All parts individually thus conspire and lend their aid, so that this cavity shall imbibe the liquid wave poured into it. All this, however, does not easily fall into the understanding, unless we make ourselves familiar with its structure; that is, unless we consider that the infundibulum itself as it were, hangs down outside the cerebrum, and that its orifice [in the interior] passes beyond the pia mater [on the outside]; and again that the pia mater doubles itself, and lining the outer surface of the infundibulum forms productions which are attached to the pituitary gland, and also to the side of the sella turcica; and further, that the fibre of the brain becomes more constricted and elongated, and that the pia mater also is urged outwards, when the cerebrum, the cerebellum and the

central ganglia—the corpora striata and the optic thalami—are in a state of commotion, that is, are swelling.

575. The reverse happens, when the third ventricle is expanded; for then the opening of the infundibulum is contracted, its cavity is stretched out into a tube or slender duct, its processus is erected, and the remaining passages and pores are everywhere opened. The constriction of the cerebrum, the expansion of the third ventricle and of the fibres; further, the action of the pia mater which is doubled back, and of the two ganglions [corpora albicantia] placed at the sides of the infundibulum, contribute distinctly to this result.

576. When the cavity of the infundibulum is constricted and its beak—the processus infundibuli—erected, the enclosed moisture is expressed by two ways, namely, its lighter, purer and spirituous portion is pressed into the porous, bibulous and medullary substance of its walls, and thence into the beaked process which is inserted in the pituitary gland; while the heavier, grosser and earthly portion is urged into some lateral ducts and interstices, in proximity to the pia mater, which acts as a lining, and thence it is expressed above, around, and below the pituitary gland. The superfluous portion, however, regurgitates into the third ventricle, and is ejected through the anterior foramen (*vulva*). The infundibulum is hence not only a *vas deferens* or an excretory duct, but it is also a *vas secernens* or a secretory vessel; for those things which in the ventricles have become mixed up, thickened, and in a certain sense amalgamated, the infundibulum separates and filters; namely, the purer from the grosser, the spirituous from the earthly, the fresh from the antiquated and obsolete; the former it instils by a fibrous channel immediately into the substance of the gland; but the latter it relegates around the gland, between the sides of the sella turcica.

577. That the purer and spirituous fluids which are also called the genuine animal essences and spirits, flash here through the interstices and pores of the medullary substance, appears very clearly from the nature of the fluid in question:

for it is volatile, highly elastic, expansile, compressible, most yielding, and hence most adapted to the pores and the network of the fibres, since it titillates gently, mildly and gratefully the sensitive fibres, so that at its approach they rather open than contract. This moisture, indeed, imparts and furnishes to the remaining fluids, for instance to the blood, all the fluidity they possess. Such a highly liquid and refined alcohol of animal nature which is utterly beyond the ken of the senses, cannot help escaping into that loose and bibulous substance of the body of the infundibulum, at the first determining force, however light, which is brought to bear upon it; and by following the interstitial ducts or medullary filaments it must needs be transferred into the processus or neck of the infundibulum: for this processus is nothing else than a collection and a bundle of the fibres of the infundibulum; just as is the case in the cerebrum with the body of the fornix, in the cerebellum with the peduncles, and everywhere in the body with the nerves and processes; for in this wise the spacious medulla, which is spread out on all sides, and appears most plentiful, is gathered up into one single axis. The above processus is inserted into the pituitary gland itself, and ramified through the same; consequently, that most refined and defecated fluid is there dispersed as it were through regular roads. This becomes still more evident and is abundantly confirmed, when we consider that the cavity of the infundibulum is not invested by any membrane or meninx, but that the fibres on their way into the interiors are interwoven in a net-like fashion, and afford everywhere passages; and, again, that when the cavity is contracted into a tube or slender duct, or when the infundibulum is stretched out, these fibres rise, occupy their respective places, and arrange themselves so as to afford a passage; and, further, that the ample medulla of the body of the infundibulum cannot determine itself anywhere else than into the processus, as into its peduncle. It is not at all wonderful that this loose and most subtly tubulous texture should be impervious to common water, to spirit tinged of a saffron colour, to melted wax, oil and to the probe; since these liquids, almost the very last of nature and of too gross a quality, cannot on any consideration enter into interstices which are open only to the most attenuated animal juice, which is also called the nervous juice. But if, indeed, we declare nothing else to be pervious, than what may be penetrated by an injection and by dye, the most sharp-sighted observers will have to abide in the ultimate dregs of nature; for even beyond the range of the microscope there lie hidden away congerics of filaments which are permeated by their liquids, and are scarcely visible except as a kind of molecule or nondescript chaos, when myriads of them are massed together. In this wise we could not be persuaded of anything from the experience of effects and phenomena, except by visible causes which strike the eye; consequently, we could never know anything about the permeability of substances in the kingdoms of nature, and still less in the anatomical organisms of least insects, all of which have their members, brains, hearts, stomachs, wombs, muscles, blood-vessels, fibres, as well as blood and spirits. If we should attempt to inject any of these most distinct little machines, we should quickly reduce them into some confused mass. So also it is an equally bootless task to endeavour to find out by any of the elementary liquids of nature or by a coloured injection, whether the infundibulum be permeable as far as the pituitary gland, or not. For such an injection, by the force brought to bear upon it, destroys the organ, stops up passages, and lacerates connections. Mercury, indeed, penetrates through the organ, but it comes out at the surface and is scattered. In order to carry on an experiment properly, it is necessary that the infundibulum should not lie in a collapsed condition, and that its cavity should not be distended by any infusion, but that it be raised a little on the outside, and gently brought into its natural position; otherwise not even the purest essences will pass through it. This secretory organ abounds also with little veins, lest the refined and defecated moisture which does not transpire through the processus into the gland, should escape into the air; but that on the contrary, it may be sipped up by the little mouths of the veins, and together with the vapour of the gland may be determined into the basilar sinuses.[1]

578. Experience, however, proves clearly that the grosser liquids which do not penetrate the pores of the medullary substance and the processus of the infundibulum, by ducts which are open in another direction, at the side near the production of the pia mater, rain down upon the surface of the pituitary gland and the parts around it; for attempted coloured injections were seen to trickle down upon the gland and around it. The structure itself of the infundibulum and of its processus confirms this manifestly; for the pia mater, from that place where it encircles the orifice [from without], is duplicated, and thus lines the body of the infundibulum; and at last it passes off into a production which, with its extremity, effects an entrance into the dura mater, and is affixed to it. Now, when this production together with the processus and the infundibulum, is erected, some ducts near the pia mater cannot help being opened, for the upper part of the infundibulum, which we call its body, is wide, its lower part, however, contracted. When this wider portion, therefore, is raised upwards, the narrower portion which is below, must needs be drawn apart a little, and some passages must be opened through which the grosser liquid may flow down. The very fibres of the wider portion also, that is, of its delicate and tubulous medulla—arrange themselves suitably; namely, one close to the other, and so far as their size is concerned, they become constricted, whereby a little space is left between the medulla and the membrane. The glands [ganglia] which are near [the corpora albicantia], also extend their fibres then, and impart to the pia mater, as well as to the fibrous substance, the power of withdrawing from each other. Besides, these humours are not only grosser, but also harder; they are not elastic, neither expansile, nor compressible; in themselves and in their own nature, they are more

[1] Concerning the manner in which Swedenborg's theory of the permeability of the infundibulum is modified by modern investigations, see Note vi. no. 15.—Editor.

sluggish, acting by a mere dead force, and by gravity, and, at the same time they abound with angular and saline particles, and thus are of a nature too little homogeneous as to dare to enter into any passages not their own. If, now, these humours are sharp, inert and cold, the fibres become chilled on their first contact with them, and spue them out; wherefore they recoil into their own ducts. In this wise, then, they separate themselves of their own accord from the spirituous fluids of the animal kingdom.

579. The infundibulum, besides, transmits to the pituitary gland not only these fluids of a diverse nature, but also a genuine and fresh spirit. For a copious fibre descends into this organ from the fornix and the centrum ovale, and the two glands also [the corpora albicantia] which were formerly called white glands, and likewise bulbs of the fornix, press against it: and this fibre makes up its ventricose body, and presently being concentrated into a process or peduncle, it enters into the pituitary gland itself, and infuses into it the spirit which it derives from its origins, that is, from its cortical substances, and thereby it restores and vivifies the older spirit, or that which arrives in the passages between the fibres. It follows hence that animal nature first mixes up and confuses as it were the menstrua and juices, namely, the purer with the grosser, the spirituous with the corporeal, the active with the sluggish, and the fresh with the antiquated, and indeed in its first reservoirs or ventricles, as has been observed above; and that presently it separates again into their elements and principles the liquids that have thus been commingled, and lightly connected, which is done here in the infundibulum, and afterwards in the pituitary gland, and in the sinuses at the base of the cranium; and, indeed, for this purpose, that it may always have at its disposal for its various uses a fresh, regenerated, and homogeneous fluid, and that thus, even in composite parts, it may live in its own first principles, into which it returns at every alternate period in its circulation, and thus purifies itself. This chymical operation which is accomplished in the infundi-

bulum and finally in the pituitary gland, may be called not only a secretion and purification, but also a rectification and alcoholisation.

580. In connection with the infundibulum it is also worthy of being mentioned that the structure, capacity, and insertion of its processus differs very much among brute animals, and that the whole arrangement among them is very different from what it is in human brains. In horses the processus is said to equal in size a goose-quill, and to be visibly distended by a fluid; in calves and sheep, we are told, an injection penetrates as far as the gland, and regurgitates, and in the dog the processus forms a uniform organ with the gland. In man, however, the extremity of the infundibulum is said to be thin, and to pass off into small productions. All these are sufficient indications, that in man that vital spirit or animal juice, which constitutes also the interior essence of the blood, is much purer, sublimer, and more removed from the acumen of our senses, than it is in brute animals; and, again, that a smaller quantity of that spirit suffices for beings who arrive at their maturity more slowly, and eat less, than for animals which acquire the whole bulk and measure of their bodies in one year, or at least within five years, and which cannot withstand the cravings of a voracious and ill-disciplined stomach.

581. It is worthy of being added here, that all the substances of which the organs of the laboratory are constructed, seem to be concentrated in the infundibulum; as if the soul here, from a certain centre or from a certain ultimate goal, desired to look around and to become conscious again of what is being transacted in the circumferences and in the universal camp; or that it may see as in a conclusion what is contained in the things that precede and in the premises. For the medullary substance of the infundibulum is derived from that of the fornix and of the stria pinealis—the ceiling of the third ventricle—which is produced downwards chiefly between the optic thalami; from that substance the soul, as it were, is able to know thoroughly what is being transacted in the third ventricle, the two lateral

ventricles, and besides, in the fornix and the corpus callosum. On this account also two glands or ganglia [corpora albicantia] are placed near the anterior commissure (*commissura crassioris nervi æmula*) or the concourse of the "geminum ventrum semicirculare" [inner capsule]. The infundibulum is also situated very near to the optic nerves or their chiasma; and as these nerves communicate with the isthmus and the pineal gland, it seems as if information was derived through them of what is being transacted there in a general manner. From the pia mater [the ependyma] with which the infundibulum is lined, the soul may learn what is being done in each of the cavities; from the two communicant branches of the vertebral and carotid arteries, which like arms embrace the area of the infundibulum and send shoots into it, what takes place in the choroid plexuses, for those branches provide for these plexuses; and from the little veins, finally, how matters are going on in the sinuses. Perhaps by the aid of additional anatomical experience, we may also be able to confirm, that the cortical convolutions of the cerebrum of this region, namely, those which are in the intermediate neighbourhood of the infundibulum, are the same which send out fibres to the corpus callosum and the fornix, and thus construct the principal fabric of the organs [of the laboratory], and which finally, after accomplishing their course, are reflected back into the infundibulum.

APPENDIX TO CHAPTER XVIII.

AN EARLIER ANALYSIS OF THE INFUNDIBULUM.[1]

581*a*. The infundibulum is like a deferent vessel through which a liquid commingled with its alcohol, or a noble spirituous essence wedded to the lymph of the choroid plexuses, is led away from the alembics and reservoirs of the laboratory. For into the infundibulum there is intruded in alternate periods a swiftly moving fluid which does not stop its course until it reaches the pituitary gland below, into which the infundibulum inserts its root obliquely forward. Its cavity swells at first, in order to receive all that is poured into it; but presently where it is inrooted in the gland, it becomes narrower; it also lines the gland with a membrane, and thus seals it up. The animal spirit, the spirituous lymph, and the serum which had been combined in the ventricles, seem to be separated here again from each other, lest on being removed from a colder region they be thickened and coagulate. The purer and spirituous portions of the liquid pass through the middle of the gland, while the more sluggish and respectively residuous portions descend on the surface of the gland, and thence are drawn off under the surface, and also between the latter and the parietes of the sella turcica. Both fluids, however, are introduced by different ways into the blood, so that they may circulate in it, and be rectified over and over again. The great secret of animal chymistry seems to consist in uniting and separating again its menstrua and extracts; so that nowhere an incongruous substance may be added to one which is congruous, and a dissimilar one to one which is similar, or in case such an addition should have been made, that it may not remain inherent. Animal chymistry is thus constantly

[1] From Codex 65, as reproduced in Vol. IV. of the photolithographed MSS. of Swedenborg, pp. 388-399. From the year 1735-1738.

active in the work of purification and refining, so that there shall always be in readiness a new lymph, invigorated, defecated, and in every way suitable, its vile and useless portion which can no longer be resolved, having been expelled; so that by virtue of these perpetual dissolutions and unitions, the animal system may always enjoy its appropriate heat, and live. In the cortical and cineritious substance of the two brains and of both medullæ, is transacted the ultimate and most consummate resolution of all particles into their elements; afterwards this same process takes place everywhere in the body. The unition of all the parts, however, and also their commingling takes place in the heart, as in a whirlpool or caldron; and likewise in a lesser degree in some veins, in the spleen, pancreas, in the glands and elsewhere. There is thus a perpetual solution and disruption into parts, and the parts that had been separated are again reunited. Hence it is that animal chymistry at the very outset separates in the infundibulum the thicker from the more volatile parts, so that the two shall not coagulate. But these points will now be examined more in detail.

581*b*. *Argument.*—By means of the constriction and expansion of the optic thalami and the corpora albicantia which are situated underneath, the infundibulum is opened and closed in alternate periods. And this is done in a peculiar manner, so that the liquid which is poured into it, shall be expressed through the fibres and ducts of its tube-like body. The spirituous lymph itself, indeed, is expressed into the pituitary gland, and the grosser serosity commingled with the purer lymph secreted from the choroid plexuses, is excreted around it. The infundibulum, consequently, is not only a deferent but also a secretory vessel to the end that the secreted liquids may enter distinctly into the blood. It is different with the brute animals, whose animal spirits are grosser, and in whom there is required a larger amount of nutritive juice.

581*c*. *By means of the constriction and expansion of the optic thalami, the infundibulum is opened and closed:* for it is situated altogether between the heads of these organs, where they are most abundantly provided with grey substance. Whenever, therefore, the grey substance of these bodies is constricted, the cavity which is established between them must needs be drawn apart everywhere throughout its whole compass. On this account also, the third ventricle swells so far as its bottom is concerned; but it does not swell as to its ceiling, as has been shown above. By this procedure the oval aperture [into the infundibulum] is then opened. That cavity which occupies the upper part of the infundibulum, and which is hollowed out between the optic thalami, presently terminates in little tubes, or in a fibrous substance; as soon, indeed, as it emerges from between the optic thalami, and bulges out into the base of the cerebrum like the helmet of a retort; and afterwards it contracts into the shape of a neck. Thus far also the cerebellum seems to extend the force of its action; since the membrane which lines the fourth ventricle, the valve of Vieussens, and consequently the aqueduct of Sylvius, the lateral ventricles and the foramina, seems to be a continuation of the meninx around the peduncles and the vermiform processes of the cerebellum; which membrane in a certain respect is also extended around the straight sinus. This membrane seems at last to be broken up in the infundibulum into little tubes; for there the proper membrane of the cerebrum —the pia mater—begins, which, with its vessels, chiefly engirds the process of the infundibulum [on the outside]. The processus of the infundibulum is also encompassed by vessels from the branches of the basilar artery, which is under the government of the cerebellum; the ampler portion of the infundibulum is engirded by these vessels, as well as by some small branches of the carotid arteries which obey the cerebrum.

581*d. The infundibulum is specially opened and closed through the mediation of the corpora albicantia, which are situated close to it.* This we are permitted to conclude from this circumstance that the optic thalami act everywhere on all the foramina of the ventricles, not only in a general way, but also in a special way, through similar cruriform prominences.

For instance, they act on the anterior foramen—foramen Monroi —through two prominences embedded in their own bodies [tuberculum anterius, *Meynert*]; on the lower or posterior foramen through the corpora quadrigemina; wherefore they also act on the oval foramen or aperture of the infundibulum through the corpora albicantia which are placed underneath: for they must needs be placed there, in order to act on the aperture in the bottom of the third ventricle. This is also confirmed by this fact, that by a certain continuation they have respect to the anterior commissure, and thus to the roots of the fornix, under which is the orifice and cavity of the infundibulum. On this account also the corpora albicantia were called by Santorini the bulbi fornicis, and by Ruysch, the two protuberances of the optic thalami. These ganglions, therefore, seem to act specifically on the above-mentioned orifice scarcely otherwise than the corpora quadrigemina act upon the posterior foramen, namely, by a reflexion of fibres from the stria pinealis; in the present case by fibres proceeding from the anterior commisure or the roots of the fornix. The corpora albicantia seem to exert an influence not only upon the orifice of the infundibulum in the bottom of the third ventricle, but they would seem also to act upon the process of the infundibulum about to be inserted into the pituitary gland. For a production of the pia mater encloses said opening [from without], and this membrane seems to be continued from the corpora albicantia. This also coincides with the action of these bodies; that is, if we grant that they expand and contract with their parent thalami. How these corpora depend upon the optic thalami may be seen on comparing Vieussens' Plates generally with his Plate XII. They are also reported to contain some cineritious substance, and, according to Winslow they are just like the remaining [ganglionic] protuberances; although others declare them to be altogether white and medullary.[1]

[1] The ganglionic character of the corpora albicantia or candicantia is admitted generally by modern science. So MEYNERT says, "The corpus candicans (or mammillare) is a ganglion, which lies in a loop made by the

581*e*. *And this is done in a peculiar manner*, as we are allowed to conclude from the application, position, and figure of the bodies [corpora albicantia] acting upon the infundibulum, and of the membranes by which that organ is constricted. For at first, so long as the optic thalami are constricted, the upper cavity of the infundibulum which is wrought into these bodies is opened, together with its opening into the third ventricle—the corpora albicantia lending their special aid. At the same time the lower, ventricose part of the infundibulum, which is fistulous or medullary, and which protrudes beyond the surface of the cerebrum, is relaxed; and this takes place at the same time when the surface or basis of the cerebrum, and the membrane by which it is invested are loosened. Then also the process of the infundibulum is drawn up, so that the upper portion of the cavity only is open to the inflowing liquid, since the corpora albicantia also relax the upper orifice and the processus. Presently, however, as soon as the grey and cortical substance of the thalami and of the cerebrum expands, the upper cavity of the infundibulum together with the bottom of the third ventricle is closed up or constricted, and its lower part which protrudes beyond the surface of the cerebrum, together with the processus itself is pulled from all sides and drawn tight, and thus swells into a belly. In this state of affairs all the fistulous and fibrous ducts are regularly opened, so that by the pressure resulting from the constriction of the upper cavity of the infundibulum the enclosed liquid is urged into the passages which are now disposed in due order. This mechanism of expansion and elevation is also confirmed by the arteries which engird the infundibulum; for as they decussate, accord-

anterior pillar of the fornix in twisting back upon itself" (Stricker's "Manual of Histology," Americ. edit. p. 689). KOELLIKER gives the following analysis of the corpus mammilare: "The floor of the third ventricle exhibits immediately underneath and behind the anterior commissure very large and also smaller colourless cells with from 1 to 4, partly very thick, productions. These are situated in great numbers in rich plexuses of fine tubules of 0,0004—0,0012,'"and they also occur, though not of the same size, yet of a very similar form, *in the corpus mammillare*, likewise mixed with most numerous, exceedingly fine fibres" ("Handbuch der Gewebelehre," 1852, p. 297).—EDITOR.

ing to the usual rule, they can be expanded only by such a method, and none other. Art does not seem to be able to imitate this disposition by its attempts at injections. For, when either spirit of wine, or a dyed liquid is forcibly injected, it overwhelms and confuses the lower fistulous or medullary texture of the infundibulum which has a spongy appearance; since there is no power co-operating from below which opens all the pores for the reception of the injected liquid. Unless, therefore, art will learn how to emulate nature, all attempts at injection will be fruitless, because they break the connexions, and disturb the order of nature rather than otherwise. For in the whole of the brain an external force is acting, which stretches apart its cavities, on which account only such a liquid can be injected as is homogeneous or congenial, or as is demanded at the other extremity. From this it follows that *the infundibulum expresses the liquid which is poured into it, through the fibres and ducts of its tube-like body;* and that there is a much easier transit through it than is shown by the experiments.

581*f*. *Its spirituous essence and lymph indeed it expresses into the pituitary gland itself*, into which a transit is effected through the process of the infundibulum; the medullary and fibrous substance of which, as we are taught by experience, ramifies through the interior texture of the gland. For the purpose of transmitting such a pure liquid or fluid there must be channels other than such as are pervious also for grosser humours, like water, alcohol dyed of a saffron colour, molten wax, oil, air, or mercury, and a surgical probe; since the spirituous essence itself is of the same character as that which passes through the fibres of the brain, which also do not offer any passage to a grosser humour. Nor is it possible that the pores or openings shall be more visible at one extremity, than at the other, if the conformity of all the parts be acknowledged. The penetration of the spirituous essence into the fibres of the cortex of the brain, and the secretion of the same in the ventricles [through the fimbriæ of the fornix], as well as in the glands of the body, no eye is able ever to perceive; wherefore it cannot be rendered more perceptible during its passage, just as in the present case. If the spirituous essence and lymph should pass through pores which would offer an entrance also to the grosser humours and to dyes—O, what an earthly quality, mixed with fæces, and O, how gross, should we possess! And instead of being animal, and at the same time rational beings, we should become mere stalks, through the fibres of which such viscous phlegms, as are the liquids hitherto used in injections of the infundibulum would scarcely be able to circulate. If, however, we should inject a kind of nervous juice, in this case we would scarcely be able to perceive how much of its more spirituous essence enters the gland itself, and how much is projected exteriorly around the gland. Meanwhile, it is sufficient for us to know that the substance of the process of the infundibulum is medullary, soft, spongy, bibulous, and that it ramifies through the gland itself. The method, however, by which the secretion adverted to above is effected, we shall be able to conceive, if we form to ourselves a distinct idea of the qualities of this essence whereby it is distinguished from grosser fluids. The spirituous essence in question is most liquid; it is the real white blood, capable of expansion and compression, elastic, divisible and most light; wherefore it is separated instanter from the grosser liquid, so soon indeed as an active force is brought to bear on both. The case is the same, as when one and the same force acts upon a highly elastic corpuscle, of an exceedingly small bulk and weight, and at the same time upon another which is heavy, non-elastic, and of greater bulk; when the former will flash off, quicker even than a puff of air, while the latter will receive from the same force a slower determination of motion. If therefore, in the present case we apply the rules which have been observed in respect to elastic and non-elastic bodies, and in respect to such as are lighter and heavier, and of a smaller and larger bulk, so far, indeed, as their propulsion, encounter and impetus is concerned, we shall be able to see the mode of secretion, whereby one is separated from the other by the action of the same force. This also is the reason why the infundibulum terminates in a beak or rostrum, and indeed in accordance with the ratio as to swiftness of the fluid which is acted upon. If therefore the immense celerity of such a fluid be taken into consideration, it is capable of being demonstrated, how immense must be the quantity which flashes across it every moment; and it appears also how such an exceedingly small process is sufficient for all the spirituous liquid, which is expressed in the ventricles from the fibres of the brain. Yet this is simply mentioned in passing, and we are not willing by physiological considerations to disturb anatomical investigations.

581*g*. *And the grosser serosity commingled with the lymph secreted from the choroid plexuses, the infundibulum excretes around the pituitary gland.* This is completly borne out by experience. For according to Vieussens the purer essence of an injection only, not the dye, that is, simply its most subtle particles, make their way upon the upper and lateral portions of the gland, after passing through the infundibulum not quickly, but gradually. According to Ridley, coloured infusions penetrate through the infundibulum only very superficially. In order not to leave any occasion for doubt, that a separation of liquids takes place in the infundibulum in such a manner that the purer fluid enters the pituitary gland, while the grosser humour is determined to its surface, both on the sides, and on the bottom, between the parietes and the gland itself, I wish to refer to M. Littre, who states that a liquid is always noticed around the gland, in which it seems to be bathed. On this subject I shall treat more at large in the chapter on the pituitary gland, for this gland is so placed in its sack, and engirded with pia mater and at the same time with dura mater, that not a single drop of the humour passing down upon its surface is able to ooze out, except through openings established for this purpose, which terminate exclusively in the cavernous sinuses, and in the inferior petrosal sinuses. We therefore see that these liquids are separated in such a manner that the one which is more spirituous penetrates into the interior, while the remainder which is expressed through little pipes seeks the surface. From this it may be concluded with sufficient clearness, that where the beak or process of the infundibulum passes through the pia mater, or where through the intervention of the pia mater it is loosely attached to the dura mater, passages are open through which in the same moment when the beak is expanded from all sides, and when the liquid presses down from the upper part, the grosser serosity mentioned above forces its way. That this takes place then is also declared by Vieussens, where he expresses his opinion concerning this secretion, as may be seen above. This liquid, however, cannot be any other than the grosser serosity commingled with purer lymph from the choroid plexuses; for composed in that manner it flows down from thence. Yet I wish it to be understood that it is the serum which is expressed from healthy and strong choroid plexuses; and not that grosser exudation which is secreted from diseased organs; for this does not seem to be able to enter the pores of the infundibulum, but instead to regurgitate into the third ventricle. The discharge of this infected serum is discussed above.

581*h*. *The infundibulum, consequently, is not only a deferent, but also a secretory vessel*, (chiefly in man, but different in animals), as is the case with most glands of the body, where there are excretory, and at the same time secretory ducts. For unless this mysterious fluid which is compounded in the lateral ventricles by a mixture of liquids, were again to be resolved into its constituent parts, the blood could not be properly supplied with its elements; inasmuch as the choroid plexuses do not always pour forth one and the same liquid, but undergo changes according to the particular states of the brain. Unless, therefore, their exudation were once more separated, congruous things would be incorporated in incongruous ones, so that in the composition of the blood the fluid of one degree would not adjoin itself suitably to the fluid of another degree. It is different with animals, whose brains are not subject to so

[1] See Vol. I., p. 641, no. 529, as well as "Editorial Note III. no. 37, in Vol. I., p. 758.—EDITOR.

many individual changes. This, therefore, is done *to the end, that the secreted liquids may enter distinctly into the blood.* This is the reason why there is no such secreting process of the liquids of the cerebellum, which descend from the fourth ventricle into the nerves of the spinal cord; for the constant regularity of the cerebellum has this effect that only such a serum is there secreted, as mixes most easily, and as is perfectly homogeneous.

581*i*. *It is different, however, with the brute animals whose spirits are grosser, and in whom there is required a larger amount of nutritive juice;* as for instance in horses, in whom the process of the infundibulum, according to Willis, equals the size of a goose-quill; and in calves and sheep, in whom according to Ridley, the injected liquid penetrates as far as the gland, and regurgitates thence. Again, in the dog, in which the cavity of the infundibulum is continued for a short distance into the pituitary gland, and the process rests upon it undivided, except that in some the productions of the beak-shaped pia mater, according to Vieussens, appear in front and behind, or only behind, as is suspected by Ridley; while in man this insertion is effected without any such production. All observations confirm that in brute animals the infundibulum is a vessel which carries the above liquid as far as the gland; and that in the gland itself a secretion takes place; yet as it seems in such a manner, that the purer essence is received in the interiors of the gland, and that a grosser humour is expelled thence towards the sides—whether this takes place around the insertion of the tube, or whether it is effected elsewhere through the pores of the membrane, shall be explained in what follows. Meanwhile, as the animal spirit, as well as the spirituous juice in animals is grosser; and as their brain does not require so sublime a blood as does the human brain, which has to busy itself with reasons, as they therefore do not require a blood which consists of elements of such consummate purity; therefore, the more imperfect and stupid animals do not require such a secretion either in the infundibulum, or in the very threshold which leads to the gland, nor do they require two ganglionic prominences for the government of the orifice, but one. Besides, they require a larger quantity of the fluid, so that in a few years or months they may attain their full growth, while it takes man five times as long to accomplish this—wherefore animals require an increase in their allowance of food in the same proportion. For the same reason also they not only have larger pituitary glands, but they also receive almost the whole of the liquid derived into the ventricles; since no danger results from the fact of this liquid not being so distinctly secreted. Moreover, their choroid plexuses scarcely distil any other serum, than one which easily assimilates itself; without mentioning other arguments which might be adduced. When all these facts are taken into due consideration, conclusions may be drawn from the infundibulum and the pituitary gland themselves, and from their difference in the various animals, as to the physical and physiological state of the animal itself, as for instance as to its vegetation and its arriving at a state of maturity, and as to the quality of the blood and the flesh nourished thereby.

CHAPTER XIX.

THE PITUITARY GLAND.

582. The pituitary gland which is appended to the infundibulum is hidden away in a sinus wrought into the sphenoid bone, and which is called the sella turcica. The whole of that sinus, as is the case with the remaining sinuses of the bones of the cranium, is invested with a production of the dura mater. The gland, resting as it does in this cavity, is a part as it were both of the bottom of the brain, and of the base of the cranium. It is also at one end of the [transverse] axis. The gland equals in size a medium-sized bean, and in shape it is almost spherical. The segment of a smaller sphere grows out of it like an appendage, and occupies the interiors of a recess hollowed out from the bone and adapted to its reception. That portion of the gland is attached to the production and duplicature of the dura mater both in front and in the rear, for this reason that the gland may be able to sustain much weight, even as to suffering itself to be pulled out. As to its remaining surface the pituitary gland is more freely suspended within the walls of the sella, yet so that it almost fills up its space, and may be pressed into a less space. Lastly, in its upper convexity it is joined to the infundibulum. The wall itself under the integument of the dura mater is perforated by vessels which pass through the bony substance. The substance of the body of the gland seems partly of a white, and partly of a reddish colour; that of the appendage, however, does not seem unlike the cortical substance of the cerebrum. Situated at one end of its brain this gland selects in the sphenoid bone a place and sinus, where unembarrassed and in a state of immunity, it may go through the alter-

nate periods of its motion; although under the auspices of the whole brain, and of its membranes. The sphenoid bone serves to the remaining bones of the cranium in the capacity of a basis, fulcrum, tegument and bond; nor could the gland betake itself into any more secure little haven. For thither returns all power, and thither is determined the action of the cerebrum and cerebellum, and also of the bones of the cranium. The sella turcica also, where the gland is situated, is fortified by dams and barriers, so that in every conceivable way levers and weights are brought to bear upon it, yet the gland poises safely in the middle, wherefore there are nowhere any points stronger and firmer than in the central base of this bone. The dura mater approaches the sella from behind, and by ligaments and vessels which extend into its flexible substance it conjoins the gland with the bone; the pia mater also accedes and encompasses the process of the infundibulum.

583. WILLIS.[1]—"The pituitary gland is situated within the sella turcica, which is hollowed out in the middle of the sphenoid bone. It is enclosed there as within an ark, sometimes more closely, sometimes more loosely. For in the dog, the cat, and several other animals it coheres with the infundibulum, and when this is removed, it is pulled out with it; and then its mass is found to consist of two glands, distinct from one another, and easily separable from one another. In the calf, the sheep, the pig, and several others, the gland is everywhere enclosed by the dura mater, except where it admits the infundibulum; and by this integument it is closely contained within the cavity of the bone. Besides, in these animals, its structure seems single and undivided; and in reality it is composed of a substance which is of a twofold kind. This gland is found in all perfect animals; for man, all quadrupeds, nay and even birds and fishes, are furnished with it; whence we conclude that it performs some necessary uses in the brain. Still, as to bulk, its proportion in the various animals does not agree with the size of the head and of the body in which it is; since in the sheep it

[1] "Cerebri Anatome," Cap. IV., XII., XIII.

is larger than in man or in the dog, and in the horse its bulk is smaller than in the ox. The reason of this difference, however, seems to lie chiefly in this, that in some animals it has respect only to the mass of the brain resting upon it, while in others it respects the cerebrum and the carotid arteries which are ascending near it; so that its size, according as it has respect only to one, or to both of these, is larger or smaller. For in some animals the carotid arteries, upon being introduced inside the cranium, are at once dissolved into various retiform plexuses, and from these plexuses several shoots of vessels enter this gland on both sides, and interweave its substance (p. 29) . . . . The carotid artery, in respect to its situation or extension near the pituitary gland, is not circumstanced alike in all; for in man it passes through a bony canal, specially dug out for it, and on both sides it lies stretched out for some distance; and from that trunk several shoots are sometimes sent out towards the pituitary gland, but not always (p. 31) . . . Besides, the fact that this gland into which the duct of the infundibulum is inserted, receives serous humours and dispatches them abroad, seems to appear also from this consideration, that it admits within its pores not only such humours as have been brought down from the cerebrum, but also such as have been secreted from the blood about to ascend into the brain; since in most quadrupeds certain vessels from both carotid arteries are inserted into this gland, and enter most intimately into its substance. A proof of this is, that when ink is injected into either of the trunks of the artery, the rete mirabile, provided it is present, and frequently the interior structure of this gland are stained with a black colour; whence we are authorised to conclude that it is the office of this gland to receive superfluous serosities. These it not only receives on their return into the body after their discharge from the brain; but sometimes it takes possession of them, and derives them from the blood, before this is introduced into the brain . . . In respect, however, to the manner in which the humours which are deposited in this gland, are despatched abroad, it is the common opinion that they are passed down into the palate through the foramina of the bone underneath. Wherefore in those animals which are furnished with the rete mirabile, of which many shoots pass into this gland, several foramina are wrought into the bone underneath. Further, if you remove the fossa of the sphenoid bone, that is, the sella of the gland, by tearing it away from the cranium; and, further, if by pulling off the membrane you expose the foramina, and then pour on water, this water will quickly permeate the compages of the whole bone, and will trickle out suddenly through other foramina which are open in the sides of the bone, and for the most part are absent in the human cranium. But when they are present, as in the calf, we have to take special notice that the foramina are filled by certain hollow vessels; and if a blackened liquor be injected by a syringe or canule, it passes through the compages of the bone, and permeates most other vessels which are below the bone, entering finally into the trunk of the jugular vein . . . But as to the vessels which invest the foramina of the bone, and which are still more numerous under the bone, they seem to be either veins or lympheducts. We may hence infer that these humours, as in the case of most other glands, are restored by the pituitary gland to the mass of the blood. In the calf, this is a matter of autopsy, nor is there any doubt in the case of all other animals furnished with a rete mirabile; for just as arterial branches extend into this gland, so also do venous branches. These latter branches absorb not only the humours which are deposited by the arteries, but in addition also those which have descended from the ventricles of the brain. We may thence conclude that even in the case of man, the horse, and other animals not furnished with the rete mirabile, there are present either lympheducts, or certain vessels of a similar kind, like those which exist in the head of a calf, which most undoubtedly carry off humours from this gland. Traces of such vessels are not so easily discovered, because before the bony bulwarks are broken through, the traces of lympheducts, in case there are any, will have disappeared. Nor are we able, by injections, to discover these vessels in all cases, as we do in the calf; because the foramina of the bone, by which, as through thread-like holes, the injection reaches vessels otherwise hidden from view, are still desiderata [of science] in most species (pp. 78, 79) . . . . As the gland seems to fulfil two kinds of duties, it is furnished with a substance of a twofold nature; namely with one which is red, more loose, and interwoven with sanguineous vessels, and which forms both of its lateral portions; and another substance which is whiter, and situated in the middle, into which the infundibulum is inserted" (p. 88). See also his Plates V. and VII. in the "Cerebri Anatome."

584. VIEUSSENS.[1]—"If all those things which are usually observed on dissecting the pituitary gland are taken into consideration, we declare it to be a whitish-grey body, a little soft, interwoven with blood-vessels, covered on all sides with membranes, and hidden away within its own sella, which is excavated in the middle of the sphenoid bone. . . . If the dura mater where it covers the upper surface of the sella turcica, is cut from the front backwards, if it is separated from the internal processes of the above-mentioned sphenoid bone, and if it is folded back on either side, until the cavities of the cavernous sinuses which are situated near the sides of the sella turcica, are plainly seen,—there is discovered first of all between the anterior portion of the gland and the dura mater which is spread over it, a short duct, which opens into the above-named cavernous sinuses. Hence it is that by the interposition of this duct these sinuses mutually intercommunicate. . . . Lastly, it is discovered that the pituitary gland by means of the intermediate dura mater adheres closely to the anterior and posterior parts of the sella turcica, and is kept suspended in it; so that its lowest part which is most closely embraced by a thick and dense production of the dura mater does not touch at all the bottom of the above-mentioned sella turcica. . . . This glandular body at one time is held more loosely, and at another more tightly within the membranes by which it is covered and which

[1] "Neurographia," etc., Cap. IX.

in the calf, the sheep, and most other animals are much thicker than in man; for in the case of the dog, the cat, and certain other animals, as Willis observed, the gland is torn out when the infundibulum is removed; and then it is perceived that its mass consists of two glands, distinct, and easily separated from each other. In man, however, in the calf, the sheep, and in many other animals, if seized by the part on which the infundibulum first bears, it is found that it is touched everywhere immediately by the membrane whereby it is invested. In animals where there is a rete mirabile, and in those where there are no sinuses in the bone under the sella turcica, the infundibulum is larger than in man, in whom there is no rete mirabile, or at least a very small one, and in whom two ample sinuses, separated by a thin intermediate bone are found hollowed out within the sphenoid bone under the sella turcica. . . . The reason, however, of this difference is chiefly this, that in certain animals this glandular body is irrigated by several shoots of arteries, and consequently secretes a larger quantity of aqueous humour from the arterious blood, than in others. Willis says that the pituitary gland occurs in all perfect animals; and sometimes, he says, it is not irrigated by any arteries. Yet, although I am not prepared to deny, that this sometimes may be the case, since we know that nature often loves to sport, still I nevertheless assert that in man I have always found it furnished with arteries, as well as with veins; and if sometimes it does not appear interwoven with vessels, I maintain that this is unnatural. This gland consequently receives arteries from the carotids, while they are hidden away within the cranium under the dura mater; and veins emerge from it which terminate in the anterior portion of the lateral sinuses, and which open into their cavities. And if any one contests the fact that this gland is furnished with blood-vessels, he may discover its truth by an experiment; namely, by introducing a blackened liquor into either of the carotid trunks; for then he will perceive the interiors and exteriors of this gland, stained very much by the black colour. When I took the gland out of its proper place, I observed very often that it was loosely connected with the membrane with which the middle of the sella turcica is lined, through the intervention sometimes of two, and sometimes of three membranous processes which looked very much like slender vessels. If, after the exterior and interior parts of the pituitary gland have been carefully inspected, the sella turcica is denuded of the dura mater with which it is covered, small foramina are always observed, some in the middle of its basis, and many around its posterior parts, as well as behind it, and also a little below its lateral parts. Some of these foramina are entered by little arteries which convey the blood down into the interiors of the sphenoid bone, and through other foramina little veins pass, which carry the residuum of the same blood either back into the two cavernous sinuses which are situated near the sides of the above-mentioned sella turcica, or into the two lower sinuses [of the sphenoid bone] which are adjacent. . . . The foramina which we have just described, and which are larger and more numerous in animals which have a rete mirabile, than in those where it is either very small, or wanting altogether, are mostly obliterated when the skull is dried; which, no doubt, is the reason why the skilful Lower declared that they are never found in the human soul. Between the anterior part of the pituitary gland, and the dura mater which is spread over it, we said a short duct is found, which admits some portion of the aqueous or lymphatic humour which showers down from the cerebrum through the infundibulum. This humour it discharges into the two cavernous sinuses which are along the sides of the sella turcica" (p.p. 51-53).

585. RIDLEY.[1]—"The pituitary gland is seated in, and fills up in a manner, all that space contained within the sella turcica, vessels only excepted. It is covered on all sides with pia mater and dura mater, except that part on its upper surface, in which there is a little round foramen, by which the infundibulum descends obliquely into it. This foramen at its entrance

[1] "Anatomy of the Brain," Chap. IX.

is surrounded by a production of the pia mater, for its firmer connection with the infundibulum. But as regards the dura mater, that membrane encompasses the gland after a far different manner than has been described by Vieussens, in his failing to suspend it in man as he does it in animals, so as to prevent its touching the bottom of the sella. For in animals the rete mirabile is not only situated on each side of this gland, but it runs quite under its posterior part, whereby one side of the rete communicates with the other, with which disposition of this part Vieussens was altogether unacquainted; whereas in man, because there is not that kind of structure in the one, that is, in the rete, it is not necessary it should be required in the other, that is, in the gland. However, neither in the one nor in the other is Vieussens' reason which he gives for nature's contrivance of this matter, of any weight; seeing that neither the rete mirabile, much less the few small veins belonging to the bone beneath, could possibly in any way be compressed by this gland, though superincumbent; because it is so firmly knit to the dura mater, which lies above and is supported by the two anterior and posterior processes of the sella turcica, in such a manner indeed as is sufficient to sustain and keep from pressing upon any subjacent part ten times a greater weight than that of the pituitary gland. Moreover, the dura mater is so far from suspending the gland from the sella turcica, that that membrane, together with the gland, is fixed to that very bone itself. The substance of this gland is very different from that of all the rest. In respect to its consistence it is indeed similar to most glands of the conglobate kind unless it is somewhat harder; but on being pressed or squeezed it emits much more water that any of the other glands. As regards the conglomerate kind of glands it does not bear the least resemblance to any of them, (pp. 71-73). . . . When the greatest force is applied in compressing and squeezing it between the fingers, it is found impossible to force out the least appearance of humidity through its enclosure or integuments (p. 75). . . . I am not so fond of guessing as to say that the pituitary gland has any ducts, and consequently all I can say is, that I look upon the infundibulum as no more than a large lympheduct variously ramified through the pituitary gland, which discharges its liquor through those many small branches into the veins dispersed through that part, to be taken back to the blood again, as this is done in all other secretory glands. And that which seems most to favour this conjecture, is the extraordinary humidity of this gland, especially in animals, above the rest of the glands in the whole body; [as serving not only to export the lymph separated from several arteries which are dispersed through it; but that also with which it is charged from the brain itself]. And to this twofold manner or double office of secretion is owing the fact of its apparently consisting of two distinct substances; the one being accommodated to that part of the lymph which comes from the brain, and which therefore is whitish; and the other to that separated immediately out of the blood, and is therefore reddish" (pp. 80-81).

586*a*. WINSLOW.[1]—"The pituitary gland is a small spongy body lodged in the sella turcica between the folds of the dura mater. It is of a peculiar kind of substance which is neither medullary nor glandular. On the outside it is partly greyish, and partly reddish, and white within. It is transversely oval or oblong, and on the lower part in some subjects it is divided by a small notch into two lobes, like a kidney-bean. It is covered with pia mater as by a bag, the opening of which is the extremity of the infundibulum, and it is surrounded by small circular sinuses which communicate with the cavernous sinuses" (Sect. X., no. 91).

586*b*. HEISTER.[2]—"The pituitary gland is a small gland situated in the sella turcica, within the duplicature of the dura mater, in which there is some cavity; it is engirded with dura mater and held suspended; and likewise by a thin membrane, like pia mater; both of which are penetrated by the infundibulum. Its size and shape are nearly those of a common

[1] "Anatomical Exposition," Section X.

[2] "Compendium Anatomicum." Amsterdam, 1748.

kidney-bean; but it has an appendage in its posterior part. It is usually larger in quadrupeds than in man. Its substance is glandular; its colour, a pale whitish red; it is usually considerably hard and firm, but somewhat softer, and of a greyish colour in the appendage. It has arteries from the carotids; its veins run to the neighbouring sinuses. Its nerves are from the fifth pair. Its excretory duct is perhaps the infundibulum; for there does not appear to be any other. The use generally attributed to this gland is that of absorbing the pituita of the ventricles, and afterwards discharging it. But there does not seem a sufficient foundation for this supposition; since the proper office of a gland is to secrete a fluid, not to receive one already secreted, and because a simple canal would have answered sufficiently to such a purpose, and the apparatus of a gland would have been therefore unnecessary; and, lastly, because its substance is so hard and firm, as to render it very improper for such a use" (Part I., no. 273, p. 139).

587. LITTRE.[1]—"The pituitary gland is placed in the cranium itself, being insculptured so to say in its base which is commonly called the sella turcica. When the dura mater reaches the edges of this cavity, it is divided into two laminæ, one of which, the lower one, invests the bottom of the cavity, and within its own thickness, along the middle of that cavity, it forms a little fossa in which there is a sinus five lines long, and one line broad, the sides of which are perforated by several holes, through some of which it communicates with another sinus which is situated near the clinoid process. The upper lamina of the dura mater, however, covers altogether the cavity of the sella turcica, except its middle portion, where it is penetrated by a round hole about a line in diameter. This lamina in the edges of the sella is thick, opaque and a little elevated, and strongly attached to the clinoid processes; in the whole of its remaining

[1] Histoire Academiæ Regiæ, 1707; Mémoire "de glandula pituitaria, sinu circulari eam ambeunte, cujus sanguis eam adluit." It is also printed in Manget's Theatrum Anatomicum, Vol. II., pp. 307, 308, whence our author seems to have extracted it.

area, however, it is found thin, transparent, and, as it were, agglutinated to the upper part of the pituitary gland. In the thickness of this upper lamina there is noticed besides a little sinus of an oval shape which engirds the whole gland. By the upper or superior lamina of the dura mater, however, which has just been mentioned, and to which the pituitary gland is agglutinated, this gland is so suspended in the sella turcica that it does not touch its bottom at all, and that a thin probe may easily be passed between it and the lamina covering the bottom from one side to the other; nevertheless, it coheres with the bottom and the sides by arterial and nervous filaments, the intervals between which are so filled up with a thin and palish blood, that the body of the gland is found bathed in that liquid. From one side to the other, or from right to left, this gland has an extent of six to seven lines; from front to rear it fills with its body four lines, and from the top to the bottom two lines. It is invested with a very thin membrane of its own, but of a closer texture, in the upper surface of which there is found a little foramen which is immediately below the above-mentioned foramen of the superincumbent dura mater. This same gland is provided with some fleshy fibres and innumerable little branches of nerves, arteries and veins. These nerves belong to the sixth pair, and to the anterior branch of the fifth pair; the arteries are derived from the internal carotids, and indeed from the rete mirabile of Galen; the veins, however, pass into the oval and into the transverse sinuses which have been pointed out above. The gland is composed of two parts, the substance of each of which is widely different from that of the other; for one part is of a cineritious colour, but the other appears much more ruddy. The cineritious part of the gland constitutes about one-third of its mass; it is soft, convex, and composed of many little vesicles filled with a white liquid; it is situated behind in a little fossa formed there by the membrane which invests the bone; to this it is firmly attached, and by its insinuation it is not a little separated from the other ruddier part. That other ruddier part throughout the whole of its upper portion is a little compressed; but over the whole remaining surface it is convex. Its texture is more compact, and it is strewed over by smaller vesicles than are observed in the cineritious part, and in these there is collected a humour which is much whiter and more attenuated. Between the two portions of the gland, where they are united, there is found a common cavity about a line and a half in diameter, in which a number of little foramina are observed, the largest and most conspicuous of which belongs to the cineritious portion." From the structure of the gland, and by some experiments which he instituted, the author of this most exact description concludes that the pituitary gland secretes a certain very subtle and volatile juice from the arteries of the rete mirabile or from the branches of the carotids with which it is supplied, by which the sluggish moisture brought down into it from the ventricles of the cerebrum through the infundibulum is diluted, and that thence through the jugular veins into which this juice is conveyed out of the lower sinuses, whither it has arrived from the sella turcica, the heart itself may be rendered more fit to continue its motions. But the fact that the humour which descends out of the ventricles of the cerebrum is duly carried from the infundibulum into the body of the gland, the author considers thoroughly demonstrated by this fact, that when spirit of wine is sent from the ventricles into the infundibulum, the cineritious part of the gland is forthwith distended thereby.

588. BIANCHI.[1]—"After the dura mater at the base of the cerebrum has invested closely and immediately the whole of the sella turcica and its sides, at a certain distance from these sides, or from the lowest part of the sphenoid bone which is about five or six lines remote from the top of the sella, it dispatches on both sides a new production towards the summit of the sella, and carries it obliquely down to the same sella and the pituitary gland which is seated upon it, covering both loosely. At the same time another production

[1] Demonstratio Anatomica F. M. Nigrisolio conscripta, 1715. In Manget's Theatrum Anatomicum, Vol. II, pp. 342-349.

of the same dura mater ascending from the region of the sphenoid bone back of the sella, and about a line removed from the base of the posterior part of the sella, and indeed rising above the sella and the pituitary gland reposing in it,—is conjoined with the two above-mentioned productions. Being thus joined above the afore-mentioned gland, and coming up from both sides, and in addition from behind, these productions of the dura mater form a species of bag or sack, in which the entire sella with its four processes, and the whole pituitary gland are embraced in all freedom and hidden away; and on account of the considerable distance of the origin of the lateral processes from the sides of the sella, there is a certain large lateral cavity—the cavernous sinus—left on either side between these productions and the sella. On account of the lesser distance of the origin of the posterior production from the back of the sella, there is also left posteriorly a smaller cavity between the sella and that posterior production; and from the meeting of these three productions almost at right angles, and no less from the general square shape of the whole body of the sella, their entire communication and their extension laterally and behind is well represented by an inverted Greek capital Π. For the lateral cavities [cavernous sinuses] have no communication between them in the anterior portion of the sella. . . . Above the anterior processes of the sella turcica the dura mater is not doubled, but simple; in fact, if this membrane is only very lightly abrased, the cavity or the open mouth underneath is at once laid bare; . . . on which account also there is no communication here between the lateral parts of the sella. At the back of the gland, however, no space is found between the dura and pia maters, even as there is no pia mater there. Nor indeed is there laterally near the sella any interval left between it and the gland; since between the carotid and the gland there is absolutely no space left at all. . . . Finally, where the dura mater at the sides of the pituitary gland covers the cavernous sinuses, it is most thin, and just as little, as near the anterior part of the sella, is it at all doubled here, and when it is only very slightly cut, it at once opens an access to the cavernous sinuses (pp. 343, 344). . . . I shall explain in my dissertation the use of the celebrated pituitary gland which reposes immediately on the sella turcica, and occupies the whole of it; further, its spongy composition which is loose and most delicate, and therefore at the slightest pressure of the fingers affords on all points of its surface, almost as from so many excretory mouths, an easy issue to the liquids contained within it; again, the simplicity of its substance which is not organized of a white and reddish portion, as Ridley will have it, for the purpose of distilling a twofold secretion; in addition, its intercourse with the ventricles of the cerebrum, and the bag-like lateral cavities—cavernous sinuses;—further, the manner in which it receives fluids from the same ventricles of the cerebrum, and emits them into the cavernous sinuses; and especially the use of the adjacent carotid which has respect to the pressure of the sides of the gland by its constant pulsations. The fact that this gland, in the middle of the bag or sack and also in front, is firmly and immediately attached to these portions of the lateral productions of the dura mater which are conjoined as for a support, with the anterior face of the sella, causes the afore-mentioned cavernous sinuses not only to be disjoined from one another by the interposition of the gland itself, but it has also this effect that these sinuses have no intercourse with one another in the top of the sack, and in addition, none, or at least only a very obscure one, near the anterior portion of the bag, or between the pituitary gland and the anterior face of the sella; although in the posterior parts of the sella they enjoy a twofold intercourse with one another, namely, *first,* between the gland and the anterior face of the back of the sella, or of the clinoid processes, since at this point the gland is not immediately connected with its osseous receptacle; and *secondly,* between the posterior face of the posterior clinoid processes of the sella and the production of the dura mater; and indeed, for this purpose, that in the posterior parts of the sella the cavernous sinuses may communicate to one another the humours which they receive from the gland and the blood-vessels, and that they may gather them together reciprocally not only between the gland and the sella, but also between the hinder part of the sella and the production of the dura mater (p. 346, L). . . . In the hinder part of the sella turcica there is a certain double, osseous eminence, with a certain concavity between them which is produced towards the middle and upper part of sphenoid bone, not unlike the sella turcica itself. This eminence is moreover situated in the centre of the sack, and it lies under the pituitary gland, and indeed under its middle and principal concave portion. The sella turcica, besides, is not only constituted by the posterior and middle portion just mentioned, but also by the other anterior portion. The anterior and posterior parts of this sella are square, wherefore the anatomists call the apices on the pointed extremities of both parts the clinoid processes; . . . nor are the anterior and posterior parts of this sella only square, but the whole sella rising up from both parts and from the middle forms a square body. Hence the cavities of the sack which are free from the parts here mentioned, and which surround laterally and posteriorly the same sella, with the pituitary gland resting within, likewise preserve the same square form (p. 346, m). . . . The anterior part of the sella is not raised so high above the base, as the posterior part; therefore also its pointed extremities are not so high as the extremities of the other part, which will be treated of presently (p. 346, n). . . The posterior clinoid processes are formed of two distinct bones; namely, below they are formed of a more solid bone, on which is placed a more tender and more spongy epiphysis; both also are tied together and are covered by strong ligamentous membranes. The epiphysis again is easily separated into distinct parts; nay sometimes even into three (p. 347, r. r). . . The heads, that is, the epiphyses of the posterior clinoid processes, are elongated laterally, and in addition are a little inflected below. They emit thence obliquely downwards a certain robust, ligamentous production, which descending on both sides to the margin of the petrous process, and being connected with it, leaves on that account underneath itself a considerable intercalary space, between the body of the above-mentioned clinoid process and the apex of the petrous process, and which communicates immediately with the cavernous sinuses. Through this space the sixth pair of nerves comes into these sinuses, and the shorter and larger basilar sinus [the inferior petrosal sinus] departs from those sinuses towards the internal jugular veins (p. 347, s. s.). . . The smaller and longer sinus [the superior petrosal sinus] derives its immediate origin on both sides from the cavernous sinuses, almost under the angle, which arises from the meeting of the productions of the dura mater; wherefore in respect to its origin it may be called the sinus of the posterior angle of the sack (p. 347, 8, 8). . . . The larger and shorter sinus [the inferior petrosal sinus] derives also its immediate beginning on both sides from the cavernous sinuses, exactly under the crura of the posterior clinoid processes of the sella turcica; it may be called the sinus of the crura of the sella" (p. 347, 9, 9). Consult, however, by all means his plate in Manget's Theatrum Anatomicum [Vol. I., p. 342, Tabula V. *extra ordinem*].

589. MORGAGNI.[1]—"In stating those points which he intends to explain in connection with the pituitary gland, Bianchi says, that 'at the slightest pressure of the fingers it affords on all points of its surface, almost as from so many excretory mouths, an easy issue to the liquids contained within it.' To this I have to observe that I have never yet succeeded, unless perchance the covering of the gland was injured, to witness this; even when I increased the pressure of the fingers to such a point, that at last a portion of its very substance oozed out through the stem of the annexed infundibulum in the form of a white liquid. I am aware that Vieussens already declared that the humour of this gland 'passed through the very loose membrane with which it is covered, and descended into the

[1] "Adversaria VI." Lugduni Batavorum, 1740.

two receptacles placed near the sella turcica;' still this is opposed by other distinguished men, such as Brunner, Littre, Ridley; the latter opposing this idea at great length, and distinctly asserting the same thing, which I do here . . . Moreover I have clearly seen that this gland consists of two substances; for its posterior part, and its appendage so to say, which is an excresence as it were of the gland itself in the form of a segment of a lesser sphere, and which is not forgotten in Vieussens' Plate IV. This part I say is in reality cineritious and softer; while the rest was found to consist of a harder substance either entirely, or in part whiter, or else of a reddish white colour (Animadv. xxv. pp. 31, 32) . . . Again Bianchi says, 'the pituitary gland is embraced in all freedom in a kind of sack of the dura mater;' and further, as stated by others, he also acknowledges 'the immediate and close connection of the gland with the vault or superior part of the same sack.' A little before, however, he states that this gland 'reposes immediately on the sella turcica and fills it up entirely;' and presently again he declares what others, and among them Littre, have taught, namely, that between the gland and the sella some interval was left by which there is a communication with the receptacles. I wonder, however, at the language in which Bianchi does this; for he says, 'between the gland and the anterior face of the posterior clinoid processes, the gland is not immediately connected with its osseous receptacle.' I am, indeed, more and more inclined to believe that he has not observed that part of the gland which I have just above called its appendage. For if he had known the double substance of the gland, he would have seen the close connection of the appendage (which has also been pointed out by Littre) with the anterior face of the posterior wall of the sella; the result of which cohesion is, that although between the posterior base of the gland, and the lowest part of the sella, and between the part of the wall mentioned above, there is some space left by which the receptacles communicate with one another, still that communication does not by any means take place there, where you ascend a little from that lowest part to the back of the sella; for so far from the gland 'at that place not being immediately connected with its osseous receptacle,' its convex appendage—the posterior lobe—reaches into the concave surface of that receptacle, in the middle of which for this very purpose, there is also not unfrequently a kind of semi-spherical excavation, corresponding altogether to the posterior lobe, and receiving the same. If we state that this appendage consists of a softer substance, it will not be difficult to form a conjecture why it is placed by nature in this kind of an excavation, or at least in this concavity in the posterior wall of the sella, especially since the learned Brunner writes that this part of the gland, especially on account of its being softer, 'is concealed under the posterior part of the sella which is sinuous, and indeed for this purpose, lest it might be compressed by the superincumbent mass of the brain, and that it may not be urged into any other direction, or be injured" (Animadversio xxvi. pp. 32, 33). In his Plate I. fig. 4, in Part VI. of his "Adversaria," Morgagni exhibits the posterior part of the sella turcica seen from the front, together with the pituitary gland which is torn out thence, both being enlarged; the figure of the appendage, and its situation in the concavity of the sella turcica are there very vividly represented. Consult also Eustachius' Plate XX., figures 14 and 16; and read the dissertations of Littre [see above], and Brunner.[1]

[1] The title of Brunner's dissertation is as follows: *De Glandula Pituitaria. Dissertatio*, Heidelberg 1688, 4to. Haller in his Bibliotheca Anatomica gives the following abstract of it. "He rightly describes it as double; its front part as more ruddy; its back part as white and softer. He says that its posterior part is inflated by the infundibulum; that animals with the head erect have no rete mirabile; that the pituitary gland of the horse is larger; that the pituitary gland belongs to the conglobate class, that the lymph of the cerebrum is discharged by it, and moves by inconspicuous lymphatic vessels towards the veins. He also points out the circular sinus."—Editor.

The Production of the Dura Mater towards the Cavernous Sinuses and the Pituitary Gland.

590. For the purpose of forming the vaults of the cavernous sinuses and the sella, the dura mater is not only doubled in this basilar region of the cranium, but through the tentorium it also descends between the cerebrum and the cerebellum, so as to concentrate itself in the other extremity of the axis. When the tentorium reaches the petrous portion of the temporal bones, almost near the seventh pair of the cranial nerves, it is attached to and implanted in, the dura mater of that region, and by a moderate arch is continued from one foramen of that pair to the other, passing over the sphenoid bone; thence stretching out somewhat it extends straightway upwards, and attaches itself to the posterior side of the sella turcica, and thence it climbs over the pituitary gland, and while applying itself to it, along the anterior and more depressed part of the gland it is at once inrooted in the dura mater below, under the foramina of the optic nerves. This same posterior production, between the above-named nerves, sends out a similar process on both sides, almost at a right angle. This process extends to the sides of the same sella, and attaches itself to the former process —to that near its anterior part. Thence it is, that a kind of ceiling spreads over the more depressed portion of the sphenoid bone, which subsides in the form of valley, and that the receptacles of the sella turcica, or the cavernous sinuses, are formed wherein are enclosed the carotid arteries, after they have just entered into the cranial cavities, and likewise several nerves which are about to leave the cranium. Hereby is also seen how the lower part in the posterior portion of the sella is covered by the expansion of the transverse production, so that the posterior cavernous receptacles or sinuses are thereby formed. The above-mentioned transverse production sends out also in an oblique direction some other ligamentous processes down into the declivitous middle plane of the sella, following the direction

of the posterior clinoid processes, so that the lateral portions of the cavernous receptacles are separated from that which is behind. The dura mater, however, of the base of the cranium itself runs together, as it were, from four quarters, for the purpose of constructing the bottom or the floor of the sella itself and also of the cavernous sinuses; it runs down from the upper region of the frontal bone around the optic foramina, and above the anterior clinoid processes; from the lower region, or from that of the occipital bone, over the middle of the sphenoid bone; and from the two lateral regions, or from the region of the petrous portions of the temporal bones, and the "upper wings" of the sphenoid bone, through the bottom of the cavernous sinuses. In this wise the dura mater of the whole cerebrum meets together from every corner for the purpose of forming the couch aud resting-place of the noble gland there where is its own proper termination, and also the common termination of all the organs of the brain. It is hence sufficiently plain, that thither also aim all the above-mentioned organs from the ventricles.

The Sphenoid Bone.

591. The sphenoid, basilar, or wedge-shaped bone, also called the winged and multiform bone, binds, as it were together, the bones of the whole cranium. It is also multiform; but in its apparent irregularity it is most regular, when regarded in respect to its offices of transmitting nerves and arteries, and of connecting together the last processes of the bones; further, of constructing a chamber for the pituitary gland and the cavernous sinuses, of serving as a bottom for the cerebrum and the medulla oblongata, and as a ceiling for the sphenoidal sinuses, the nose and palate. Interiorly and anteriorly it is articulated with the frontal and ethmoid bones, the vomer and malar bones, the two bones of the palate and the zygomatic processes; laterally by the wings sent out upwards in an oblique direction with

the two large parietal bones, the orbits and the temporal bones, posteriorly, however, with the petrous portions of the temporals; and lastly with the occipital bone. The centre of gravity of the whole of this bone, and consequently of all the bones of the cranium, is the sella turcica, or the bosom and couch of the pituitary gland. This sella is encompassed with walls slightly concave, which are also in their centre fitted for the reception of the appendage of the gland. Upwards on both sides, two processes are insinuated from the frontal bone, called the anterior clinoid processes, which are inserted in the base of the sphenoid bone. These processes with their apices tend towards the centre, and enclose two holes for the nerves of the eye connected by an open groove, which is strengthened by a bony elevation [olivary process or eminence]. The holes which have just been mentioned, or the optic foramina derive their walls and septum from the frontal bone, but their lower portion from the sphenoid bone; for both bones thus slide in an oblique direction into one another. To these processes correspond two lower ones called the posterior clinoid processes which are like the apices or angles of a certain dam, which being continued below, is attached to the occipital bone. Meanwhile these clinoid processes become sharper in their inclination forwards, yet having respect to the same centre of gravity. These processes are the props, walls and termini of the receptacles of the sella—the cavernous sinuses—which being encompassed and invested by the dura mater, receive in their cavity, as in marine docks, the carotids and several nerves; and in the middle lies enclosed the pituitary gland. At the side of this dam or rampart the carotids pass out, and they at once enter into the porch formed by the cavernous sinuses at the sides of the middle portion of the sella, towards which they incline. Under the bottom of both these sinuses are two caverns, called the sphenoidal sinuses, which are invested with a general, thinner mucous membrane, and irrigated by little arteries which pass through them, and which are conveyed thither from other parts. The anterior clinoid processes let themselves down obliquely, for the purpose of forming the walls of the same; and after making an almost oval circuit they conjoin themselves with the dam of the posterior clinoid processes before the carotid foramina. From the septum between the carotid foramina under the sella turcica, a wall or lamellated septum [septum sphenoidale] runs out which has its termination in the middle of that dam, and separates the sphenoidal sinuses from one another. Nature, however, as everywhere else, so also in hollowing out and constructing these sinuses, delights in variety. Sometimes it erects this intermediate lamellated septum higher up in the left cavern, and thus enlarges the right; and at another time there is an opening in it conjoining the two; sometimes it removes the septum altogether, and makes one out of the two cavities; sometimes even it fills up the whole with a spongy bone, so that there is no continuous cavity under the cavernous sinuses. In infants these cavities are not yet open; in older subjects they coalesce. In those subjects where the cranium is thick, and the frontal bone does not swell out; and where the frontal sinuses are missing, and the frontal bone is divided by a suture, according to Riolanus, the sphenoidal sinuses do not exist. These sinuses, where they are deeper, near the middle septum, have two openings towards the upper part of the conchæ narium [*i.e.* the turbinated portion of the ethmoid bone], so as to communicate with the turbinated or spongy bones, and with the cavities of the palate.

[MODERN AUTHORS.

591*a*. FREY.[1]—"The pituitary body, or hypophysis cerebri, was formerly supposed to be a glandular structure, but was subsequently classed among the nervous organs. Present in all five classes of vertebrata, but smallest in man and the mammalia, it consists in the latter of two portions or lobes.

[1] Frey (Heinrich). "The Histology and Histochemy of Man," translated from 4th German edition by Arthur E. J. Barker, and revised by the Author. London 1874.

In the smaller 'posterior part,' which is greyish in colour, we meet in a connective-tissue substratum with fine isolated nerve tubes, cells resembling ganglion-corpuscles, a quantity of sustentacular connective-tissue, with fusiform cells and blood-vessels, but no glandular elements. The 'anterior lobe,' much larger and redder, has by no means the same structure. It is traversed by a canal, according to *Peremeschko*,[1] and, as was found many years ago, by *Ecker*, it possesses great similarity with the so-called blood-vascular glands [*i.e.* ductless or vascular glands]. Here we encounter within a connective-tissue framework very richly supplied with blood-vessels, round or oval glandular cavities, measuring in man and among mammalia 0.0496-0.0699mm. These are occupied by cells of about 0.0140mm. in diameter, with tolerably large and finely granular bodies. Here also we find, according to *Ecker* and *Peremeschko*, a colloid metamorphosis of the cell, like that which takes place in the thyroid gland. The canal, whose form is very various in different animals, is lined among the latter with flattened cells, which in man are ciliated. It is continuous with the cavity of the infundibulum. Behind the canal the tissue assumes a somewhat different character. Here we remark besides a finely granular mass and free nuclei, cells whose bodies seem poor in granular substance. Colloid vesicles are also to be found there; the framework is formed of a somewhat more highly developed connective-tissue than elsewhere. —The pituitary body is richly supplied with interlacing capillaries, 0.0050mm. in diameter, the anterior portion being most vascular (*Peremeschko*)" (p. 446, § 238).

519*b*.[2] QUAIN.—"The general nature of the pituitary gland or hypophysis cerebri, in its joint connection with the infundibulum of the brain on the one hand, and a diverticulum of the alimentary canal on the other, was first pointed out by *Rathke* (Müller's Archiv., 1838, p. 482), although he afterwards aban-

[1] *Peremeschko's*, and also *Sapolini's*, accounts of the central canal of the hypophysis will be found in the Appendix, in Note vi. no. 17.—EDITOR.

[2] Quain's "Elements of Anatomy. Eighth Edition. London 1876.

doned the view there set forth. It was, however, fully confirmed by others; and among recent observers, we owe more especially to *Wilhelm Müller* an elaborate investigation of the whole subject (Jenaische Zeitschr.; vol. vi., 1871), who traced most carefully the nervous and diverticular elements in their development, and their union with mesoblastic elements in the formation of the gland. *Goette* next ascertained that the diverticulum from below is connected with the buccal cavity and epiblast, and not with the pharynx and hypoblast, as was previously supposed (Archiv für Mikroscop. Anat., vol. ix., p. 397). The observations of Mihalkovics on Mammals complete the history of this point in development, and will be mainly employed in the following description.

"The formation of this body may be shortly described as consisting in the meeting and combination of two outgrowths from very different fundamental parts; one cerebral or medullary from above, and the other corneous or epiblastic (glandular), from below in a recess of the cranial basis which afterwards becomes the pituitary fossa. The cerebral outgrowth, the posterior of the two parts, takes place by the formation of a pointed projection downwards of a portion of the lower medullary wall of the vesicle of the third ventricle, and its firm adhesion to the base of the cranium. This is the commencement of the infundibulum. Meanwhile a little in front of the same place, there is projected upwards from below a part of the basilar surface of the cranium, so as to form a deep recess lined by the corneous layer from the back and upper part of the future mouth. This recess is the commencement of the hypophysis or pituitary body in its glandular portion. . . . The flask-like outgrowth of the buccal epiblast which gives rise to the hypophysis cerebri, is now gradually shut off from the corneous layer and cavity of the mouth, first by constriction, and subsequently by the closure of its place of communication. There remains, however, for a considerable time a longish thread of union between the two. The epithelium of the enclosed portion subsequently undergoes development into glandular cœca and cell-cords, and its internal cavity becomes gradually obliterated. This forms the anterior part or lobe of the pituitary body. The posterior part owes its origin to the combination with mesoblastic tissue of a widened extension of the infundibular process of the brain, which is thrust in between the sac of the pituitary body and the dorsum sellæ. The nervous structure of this posterior lobe afterwards disappears in the higher animals, but in the lower it retains its place as a part of the brain" (vol II. pp. 735-737).[1]

519*c*. EKKER.[2]—"The pituitary gland surpasses all parts of the brain and spinal cord, not only in the size and immense number of blood-vessels, but also in the size of their diameter. The vessels pass into the gland chiefly out of the infundibulum, and from the middle they are directed into both lobes. Other central vessels pass into the gland, especially towards its circumference. The formation of an extremely dense net happens in this wise, that the single larger vessels wind themselves in a serpentine manner, and communicate with one another by simple anastomoses; only a few finer vessels are here observed. This peculiar net is by no means confined to the gland, but it begins already in the infundibulum, for several larger vessels of the pia matter pass around the inner side of the optic tract in the neighbourhood of the chiasma. There larger vessels which produce several branches run in a parallel direction towards the infundibulum into which they despatch several tortuous little branches. The lumen of several of the larger vessels amounts to 0.234mm.; the vein in the neighbourhood of the infundibulum in its diameter measured 0.31mm., the capillaries in the infundibulum 0.038mm. In the gland itself the diameter varied between 0.0204mm. and 0.0255mm.; fine vessels with a diameter of 0.0013mm. were

[1] Additional particulars concerning the formation of the anterior and posterior lobes of the pituitary gland, furnished by *Mihalkovics*, will be found in the Appendix, Note vi. no. 4.—EDITOR.

[2] Ekker (E. H.). "De cerebri et medullæ spinalis systemate vasorum capillarum." Dissertat. anatom. inaugural. Utrecht, 1853.—See also, "Schmidt's Jahrbücher," etc. Vol. lxxxix. p. 151.

rare, but a few larger vessels had a diameter of 0.112mm. The capillaries of the pituitary gland, therefore, are more than five or six times larger in their diameter than those of the brain. The gland seems to derive also a few vessels from the integument of the sella turcica, and a few capillaries from the carotid."[1]

519*d*. MIHALKOVICS.[2]—"The 'anterior lobe' of the hypophysis is an oblong body, lying in an almost horizontal position, which sends off a narrow production in front towards the chiasma of the optic nerves. The lower surface of the gland is convex; its upper surface from right towards left is concave, and in the depression thus formed the process of the infundibulum is inserted. That portion of the pituitary gland which is situated in front of its central canal, as well as the production of the gland towards the [front of the] infundibulum, consists of blind epithelial ducts, 0.018-0.03mm. in diameter. These blind ducts on the outside are enclosed by a fine membrana propria, and interiorly they consist of small roundish and polygonal epithelial cells (4-5 μ). Horizontal sections of these ducts exhibit those cells arranged in the form of rays, although here and there a narrow lumen may be discovered in the centre. Between these blind ducts there is a scanty supply of connective tissue with an abundance of vessels, whereby the ducts are entwined in the manner of wicker work.[3] That production of the gland, which ascends and embraces the process of the infundibulum, in a central direction consists of cylindrical epithelia, while its external portion is composed of roundish and polygonal cells furnished with short productions. These cells have entered into such an intimate conjunction with the homogeneous substance of the process of the infundibulum that

[1] A more detailed account of the arterial and venous vessels of the pituitary gland, as given by Wilhelm Müller, Luschka, and especially Sapolini, is contained in the Appendix, Note vi., nos. 8 and 9.—EDITOR.

[2] Mihalkovics (Prof. V. von). "Entwickelungsgeschichte des Gehirns," etc. Leipzig, 1877, 4to.

[3] For further particulars concerning the organization of the anterior lobe, see *Peremeschko* in Appendix, Note vi., no. 22.—EDITOR.

the sharp border between the posterior wall of the buccal projection—the anterior lobe of the gland—and the process of the infundibulum has been wiped out. . . . In the lowest part of the infundibular process, sections of ample lymphatic vessels are also visible" (p. 88).

519*e*. LUSCHKA.[1]—"The fundamental substance of the posterior lobe of the pituitary gland appears to be a certain molecular mass, differing in quantity in different places, which mass is composed of immeasurably minute elements, and also of some which are a little bigger. Said mass seems to be a kind of cement by which other formations of various kinds are kept in connection. Among these there are undoubtedly *nervous* elements, but they are very few in number. They coincide with those elements which are noticed in the brain, but they are very much inclined to become varicose, and to break up generally. These elements consist mostly of fine nerve-tubes, which are found isolated, and, in a certain sense, forced apart, and they are met with chiefly in the circumference of the posterior lobe. These elements, as a matter of course, are conveyed into the pituitary gland by the infundibulum. . . . Notwithstanding the small quantity of nervous tubes in the gland, at the edges of mikroscopical objects taken from the posterior lobe, by the addition of water and other re-agents, there are discovered numberless drops and streaks of *myelin*—a medullary substance—presenting all sorts of forms. . . . Not all observers who have devoted themselves to the examination of the matters under consideration have succeeded in finding nervous tubes in the posterior lobe; especially *Hannover*[2] was not able to discover them—he says, 'I have not been able to discover cerebral fibres in any part of the gland;' while *Ecker* demonstrated their existence by the mikroscope. Thus far I have not been able to discover in the posterior lobe of the hypophysis of

[1] Luschka (H. v.). "Der Hirnanhang und die Steissdrüse des Menschen." Berlin, 1860, 4to.

[2] Hannover (A.). "Recherches mikroskopiques sur le système nerveux." Copenhagen, 1844, 4to.

adults formations which indubitably might have been claimed as ganglionic cells, although, in all mikroscopic objects, corpuscles are exhibited which bear some likeness to these cells" (p. 21).

"The elements, overwhelmingly larger in number, which enter into the composition of the posterior lobe of the hypophysis are connective-tissue cells, extremely manifold in form and size. Most frequently fusiform formations are met with, which sometimes are very much drawn out in length, and are provided with a nucleus, the outlines of which sometimes are more distinct, and sometimes more obscure; sometimes also not a vestige of such a nucleus is visible. In this latter case the middle section of the cell, which is perfectly homogeneous, very gradually passes off into a thread-like production, which sometimes is extremely prolonged" (p. 23).

"In the substance of the posterior lobe of the hypophysis there are not a few formations, which can only be explained as degenerate ciliated *epithelial cells*. . . . The conically-shaped, nucleated, very pale cells are furnished with surprisingly long, thin productions or stems. . . . Unless these little stems, which are very long, and proportionably wide, and which are sharply and darkly outlined, are recognized in their full connection, they might easily be mistaken for nervous fibres; especially as occasionally they are nodose" (pp. 24, 25).

"In the face of the results of numerous investigations detailed above, we cannot seriously entertain the thought that the posterior lobe of the hypophysis is a cerebral organ of any important functional significance. But all indications are rather in favour of our regarding it as a cerebral formation, in which the cerebral elements are undergoing a process of degeneracy, and are breaking up generally" (p. 26).[1]

519. Wenzel.[2]—"The upper surface of the hypophysis is covered with dura mater, all except a small place around

[1] See also *Peremeschko's* account of the structure of the posterior lobe in the Appendix, Note vi., no. 14.—Editor.

[2] Wenzel (Josephus et Carolus). "De penitiori Structura Cerebri hominis et brutorum." Tubingæ, 1812, Fol.

the infundibulum. This small place, generally round, in the middle of which the infundibulum is inserted in the hypophysis, is so much the larger and more conspicuous the farther advanced a person's age is. In infancy and early youth, although it is not absent, yet it is very small, and therefore almost escapes the eyesight. The exterior boundaries of this small place, as already stated, are formed of dura mater, arranged so as to present a kind of smooth circle, which in youth is contiguous to the surface of the hypophysis.[1] The dura mater is indeed thinner in that place, as is taught manifestly by experience when this same membrane is separated there from the exterior part of the sella. Nevertheless, there is still so much firmness in it, that the remaining part of the dura mater, which covers the hypophysis, serves to prevent or to moderate the pressure of the brain on the hypophysis. Within the little circle mentioned above there is situated around the infundibulum a certain thin, although dense, reddish membrane, which is a continuation of the external integument of the infundibulum, and thus of the pia mater of the cerebrum. For in a boy, one year old, we tried to pull one half of that membrane around and above the infundibulum, and we succeeded so well, that afterwards the infundibulum was left quite slender. This same membrane, which, under the circle of the dura mater, is continued over the surface of the hypophysis, lines its anterior and posterior, its inferior, and also both lateral surfaces—the smaller lobe of the hypophysis not being excepted. In certain places on the surface of the hypophysis this membrane is thinner than in other places ; whence it is, that the substance of the hypophysis is translucent in those places. That portion of the membrane, however, which lines the smaller lobe of the hypophysis, seems thinnest of all ; wherefore, if you wish to extract the hypophysis unimpaired, you must be extremely careful just there. If the membrane is removed in that place where the two lobes meet,

[1] Key and Retzius discovered on the surface of the pituitary gland, between the integument of the gland and the dura mater, a receptacle of the subarachnoid fluid. See Appendix, Note vi., no. 5.—EDITOR.

and where they are contiguous to one another, the cohesion between the two lobes is for the most part destroyed. Whenever the membrane is loosened from the surface of either lobe, the substance of the hypophysis appears exposed" (p. 210). "In adults and persons further advanced in age, if the examination be carried on with due care, vessels are clearly and distinctly noticed between the two lobes" (p. 220).[1]

"*First Experiment* [of injecting the hypophysis].—In the month of October, 1796, we introduced several times into the third ventricle of a young man the contents of a small syringe charged with an infusion of red poppy flowers, for the purpose of seeing whether anything of the infusion would penetrate into the infundibulum, and thence into the hypophysis. We kept the cerebrum unmoved in its natural position until the next morning. On examining with the greatest care the infundibulum, together with the hypophysis, we did not discover any trace of the injected liquid in whatever direction we carried on the dissection. The liquid must have escaped through the fourth ventricle, since we did not discover it anywhere in the cerebrum."

"*Second Experiment.*—On the 16th of May, 1797, we dissected the infundibulum of a robust young man, near its upper extremity, where it is joined with the third ventricle. We took the whole brain out of the cranium, leaving the hypophysis untouched. With a syringe Anelii (for a lacrymal fistule), the little tube of which was introduced into the infundibulum as far as the place where it is inserted in the hypophysis, we injected a sufficient quantity of ink, until we experienced somewhat of a recoil. After cutting out the whole hypophysis, nothing of the injected liquid appeared on the surface of the anterior lobe, but it had penetrated everywhere into the posterior lobe. Upon making a horizontal dissection of the hypophysis, the substance of the smaller lobe was found everywhere coloured with ink. In the larger lobe, on the other hand, we saw only a few subtle, black streaks, which, proceeding from

[1] See the Observations of the Brothers Wenzel in the Appendix, Note vi., no. 16.—Editor.

the place where the infundibulum is inserted in the gland, were dispersed through the substance of the larger lobe" (p. 225).

"*Ninth Experiment.*—On the 9th of October, 1800, we dissected the infundibulum of a young man near the third ventricle. The brain was afterwards taken out. On examining with a loupe the dissected surface of the infundibulum, we could not discover in it any aperture. This time we had decided to effect an injection through the posterior lobe of the hypophysis, in order to see whether any of the injected liquid would pass into the infundibulum and the anterior lobe. For this purpose we removed out of the posterior wall of the sella with a chisel so much of the bone, until a little portion of the surface of the posterior lobe was distinctly visible. After perforating, with a pair of scissors, the membrane which lined the lobe, we introduced the little tube of a syringe through the opening into the substance of the lobe, yet not beyond the distance of a line. In order to give to the syringe a horizontal direction, we cut out a triangular segment from the occipital bone. At the first injection the injected liquid rose from the surface of the dissected infundibulum like a little fountain. But whether it issued out of one, or out of several openings in the infundibulum, we were not able to tell. We repeated this experiment several times, always with the same result. Finally, we took out the hypophysis, and dissected it horizontally through the middle. In the anterior lobe we did not discover anywhere any trace of the injected liquid; but chiefly the middle part of the posterior lobe, into which the little tube had been inserted, was blue. At its anterior margin, except where the infundibulum is inserted, nothing whatever of the injection appeared" (p. 229).[1]

"*Results.*—From the twelve experiments which had been instituted, the following results may be deduced:—

[1] See the comment on the ninth experiment of the Brothers Wenzel in Appendix, Note vi., no. 25, and compare the experiments of the *Brothers Wenzel* with the interesting experiments instituted by *Sapolini*, who, by a novel plan, injected a solution of aniline through the infundibulum into the hypophysis; see Appendix, Note vi., no. 26.—Editor.

"*First*, when any suitable liquid is injected into the third ventricle, nothing passes into the infundibulum, no matter how long the liquid is left in the third ventricle. Wherefore, in order that anything may pass from the brain into the infundibulum, an energetic or violent injection made into the infundibulum itself seems to be necessary.

"*Secondly*, if the little tube of a syringe be introduced from the third ventricle as far as the infundibulum, where it is inserted in the hypophysis, the posterior lobe is either coloured entirely, or as to some of its portion, but only very little of the anterior part. Wherefore, the infundibulum is either conjoined more closely with the posterior lobe of the hypophysis than with the anterior lobe, or the cause lies in the greater softness of the posterior lobe, for which reason more of the injected liquid would enter into it, and more easily.

"*Thirdly*, if in mammals the point of the syringe be introduced from the brain into the infundibulum, to where it touches the hypophysis, or where it inclines towards it, the infundibulum is indeed coloured as far as the place of its insertion into the hypophysis, but neither the anterior, nor the posterior parts of the hypophysis are coloured. The force, therefore, with which the fluid is injected, it seems, must be brought to bear nearer to the place of insertion of the infundibulum, in order that anything may pass into the hypophysis.

"*Fourthly*, if the little tube of the syringe is inserted into the posterior lobe of a human hypophysis, and if an injection is made through the same, the injected liquor darts out as soon as possible through the dissected surface of the infundibulum. This way, therefore, seems to be more adapted to the structure of the infundibulum, and to correspond more to it, and also to be more natural" (p. 232).

Swedenborg's theory of the pituitary gland is examined in the combined light of modern science in the Appendix, Note vi., F, which is entitled, "Functions of the Infundibulum and the Pituitary Gland."]

ANALYSIS.

592. The pituitary gland is the last of the organs of the whole chymical laboratory of the brain. It is their complement and crown, and, at the same time, the only undivided organ belonging to both hemispheres. Thither also converge, in company with the infundibulum, the three ventricles, the five foramina, the nine ganglionic prominences [tubercula anteriora of the optic thalami, corpora albicantia, corpora quadrigemina and pineal gland], the isthmus, the fornix, and the corpus callosum. Almost an entire half of the cerebrum also tends thither, together with the corpora striata and optic thalami, and the cerebellum; the latter, however, tends thither obliquely or indirectly. The very longitudinal axis, and the transverse axis from the straight sinus and the pineal gland, converge thither, because it is the terminus. Two pairs of the lobes of the cerebrum cherish the pituitary gland in their bosom, as it were. The carotids lie most closely to it, and the vertebral arteries, without mentioning the rete mirabile, approach towards it; several nerves also apply themselves to its sides. The tentorium, which is the arm of all the processes of the dura mater, also inflects itself in this direction, together with the dura mater itself, both of which look for their centre of gravity in this bottom of the cerebrum, and in this base of the cranium, where they find their port and harbour. The pia mater also forms a duplicature here, and associates itself from above. Some of the sinuses of the base of the cranium likewise encompass it; the larger ones [the inferior and superior petrosal sinuses] lean their heads against it, and take their origins thence, like brooklets from a fountain. The sphenoid bone, and consequently the bones of the whole cranium, which are all connected with the sphenoid, meet together for the purpose of forming a chamber and saddle for the gland, and for protecting it, and taking their rest there. Underneath, the gland sinuses [the sphenoidal sinuses] are

excavated, and gape open, in company with the remaining osseous sinuses; and in this wise a communication is maintained with the nose and the palate. Nor can there be anywhere a station more secure against harm and the destructive influences which press in from the circumferences. If, therefore, the brain, with its substances and membranes, its intermediate and ultimate integuments, its processes, arteries and sinuses, concentrates in this one gland, as in a certain terminus of its work, it must needs be that it has in view, and carries out here, some sublime and grand work which concerns the whole kingdom, and on which its welfare depends. On this account the pituitary gland may deservedly be styled the gland of life, or the arch-gland. But that it is of such intrinsic importance, and that its nature is such, can never be known from itself alone, but only when it is regarded in connection with the parts that precede and follow it; and thus when it is considered from them.

593. This gland, as it resides thus in its celebrated curulian chair, is expanded and constricted by alternate motions, just like the cerebrum and the cerebellum, and by this means receives within itself liquids of a threefold order, or three kinds of liquids, namely, (1), the purest essence or the genuine animal spirit through the fibres from the cerebrum itself; (2), a species of a middle kind [the animal spirit wedded to serum from the choroid plexuses] through the network between the fibres, from the infundibulum; and (3), a serous [grosser] portion through the membranous productions of the beak—the processus infundibuli—also from the infundibulum. The two first kinds it receives in its interiors, but the third on its outside. As it receives these liquids distinctly, it also dispatches or excretes them distinctly. The purest, that is, the spirituous essence, it commits to its own little sinuses, namely, the lower transverse and the upper circular sinuses; the liquid of a middle kind it emits through lympheducts and venous vessels into the bones of the cranium, but the serous liquid it empties into the cavernous sinuses. All three liquids, however, it consigns to the jugular veins, and thus conveys and contributes them to

the common mass of the blood. Neither the size of the gland, nor its exceedingly small tubes, offer any obstacle to this function.

594. That the gland alternately expands and constricts itself in its sella follows from its white and reddish, or from its fibrous and slightly cineritious substance; likewise from the cavities and follicles which are in the gland itself, and in its appendage; further, from the distance and space between the gland and the wall of the sella; again, it follows from the fact of its being attached with its roof to the dura mater, so as to be held suspended and in the capacity of swelling. Its oval shape, its lateral convexity, and the softness of the appendage, indicate the same thing; these particulars also point out the mode of its expansion. For all things whatever, which live in the body from the blood and from the spirit of the blood, breathe and are moved in alternate times; rest and inertia are their final condition. Still, the gland does not seem to be moved by an active principle, like the cerebrum and cerebellum, that is, by a certain cortex or cineritious substance. For it is outside the brain, and receives its fibre from thence, perchance also from the branch of some nerve, and it does not create its own fibre. It receives also some delicate arterial shoots from the carotid and the rete mirabile, whence, as everywhere in the body, there is born and produced a muscular or motory fibre, which constitutes the greater part of its appendage,[1] and also some portion of the gland itself, and stirs its body into its own diminutive little motions. This motion of the gland coincides with the times of motion of the cerebrum, cerrebellum, and medulla oblongata, so that its movements of expansion and constriction are synchronous with theirs. For when the infundibulum is erected, and its process, the fibre of which ramifies through the body of the gland, is thus on a stretch, the gland itself is contracted, and admits into its motory fibre arterial blood, and into its parietal interstices the serous humour flowing in from

[1] Concerning the muscular fibre-cells, generated in the posterior lobe of the pituitary gland, see Note vi., no. 7.—Editor.

the infundibulum, even as is the case in each of the muscles of the body. The gland thus enters upon its systaltic motion when the brain has its systole, or when the ventricles overhead have their diastole; and *vice versa.*[1]

595. That the pituitary gland receives three kinds of liquids, and, further, that it receives genuine animal spirit from the brain, through the very fibres, I believe, has been shown by what has been stated above respecting the fibre of the infundibulum. For this fibre is abundant in its tumid belly, but presently is contracted into a slender beak or process, and then again it becomes diffused through the pituitary gland, scarcely otherwise than the medulla of the cerebellum is first collected into a peduncle, and then again divides into processes, and is diffused through the central ganglia, the corpora striata, and the optic thalami, and afterwards through the ample viscera of the body. That fibre of the infundibulum, which is gathered together in its process, and afterwards dispersed through the gland, does not again pass out of it, but terminates there, and deposits the spirit which it has brought thither. This fibre, from a certain point in the centre of the surface of the gland, where the beak-shaped process of the infundibulum is inserted into it, is continued throughout its whole extent, and also throughout its appendage or posterior lobe, where the delicate muscular fibre commences. Here it pours out that mysterious essence which it has brought thither from the substances of the cortex of the brain, and indeed into the blood of the little arteries which, taken together, form a muscle. All the fibre in the body also lapses into arteries and veins, and breathes into them its spirituous alkahest. This most liquid animal essence, which is born in the cortex of the brain, and is conveyed by the fibre alone, is hence discharged nowhere else than in its own termini or ultimate asylums; and hence nowhere else than in the outermost parts and circumferences of the pituitary gland, where the muscular fibre and an abundant

[1] The motion of the pituitary gland is discussed in the light of modern science in the Appendix to the present volume, in Note vi., nos. 5-12.—EDITOR.

artery reign. This, however, takes place when the gland contracts the motory fibre, or the latter the gland.[1]

596. Besides this spirit infused by the fibres themselves, a kind of fluid of a middle quality [the animal spirit wedded to a refined serum of the choroid plexuses] is likewise conveyed thither. This fluid permeates the interstices and retiform plexuses of the fibres, and is similar to that liquid which is frequently met with in the pores and clefts of the brain, and which, when exposed by chemists to a gentle heat, is said to evaporate completely without leaving any residuum behind. That this liquid is received by the spongy and porous body of the infundibulum, or that it collects between its fibres, and through its beak-shaped process likewise flows down into the gland, has been maintained above. This liquid cannot be instilled immediately into the arteries, or into the blood of the least arteries of the gland, like the former liquid; but because it percolates between and around the fibres, it must needs descend into the cavities and follicles of the very gland. For that which presses upon the interstices between the fibres, must necessarily be discharged into the clefts which are caused by these interstices themselves, or into that larger interstice which is common to all. This also is confirmed by the very texture of the gland, which, in this respect also, is a model of the glands of the body, for it abounds with innumerable follicles, and, in addition, has a certain larger cavity, which it shares also with its appendage. Diligent scientific explorers have not only discovered that such is really the case, but they have also accurately sketched and measured the cavity itself.[2] The liquid contained in this cavity, according to the statements of those that describe it, is of the same quality as the lymph of the brain; namely, it is limpid, fluid and pellucid, and thus it is

[1] The mode in which the animal spirit, the fluid of the first order, is infused into the pituitary gland is examined in the light of modern science in Note vi., nos. 11, 12.—EDITOR.

[2] The result of Peremeschko's investigations into the character of the central cavity of the pituitary gland will be found in Note vi., no. 17; and the result of Sapolini's experiments in Note vi., no. 26.—EDITOR.

not inconspicuous and volatile like the most refined liquid of the fibres themselves. Whether the secretion of the little arteries which are very plentiful in the texture of the gland is also added to the volume of the lymph may be inferred, but not asserted with certainty. This kind of lymph we call the liquid or fluid of a middle nature, for there is the spirituous essence [the animal spirit], the liquidity of which is acknowledged by all; there is, further, an elementary lymph or a common water; and there is a lymph which, upon being mixed or married to the first essence, constitutes the liquid of a middle nature.[1] [Of this quality is the liquid which distils from the choroid plexuses into the lateral ventricles].

597. It has been proved above that the pituitary gland admits into its organism also a grosser, serous fluid, namely, one which is unable to pass through the delicate network of the fibres, and which also trickles down from the infundibulum, following the course of its membranous productions. The gland, however, does not open its interior recesses for the reception of this fluid, but rejects it between itself and the walls of the sella, that is, above, around and below itself, thus separating it by the whole of its own body from the two purer liquid essences. The records of experience, indeed, declare that injected humours of a nature similar to that of the serous fluids themselves have poured down over the gland itself, not a particle of them entering into the interiors of the gland; further, that the gland is bathed with the perennial stream of a humour which at times appears like blood, in which it seems to float; and, finally, that not even a dew can be expressed through the membrane or integument of the gland, no matter how much it may be squeezed or compressed; whereby it is proved that there is no passage from the interiors of the gland into its exteriors. Thence it follows that the liquids, which are separated in the infundibulum, are received by the gland in separate compartments, and, indeed,

[1] The mode in which "the fluid of a middle nature"—the fluid of the second order—is received by the pituitary gland is examined in the light of modern science in Note vi., nos. 13-20.—EDITOR.

during the moments of its constriction, for then the gland is contracted, and raises itself a little, its appendage—the posterior lobe—likewise becoming erect in its fossa. Thus the gland removes itself from the wall, and the membranous coating of the roof becomes slack; indeed, since the cerebrum and the cerebellum are then constricted as well, their productions are relaxed down to this centre; wherefore every fold and cleft gapes open, and admits the shower from the infundibulum above and around the gland.[1]

598. But as this celebrated gland receives these various kinds of liquids distinctly, so also it sends them forth and excretes them distinctly. It accordingly discharges the first purest or spirituous fluid into its own little sinuses, namely, the [inferior] transverse and the [superior] circular, or, as it is called by some, the oval sinus, for these sinuses are nearest and at hand. The inferior transverse sinus of Littre, like a sector or falcated arc, passes through the broad concavity of the sella, below the wider diameter of the gland; the [superior] circular sinus of Ridley encircles it on top like a crown. Both sinuses are in a certain duplicature of the dura mater which is stretched over and cast around the gland, and both have been seen, described, delineated and confirmed by the most experienced anatomists.[2] These sinuses also are most delicate, and adapted to the nature of this fluid, and to its swiftest flight, and hence are born and created for the reception of such a spirituous and virginal blood. The blood itself, also, is of a palish, flesh-coloured and yellowish hue. Venous capillaries, springing forth from the gland itself, likewise pass out and in by way of the membranous covering of the gland, just as on the opposite side of the cranium do the veins of the sinuses of the falx cerebri; and by reason of the fore-mentioned causes they cannot help frequently escaping the sight. Still it is a fact, proved by experience, that numberless venous threads run across here. Experience also further induces

[1] The reception of the grosser serum—the fluid of the third order—by the pituitary gland, and its discharge thence, is considered in the light of modern science in Note vi., nos. 24-29.—Editor.

[2] Concerning the discharge of the fluid of the first order from the pituitary gland, see Note vi., no. 10.—Editor.

us to believe that the spirit of the fibres, that is, the animal spirit married to the purer blood, betakes itself, first of all, into the sinuses which are proper to the gland. Whither it is discharged afterwards will be pointed out in the following chapters.

599. The second kind of liquid which is collected in the cavities and follicles of the gland, and which at each alternate period of constriction and expansion is tossed to and fro like a fluctuating and harrassed wave, has also allotted to it its separate passages distinct from the rest. Wherever any lymph is kept enclosed, there also must necessarily be emissary ducts and outlets; otherwise it would become stagnant, and would be turned into a putrid, yellow or solid mass, and the moveable little body would be deprived at once of all power of action, and of the use of life. A great number of threads, muscular cords and shining white ducts, however, are extended between the gland and the walls of the sella. Apertures may be noticed in the bottom when laid bare—but these are sometimes obliterated—which are called lympheducts, and when water is injected into them it penetrates into the jugular veins. Such a power of penetration corresponds to the quality and the abundant quantity of this fluid. This species of liquid, therefore, is discharged through an osseous way, while the former is sent off by a membranous path through the dura mater.[1]

600. The third kind, also, or the circumfluous serum in which the gland is said to float constantly, does not mingle with the other more defecated liquids, but is expelled into the cavernous sinuses through its own proper foramina; namely, the duplicature of the dura mater. For the farthest production of the tentorium, and the dura mater with which the cranium is lined, that is, each of its laminæ, contribute to the formation of this little cave and couch for the gland; and while climbing over its upper extremities, on either side, as well as behind, these laminæ are duplicated in a remarkable manner. On the left and right

[1] The discharge of the fluid of the second order through lympheducts in the sphenoid and occipital bones is discussed in the light of modern science in Note vi., nos. 18, 19, and 38-40.—Editor.

the carotid artery is closely attached to the gland ; there also is a more depressed valley, as well as behind in the sella—which receptacles are called the cavernous sinuses. Between this aggregation of valleys and the cavity of the sella, the dura mater, as said above, is duplicated. If we follow nature as our guide, we must look nowhere else than here for the emissary ducts or outlets of the serum which bathes the gland; and, indeed, behind, where the cavernous sinuses meet, for these places are always found moist or bedewed. The gland also is anteriorly fastened to the process of the infundibulum, and when it swells in that direction in its own cavity, it fills the same entirely with its body and convexity. With a sufficient force, which sometimes overcomes the weight of its mass, it presses upon the humour with which it is surrounded, and displaces and expels it through the duplicature in that part. The gland acts within, and at the same time the humour with which it is encompassed at the sides and below, and outside the two carotid arteries also act; they raise themselves at the same time, and draw apart the intermediate duplicature; assistance is also afforded by little bands or ligaments on the part of the cavernous sinuses, of which we shall treat below. The appendage [posterior lobe] of the gland also swells at the same time and fills up its little fossa. All anatomists agree that there is some communication between the cavity of the sella and the neighbouring cavernous sinuses, but they dispute concerning the mode of communication. Some insist that it exists in the anterior part; while others doubt and deny it, because the dura mater is not duplicated there. Others maintain that the point of communication is at the sides under the carotid arteries, yet that way is said to be closely shut up. Others again declare that the communication exists at the very bottom, and that thence, through blind passages, there is a discharge into the caverns, or into other places; still the bottom, together with the whole cavity of the sella, is lined with dura mater. This disagreement, however, is reconciled, when it is admitted that the humour bursts out in the back where the cavernous sinuses meet, and where the duplicature is pulled apart for the reasons stated above. The clefts or gaps in that part have not yet been sufficiently examined; for when the ceiling or covering of the gland is thence removed at the outset, everything which affords a passage is removed at the same time. Yet so long as experience has not explored whether there is a passage there or not, the mere rationale, based on connections and motions, is insufficient to establish this, unless it be supported by experience.[1] This, however, we may take for granted, that unless, somewhere about the edges of the sella, some ducts are open, through which a passage is afforded into the circumjacent sinuses, the gland, with the humour poured around it, would at once stop its periodical intumescence, and, deprived of the power of acting, would grow torpid in its stagnant stream; every approach from the ventricles through the infundibulum would also be closed up, and it would be all over with that grand laboratory of the cerebrum. All three liquids are discharged during the period of the expansion of the gland. Its very follicles, also, or its interior cavities, are then opened, just as are the ventricles, when the brain is constricted; on which subject we have treated above.

601. The gland receives in distinct meeting-places those essential juices which are commingled in the ventricles, and afterwards separated in the infundibulum, and by distinct ways it again discharges them. The most intimate art of animal nature consists in combining and separating its liquids and essences. By this means it can so often depart and return, as it were, from spirit into body, and from body into spirit, and live in each distinctly, and yet at the same time conjointly; otherwise it could not perpetuate a gyre or circle through blood-vessels into fibres, and from fibres into vessels, which gyre we call the circle of life. Neither would it have anything to impart distinctly to so many various juices of the animal body, nor anything to separate, and cast off as vile and useless to its uses; but the

[1] The experience advanced by science in favour of the existence of a posterior receptacle in the sella turcica is collected and discussed in Note vi., no. 27.—EDITOR.

ocean of liquids and of terrestrial particles would clog up and blunt the activities of the spirits, and the spirits arriving in abundance, as soon as they should immerge into earthly particles, would perish like shipwrecked mariners, and thus would be powerless to actuate life, and to institute the various kinds of intercourse.

602. The small size of the gland, and the slenderness of the ducts, are no obstacle, for the whole of nature is expended upon its measures and ratios, that is, upon the harmonies and correspondences of active with passive forces, or of fluids with their organs. A fluid so very pure, that is, the most fluid essence of nature, such as the animal spirit which flashes through inconspicuous fibres, and also a lymph of such consummate purity as flows through the reticular tissues and interstices of the fibres, do not require a body of a larger size than the gland, nor do they require more conspicuous ducts than are those of vascular capillaries. The purity and swiftness of these fluids make up a quantity which is immense, and which is sufficient for their purposes. For the more sluggish and grosser lymphs, which act simply by gravity and by the shape of their particles, canals have to be constructed of a diameter a thousand times larger than are required for the above fluids, the measure of a line in the latter case being equivalent to that of a finger in the former. Both practical experience and theory teach this; who, for instance, would believe that through a most slender lymphatic duct, consisting of the thinnest membrane, and most irregular in size, the greater part of the chyle is furnished to the blood, and almost as many fæces as are daily excreted by the ureters and bladder? The same is the case everywhere in the body, the mere recapitulation of which would be prolix and tedious. A transflux or passage must not be denied because of the small size of a duct, or because a probe and ink cannot penetrate through it, and it must not, on that account, be excluded, as it were, from the circle of experience. Liquids do not become stagnated in the smallest insects, in chrysalides, caterpillars, moths, nor in still smaller insects which escape the sight, and thousands of which represent one moveable particle; their arteries and veins,

without mentioning their fibres, are not on that account impervious, because they cannot be inflated by the blast of a little syringe; and yet all of these creatures have brains, little hearts, pulmonary follicles and tubes, stomachs, intestines, genital members, with muscles and glands in each. Nature, however, acts more perfectly, more distinctly, and with a greater certainty in them, than in bodies of greater bulk. For when nature is in its purer spheres, or when it is nearer to them, it is fully in itself, and in its own principles; but it is more remote from, and, as it were, outside of itself, and in its circumferences, when it is in its grosser spheres, and in the composite or ultimate substances of the world, that is, within the sphere of the senses. How distant the naked sight is ever from the ultimate particles of the world, and how blunt and obtuse its sharpness is, sight itself has taught us, when the art of the opticians showed it how to arm itself with microscopes. Where the eye before saw only a simple or shady point, and where before it was unable to fix a single ray of vision in any of its parts, afterwards when it was armed with the lens of the microscope, it discovered there myriads of filaments and connective elements; and yet the eye still cleaves to the surface, and acknowledges that there are many things which escape its vision and are hidden from it. These things appear the more indistinct, the purer and the more distinct they are. How much does not appear small and obscure to the external sense in the pituitary gland, which is organized of so many myriads of filaments, and furnished with so many motory powers, and in addition is interpolated with follicles! And yet all this appears of a large size and distinct to the same sense when armed with the microscope! This gland, however, is very large and most distinct, that is, it is quite sufficient and accommodated to the functions which it has to fulfil, and if we examine it in all its parts, and raise ourselves a little above our senses, we shall see that its own capacity or size answers completely, and is proportionate, to the size of the beak or process of the infundibulum as an excretory passage.

APPENDIX TO CHAPTER XIX.

AN EARLIER ANALYSIS OF THE PITUITARY GLAND.[1]

602*a*. *Argument.*—Through the process of the infundibulum the pituitary gland receives in the vesicles of its body a spirituous lymph, and transmits it partly into the inferior transverse and superior circular sinuses, and thence into the superior petrosal sinuses, partly, also, it dispatches it through foramina of the sphenoid bone into the lateral sinuses, adding thereto a quantity of lymph expressed from its little arteries. The second or serous fluid, which is admitted into the surface of the gland and around its sides, it discharges partly into the inferior petrosal sinuses, and partly into the cavernous sinuses themselves, in order that there it may be absorbed by the mouths of veins. This it effects through its alternate expansion and constriction, which is accomplished by a muscular force, and which coincides altogether with the periods of expansion and constriction of the brain. Consequently, this gland expends its whole action, both in its interiors and on its surface, on the reception and transmission of liquids, and to some extent on their secretion, with a difference, however, in animals, so that it deserves to be called the arch-gland.

602*b*. *Through the process of the infundibulum the pituitary gland receives, in the vesicles of its body, a spirituous lymph,* as has been shown in the chapter of the Infundibulum. This, also, is confirmed by the anatomy of the gland itself. For, according to Willis, the medullary substance is continued through its middle, and ramifies thence. This ramification appears when the gland is squeezed with the fingers; for, then, according to Morgagni, a white substance, under the appearance

[1] From Codex 65, Photolithographed MSS., Vol. IV.

of a kind of liquid, is urged, as it were, towards the outlet. The vesicles in its anterior lobe are smaller, and they are larger in its appendage or posterior lobe, while there is a large cleft or follicle in the middle, as reported by Littre. The gland, consequently, imbibes a spirituous lymph which it transfers into its vesicles, scarcely otherwise than is done by the glands of the mesentery and most other glands which propel and direct a lymph from the various viscera into the thoracic duct and the receptaculum chyli. These glands are vesicular in a like manner, and whether they secrete or excrete, or whether they simply transmit what is commited to them, no one objects to their being called glands. Such glands are required when on the opposite side there is either a lymphduct, or an artery, or a vein, which receive the liquid that had been accepted, and which is transmitted by the gland at such moments when the desired quantity is required.

602c. *And the gland transmits this spirituous lymph partly into the inferior transverse and superior circular sinuses;* on which subject consult Littre, Ridley, Morgagni, and the rest of the authors quoted. Whether these vessels be sinuses or veins, nevertheless they receive from the gland this subtle juice, as is declared by the celebrated Winslow. These sinuses also occupy such a position, and their connexion with the gland is such that they proximately receive this lymph. For innumerable filaments which in appearance are nervous or membranous, in company with little arteries and veins, run across from the body of the gland into the integument or membrane wherewith the cavity of the sella turcica is lined. Numerous little veins also enter into the inferior transverse sinus, and communicate with the superior circular or oval sinus, according to the description furnished by Littre. As these little sinuses imbibe a palish kind of blood, or a lymph mixed with venous blood, they cannot always become visible. Sometimes their capacity or diameter corresponds altogether to the diameter of the process of the infundibulum; for the diameter of each, according to Littre, amounts to a line. Nor is a larger diameter required for such a subtle and spirituous lymph, as, by its swiftness, makes up for the greater volume of the other, more sluggish lymphs. For, if its purity and perfection indefinitely, or to speak numerically, a thousand or ten thousand times exceeds that of the other lymphs, it will also at the same rate surpass these lymphs in the power and swiftness of its transflux, so much so indeed that the same quantity will flash through a tubule one line in diameter in the same fraction of time which, for a grosser or more imperfect lymph, will require a canal ten or a hundred lines in diameter. Such also is the case in the fibres themselves. Wherefore there is a mutual correspondence between the volume and the swiftness, as is known from hydraulics.

602*d*. *And thence this spirituous lymph is transmitted into the superior petrosal sinus*, which is longer and more slender than the inferior petrosal sinus. The former of these sinuses applies its mouth to the superior circular sinus; which communication has also been delineated by Ridley. And in its description he says, that the circular sinus passes through the duplicature of the dura mater forwards, and also backwards and sidewards. "Vieussens," he adds, "it may be, saw some part of this sinus where he thought that the cavernous sinuses communicated." Morgagni says that the circular sinus, "with its blood-colour, shone through the part of the dura mater around the upper circumference of the gland." The superior petrosal sinus applies itself to the same summit, where the superior circular sinus chiefly shows itself; namely, under that angle which, according to Bianchi, arises from a meeting of the productions of the dura mater. This same petrosal sinus also by a slender trough, and through an exceedingly small orifice, which sometimes is blind, terminates constantly in the enlargement of the lateral sinuses. All things thus correspond to the purity and swiftness of the liquid. Compare also the description of the above sinuses in Chapter XX.[1]

[1] Concerning the relation of the superior petrosal sinuses to the circular sinus of Ridley, see Note vi., no. 31.

602*e*. *The spirituous lymph is also dispatched partly into the lateral sinuses through foramina of the sphenoid bone*, as has been proved through the experiments of Willis. For when the bone of the sella turcica is laid bare, or when its covering of dura mater is removed, chiefly in the calf, foramina are presented to the sight, and when they are injected the liquid penetrates into the lateral sinuses. Willis suspects that similar foramina exist also in the sella of the human cranium, and Vieussens demonstrated them by autopsy; although, he says, they are obliterated in dried skulls. He supposes, however, that they terminate either in the cavernous or in the petrosal sinuses, and that they derive their liquid thither; this, however, he has not proved experimentally. The existence of what Willis terms "lympheducts" is thus placed beyond doubt. That the above-mentioned lymph of exquisite purity is carried away from the gland through foramina in the bottom of the sella, appears from the filaments or small membranous processes, seemingly nervous, which are continued from the body of the gland into the membrane of the parietes. Of these filaments, or processes, Vieussens always observed two or three, but Littre innumerable. That similar processes emanate also from the appendage of the gland is scarcely doubtful, since it is closely fastened to the bottom or to the dura mater underneath. That no other essence is transmitted through these bony foramina, except one which has been admitted in the first place through the process of the infundibulum—unless you choose to add some secretion of the gland itself—consequently, an essence similar to that which is also communicated to the inferior transverse and superior circular sinuses, and thence to the superior petrosal sinuses, appears from this consideration, that through the same way that essence also is carried into the lateral sinuses, and thence into the same terminal vessels.

The wisdom which nature displays in the conveyance of this lymph appears plainly from this consideration, that it carries it away not by one, but by several ways, even by avenues which are wrought into bone, and hence are most safe. For wherever nature intends a constant and sure purpose and effect, as in the present case and also in others, it multiplies ways and means. Nature also observes a proportion between the ways or channels and the liquid which is to be conveyed; wherefore, in the calf these foramina are exhibited to the sight, and they are pervious to injections, as is also the case with the beak itself of the infundibulum. But in man these foramina are almost invisible, except in fresh bone, and so also are the pores of the beaked infundibulum. There is also a force in this argument that the above-mentioned lymph flashes afterwards through the bone by the sole impetus given to it in the gland, or is carried along of its own accord, as it were, since there is nothing in the bone to press and urge it along, as is the case with veins, sinuses and arteries, which are engirded by membranes. A reason also may be derived from this circumstance, that these passages are in the sphenoid bone and also in the petrous portion of the temporal bone, which bones are always tremulous through the membranes of the ear; for by the aid of this tremulousness the spirituous lymph of the gland will hasten into its terminal vessels, that is, into the lateral sinuses, with the greatest ease, according to the nature of its elasticity.[1] Wherefore, experience testifies that the blood is considerably vivified by the expansion and dilatation of the cerebrum and its cranium, as well as by the hilarity of the mind, the harmony of sounds, and the vibration of the parts mentioned, through laughter and other causes.

602*f*. *To this spirituous lymph the pituitary gland adds a quantity of lymph expressed from its little arteries.*—This we are allowed to infer from this circumstance, that numerous arterial vessels, departing from the carotids close by, or also springing from them mediately through the rete mirabile—chiefly in animals—enter into the pituitary gland, and when the gland is dilated and compressed in alternate periods, it follows that, just as in other glands and muscles, there is expressed thence a lymph, which immediately lays hold of the

[1] Concerning the lympheducts in the sphenoid and temporal bones, see Note vi., nos. 18, 19, and 38-40.—EDITOR.

volatile spirituous fluid, in a manner so as to contain it within its cells. That this is the case with a small quantity seems to flow from the fact, that arterial blood from the carotid of one side either passes over into the carotid of the other side through the rete mirabile (whether this be situated outside or inside the gland), or else returns into the carotid from which it has started. This will be discussed in the chapter on the rete mirabile.[1] Meanwhile, the fact that some arterial secretion is sprinkled on the spirituous lymph is evident from the vesicular substance of the gland, and from the circumstance that the vesicles, according to Littre, are smaller than in the appendage; on this account also the body, or the anterior half, of the gland is harder than its appendage, or its posterior half. It is further evident from this circumstance that little veins apply themselves to the inferior transverse, and superior circular sinuses, and that those, also, which enter the substance of the bone, communicate with the lateral sinuses; from which it is rendered probable that they communicate also with the lympheducts in the bone, and that everywhere a lymph from the blood is poured on to prevent the evaporation of the spirituous essence.

Moreover, it cannot be denied that that essence which, after passing through the pores of the process of the infundibulum, enters the inmost vesicular substance of the gland is dispatched abroad through the above-mentioned channels, since the whole ramification from the gland tends in these directions, as is also manifestly proved by experience. For when the gland is squeezed between the fingers no liquid pours out through its proper membrane, according to Morgagni's experience. It is also of considerable hardness, and in addition to the membrane is enclosed by an arterial texture. Nevertheless, it is spongy, and filled with such a large quantity of liquid, that there is no more humid gland throughout the whole body, according to Ridley's expression. The liquid contained within the gland, owing to the general resistance of the enclosing

[1] Concerning the serum excreted from the arterial shoots in the pituitary gland, see Note vi., nos. 22, 23.—EDITOR.

membrane, cannot be discharged anywhere else than through the appropriate, visible little channels, which have already been treated of, and which, taken altogether, have of a greater capacity than the deferent minute channels of the beak; wherefore, I believe, that a peculiar secretion of the gland itself is added to the above lymph or spirituous essence. But if any one does not summon causes and unseen things in aid to experience and things seen, he will not be able to deal with organs which are subservient to mind. For the eyesight is so gross and dull that it must be fortified in order to transcend but little its own sphere. If nothing passes through pores except what the external sense attests, our bodily machine would be a mere stock devoid of spirits. Liquids are not stagnant in those insects which often conceal the whole of their little bodies from the keenest vision of our eyes, and thousands of which scarcely equal one moveable, least particle. Nor are their arteries and fibres impervious, because they cannot be exposed to the sight by pipes or syringes adapted to their least veins or cavities, through which air or a liquid may be injected, and the vessels thus be expanded. Nor do the leaves of a lofty poplar, on the other hand, lack the nourishing juice supplied by the roots, because the syringe or canule is unable to find a cleft, through which an injected dye is able to fill the fibres which are continuous from the lowest part of the tree even to its top, and which reach into the very air, and, on the other hand, extend into the minutest centre of the seed. And still less would it be believed that a noble and ignoble juice passes through the very rocks. Through myriads of pores there transpires through every point of our skin a perennial stream of exhalations, which in large quantities, and charged with many obsolete substances, are rejected as useless into the air from the blood and the vesicles; while refined and more simple ethereal substances constantly return through filters to the fountain-head, which experience forbids us to deny. How much more must this be the case in a congeries palpable to the sight, and which is manifestly moist; and especially so in little glands, whence, after they are agitated, there distils a copious moisture; as from the parotid glands, which, when they are wounded, flood the cheeks, as it were, with a foaming torrent. What, then, must be the case with the pituitary gland into which there presses down such a copious mass of liquid from the ventricles; which gland is pulled in opposite directions in its sella, and which, at regular intervals, is constricted and relaxed by its enclosing membranes and its own muscular substance, or which is continually agitated by being stretched in alternate periods in breadth and also in length?

602*g*. *The second or serous fluid is admitted into the surface of the gland and around its sides*, as has been shown above; namely, through the experiments of Vieussens and Ridley, by which it is rendered manifest that not the whole of the liquid, which has been injected into the infundibulum, enters the gland itself, but that the grosser portion of it escapes over its surface. On this account, also, that grosser portion is kept back between the gland itself and the posterior and lateral walls of the sella. Numerous sanguineous, membranous, and, as it were, nervous filaments, indeed, intervene there, so that the gland is filled with a palish, reddish, and again with a seemingly sanguineous lymph, and that, according to Littre, it seems, as it were, bathed in it. Since this liquid, as proved by experience, cannot transude through the membranes, it must needs flow down from the infundibulum through its pipes, where its process pierces the integument of the gland, which, according to Ridley and Vieussens, consists of pia mater. And this happens while this process [that is, its membranous production] is spread apart in every direction, and the liquid within the gland, by the expansion of the same, is pushed out sidewards, and raises the ceiling of the gland; this takes place simultaneously with the expansion of the brain. That this, moreover, takes place chiefly in the direction of the posterior portion of the gland, may be concluded from the oblique insertion of the process in the direction of its anterior portion, and likewise from the reciprocal obliquity of the position of the gland itself in a posterior direction; so that when the brain and, at the same time, this glandular body expands, there must needs be a certain divarication or spreading apart in that particular place. Into that portion also, in the case of animals, there is reflected a certain production from the infundibulum, which is at the same time inserted into the bone, or into the epiphysis of the sella, as well as into the gland itself, and prevents the latter from being injured by such a spreading apart. It, therefore, does not seem doubtful that a liquid, and indeed a grosser one, is expressed over the surface of the gland, since coloured injections, according to experiments, were able to dye only its surface, although Littre declares that they also have caused a swelling in the posterior lobe. The above liquid, namely, that with which the surface of the gland is bathed, cannot proceed from the interior compages of the gland, since no transudation takes place through its membrane, nor can it be secreted from the little arteries of the rete mirable, since that rete exists around the glands of the human brain only very rarely, and, nevertheless, there is always observed an abundance of such a liquid. Nor is this an objection that the covering, which lines the upper and compressed face of the gland, is, as it were, agglutinated to it, since the instillation of such a juice from the infundibulum requires only pores or minute ducts continued thence, of that kind indeed as have afforded a passage to injections in the above-mentioned experiments; such ducts as exist also in the beak or process of the infundibulum. Besides, the membrane is not agglutinated to the gland at its sides where its plane figure passes over into one which is convex.

602*h*. *This serous juice the gland discharges into the inferior petrosal sinuses, and partly into the cavernous sinuses themselves*, namely, it discharges it in the direction of that posterior part of the sella, where a quantity of it collects and bathes the gland. This part is between the two sides of the gland which are occupied by the carotids; it is a kind of posterior receptacle, and is a complement of the two cavernous sinuses. It is there where the two posterior clinoid processes, with their ligamentous production, reach out towards the gland, and, as it were, enclose said posterior receptacle, distinguishing it from the lateral cavernous receptacles. Manget places it beyond doubt that there is here, under the production or duplicature of the dura mater, a communication between the gland or between the cavity of the sella turcica and the cavernous sinuses; he states that "there is a channel of communication between the posterior face of the posterior clinoid processes and the production of the dura mater no less than between the gland and the sella, which latter communication is of the same kind as the former." Morgagni does not disprove this statement by his own experience, as he does where he states that there is no communication in the lowest part of the gland, and that its appendage, or posterior lobe, closely adheres to the integument of its fossa. As to the rest, the fact that there is a communication in that place seems to be denied by most authors.[1] [After entering largely into a discussion of the opinions set forth by the various anatomists on this subject, Swedenborg continues:] This now is the reason why the experience of one anatomist is contradictory to that of another, namely, the mind taken up by preconceived ideas, or illuminated simply by its own discoveries, sees that which it favours beforehand, and it passes by those things which it does not favour. This is human, and occurs even among the greatest lights of the world. Nevertheless, if the spirituous lymph passes through the inferior transverse and superior circular sinuses into the superior petrosal sinuses, and the remaining juice, which is urged into the circumference of the gland, flows into the cavernous sinuses, and at the same time into the inferior petrosal sinuses, an element of harmony is introduced into these divergent views, and the difference between the results of the various experiments is reconciled. Winslow also settles this difference in the same way; for he states that the small circular sinuses communicate with the cavernous sinuses. So long, however, as there is this clash among the opinions of the learned, in order to put an end to the difficulty, we must not appeal simply to experience, but also to

[1] Concerning the posterior receptacle in the sella, see Note vi., no. 27.—Editor.

the nexus between the various adjacent parts, and their alternate actions. . . .

602*i*. *This the gland effects through its alternate expansion and constriction, which is accomplished by a muscular force.* This is confirmed by the texture of the gland, which in this respect is similar to that of the remaining glands; for they are impelled to action by muscular fibres which are carried about in them, as appears plainly from Malpighi's description. For the production of muscular action there is required an influx of arterial blood, and a reflux of arterial as well as of venous blood; further, there is required a nerve with its fibres which adjoins itself to the little arteries. Both are present in the pituitary gland. Innumerable vessels flow in from the carotid which is very close to it, and stretches along its shorter side. All authors confirm this except Willis, who, instead of using the word "innumerable," says "very many." Vieussens, however, proved experimentally that there is such an arterial structure in all human pituitary glands. In animals, whose pituitary glands are comparatively larger, and which pour forth a grosser and, at the same time, a more copious juice, there is added on either side the rete mirabile, and according to Ridley, also in front. Thence little arteries enter into the gland; and thither the reflux of blood takes place when the gland contracts itself. The body of the gland on that account is quite reddish, and by Littre it is called its red portion, and is said to be furnished with fleshy fibres.[1] That a few little veins depart thence into the membrane which holds the place of a periosteum, and that afterwards they are carried into the inferior and superior circular sinuses, and partly, also, into the substance of the sphenoid bone in the direction of the lateral sinuses, has been pointed out above, and is also confirmed by the anatomical authors. But as regards the nerves, all authors confirm that the pituitary gland is approached by branches of the fifth and sixth pairs. . . .

Nothing, consequently, is wanting to the proof that it is a

[1] Concerning the arterial and venous vessels in the pituitary gland, see Note vi., nos. 8, 9.—EDITOR.

muscular force which rules the gland, and that its muscular texture surrounds its medullary and vesicular substance. This is affirmed by Willis, who says that the exteriors of the gland are occupied by a compages of little arteries, and its interiors by a medullary substance. For the gland is an appendage of the brain; but though through the slender beak of the infundibulum it adheres to the brain, it yet reclines in its own cavity in such a manner as to be outside the brain, and so that it cannot be acted upon by the animation of the brain; wherefore, its motion is caused mediately through an inflowing nerve, the little ganglion of which is placed near the entrance of the nerve into the cavernous sinuses, so that each time, when this little ganglion compresses itself, the nerve also exerts a living force upon all those fibres, and causes the gland to compress itself. Nor is the nerve of the cerebrum any different in its action when closer to its beginnings; for near its approach to the gland it swells into a little ganglion; it fortifies itself with a muscle; it sometimes places itself near the sesamoid bone, and even as it continues its ramification into the gland, it does so also around the carotid, into the inferior petrosal sinuses, into the little arteries and veins of the cavernous sinuses, and into the dura mater. And even if it should not extend its ramification immediately into the gland, it does so mediately through the carotid into which fibres are reflected from the fifth and sixth pairs, and from the expansile force of this artery there would arise an equally living muscular action. On this subject we shall treat more at large in the chapter on the Rete Mirabile. From all of this it follows, that the nerve cannot fail to act upon the gland by a living force, and also upon all the parts which are around the gland, and which must contribute their share towards the promotion of the object.[1]

602*j*. *This muscular action of the gland coincides altogether with the periods of expansion and constriction of the brain.*

[1] Concerning the nervous fibres which enter into the pituitary gland, see Note vi., no. 10.—EDITOR.

This may be concluded both from the inflowing nerve and from the carotid. For when the cerebrum constricts itself, the little ganglion of the nerve acts upon the gland or its little arteries, constricting them and also expelling therefrom the blood. The proof from the *carotid* is as follows: When the brain constricts itself, the carotid is expanded, according to the general rule that a reflux of arterial blood takes place into that vessel, when, that is, the muscle or the gland are deprived of this blood. On the contrary, however, when the brain expands itself, or the carotid is constricted, the blood is expressed into the gland and expands the same, and thus it fills with blood the vessels which, during the period of constriction, have been deprived of the same. Wherefore, the constriction and expansion of the gland coincides altogether with that of the brain. This glandular muscle in the pituitary gland, in the case of man, seems to be smaller and weaker than in the case of animals; so far, indeed, as the spirits are purer and are determined into efflux by a smaller force; besides, in the case of man also there is a smaller amount of the liquid in question. Granted now, that there is such an alternate expansion and constriction of the pituitary gland—since on no account whatever can it be denied that the blood flows into it and flows out of it again—it follows that the gland acts not only upon its own vesicular substance, and upon the vesicular liquid, but also upon that liquid which is contained between the gland and its parietes, and which, by this means, is expelled outside whenever it fills the whole of the cavity; for which purpose no other exit is open for it, than in the direction of the posterior part of the sella, as has been remarked above.

The motion of the pituitary gland, and the coincidence of the same with that of the brain being given, we are able to explain more fully those things which have been adduced above on the subject of the liquids, and their admission and expulsion; and we can also inquire into the meaning of the appendage of the gland or its posterior lobe, and of the large vesicle or follicle in the middle. Let us here sum up the information gathered from experience; namely, that the gland about its posterior and broad, wide part is distant from the wall of the sella, so that a probe may be introduced there, and that it admits a little volume of liquid; that, nevertheless, in the middle of its posterior part it is attached to the bone, exactly there where its fulcrum is, by which, as well as by its adhesion to the ceiling, it is held suspended; and, further, that at its anterior part it is not so loosely fastened to the wall of the sella, nor at the sides where the carotids are, to which the gland does not offer so wide a margin. Further, that the appendage or posterior lobe itself remains attached to the bottom of its fossa. Thence results: *First*, that, when the gland expands, it acts chiefly in the direction of the posterior side of its sella, and at the same time pushes the whole of the liquid, which is contained in that interstice, towards the production of the dura mater; that it also urges some portion of it under the ceiling, namely, where it does not adhere to the upper part of the gland; consequently, that by this action of the liquid there are opened the foramina between the cavernous sinuses and also those leading to the beak or process of the infundibulum, with which the production of the dura is conjoined in the fashion of a knee-joint. All these foramina, both those in the direction of the ceiling, and those which lead towards the walls of the sella, must gape open under the pressure of the liquid, since the whole production of the dura outside of the sella yields, namely, while the carotids subside, and the cerebrum is incumbent above. *Secondly*, that the blood from the carotids also, during the same period of expansion, rushes into the gland; likewise, from the anterior side when the rete mirabile is present. *Thirdly*, that then the entrance from the process of the infundibulum is opened into the gland itself, as well as over its surface. It is open into the gland, because when the gland is expanded its vesicles are expanded, and together therewith the large cleft or follicle in the middle, which is the general regulator of the rest. When this middle cavity is expanded, almost of its own accord, the whole of the juice is brought thither from the process, being driven along by continuity. Consequently, the above-mentioned expansion is an additional force by which the liquid is driven into the gland itself, while extraneously it is urged towards the same centre by the liquid of the upper part of the compressed infundibulum. In this way, then, all the roads leading thither are kept open in the most regular order. *Fourthly*, it follows that the larger cleft or follicle, which is almost between the body of the gland and its appendage [or between its anterior and posterior lobes], is the regulator and ruler of the gland; namely, so that the gland swells just so far, that by swelling it is able to fill that space, and to expel thence completely the wave by which it is bathed; that is, that in harmony with the action of the brain, to which it corresponds altogether, it acts upon its liquid both from without and from within. For the same reason also, by the alternate periods of a deeper animation and respiration which coincide with the breathing of the lungs, there is attracted into the gland from the laboratory of the brain a larger amount of spirituous lymph, and again, according to the exigencies of the body, a larger amount is expelled. *Fifthly*, again, from the posited animation of the gland, and at the same time from the fact of its posterior lobe being fastened to the bottom of its little fossa, follows the reason why the gland is divided by a notch into its body proper and into its appendage; for, since the upper part of the gland constantly expands in the direction of its posterior part, and at the same time raises itself, there seems to be a necessity for its lower part to be fastened and to pass off into an appendage, and for it to have its place in a little fossa, excavated in this wise, and that between the two parts there should intervene on the outside a notch, and in the inside a follicle, without which the expansion could never be effected. *Sixthly*, supposing the appendage or posterior lobe of the gland should not by its bottom be kept attached to its own fossa, in that case the compressed liquid, namely, that on its surface, by the expansion of the body of the gland, would be driven also towards the anterior portion of the gland and towards its sides, whereby the regular supply of fluid through the process of the infundibulums, and also its regular discharge, and at the same time the communication between the carotids, would be disturbed, when yet the whole force of the action from without should be determined towards the posterior part of the sella, and that of the action from within towards the lympheducts and veins: wherefore, openings which lead into the bone appear at the bottom where the posterior lobe retreats inwards; for the same reason also the process of the infundibulum is inserted in the anterior portion of the gland, and the gland itself applies itself most proximately to the superior circular sinus, and thereby to the head of the superior petrosal sinus, which is also governed by a little nerve of the fifth pair. This appears from the fact that the beginning of this sinus passes over the trunk of the fifth pair of nerves, even as, according to Morgagni, the sixth pair of nerves also progresses in this manner along the external side of the inferior petrosal sinuses, and within the trough excavated for the same. This also furnishes an argument why both these sinuses receive from their gland at these stated moments some portions of a fluid. *Seventhly*, so far as the separation of the liquid in the gland itself is concerned, all this cannot be thoroughly explored before the economy of the blood has been investigated, which depends in a great measure upon this gland. At any rate, from the size of the gland and of its muscle, from the structure and slenderness of the process of the infundibulum, and at the same time from the humour of the little sinuses, lympheducts and fibres which are derived thence, from the rete mirabile and many other parts, inductions may be made as to the quality of the blood, and the ratio of the influx of the blood into the parts of the body, and at the same time into the organism of the brain.

602*k*. *Consequently, the pituitary gland expends its whole action in its interiors and on its surface on the reception and transmission of liquids, and to some extent on their secretion.* In this respect it is altogether like the lymphatic glands . . . which are in a like manner vesicular and engirded by muscular fibres. Whether they secrete or simply transmit, they are nevertheless counted among the glands, and thus are in some respect like the pituitary gland; they are like it also in this respect, that the fluids which they transmit are finally conveyed in veins, as, for instance, in the subclavian.

602*l*. *With a difference, however, in animals;* as, for instance, in the dog, cat, etc., where the tube of the infundibulum embraces the pituitary gland, so that when one is removed, the other is extracted also. The difference is that the spirituous lymph of animals does not require such minute ducts. On this account also two distinct glands, in their case, are under the infundibulum [that is, the pituitary gland itself consists of these two glands], for this reason that the liquids which, through open pipes, have penetrated so far may be separated there, and not in the infundibulum. In the remaining animals also a much freer passage is open into the interiors of the gland. Their pituitary glands, therefore, on account of the greater consumption of nutritive juice, are more moist, and the very openings through the sphenoid and petrous bones are more palpable, as in the case of the calf. In harmony therewith also is the muscular development of the gland, which derives its supply of blood from the carotids also through the rete mirabile; and hence in most cases the increased size of the gland.

602*m*. *Wherefore the pituitary gland deserves to be called the arch-gland.* This appellation it also deserves on this ground, that it devotes its whole force to the transmission of the genuine liquids of the brain in the interiors, and also in the exteriors, of its body, notwithstanding both being so well closed up; but chiefly, on this ground, that it receives the whole spirit of the brain, and communicates it to the blood, to which it thereby imparts a special quality, upon which quality, compared with its quantity, depends the life of the whole of its kingdom. And further, on this ground, that all the members of the brain, and also those of the dura mater, their planes, axes and centres, and the very bones of the cranium itself have respect to that gland as to their final terminus; and since it repels the *pituita* of the brain, rather than carries it abroad, it may deservedly be styled the arch-gland.

CHAPTER XX.

THE CAVERNOUS SINUSES.

603. The cavernous sinuses are also called the receptacles of the sphenoid bone, or of the sella turcica; for the sphenoid bone, towards the middle, has some grooves, as it were, drawn into it, and is hollowed out into sinuses [on its surface]. On either side it blocks up these sinuses by the so-called clinoid processes; the anterior of which are sharpened into apices, but the posterior ones form a continuous dam. In the middle of this sphenoidal sella is the sella turcica of the pituitary gland. Those grooves or fossæ the dura mater lines with its membrane. Upon reaching the walls of the sella it meets with a production from the side, which encloses an oblong space, or, if it be taken together with the enclosed sella, an almost square space. By making an injection it appears that these sinuses intercommunicate. They consist of a [cavernous] substance almost like that of the spleen, or urethra. As soon as the carotids through their foramina enter the cranium, they betake themselves into these sinuses, and keep closely to the wall of the gland, so as not to allow there any space. On entering the brain, they wind themselves tortuously like a plough-tail. The third, fourth, and sixth pairs of nerves, and likewise two branches of the fifth pair, before leaving the cranium through their foramina, pass through these sinuses, close to the carotids. The superior petrosal sinuses near the carotids are inflected in the shape of the letter *e*; the inferior petrosal sinuses in that of the letter *f*, namely, in the vicinity of that posterior part near the production of the posterior clinoid processes.

604. VIEUSSENS.[1]—"Where the dura mater adheres most

[1] "Neurographia Universalis," etc., Cap. II., III.

closely to the base of the cranium, namely, near the sella turcica, which it lines everywhere in its interior, it is folded back on itself, so as to pass off, as it were, into two caverns, which, on account of their office and situation, we call the receptacles, placed near the sides of the sella turcica—the cavernous sinuses. These two receptacles, to which four sinuses are attached by very conspicuous mouths, are separated from one another by the interposition of the pituitary gland; yet the passage from one into the other is not altogether shut off, since each communicates with the other as well by the upper as by the lower surface of the pituitary gland. This I observed with my own eyes, and it may be proved experimentally by injecting a liquid into either of the inferior petrosal sinuses, which are adjacent to the sella turcica; for in that case the injected liquor, even though it be not propelled with great force, will be at once carried from the sinus into which it entered at first, into the other sinus. If, on examining the cavernous sinuses, the dura mater which constitutes their upper and hinder part is cut away in an antero-posterior direction, and is folded back on either side, it appears manifestly that within their cavities are contained the rete mirabile of Galen (in those animals where it is found), the anterior nerves of the fifth pair, together with the trunks of the carotid arteries, which rise up obliquely with the sympathetic nerves placed upon them, and which pass by the nerves of the third and sixth pairs. Besides, the cavities of these receptacles, in those animals where the rete mirabile is more extensive, appear very much larger than in those where it is wanting, or is smaller (p. 7). . . . Lastly, the venous vessels which emerge out of the sphenoid bone open with conspicuous, though small, mouths, partly into the cavernous sinuses, and partly into the dura mater with which the base of the same sella turcica is lined, and they consequently discharge the arterial blood, which they reabsorb in the interior spongy substance of the sphenoid bone, partly into the above-mentioned four [petrosal] sinuses, and partly into the cavernous sinuses. This may be proved by the following experiment: If the cavernous sinuses, together with the other sinuses, are opened, the vessels of the rete mirabile on either side being left intact, and if the trunks of the carotids, a little above the sella turcica, are tied, and a blackened liquor is injected into one of the two carotids; if then the pituitary gland, near its back part, is raised a little with a thin probe, and inclined anteriorly, it will be seen that some of the injected liquor flows out of the little mouths of the vessels which terminate in the dura mater wherewith the base of the sella turcica is lined, and in the inferior petrosal sinuses which are adjacent to it. If, after concluding this experiment, the sphenoid bone be cleft open, its interior substance, that is, where it is spongy, will be found somewhat imbued and stained with the blackened liquor. While this experiment is being carried on, only a small portion of the injected liquor flows out of the interior substance of the sphenoid bone, because the blood which is contained within the vessels, and within the loose pores of that spongy part, is cold, and a little coagulated, and therefore obstructs the movement of the injected liquor; hence the injected liquor is discharged only gradually, and in drops, from the interiors of the sphenoid bone. On this account we recommend that, when any one desires to try this experiment, he should always inject first a little hot water, so that he may not try in vain. . . . In respect to the above-mentioned experiment, by which we demonstrate the fact that the vessels, the mouths of which are discovered in the membrane lining the sella turcica, are little tubes bringing back arterial blood or veins, we have to say that it is often, very often, we do not say always, tried in vain in human subjects. For when both carotids are tied, about the middle of the neck, and a little above the sella turcica, if then a tepid liquor is injected into either carotid, whatever portion of the injected liquor enters the little arteries which are inserted in the membrane lining interiorly the cavities below the sella turcica, as we have often observed, is conveyed into these cavities, and nothing of it enters the little veins, the little mouths of which are noticed in the membrane lining the middle of the sella turcica. The reason is, that in the human subject, by the extinction of the natural heat of the parts, these little veins are constricted, and their little mouths subside, and are closed up (pp. 8-10). . . . The four sinuses near the sella turcica perform each their own functions, for, besides receiving the blood which is conveyed to them by the veins which open into their cavities, they intercept a certain aqueous humour which showers down from the brain, and which they dispatch towards the internal jugular veins. The two cavernous sinuses, like the above-mentioned sinuses, are appointed to receive blood; for they receive immediately the blood which is carried back from the interior substance of the sphenoid bone; nor do they receive simply blood, but, in the manner of a cistern, they receive also an aqueous humour from the brain, which descends through the infundibulum and the pituitary gland into their cavities. The humour from these sources, together with the blood with which it is mixed, is conveyed to the internal jugular veins through the mediation of the four sinuses adjacent to the sella turcica" (p. 15). See also his Plates I., IV., XVII.

605. RIDLEY.[1]—" Vieussens, it may be, saw some part of the circular sinus where the other small sinuses enter it, which is at the back part of the 'receptacula sellæ equinæ lateribus adjacentia' [cavernous sinuses], and thence he thought that these 'receptacula' communicate with, and are capable of performing, the office he assigns them; namely, that of bringing back blood from the nourishment of the subjacent sphenoid bone, together with the aqueous humour separated from the pituitary gland, into these four lower or inferior sinuses. Now respecting these receptacles of his, namely, the 'receptacula sellæ equinæ lateribus adjacentia,' it is certain that they are not anywhere existent in human brains, according to the description he gives of them, seeing that both the third, fourth, the two anterior branches of the fifth, as well as its third posterior one, together with the sixth pair of nerves, do not only run out of the brain enclosed into so many distinct little capsulas

[1] "Anatomy of the Brain," etc., Chap. V.

or coverings made of the dura mater, during their passage through that part of the base of the cranium by him called 'receptacula,' etc., but even the whole dura mater, together with its membranous productions constituting the aforesaid coverings of those nerves, in that place clings closely to the basis of the subjacent bone, that is, to the external process of the sphenoid bone, on its under side, and to the carotid artery, which also, above and below, by its borrowed coat, clings closely to the dura mater on the side turned towards the pituitary gland, leaving no room at all for either blood or serum to be contained there, as he would have it. Still, in the same place which he describes for his 'receptacles' [the cavernous sinuses], in several injected bodies I observed two very fair and large veins, one coming into the cranium at the optic foramen from the orbit of the eye [the ophthalmic vein], and so climbing up on the side of the lateral process of the sphenoid bone, almost up to the circular sinus; the other at the foramen ovale, which climbs up upon the same bone till it meets with and joins the other, whence they make one short branch, which enters the circular sinus very near the place where the other two inferior petrosal sinuses on each side descend down from it; which, if they should chance to be cut by accident in any inquiry made into that part, might cause an appearance of blood, and thereby become an occasion of the aforesaid erroneous hypothesis. Neither is it possible, granting there were any such 'receptacles' [cavernous sinuses] as he mentions, that they should serve to the end he assigns, seeing the pituitary gland is on all sides enclosed by both the dura and the pia mater; which first, notwithstanding what Vieussens says to the contrary, is on all sides of this gland of a very strong and equal thickness; yea, in that very part where, as has been observed above, there is a kind of a groove made by a certain duplicature of the dura mater, constituting the anterior portion of the circular sinus. And if this also were granted, yet would the manner he describes of the serum or water getting into these 'receptacles,' which is by percolation, render this supposition very unlikely, seeing it is by no means conformable to the custom of nature in all other parts of the body that arteries should deposit a serum, or anything else but blood (except what goes to the nourishment of the part itself), in any part, without being furnished either with its excretory or secretory ducts, neither of which was ever pretended to have been found here. And as a thorough confirmation of all this, said in opposition to the aforesaid hypothesis, I shall only add this, and conclude, that in several injections made use of in order to find out the use of parts, I never found one drop of the tinged liquors on that side of the carotid artery where he had made the situation of these 'receptacles.' The use of this circular sinus, in common with the rest, is to bring back blood from all the adjacent parts, such as the pituitary gland, the sphenoid bone also, and, it may be, from the rete mirabile, which in brutes is very large, and therefore seems to require the service of this sinus, either mediately or immediately, for bringing back a share of its blood, seeing the pituitary gland appears nowhere furnished with veins terminating anywhere else sufficient to carry off the refluent blood from this plexus: notwithstanding Vieussens says, on the contrary, that it has no veins, and therefore is forced to have recourse to those small branches of veins which accompany the branches sent out by the carotid artery, before it perforates the dura mater with the optic nerves, or those which go to the gangliform plexus of the fifth nerve, or those coming out of the sphenoid bone, for reductory vessels to this part; but with what probability I know not" (pp. 44-48). Consult also his Plate II.

606. BIANCHI.[1]—" On account of the considerable distance of the origin of the lateral productions from the sides of the sella turcica, a certain large cavity is left on either side between these productions and the sella. But on account of the smaller distance of the posterior production from the back of the sella, a small cavity is left in the back part between the sella and the same posterior production.[2] . . . The trunks of the internal

[1] In Manget's "Theatrum Anatomicum," Vol. II., pp. 345-347.

[2] We were unable to verify this quotation.—EDITOR.

carotids enter the cranium after their first skilful inflections in the lower part of the petrous process, or in the osseous canal specially dedicated to them; thence, after making a second inflection, they at once continue their course along the sides of the sella turcica, and in close contiguity to the pituitary gland, from the posterior region of that same sella to its anterior region, through a certain peculiar trough lengthened out straight, after which they are inflected a third time, and pass on either side through a round foramen carved near the margins of the anterior processes which are nearer the sella; from this foramen they finally rise and continue their way directly to the base of the cerebrum. . . . The nerves, however, are separated from the trunks of the arteries by a certain new and highly tendinous expansion of the dura mater, in the form of a bulwark (*claustrum*) (p. 345, i. i.). . . . This new and tendinous production of the dura mater arises from the anterior, lower, and, as it were, beak-like petrous process, and it is produced thence in the middle of the so-called lateral cavities transversely towards the front, even to the lower part of the anterior clinoid processes. In order, therefore, that this tendinous septum may subdivide the bag-like lateral cavity on both sides into two partial cavities—which division, however, is not absolute, since that septum does not reach up to the top of the bag, but only to the middle of the afore-mentioned lateral cavities—it follows that the lateral cavities on both sides in their upper part are again one and common; that therefore, on opening the vault or ceiling above the lateral cavities, at the first inspection not only the nerves, but also the arteries, are exhibited to the sight. The transverse osseous closing-up of the cavities in question we have observed in several subjects; it was covered besides with a production of the dura mater. . . . I only desire to add here, that the sympathetic pair of nerves formed by a twig of the sixth pair and by two branches of the fifth, in the space of the lateral cavities between the fifth and sixth pairs, from its very origin passes over the membranous bulwark mentioned above; that therefore it is brought down into contiguity with the carotids; namely, that it enters its sheath, and that, under cover of this sheath, it finally leaves the cranium by the same foramen, through which this arterial trunk made its way to the sides of the sella" (p. 346). In Bianchi's Plate, "the crura of the posterior clinoid processes are represented, namely, the elongated heads of the lateral processes of this apophysis, which are, in addition, bent in a little before, and which send out below a certain robust ligamentous production which descends on both sides to the margin of the petrous process, and, being connected to the same, leaves therefore underneath itself a certain broad interval or vacuum, which is between the body of the aforesaid clinoid process, and the apex of the petrous process, and which communicates immediately with the lateral cavities" (p. 347, s. s.).

607. MORGAGNI.[1]—"It is wonderful, if it is indeed true, that the following words are used by so skilful and so learned an anatomist [he speaks of Ridley]: 'Respecting the "receptacula" of Vieussens, it is certain that they are not anywhere existent in human brains, according to the description he gives of them. For,' he adds further, 'the whole dura mater . . . in that place clings closely to the basis of the subjacent bone.' The ancient anatomists also were aware that this was not consonant with the truth, as is shown by Riolan,[2] who, I find, acknowledged 'receptacles' in that region, which he called 'fossulæ.' He says—'After the dura mater which encompasses the sella turcica is cut and torn off, you will find little grooves (*fossulæ*) filled with innumerable little arteries, which have the appearance of a rete mirabile.' Ridley, however, adds, 'In several injections made use of in order to find out the use of the parts, I never found one drop of the tinged liquors on that side of the carotid artery where Vieussens had made the situation of these "receptacles."' Ortlob,[3] on the other hand, states that, on injecting green wax into the sinuses, he filled on each side certain large

[1] "Adversaria Anatomica," vi.

[2] J. Riolan, Jr. "Anthropographia ex propriis et novis observationibus concinnata." Paris, 1618. Lib. IV., Cap. 2.

[3] J. Friedr. Ortlob. "Historia partium et œconomiæ hominis secundum naturam." Leipzig, 1697, 4to. Dissertat. 20.

sinuses, which I conclude from his figure to have been the very 'receptacles.' But lest I may not seem to condemn this illustrious author, not having seen his MS., and without having properly heard his cause, it seems better for me to confirm by my own observations some other things which follow on the uses of the sinuses (Animadv., vi, p. 7). . . . Vieussens, you say [he speaks of Bianchi], did not know that third posterior and transverse production, and consequently did not know the cavity which communicates with the lateral cavities. Still, Ortlob[1] did know that posterior cavity, and gave a drawing of it, and he said that this was 'a communication between the sinuses which are adjacent to the sella turcica, and which is situated near the posterior process of the sella.' He further says that 'this production may not improperly be called the transverse or conciliatory sinus.' If you perchance should ask, why Vieussens neither mentioned those cavities which encompass the sella on its sides and on the back, nor stated that, upon inspection, after having been opened, they all 'represent an inverted Greek capital *Pi*, that is Π,' you will obtain from me the following reply: that it often perhaps has happened to that most expert man, as it has to me with two bodies within a short time, that this posterior cavity either did not exist at all, or that it was so small, or again that it was so obstructed by the spongy, osseous substance of the posterior process of the sella equina—as I have seen in the head of a man fifty years old—that he did not think that it ought to be described as equal with the other receptacles, or to be classed with them (Animadvers., xviii., p. 22). . . . Besides, that which is subjoined [he means by Bianchi] in respect to the position of the arteries and nerves in the cavernous sinuses is either deficient, or it differs greatly from what I have frequently observed by diligent study. First, in respect to the deficiencies: It ought not to have been omitted that the third pair of nerves, and, at its exterior side, the fourth pair, without anything else being intermediate, except that very thin little sheath, were placed on the

[1] *Ibid.*, Dissertatio 20, § 6.

upper and posterior part of the artery. Again I have not only observed this, and indeed many times, but also that the sixth pair is lying near the exterior side of the artery, being in contact with it for a longer distance than the third and fourth pairs, and without anything intermediate; so that I am unable to approve in the Plate the position which I see the sixth pair has, especially on the right side of the head, nor can I give my approval to what is given in the explanation which runs on continuously, thus: 'The nerves, however, are separated from the trunks of the arteries by a certain new, and highly tendinous, expansion of the dura mater, in the form of a bulwark.' . . . This 'bulwark,' or septum, however, although it is soon called 'transverse,' and is said to be produced 'transversely,' nevertheless from the description itself appears not to run transversely through the 'receptacula' [*i.e.*, the cavernous sinuses], but to be disposed in them longitudinally; and again it appears not to ascend to their summit, but only to the middle, and in many cases finally it is said to be observed of an osseous quality, although covered by a production of the dura mater. I also have seen in some heads a certain septum, which sometimes was osseous and at other times firmly tendinous; in many cases, however, I have found it either wanting altogether, or certainly so low and small that neither the use attributed to it, nor the description given of it, could apply to it at all. Suppose then, near the external side of the foramen, through which the artery enters the cavernous sinus, there is raised a little, and produced in an anterior direction, the very embankment of the foramen by the addition of a substance which is intermediate between a ligament and tendon; yet, as I acknowledge to be true, this is done so little that it cannot afford to the sixth pair, nor even to the greater part of the fifth pair, the office of a separating and protecting septum" ("Animadvers.," xxiii., p. 29).

608. WINSLOW.[1]—"The cavernous sinuses of the sphenoid bone are receptacles of a peculiar kind, containing not only

[1] "An Anatomical Exposition," etc., Sect. x.

blood, but considerable vessels and nerves; and likewise a spongy or cavernous substance filled with blood, much like that of the spleen, or the corpus cavernosum of the urethra" (Sect. x, no. 46).

b. The Superior Petrosal Sinuses.

609. These sinuses have also been called the longer, but smaller and more slender sinuses of the base or of the sella turcica; those of the posterior petrous angle; and likewise the interior basilar sinuses. They extend from the cavernous sinuses of the sphenoid bone to the petrous portion of the temporal bone, and terminate in the lateral sinuses, where they are twisted into the tortuous shape of an alembic. They, therefore, derive their blood from the cavernous sinuses, and, at the same time, by the insertion into them of many veins from the inferior or anterior part of the cerebrum, which takes place by many orifices. They also progress in a somewhat triangular shape through the duplicature of the dura mater.

610. Vieussens.[1]—"Four sinuses open into the receptacles of the sella turcica [cavernous sinuses]. These sinuses are situated in that part of the dura mater which is spread over the base of the cranium. . . . The superior sinuses, traces of which are slightly impressed on the temporal bones, with those ends which are turned towards the sella turcica, open into the cavernous sinuses; by their other ends they terminate in the lateral sinuses; once, however, I found a portion of them impervious" (pp. 6, 7).

611. Ridley.[2]—"The superior petrosal sinuses, which are longer and narrower, according to Vieussens, arise from the cavernous sinuses, though more truly from the circular sinus, running down from thence upon the internal process of the temporal bone, and terminating in the lateral sinuses" (pp. 42, 43).

[1] "Neurographia," etc., Lib. I., Cap. ii.

[2] "Anatomy of the Brain," etc., Chap. V.

612. MORGAGNI.[1]—"Vieussens, in his Plate,[2] is careful not to represent the part of the superior petrosal sinus nearest to its end wider than the rest. I also in six heads, which I carefully inspected, could not see it enlarged, except in one single sinus, and this was partly obstructed by some fibrils, as it were woven into nets, ascending. In five heads, however, and also in many others, so far from its being larger, I really found it smaller; nay, in two of them the end was actually blind or impervious. The other end, however, which is inserted in the wall of the lateral sinus, in one case I found consisting of two small orifices, and in another of one only, but the opening of which was larger. This was the way of the blood into the lateral sinus; on which account I am inclined to believe that such also must have been the case with Vieussens' subject in which he found one of the two sinuses impervious at the same end; which, as he said, happened to him only once" (p. 35).

613. BIANCHI.[3]—"The narrower and longer of the sinuses, placed in the base of the cranium, derive their immediate origin from the cavernous sinuses almost under the angle which arises from the meeting of the productions of the dura mater. They run out thence in an oblique direction over the petrous portion of the temporal bone, into which, on that account, is imprinted a groove corresponding to their passage. Although this sinus measures a considerable length before reaching the top of the petrous portion, it, nevertheless, falls down again, and inserts itself into the lateral sinus, where this is first bent over the temporal bone in its progress towards the beginning of the jugular veins." See his Plate in Manget's "Theatrum Anatomicum;"[4] and especially also Ridley's second plate, where he deduces its origin from his circular sinus;[5] likewise Vieussens' Plate XVII.[6] This represents the continuation both of the

[1] "Advers. Anat.," vi.; Animadvers., xxviii.

[2] Plate XVII., p. 93.

[3] "Demonstratio Anatomica F. M. Nigrisolio conscripta," 1715, in Manget's "Theatrum Anatomicum," Vol. II., p. 347, nos. 8. 8. and 10.

[4] *Ibid.*, Vol. I., p. 342, *Tabula V.*, *extra ordinem.*

[5] "Anatomy of the Brain," etc.; Appendix, Figure II.

[6] "Neurographia," etc., p. 93.

superior and inferior petrosal sinuses by the curve where the sixth pair of the nerves, together with the carotids, crosses the cavernous sinuses. *Morgagni* declares that "in seven heads he observed most clearly that the fifth pair does not pass over the beginning of the superior sinus, but, on the contrary, that the beginning of this sinus passes over the trunk of the fifth pair."[1]

c. The Inferior Petrosal Sinuses.

614. These sinuses, which are also called the inferior, interior, larger but shorter, petrous sinuses of the sella turcica, or those of the crura of the sella, start from the sides of the cavernous sinuses or of the receptacles of the sella; or, according to Ridley, from the circular sinus; and they run out thence between the sphenoid and temporal bones. They become larger on the way, and, being but slightly bent, seek those petrous reservoirs into which the lateral sinuses discharge themselves with a view of entering the jugular veins. These sinuses, together with the superior petrosal sinuses, and the bent portion of the lateral sinuses, separate that part of the cranium which tends towards the temporal bone, almost as an island from the remaining continent, and also from the occipital and sphenoid bones. In this island the seventh pair of cranial nerves, the auditory nerve, leaves the cranial cavity and enters the temporal bone. Thither also reaches the extreme end of the tentorium, and thence, as from a fixed station, it extends towards the sella turcica and the cavernous sinuses.

615. Vieussens.[2]—"The inferior petrosal sinuses, whose traces are deeply imprinted upon the temporal and sphenoid bones, with one of their extremities, open into the cavernous sinuses, and with the other they enter into the jugular veins, where the lateral sinuses pass into them, and from these they

[1] "Adversaria Anatomica," vi.; "Animadvers.," xxi., p. 27.
[2] "Neurographia," etc., Lib. I., Cap. ii.

are separated partly by a bony and partly by a membranous partition" (p. 7).

616. RIDLEY.[1]—"The inferior petrosal sinuses, which are much shorter and wider than the others, descend from the same place as the superior, between the temporal and occipital bones, down to the aforesaid foramen of the cranium where the jugulars come up, and end there" (p. 43).

617. BIANCHI.[2]—"The inferior petrosal sinus derives its beginning on both sides from the cavernous sinuses, exactly under the crura of the posterior clinoid processes of the sella turcica; it runs out thence, immediately on the place where the sphenoid bone is articulated with the petrous process, where there is also a kind of furrow made for its passage. It is, however, much lower than the other, almost like a serpent lying at the bottom of the posterior side of the petrous process; while the other, the superior petrosal sinus, occupies the terrace of the same process. . . . Though the lateral sinus, after its first curve, descends inwards towards the centre of the cranial cavity, it nevertheless is inflected there a second time, and ascends; finally, however, it descends, and leaves the cranium on both sides through an ample, open foramen. Between the petrous portion and the occipital bone, or at the base of the posterior surface of the same petrous process, it is previously enlarged into a sort of lacuna, which is received in a peculiar bony fovea, called [by some] the specus rotunda. Soon it sends out backwards on both sides, from the posterior side of each lateral sinus, the vertebral vein which is about to enter the vertebral specus [plexus], and at last the whole lateral sinus is wedded with the beginning of the internal jugular, and runs with it into one channel. For carrying back to the heart, by means of the lateral sinuses and the internal jugulars, the liquids collected in the cavernous sinuses at either side of the sella turcica, and for conveying them thither, there are thus given four emissary vessels,

[1] "Anatomy of the Brain," Cap. V.

[2] "Demonstratio Anatomica," etc., 1715, in Manget's "Theatrum Anatomicum," Vol. II., pp. 347, 348, nos. g. g. and 11.

or four sinuses, which communicate immediately with these same cavernous receptacles; the former carry away from the latter its liquid contents, in order that the humours which are deposited, or which trickle into these cavities, of which there is one at either side of the sella, and which are exhausted of their uses, and therefore sluggish, may return into circulation more swiftly and easily, and without danger of delay and coagulation." See the Plates referred to above, and likewise that of Valsalva respecting the ear.

618. MORGAGNI.[1]—"Vieussens was quite right in representing the sixth pair of nerves at the external side of the inferior petrosal sinuses. I only could have wished that he had drawn the sixth pair of nerves along the same external side, and as received within the cavity of these same sinuses, and passing on for some distance, as I have seen in many heads" (p. 27).

d. The Circular Sinus.

619. The circular sinus, which runs around the pituitary gland and the sella turcica almost in the form of a circle, was first discovered by *Ridley*, who describes it in the following words:[2] "By having first injected the veins with wax, I discovered another sinus running round the pituitary gland on its upper side forwards, within a duplicature of the dura mater backwards between the dura mater and pia mater. Here it is somewhat loosely stretched over the subjacent gland itself, and laterally it is a sort of canal, made up of the dura mater above, and the carotid artery on each outer side of the gland, which, by being fastened to the dura mater above, and below at the basis of the skull too, leaves only a little interstice between itself and the gland, thereby constituting a cavity communicating with the aforesaid arteries (from whence the above-mentioned four small sinuses descend) by a visible continuity, on each side, from a little beneath the hinder

[1] "Adversaria Anatomica," vi.; "Animadversio," xxi.
[2] "Anatomy of the Brain," Chap. V.

process of the sella turcica. . . . Vieussens, it may be, saw some part of this sinus where he thought that the cavernous sinuses communicated. . . . The use of this circular sinus is to bring back the blood from the pituitary gland, the sphenoid bone, and, it may be, also from the rete mirabile, seeing the pituitary gland appears nowhere furnished with veins to carry off the blood from this plexus" (pp. 43, 44, 49).

620. *Bianchi* impugns and denies the existence of this sinus, observing that "the dura mater in the anterior region of the pituitary gland, or above the anterior processes of the sella turcica, is not duplicated, but simple, so that no sinus can be concealed in it. In reality, when the dura mater is scraped off in this place only very lightly, the bare bone underneath at once appears everywhere. Between the gland and the anterior elevation of the sella there is no space, nor is there any communication between the lateral parts of the sella. On the back of the gland, however, no space is found between the dura and pia mater; consequently, also, no pia mater is there, and therefore this sinus has been confounded with the cavernous sinuses. The dura mater, also, which covers the cavernous sinuses at the side of the gland, is exceedingly thin, and by no means duplicated; and if it is but slightly dissected, it at once opens an access to the cavernous sinuses." [1]

621. *Morgagni* [2] replies to these arguments thus: "Brunner, in his dissertation concerning the pituitary gland, wrote about thirty years ago that, on dissecting the human head with a syringe, he injected red wax into one of the two jugulars, the other having been tied; that the wax penetrated splendidly as far as the pituitary gland, which, on its anterior side, it encompassed like a crown. This sinus also was drawn by Cowper's own hand, and in his Appendix to the 'Anatomy of the Human Body' he distinctly represented a circular sinus or a vein which encircled the gland. Littre also writes that, between the thick-

[1] "Demonstratio Anatomica," etc., 1715, in Manget's "Theatrum Anatomicum," Vol. II., p. 343, no. a. a.

[2] "Adversaria Anatomica," iv.; "Animadversio," xix.

ness of the superior lamina of the dura mater, which covers the sella from above, a sinus of an oval shape could be observed, by which the superior portion of the pituitary gland is encircled, and into which a portion of the veins of the same gland is derived ('Mémoires de l'Acad. R. des Sc.,' 1707, p. 308). I myself, before removing the dura mater by which this gland is covered, observed a not obscure outline of an annular vessel, which, with its blood-colour, shone through that part of the dura mater, and around the superior circumference of the gland; and I noticed this so often, that out of nine heads there were only two in which I could not see it" (p. 24).

[Modern Authors.

a. *The Cavernous Sinuses.*

621*a*. Haller.[1]—"*The cavernous sinus near the sides of the sella turcica.*—At either side of the sella turcica the external lamina of the dura mater retreats from the internal lamina to a certain distance, namely, from the very declivity of the sella to the foramen through which an artery, coming from the external carotid, penetrates as far as the dura mater. The figure of the cavernous sinus is almost triangular. One side of this triangle is formed by the first nerve from the fifth pair; its second side by the clinoid process; and its third side by a very small ligament of the dura mater, which is very strong and rounded off, and is carried from the petrous bone to the clinoid process. Blood of a venous character is contained in the whole of this cavity, together with some cellular tissue. This blood is brought by four or five anterior, inferior veins of the lobes of the cerebrum, which descend from the Sylvian fissure. Sometimes I have seen them inserted in the superior petrosal sinus. The ophthalmic vein also betakes itself into the cavernous sinus out of the orbit of the eye; climbing over the optic

[1] Haller (Albert v.). "Elementa Physiologiæ corporis humani." 8 Vols. Lausanne, 1757-1766.

nerve, where it emerges out of the orbits, it communicates with the facial vein. Before the ophthalmic vein approaches the eye, a not insignificant branch departs thence towards the dura mater, as an attendant of the meningeal artery. I have seen the ophthalmic vein empty into the circular, and not into the cavernous sinus.

"The superior petrosal sinus opens into this receptacle at the anterior side of the fifth nerve; the inferior petrosal sinus under the ligament which springs from the dura mater (which was noticed above) before the nerve of the sixth pair; the circular sinus under the third pair and above the sixth pair, between the posterior clinoid process and the nerve of the third pair; the anterior occipital or transverse sinus near the exterior and interior side of the carotid. Lastly, the blood of the receptacle follows the carotid through its entire first transverse flexure. The internal carotid is bathed in the receptacle by much blood, as is also the case with the nerve of the sixth pair and the great sympathetic nerve. A proper lamina, which is generated from the dura mater, and descends under the origin of the superior petrosal sinus, separates the fifth nerve from the receptacle. This same lamina, which is inseparably connected with the ophthalmic nerve, separates this nerve from the remaining portion of the receptacle; and at last it passes off into a cellular tissue. To a certain distance also the dura mater, which is produced out of the carotid foramen, fences off the carotid artery from the receptacle. The third and fourth nerves are carried along, above the receptacle, untouched by blood" (iv., p. 154, *et seq.*).

621*b*. BELL.[1]—"The cavernous sinus is a great irregular centre of communication with the lesser sinuses in the base of the skull. This sinus is sunk upon each side of the sella turcica, and is formed in the irregular splitting of the lamella of the dura mater. It is of a triangular shape. It extends from the sides of the sella turcica to the foramen spinale (*Malacarne*).

[1] Bell (Sir Charles). "The Anatomy and Physiology of the Brain and Nerves, the Organs of the Senses, and the Viscera." Fourth Edition; 1816.

The pointed extremity of the tentorium, which extends forwards from the angle of the petrous bone to the posterior clinoid process, covers and protects it. The cavernous sinus is different from all the others. It is irregular, having fibrous cords traversing it, which gives it a kind of cellular appearance. It is like a diseased part into which the blood has been driven, till the cellular texture had been distended and partly destroyed. After a minute injection, small arteries are seen to ramify among these fibres. The internal carotid rises through it, and the sixth pair of nerves is involved in it, in their passage from the skull.

"This sinus is the centre of the little sinuses and veins of the anterior part of the base of the brain and cranium. Four or five veins pour their blood into it, from the anterior lobes of the brain and the fossa Sylvii. Sometimes [?] even the ophthalmic veins open into this receptacle. The superior and inferior petrous sinuses, and the basilar [transverse] sinus, open into it behind, the circular before; the sphenoidal sinuses and veins of the dura mater upon the side; while the right and left sinuses often communicate by means of the transverse sinus. Besides these, the cavernous sinuses have several communications, or emissaria, as they are called, viz., by the inferior orbitary foramen; the funnel of the carotid, through which descends a vein (the *vena sodalis carotidis*), which terminates in the pterygoid plexus of veins; the sphenoidal fissure; the interosseous sinus of Malacarne[1] (the 'Emissaria of Santorini,' see 'Observationes Anatomicæ,' p. 42, *et seq.*)." (Vol. II., p. 429).

621*c*. Theile.[2]—"*Sinus cavernosus.*—This sinus is situated along the side of the sphenoid bone, between the anterior and posterior clinoid processes. When filled with an injection its size amounts to four lines. Its entire cavity acquires a cellular

[1] The emissary vessels of the cavernous sinuses will be found fully discussed in the Appendix, Note vi., nos. 49-52.—Editor.

[2] Theile (F. W.). "Lehre von den Muskeln und Gefässen des menschlichen Körpers." In Sömmering's "Vom Baue des menschlichen Körpers." Leipzig, 1841.

appearance from the fact of numerous fibrous and filamentous cords being stretched out in it. Enclosed in its cavity, although lined by a covering of the interior venous coating, lies the interior carotid, with the plexus caroticus and the nervus abducens. The cavernous sinus carries blood in an antero-posterior direction. This blood is received behind by the sinus petrosi. Through the foramen ovale and the foramen anterius lacerum the sinus cavernosus is connected with the pterygoid plexus.

"It receives its supply from the following sources:—1, the vena ophthalmica—the interior vena ophthalmica corresponds altogether to the artery bearing the same name . . . . 2, the sinus spheno-parietalis, sinus alæ parvæ; 3, the vena fossæ Sylvii. . . . Haller already delineated a vein which empties into the sinus cavernosus, which cannot be any other than the vena fossæ Sylvii, and he characterizes it as a *constant* branch. On the basis of my own investigations I must declare myself entirely in favour of Haller's statement, which is also the generally prevailing one.[1] 4, the sinus circularis Ridleyii.—The sinus cavernosi of both sides frequently communicate by a transverse canal, which has its course under the pituitary gland (sinus circularis inferior, *Winslow*)" (p. 272).

621*d*. Luschka.[2]—"The anterior smaller end of the sinus cavernosus, which was formerly called the 'ophthalmic sinus,' represents the expanded end of the vena ophthalmica, which empties into the sinus cavernosus interiorly of the nervus oculomotorius, under the anterior clinoid process. This venous vessel corresponds to the artery bearing the same name, and accordingly is the recipient of the blood of the eye through the venæ ciliares and vorticosæ. . . . Posteriorly, the sinus cavernosus is continued chiefly into the superior petrosal sinus. The space of the sinus cavernosus is considerably reduced in size, on account of the

[1] The vessels through which the cavernous sinus receives its supply of venous blood are minutely discussed in the Appendix, Note vi., nos. 44-47.—Editor.

[2] Luschka (K. von). "Die Anatomie des Menschen," etc., Bd. iii, Abth. 2, "Der Kopf." Tübingen, 1867.

carotid interna with two of its bends, together with the plexus caroticus internus by which it is encircled, and the nervus abducens which presses against its outer side—having assigned their places in it. These parts, however, are not immediately bathed with blood, but they have a delicate membranous covering, which must be regarded as a portion of the venous coating of the sinus. This venous space, besides, is crossed by a delicate system of trabeculæ, by which the sinus is broken up into compartments. The component parts of this trabecular system, which, to some extent, contains least vessels and nervous fibres of the sympathetic nerve, consist of cellular fibrils and elastic filaments.

"Two sinuses, which have hitherto been regarded as special sinuses, may be defined as branches of the sinus cavernosus, namely, the *sinus spheno-parietalis* or *sinus alæ parvæ*, which has been described by Breschet.[1] This sinus is embedded in a groove, at the lower end of the ala parva of the sphenoid bone, which extends to the anterior extremity of the sinus cavernosus. It receives the vena diploica temporalis anterior, and, almost without exception, is connected with the vena meningea media. At the extreme end of the fissure of the superior orbit, according to Hyrtl,[2] there empties into Breschet's sinus not unfrequently a vein—vena ophthalmo-meningea—which extends from the fissure of Sylvius to the above fissure.—*Secondly*, the so-called *sinus caroticus* (Rektorzik)[3] must be regarded as an appendage of the sinus cavernosus. The lacunæ of this sinus are pushed in between the carotid interna and the walls of the canal, and therefore allow modifications in the lumen of the carotid even during its sojourn in

[1] Breschet (M. G.). "Recherches anatomiques sur le système veineux," Liv. ii, pl. 3.

[2] In "Oesterreichische Zeitschrift für praktische Heilkunde." Jahrgang v. Wien, 1859; p. 768.

[3] Rektorzik (E.). "Ueber das Vorkommen eines Sinus venosus im Canalis caroticus des Menschen." Wien, 1868. This sinus was first discovered and described by *Santorini* in his "Observationes Anatomicæ," Venice, 1724. The history of this sinus, and its function, will be found minutely discussed in the Appendix, Note vi., no. 49.—Editor.

said canal. At the apex of the petrous bone the lacunæ of said sinus are connected with the sinus cavernosus, and towards the entrance of the carotid canal they gradually unite into several veins which empty into the vena jugularis interna" (p. 151, *et seq.*).

621*e*. LANGER.[1]—This observer made careful injections of the cavernous sinuses and their venous connections with a resinous substance; and afterwards removed the animal tissues by corrosion, that is, by treating them with acids and macerating them in water. He thus obtained perfect casts of these sinuses and their connections. These casts form the basis of his observations. He says, "In investigating the sinuses, especially those which are situated at the base of the cranium, it is essential to make use also of the heads of young subjects, and even those of newly-born infants; and, indeed, for this reason, because later in life and especially in old age, originally slender and venous canals become very generally sinuous, and by confluence even form large spaces and lacunæ, which no longer correspond to the original plan according to which they had been formed.

"The sinus cavernosus is usually represented as an irregularly bounded space which is traversed by trabeculæ, and which, especially in sections, presents to the sight a system of continuous lacunæ. The greater the number of the trabeculæ, the more, consequently, the space is broken up, and the greater the likeness which it bears to a corpus cavernosum. This form, however, is by no means the general one; certainly not in the case of adults, and least of all in old age. The number of trabeculæ then is small, and the sinus, consequently, presents then the form of one large lacuna; quite different from what is the case in childhood: for then, when the sinus is laid open, there never appears a large space, but rather a sinuous tissue, which is traversed by numerous trabeculæ. . . .

"If now we hold fast to the similarity of the sinus cavernosus

[1] Langer (Prof. K. v.). The sinus cavernosus of the dura mater. (Sitzungsberichte der Kaiserl. Akad. der Wissenschaft. Jahrgang, 1885. Dritte Abtheil., Wien.)

to a corpus cavernosum, which can scarcely be doubted—the question here arises of a venous network, which originally, in the child, exists purely in this form; but which by-and-by through age, and indeed by a process of confluence, becomes sinuous. In order to prove the existence of such a network, we require casts obtained by corrosion; not, indeed, casts obtained from the sinuses of adults. From that source they are indeed found to be articulated by trabeculæ, which at one time are flattened, and then again round, and between them there exists also a certain connection; yet the regular form of a network can be traced there only with difficulty. It is different in infantile subjects, which, for the following reason also, are more favourable for experiments of this kind; namely, their circumference being smaller, there is a possibility of their being filled with one injection at once. In successful casts the original net of the sinus cavernosus may thus be seen freely in its full originality and purity; these casts also permit us to examine more accurately the inflowing and outflowing veins.

"The first thing with which we are struck in such preparations is the fact of the sphenoid bone and the entire clivus being covered, as to their surface, with dense venous nets. An exception is made in favour of the free margin of the back of the sella, with its clinoid processes, which always remains denuded of such plexuses.

"In this net there may be distinguished a superficial layer, which consists of more slender vascular tubes, the meshes of which are not too close, and which spreads out leaf-like along the sides of the sella, and may be traced into every direction, especially into the tentorium, by the way in which it is fastened to the back of the sella. Smaller portions of this net accompany also both petrosal sinuses, and even the intercavernous sinuses. It spreads out also in the fibrous roofing of the sinus Meckelii for the ganglion of the trigeminus.

"In this superficial layer of the net there is imbedded the nervus oculomotorius, together with the trochlearis nerve, during the whole of their passage, until they reach the sphenoidal fissures.

"Underneath this superficial, more delicate net, there is another which consists of larger vessels, and is attached immediately to the bone. The ophthalmic veins, and generally also the spheno-parietal sinus, upon their arrival enter into this net; and the departing larger veins, whether they bear the character of anastomoses, emissaria, or sinuses, proceed from it. This lower, grosser net constitutes the *sinus cavernosus* proper, which, therefore, in harmony with its original form, may be defined as a 'plexus cavernosus.'

"By a removal of the upper, more delicate net, or also by a mere examination of that lower side of a cast of the sinus which is turned towards the bone, it becomes evident that the little trunks of the ophthalmic veins, whether they be single or double, immediately after their passage through the inner part of the sphenoidal fissure, become ramified, and in this divided form enter the plexus cavernosus. The roots of the departing veins usually proceed from this plexus in such a way that they are recognised as the immediate successions of the branches and twigs of the arriving veins (mostly also of the vena spheno-parietalis), in such a way, indeed, that small twigs of the ophthalmic veins may be traced directly, not only into the plexus which encompasses the pituitary gland, but also into the emissary vessel of the foramen ovale, as well as into the inferior petrosal sinus.

"If the sinus cavernosus is thus regarded as a peculiar vascular formation, in agreement with its original plan, it may be defined as a (bipolar) *rete mirabile*" (pp. 307-311).

"There can be no doubt whatever that the superficial net of the plexus cavernosus, which may be observed in successful casts taken from infantile subjects, is situated inside the thick lateral wall of the sinus, and that it invests the nerves which pass through here. The fact of the nervus oculomotorius being imbedded in this layer was mentioned above. Whether this net be looked upon as a part of the plexus cavernosus, or as forming already a part of the dura mater, does not alter the circumstance of its being continuous with the lower net" (p. 315, *et seq.*).

The functions of the cavernous sinuses will be found fully discussed in the light of modern science in the Appendix, Note vi., nos. 41-52.

b. The Superior Petrosal Sinuses.

621*f*. Haller.[1]—"The anterior end of the superior petrosal sinus is constantly in the cavernous sinus, near the interior side of the fifth pair of nerves, and near the anterior side of the posterior clinoid process; *which part may also be ascribed to the circular sinus.* It communicates with the inferior petrosal sinus under the fifth nerve, and further back; and finally with the anterior occipital or transverse sinus, near the interior side of the posterior clinoid process. Its posterior end is in the angle of each lateral sinus, where it begins to incline its horizontal course downwards along the petrous bone; and it is inserted in the convex side of this sinus. I saw the whole of our sinus inserted in the inferior petrosal sinus.

"The inferior veins of the cerebrum, at least of its posterior lobes, sometimes open into the superior petrosal sinus, as they do into the lateral sinuses. The inferior cerebellar veins, however, are constantly inserted into this sinus, not far from its posterior end, in company with the veins of the medulla oblongata and of the pons Varolii, which arrive between the medulla oblongata and the cerebellum. Sometimes also they receive the ophthalmic vein.[2] Occasionally the veins which spring from the anterior lobes of the cerebrum, instead of discharging their contents into the cavernous sinus, empty by preference into the superior petrosal sinus. This sinus also derives some blood from the veins of the dura mater, which make their approach over the higher breadth of the petrous bone;[3]

[1] "Op. citat.," Vol. IV., p. 152.

[2] With the ophthalmic vein the superior petrosal sinus is connected by the *sinus ophthalmo petrosus*, described by Hyrtl; concerning which, see Appendix, Note vi., no. 34.—Editor.

[3] The largest meningeal vein which empties into the superior petrosal sinus is the *great anastomotic vein*, described by Trolard; see Appendix, Note vi., no. 33.—Editor.

one of these veins, which is honoured by some observers with the name of a sinus, makes its approach over the same ridge, but nearer the temples, and is inserted in the transverse sinus exactly where it begins its descent."

621*g*. KNOTT.[1]—*Sinus petrosus superior;* sinus petrosus basilaris (Langer), s. tentorii lateralis (Weber), etc.—This sinus runs along the upper border of the petrous bone, between the layers of the tentorium, from the posterior extremity of the cavernous sinus in front to the lateral sinus behind. It joins the latter at the junction of the horizontal and descending portion. It varies considerably in size. Its absence was noted in three cases—two of the right side, and one of the left. A communicating *vas aberrans*, between the ophthalmic vein in front, and the superior petrosal sinus behind, has been described by *Verga*[2] (Annal. Univ. di Medic., 1856). I have found a vessel answering to this description in three instances. They all occurred on the left side."[3]

c. THE ANTERIOR OCCIPITAL OR TRANSVERSE SINUS.

621*h*. KNOTT.[4]—"*Sinus Transversus;* s. basilaris (Cruveilhier); s. fossæ basilaris (Breschet); plexus basilaris (Virchow), etc.—The so-called transverse sinus of our handbooks ill deserves the name, for it does not form a separate and distinct canal, as in the case of the vessels previously described. The name of *plexus basilaris,* given to it by Virchow,[5] is much more

[1] Knott (J. Freeman), Dublin. "The Cerebral Sinuses and their Variations." In the "Transactions of the International Medical Congress," 7th Session, held in London, 1881. London, 1881; Vol. I., p. 195, *et seq.*

[2] This *vas aberrans* of Verga is discussed in Note vi., no. 34, and a misapprehension of Knott corrected.—EDITOR.

[3] The function of the superior petrosal sinus, assigned to it by Swedenborg, will be found fully discussed in the light of modern science—in the Appendix, Note vi., nos. 30-36.—EDITOR.

[4] See "Op. citat."

[5] An *exposé* of the state of modern science, in respect to the "transverse sinus," together with Virchow's interesting account of the *plexus basilaris*, will be found in full in the Appendix, Note vi., no. 37.—EDITOR.

applicable, as it is formed of a network of anastomosing veins placed between the layers of the piece of dura mater which covers the clivus. Some of these open into the inferior petrosal sinus of either side; some communicate anteriorly with the receptaculum, or sinus cavernosus posterior; while others pass downwards to the margin of the foramen magnum, to anastomose with the anterior rachidian veins."

621*i*. HALLER.[1]—"*The anterior occipital sinuses.*—The sinuses which follow here do not receive any vein from the brain, but they are received in a like manner between the laminæ of the dura mater. In the first place, the whole of that anterior process of the occipital bone, which is conjoined with the sella turcica, is penetrated by venous sinuses which are filled either with blood, or [in injections] with wax which takes the place of blood.

"The transverse sinus, almost perpetual, and mostly wide and important, conjoins the right inferior petrosal sinus with the left, and, where it joins these sinuses, it communicates with the cavernous sinuses. Often a multiplex sinus, with various branches, passes through the dura mater of the cuneiform process of the occipital bone, and is inosculated in the cavernous sinuses, along the sixth pair of nerves. Again, in the same place, it is inosculated with the inferior petrosal sinuses, exteriorly in the neighbourhood of the carotid. This same sinus again, interiorly of the carotid, communicates with the posterior semi-circle of the circular sinus. With the superior petrosal sinuses it is inosculated in various ways, and finally with the trunk of the jugular vein.

"Those sinuses, which follow the cuneiform process of the occipital bone longitudinally, extend from the seat of the auditory nerve downwards towards the foramen magnum. There are two of these almost at the margin of the petrous bone; they are like unto, and equal with, one another. Their anterior extremity is a vein which passes out of the skull in company with the ninth cranial nerve, and which directs its

[1] "Op. citat.," iv., p. 157.

course towards the vertebral vein. Several veins from the beginning of the spinal cord, and from the medulla oblongata, join this emissary. The posterior end of these sinuses goes backwards towards the posterior margins of the occipital bone, and, through the funnel-like expansion of the dura mater which descends from the cranium, it is inserted in the spinal sinuses.

"To the present sinus I would also refer a new sinus, of which Pietro Tabarrani[1] says, that it springs from the funnel of the carotid, and terminates either by a single orifice in the jugular fossa, or has an oblique termination in common with the inferior petrosal sinus.[2] He also attributes to his sinus a diverticle which enters into the vertebral vein, and opens also into this sinus."

621*k*. VICQ D'AZYR.[3]—"Behind the posterior clinoid processes there is a furrow which contains the sinus called by some the *posterior clinoid sinus.* Six or eight lines further down is the *basilar* or anterior occipital sinus" (p. 107).

"The extremities of this posterior clinoid sinus open into the cavernous sinus. This same sinus communicates on the one hand with the superior petrosal sinus, and on the other hand with the anterior occipital sinus. Its form is not at all constant" (p. 102).

621*l*. SAPPEY.[4]—The anterior occipital sinus, called also the transverse, and the basilar sinus, like the circular sinus, belongs

[1] Tabarrani (P.). "Observationes Anatomicæ." In "Giuliani (C.A)., Memorie sopra la Fisica e Istoria naturale di diversi valentuomini." Tom. I. Lucca, 1743.

[2] The canal or sinus described by P. Tabarrani in 1743 is identical with that discovered by Dr. J. Englisch in 1863, whereby, as he says, there is effected "a constant communication between the sinus cavernosus and the sinus petrosus inferior, outside of the cranium." The canal of Tabarrani also is identical with the "lower petro-occipital sinus" described by Trolard in 1870. The whole history of this canal, and the satisfactory way in which it accounts for an important particular in Swedenborg's theory of the Function of the Pituitary Gland, are fully discussed in the Appendix, Note vi., nos. 38-40.—EDITOR.

[3] Vicq d'Azyr. "Traité d'Anatomie et de Physiologie." Tom. I. Paris, 1786, Fol.

[4] Sappey (Ph. C.). "Traité d'Anatomie descriptive." Troisième édition. Paris, 1876; Tom. II., p. 735.

to the anastomotic sinuses. It is formed of two or three irregular ducts, which open into one another, and which extend transversely from the confluent of the petrous and cavernous sinuses of the one side to the analogous confluent of the opposite side. This sinus is situated behind, and below, the perpendicular side of the sphenoidal bone. In *reuniting the two superior petrosal sinuses,* it forms with them a large anastomosis, extending transversely from the right lateral sinus to the left lateral sinus. Sometimes the anterior occipital sinus communicates with the interior spinal veins."

621*m*. THEILE.[1]—"On the base of the occipital bone, near the dorsum sellæ, there are situated transverse, reticular, venous spaces, which, with the exception of a few small branches from the pons Varolii and the medulla oblongata, do not receive any blood from parts of the brain, but, on the contrary, *out of the substance of the bone.* They are connected on each side with the cavernous sinuses and the inferior petrosal sinuses, and posteriorly with the venous plexuses of the vertebral column. These spaces connect the anterior sinuses of the cranium with the plexuses of the vertebral column. This part really does not deserve the name of a sinus. It is a venous plexus in the base of the occipital bone, which is quite analogous with the venous plexuses on the vertebræ."

621*n*. LANGER.[2]—"The venous net, the *plexus basilaris* of Virchow, which covers the clivus and conjoins the two inferior petrosal sinuses, is perfectly developed in the child. It consists of two layers of interwined vessels; of a superficial one composed of more delicate vessels, and of a lower one which is composed of thicker tubes. While the entire complex of vessels is continued downwards into the immediate neighbourhood of the veins which line the foramen magnum occipitale in an anterior direction, it terminates sharply underneath the margin of the

[1] In Sömmering's "Vom Baue des mensehliehen Körpers." Leipzig, 1841. (Lehre von den Muskeln und Gefässen, p. 276.)

[2] Langer. "Der Sinus Cavernosus der harten Hirnhaut." (Sitzungsberichte, etc., Vienna, 1885.)

back of the sella. In adults the part of the clivus which is covered with this net is often sunk in, and mostly also seems carious and perforated. This is due, as has been observed already by Virchow, to a tissue, the foundation of which is formed by a sinuous texture of veins. This texture is circumstanced exactly like the sinus cavernosus. The veins, which are originally arranged in the distinct form of a net, in the course of time through enlargements become sinuous, and by confluence they at last give rise to an extensive, common lacuna, which is traversed by fibrous trabeculæ" (p. 314). See above, no. 621*e*.

d. The Inferior Petrosal Sinuses.

621*o*. Haller.[1]—"The inferior petrosal sinus has its anterior end in the cavernous sinus. With that sinus it communicates through the venous tract which accompanies the sixth nerve; and also very amply back of the posterior clinoid process, and indeed exteriorly to, and more posteriorly than, the carotid, before the nerve of the fifth pair, between the carotid and the back or ridge of the petrous bone ; in the same place where also the circular sinus opens into the cavernous, under a very hard ligament which springs from the dura mater, and which extends from the back of the petrous bone to the posterior clinoid process. This sinus is also considerably conjoined with the anterior occipital sinus, from whence that venous tract which accompanies the sixth nerve proceeds at other times. It empties into the jugular fossa, or into the lower end of the lateral sinus. Nevertheless, I have seen the inferior petrosal sinuses terminating blindly this side of the lateral sinuses, so that they had nothing in common with them. Some veins of the dura mater from the region of the vertebræ, and from the place where they join the occiput, discharge their contents into this sinus.

[1] "Op. citat.," v., p. 153.

Some veins also come from the beginning of the spinal marrow and from the medulla oblongata."[1]

621*p*. VICQ D'AZYR.[2]—" It has been thought that the inferior petrosal sinus opened into the jugular fossa together with the lateral sinus. My observations have taught me that it is separated from that fossa by an osseous production covered with a cartilaginous lining,[3] and by the eighth pair of nerves, to which the foramen lacerum posticum lends passage. This same sinus discharges itself through the intermediation of a vein which is found at the base of the cranium, before the internal jugular vein.

"This sinus communicates with the cavernous sinus, and with the anterior transverse sinus, from which it receives the blood which it conveys. When the internal jugular vein is injected with a view of filling the sinuses, the fluid does not pass into the inferior petrosal sinuses, except after first passing through the cavernous sinuses. The structure, as here given, is not in accordance with the description as it is usually given; but it describes what I have observed in the subjects where I made my researches."

621*q*. LUSCHKA.[4]—" The *sinus petrosi inferiores* are considerably wider, but shorter, than the superior sinuses, and they are contained in the grooves, which laterally are in that division of the clivus which is furnished by the body of the occipital bone. Their anterior extremity is bridged over by a fibrous, little ligament which passes over the nervus abducens, and is conjoined with the sinus cavernosus; while the posterior extremity, at the anterior end of the foramen lacerum, passes over into an independent vein, 2mm. in width, and 6mm. in

[1] The venous supply of the inferior petrosal sinus is detailed from modern sources in the Appendix, Note vi., no. 53.—EDITOR.

[2] "Op. citat.," p. 103.

[3] The *sulcus pro sinu petroso inferiori*, it seems, was newly discovered by Prof. Theile in 1855. It will be found fully discussed in the Appendix, Note vi., no. 55. In the same place also there is discussed at large the fact, which was likewise discovered first by Vicq d'Azyr, that the inferior petrosal sinus, at its posterior extremity, alters its character as a sinus, and passes over into a vein.—EDITOR.

[4] Luschka (H. von). "Die Anatomie des Menschen." Tübingen, 1862-1867.

length, which, below the basis of the skull, terminates in the jugular vein. Into the above vein, according to the observations of J. Englisch, there lapses a canal,[1] 1½mm. in width, which is contained in the cartilage between the petrous bone and the pars basilaris of the occipital bone, and which communicates with the posterior end of the cavernous sinus" (iii. 2; p. 153).

"Shortly after the internal jugular vein has made its appearance at the external surface of the cranium, there enters into its anterior circumference the posterior end of the inferior petrosal sinus. This sinus, which pursues its course in a groove between the petrous bone and the body of the occipital bone, at the anterior extremity of the foramen lacerum posticum, through which it descends, usually passes over into a vein with its own independent coatings and walls. . . . Closely behind the place where this vein penetrates the foramen lacerum, three nerves, the glosso-pharyngeus, the vagus, and the accessorius Willisii, all surrounded by special productions of the dura mater, pass through the anterior smaller division of the foramen lacerum, and during their passage they are separated from the internal jugular vein by the processus jugularis spurius, or by a fibrous partition which replaces said processus" (i. 1; p. 356).

621*r*. TROLARD.[2]—"*The inferior petrosal sinus.*—The lower wall of this sinus sometimes presents openings, through which it communicates with the *inferior petroso-occipital sinus* [the canal of Tabarrani]. The inferior petrosal sinus does not terminate in the lateral sinus. After reaching the internal extremity of the foramen lacerum posticum, it traverses that foramen, placing itself in front of a nervous trunk, and it goes to meet the internal jugular vein below the jugular fossa. It opens into it through an oblique opening. During this passage it is no longer a sinus, but a vein.

[1] This canal is the "Canal of Tabarrani" which is discussed in the Appendix, Note vi., nos. 38-40.—EDITOR.

[2] Trolard (P.). "Recherches sur l'Anatomie du Système veineux du Crâne et de l'Encéphale." In "Archives Générales de Médecine." Tom. XV. Paris, 1870.

"This vein, about its middle portion, presents an opening whereby it communicates with the 'anterior condylar confluent.'

"In the foramen lacerum posticum, proceeding from within outwards, there are: (1) the vein which unites the inferior petrosal sinus with the jugular vein; (2) three nervous trunks; (3) the internal jugular vein. I have often seen the foramen lacerum posticum divided very neatly into three orifices by the interposition of two complete osseous bridges; the most internal of these orifices was intended for the petrous sinus, the middle for the nervous trunks, and the external for the jugular vein. The grand anastomose, admitted at the present day, between the anterior and posterior sinuses, through the intermediation of the inferior petrosal sinus, consequently does not exist"[1] (p. 264).

e. The Superior Circular Sinus, and the Inferior Transverse Sinus.

621s. Haller.[2]—"Between the interior and external laminæ of the dura mater there is a sinus which, in most cases, certainly in my own specimens, is like a perfect ring. Its anterior semi-circle is placed before the pituitary gland, and is sometimes narrower, while the posterior semi-circle, which is between the pituitary gland and the posterior clinoid process, is often wider. More frequently, however, I have seen the anterior semi-circle larger. These two semi-circles meet in the middle of the sella. There they are bounded by the cavernous sinus, with which they communicate by an opening near the carotid. . . . These semi-circles, however, are also united with the superior petrosal sinuses in the same place, before the posterior clinoid process, under the third and fourth nerves. With the inferior petrosal sinuses they meet between the posterior clinoid process, and between the internal carotid and the third nerve,

[1] The communication of the inferior petrosal sinus with the "anterior condylar confluent," is discussed more minutely in the Appendix, Note vi., no. 54.—Editor.

[2] "Op. citat.," iv., p. 156.

and with the anterior occipital sinus almost in the same place, but near the interior and upper surface of the carotids.

"Often a transverse sinus, either under the gland, or sometimes a posterior one, conjoins the cavernous sinuses, or, finally, a transverse sinus in front. Sometimes, but more rarely, the ophthalmic vein terminates in the sinus at the sides of the sella equina so far inwards that it can justly be claimed for the circular sinus. Not seldom this sinus receives considerable veins from the sella equina, and from the osseous, spongy substance of the sphenoid bone. Finally, the little veins of the pituitary gland pour into this sinus."

621*t*. THEILE.[1]—"The circular sinus receives little veins from the tuber cinereum, the infundibulum, the pituitary gland, and the sphenoid bone. It opens on either side into the sinus cavernosus, but it is also conjoined with the anterior occipital or transverse sinus, and with the superior petrosal sinus. The posterior semi-circle seems to be regularly a little narrower than the anterior."

621*u*. KNOTT.[2]—"The receptacula of opposite sides are connected by means of one or more transverse vessels which cross the pituitary fossa. There are frequently two; one in front the hypophysis, and the other behind. The anterior is the larger, the posterior is often completely absent. Its absence was noted in twenty of my forty-two cases. In two of the others the posterior branch was the larger of the two, and in another case it was the only one present. In fifteen cases only did the above-described arrangement of two transverse branches exist. When present they form, with the cavernous sinus on each side, the *sinus circularis* of Ridley (sinus ellipticus, sinus coronarius, clinoid sinus, Sir Ch. Bell).

"A single vein forms the *sinus transversus sellæ equinæ*, described by Haller.

"A *sinus circularis inferior* is described by Winslow beneath the pituitary gland, and formed by branches which

[1] "Op. citat.," p. 274.

[2] "Op. citat.," p. 195, *et seq.*

take a course nearly parallel to the one usually described. I have found it in six cases only; in twelve cases there was a single intercavernous vein beneath the pituitary body."

621*v*. HENLE.[1]—"The sinus cavernosi of either side are connected by one or several canals, which run along the anterior and posterior walls of the sella turcica, or at its bottom, and which are called the *anterior and posterior intercavernous sinuses*. These intercavernous sinuses, together with that part of the sinus cavernosus which is situated between their origins, form an ample venous ring around the stem of the pituitary gland, which has been called the *sinus circularis*. The communicatory canal at the bottom of the sella is identical with Winslow's *inferior circular sinus*. Among the two intercavernous sinuses, the one in front is the more powerful one, while the one at the bottom is more frequently absent" (p. 333).

621*w*. KEY and RETZIUS.[2]—"As the hypophysis on its upper surface has a subarachnoidal space completely filled up by cerebro-spinal liquid, so at its lower surface also it has a broad venous sinus—sinus intercavernosus inferior (*Henle*)—which on either side passes over into the sinus cavernosus. Besides, it is encompassed also by the sinus circularis Ridleyi, or sinus intercavernosus anterior and posterior (*Henle*). In respect to this sinus, Henle says that the anterior sinus intercavernosus is the larger one of the two, and that the sinus intercavernosus inferior is wanting most frequently; in a footnote also he designates the latter sinus as a communicating canal. Our experience regarding this sinus is somewhat different. In the numerous subjects examined by us for this purpose, we have *never* found it missing. Further, we usually found the canal at the bottom larger than the sinus intercavernosus anterior, and always spread over the bottom of the fossa pituitaria, serving as a means of conjunction between the two sinuses cavernosi. It is possible,

[1] Henle (Dr. J.). "Handbuch der systematischen Anatomie des Menschen," Bd. iii., Abth. 1. "Gefässlehre," Braunschweig, 1868.

[2] Key and Retzius. "Studien in der Anatomie des Nervensystems und des Bindegewebes." Vol. I. Stockholm, 1875.

indeed, that there is a greater variety in this sinus than we have discovered; but the form in which we have delineated it in our plates is probably the most common. The fact of the hypophysis being thus imbedded between a serous cistern and a venous sinus is no doubt a matter of interest, and it even seems to us to enhance the peculiarity of this enigmatical organ" (p. 97).

621*x*. Langer.[1]—"The anastomotic veins between the two cavernous sinuses, which are called *sinus intercavernosi*, are only parts of a net spread out flat, which lines the whole pituitary fossa, and which, basket-like, receives in itself the pituitary gland. This net consists of a thicker kind of little tubes, separated from each other by small longitudinal clefts, and which closely adhere to the sphenoid bone, and receive from it a diploic venous twig. Fragments of more delicate little tubes point out the existence of vessels which enter into this net from the pituitary gland. We have stated above that some peripheral twigs of the ophthalmic vein enter directly the larger vessels of this net inside the pituitary fossa; we also stated there that root-branches of the two sinus petrosi originate here" (p. 312, *et seq.*). See above, no. 621*e*.]

[1] Langer (Prof. K. v.). "Der Sinus Cavernosus der harten Hirnhaut." (Sitzungsberichte, etc., Dritte Abth., Wien, 1885.)

ANALYSIS.

622. The cavernous sinuses surround the arch-gland on three sides. Their ceiling they borrow from a production of the interior lamina of the dura mater; their bottom from the interior stratum of the same. Within this duplicature they receive the trunks of the carotids, thus, all the arterial blood which is to be scattered through the hemispheres of the cerebrum; further, a phalanx of nerves which are about to depart into those provinces of the kingdom which have been allotted to each; likewise veins, and the highest parts of the petrosal sinuses, which receive the essences of the brain through the pituitary gland, and convey them to the receptacles of the lateral sinuses and the jugular veins. The cavernous sinuses thus summon together, *first*, all the arterial blood which is about to enter the brain; *secondly*, the purest essences of the blood, which are prepared and secreted in the most refined manner, and which are about to depart from the brain; further, the recently born and still virginal nerves which are on the point of escaping from their bony walls and ramparts. All these generals and leaders who are about to administer the affairs of a unanimous republic are summoned, as it were, by these sinuses into their council chamber and to a cabinet meeting under the presidency of the brain; and they pass in and out as if to pledge here their faith and loyalty, and to take up an oath that, like blood-relations, as it were, they will not intend and undertake anything except under mutual advice and consent, nor anything but what will contribute to the welfare of the kingdom. Neither is there any safer place of meeting than near the footboards of the gland, where the brain, wearied by action, takes its rest, as it were, in a certain centre and secure haven.

623. The longer, exterior and more slender sinuses of the base [the superior petrosal sinuses] receive from the circular sinus, and also through veins immediately from the gland, that first and purest essence which the gland expresses, and they convey the same to the receptacles of all the sinuses, and the jugular veins. Those sinuses have their heads and lips high up and close to the circular sinus; for near the carotids they curve themselves in the shape of the letter *e*, and thence they incline and project themselves upwards towards the above sinus.[1] They are comparatively long and slender, and their tube-like bodies are completely adapted to the quickness and the swift flashes of the above fluid. Their colour also indicates the extreme liquidity of their blood. Where these sinuses are inosculated in the widened ends of the lateral sinuses, the foramen, through which their contents pass, is sometimes found impervious, like that of the beak of the infundibulum, to which it corresponds in point of dimension, and through which this kind of fluid is instilled into the gland. These same sinuses also seem to admit, in addition, the fluid of the second order, which passes through the bones of the skull, namely, that portion of it which is not poured immediately into the jugular veins.[2]

624. The larger, interior and shorter sinuses of the base [the inferior petrosal sinuses] seem to swallow up all that serous fluid in which the gland is bathed on all sides, and which is derived into the cavernous sinuses, and ejected thence. This serum they convey into the common receptacle of the sinuses; for those inferior sinuses lie a little more to the back than the former or superior ones, and bend themselves in the shape of the letter *f* towards the production of the posterior clinoids,

[1] According to *Sapolini*, the contents both of the circular and the anterior occipital sinuses are diverted into the superior petrosal sinuses by a peculiar trabecular and valvular arrangement in the cavernous sinuses. See Appendix, Note vi., no. 31.—EDITOR.

[2] This fluid seems to be conveyed towards the superior petrosal sinuses through the anterior occipital or transverse sinus. See Appendix, Note vi., nos. 32-37.—EDITOR.

and, at the same time, with their stretched-out veins and lips, they sip in mediately and immediately the vapour which showers down, and in this wise they drain the caverns. This we learn from injections, and it is confirmed by the situation, extent, and abundance of their lips, so that they must needs be canals intended for the conveyance of a more sluggish and grosser fluid. Besides, they also derive blood out of the spongy substance of the cranium, which is immediately underneath them, and which is irrigated by branches of the internal carotid.[1] They also receive some other blood which cannot be discharged in any other direction.

625. These cavernous cisterns which are sealed up all around by membranes, or which are enclosed within a duplicated lamina of the dura mater, cannot help being imbued with a more intense heat than the remaining organs; and, like the fire-place in a hot-water bath, they supply fire from underneath sufficient to separate the various menstrua. For the two carotid arteries, with an abundant supply of arterial blood, flow through the cavernous sinus, as well as two sinuses, two large veins, and likewise several infant nerves which are in a perpetual tremor and vibration; all of which act as mild dispensers of heat. The bottom also or the floor is thin; for the sphenoid sinuses are hollowed out underneath, and a mean temperature prevails there, lest the cavernous sinuses by the interposition of a thicker bone should be in too tempestuous a glow, and lest a slowly consuming vapour bath might destroy the enclosed parts, and lest by either too acute or too obtuse a heat they might become flaccid and withered. As the ventricles therefore are a kind of cooling stations, so the cavernous sinuses are places for warming, where the gland, as it were, enjoys a warm bath, and where it is gently heated with fire.

[1] See Appendix, Note vi., no. 38.—EDITOR.

APPENDIX TO CHAPTER XX.

AN EARLIER ANALYSIS OF THE CAVERNOUS SINUSES.[1]

625*a*. ARGUMENT.—The receptacles—the cavernous sinuses—which are adjacent to three of the sides of the sella turcica, afford a convenient and safe passage to the carotids, to sinuses, veins and nerves, and they warm all parts with the heat, as it were, of a bath which is increased to such a point that the processes of dissolving, commingling and transmitting liquids are carried on in a satisfactory manner; and, further, that through the mediation of the cavernous sinuses there may exist a due communication, *first*, of the liquid—the grosser serum—which presses in from the sella turcica; *secondly*, of the carotids with one another, as well as with the arch-gland; and *thirdly*, of the lympheducts with blood-vessels, both in the subjacent bone and in the meninx which lines the sella. It seems also as if the cavernous sinuses did not admit [from the pituitary gland] into their cavity any other fluid except that which collects around the gland, while the larger veins at the bottom of the cavernous sinuses, which are mentioned by Ridley, seem to receive the nutritive blood of the bone underneath. The mass of blood which approaches the brains is thus re-made and restored by the essences of the brain in the same order in which it is deprived of these essences in the cortical and cineritious substances and in the choroid plexuses.

625*b*. *The receptacles—cavernous sinuses—which are adjacent to three of the sides of the sella turcica, afford a safe and convenient passage to the carotids,* which effect an entrance immediately behind the posterior clinoid processes and perforate the dura mater, allowing themselves to be covered by its lateral

[1] From Codex 65, Photolithographed MSS., Vol. IV.

productions, and which, with a view of emerging thence, and ascending into the cerebrum, pierce the meninx. All this is for the purpose, that, by their passage through the cavernous sinuses, the carotids may be able to inflect themselves in various ways, and to rid themselves of the action of the heart which reaches almost so far, and to accustom themselves instead to the alternate motion of the brain ; and, indeed, by their keeping close to nerves on the one side, and near the pituitary gland on the other, and by receiving filamentous braces from the nerves, and at the same time from the dura mater, by which they also allow themselves to be acted upon in a general way, as well as by uniting themselves to the pituitary gland through arterial branches. The dura mater, together with the nerves by which the carotid is thus engirded, produces this effect, that this artery is also kept completely under the obedience of the brain which acts from above. In this same space—that is, within the cavernous sinuses—the carotid is further able to serve in the capacity of a certain diverticle, which summons and dispatches no more blood than the brain demands, or which does so entirely in accordance with the action of the brain. It is impossible, therefore, that there should be any more appropriate passage for the carotids than through the cavernous sinuses.

625*e*. *Likewise for the sinuses*, namely, for the four sinuses of the basis of the skull, which have their origin near the sella, and in the posterior angle of the cavernous sinuses; thus, 1, for the superior petrosal sinus, which is longer or more slender, and which near the carotid inflects itself in the manner of the letter *c*, in order to receive its liquid from the circular sinus ; and, 2, for the inferior petrosal sinus, which is shorter, wider or larger, and which bends itself in the manner of the letter *f* around that posterior part towards the productions of the posterior clinoid processes, so that it may sip in that liquid which is expressed into the third or posterior receptacle. Venous orifices also open there into that same receptacle.

625*d*. *Also a passage for the veins*, namely, for the two of which Ridley makes mention [viz., the ophthalmic vein and the vein of the foramen ovale[1]] and which he declares to have found in that same place where Vieussens places his receptacles, namely, the cavernous sinuses; besides other venous shoots which open into the inferior petrosal sinus.

625*e*. *And for nerves*, namely, for all the motor nerves of the eye, and for branches of the fifth nerve, which by that way tend towards the orbit, and which apply themselves to the carotids, in order that they may be warmed by its heat, so that they may never grow torpid as long as the brain is heated by blood. These nerves also tie the artery to themselves in such a manner that they are of one spirit in their work and their activity. This also is demanded by the organ of so subtle a sense as the eye.

625*f*. *The cavernous sinuses also warm all parts with the heat of a bath, as it were, which is increased to such a point that the processes of dissolving, commingling and transmitting liquids are carried on in a satisfactory manner.* Without degrees of a moderate heat, animal chemistry in vain secretes its essences, and prepares its spirits and extracts. Since there is in the brain the most perfect application of that art and science, we must therefore observe that in the brain there are similar degrees, or similar shades of temperature, namely, by reason of the abundant blood of the pia mater, by the perpetual dissolution of parts, and the constant modification of the substance, much heat is set free near the cortex of the brain. Again, a less degree of heat prevails in the medullary substance, where, nevertheless, there are small, but numerous diverticles of blood. The heat is still more reduced in the ventricles; for this reason, namely, that the nervous fluid, the animal spirit, may there be inviscated, and wedded to the serous fluid expressed from the choroid plexuses. Beyond the ventricles, through the infundibulum, the colder region again gives way to one which is warmer; that is, on approaching the pituitary gland the heat increases in order that the mixture may again

[1] See Appendix, Note vi., no. 50.—EDITOR.

be resolved. The cavernous sinuses themselves are a kind of hot bath. This appears from these considerations: *first*, so far as the infundibulum is concerned, there is poured around this organ the whole arterial supply which ascends to the brain; the stem of the united vertebral arteries presses gently against its sides; the carotids of both sides, on the other hand, inflect thither their trunks, and the communicating branch embraces the infundibulum; for both these vessels, on their way towards the posterior parts of the cerebrum and the choroid plexuses, incline themselves obliquely in the direction of this organ; little shoots also penetrate its substance; and there is a certain texture of vessels by which it is engirded. Numerous sanguineous shoots, on the other hand, pass through the pituitary gland itself, and the newly-arrived carotids, on either side, by pressing against the gland, with their arterial stream, foment it with a great heat—without mentioning the little sinuses of the gland, the rete mirabile, and other little vascular plexuses, all of which give out some heat. The very walls of the cavernous sinuses also, with sinuses and veins opening into them, replete with blood, exhale a perpetual warmth; which warmth is kindled by the plexiform shoots which are scattered in every direction from the carotids. Besides, the mutual tremors of dissolved and connected particles are productive of heat from their inmost nature. The cavernous sinuses are thus regular caldrons, which are subservient in a most suitable manner to the separation of the ventricular wave. Thus a most mild heat in this fire-place of the laboratory, increased by degrees, penetrates the texture of the parts, and with the aid of a suitable disposition of the organs themselves, and of the recipient vessels, it resolves that liquid gradually into its individual component parts, and indeed in accordance with the intentions of the operating brain. In order that this thermal temperature may constantly be preserved under the gland, and throughout the whole of that space through which the spirituous lymph—the fluid of the *second* order—makes its way in the bone, the sphenoidal sinuses are planted and excavated under the sella turcica itself, and under the cavernous sinuses by which it is surrounded, and only a thin ceiling or bottom intervenes. In these sinuses there prevails a tepid air which foments the bottom, and which is renewed during each respiratory interval by a communication with the cavity of the nose; and, indeed, lest the heat in the cavernous sinuses, by becoming too dry, might be productive of harm. All around, also, the substance of the bone is porous, so that there may be a thorough communication of heat, and also of the tremor which concentres towards the cavernous sinuses and the gland, and that the spirituous vapours may find an exit.

625*g*. *And, further, that through the mediation of the cavernous sinuses there may exist a due communication*, FIRST, *of the liquid—the grosser serum—which presses in from the sella turcica.* For the two lateral receptacles of the cavernous sinuses intercommunicate through a third receptacle which is called the mediating or conciliatory receptacle. Vieussens thinks that this intercommunication takes place also on top. Suppose even that there is a certain membranous, tendinous or bony septum which divides each cavernous sinus in a longitudinal direction, nevertheless this division extends only to a middle height, and is mostly low; so that there is always an open communication in the upper part of each cavernous sinus, even if there is not an intercommunication between the sinuses of either side. It follows, therefore, that all the serum which presses into these cavities is equally distributed among the cavernous sinuses of either side; and this is possible if the third or lower receptacle [in the back of the sella] is small or furnished with a spongy substance; which, according to Morgagni, is the fact in some cases.

625*h*. SECONDLY, *that there may exist a due communication of the carotids with one another, as well as with the arch-gland.* This is produced in animals by means of the rete mirabile, which will be discussed in the next chapter. The carotids also, like satellites, keep close to both sides of the gland, and if they do not communicate through a rete mirabile, they do so at least in the gland itself, into which they despatch shoots, and a vascular plexus.

625*i*. *Thirdly, that the lympheducts may communicate with blood-vessels in the subjacent bone.* The appellation "lympheducts" Willis applies to those passages in the sphenoid bone which depart from the sella turcica; and since the mouths of these ducts gape open in the calf, they manifestly differ from the remaining orifices into which arterial shoots are inserted. For the very liquid, the existence of which in the gland has been demonstrated, is carried abroad; and this discharge takes place not only into these lympheducts, but also into the dura mater which is spread out over the gland, through which said fluid is conveyed into the circular sinus.[1] By both ways, the fluid in question seeks the lateral sinuses. The lympheducts, so-called, communicate in the interior of the bone with blood-vessels, as appears from Vieussens' experiment. In making that experiment the two carotids are tied above and below [the sella turcica], and then a coloured liquid is injected, when the bony substance becomes dyed, and the injected liquid flows out of a section of the bone. This is a decided proof that arterial shoots of the carotids not only penetrate the bony substance, but also communicate with those lympheducts; especially when it is noticed that the injected liquid trickles out in drops. This communication is for the purpose that the spirituous lymph may be mixed with blood, so that it may pursue its way towards the lateral sinuses, and may not be dissipated on the way, and escape.

625*j*. *That this communication between lympheducts and blood-vessels may also be effected in the meninx which lines the sella.* A similar communication to that which is effected in the bone itself, seems also to take place in the dura mater; in that the spirituous juice of the gland—the fluid of the *first* order—through nervous filaments which are mentioned by Vieussens and Littre, is derived into the spread-out meninx, and

[1] Concerning the derivation of the spirituous juice of the gland into the circular sinus, see Appendix, Note vi., no. 16.—Editor.

thence into the little sinus [the circular sinus], together with the venous blood which flows into the same sinus, namely, with that blood which is carried away from the muscular part of the gland, which seems to bear a venous character, in so far as it enters the little sinuses of the gland (Vieussens and Ridley also describe it as venous). That same blood, however, is not introduced immediately from the carotid or from the rete mirabile, as is the case with the blood which enters into the bone, which has been treated of above. But it amounts to the same thing, namely, the spirit which leaves the gland embodied in lymph, is wedded also to blood.

625*k*. *It seems also as if the cavernous sinuses did not admit into their cavity any other fluid [from the pituitary gland] except that which collects around the gland;* that is, it does not admit any other by the way between the production of the meninx, where the inferior petrosal sinuses apply themselves to the sella; or, in other words, it does not admit any other liquid into the intercommunicating receptacle [in the rear of the gland]. Here Vieussens' and Ridley's experiments, and that of Ortlob mentioned by Morgagni, seem to conflict with one another." After discussing these experiments at considerable length Swedenborg concludes,—"It therefore seems that it cannot yet be contested by contradictory experience that any other fluid is discharged from the gland into the cavernous sinuses, excepting that which is diffused over its surface, and which is expressed into the sinuses."

625*l*. *While the larger veins*[1] *at the bottom of the cavernous sinuses, which are mentioned by Ridley, seem to receive the nutritive blood of the bone underneath.* This we are allowed to conclude from the fact that these veins do not discharge their contents altogether into the petrosal sinuses, or into the lateral sinuses, but, according to Ridley's description, after

[1] These veins are the "ophthalmic vein," concerning which, see Appendix, Note vi., no. 46; and the "vein of the oval foramen," concerning which see *Ibid.*, no. 30.—Editor.

having been conjoined, pass through the optic foramen into the orbit, as well as through the foramen ovale. For if these veins did receive any spirituous essence from the brain, like the remaining ducts, they would convey it either into the sinuses of the base of the cranium, or immediately towards the jugular veins. Wherefore, suppose they carry their blood outside the cranium through other foramina, there is ground to conjecture that they imbibe a different blood from the bone, namely, such blood as the external carotids dispatch thither, as well as into the spacious mucous membrane of the sphenoid cavities, for the purpose of nutrition. All this, however, still requires to be confirmed by experience; nevertheless, the position of those veins, the connection, substance and thickness of the sphenoid bone, and the consideration that the proper blood of this bone can scarcely be sent outside the cranium, seems to confirm the probability of the above conjecture. We begin to see here what road the brain selects for dispatching its spirit into the blood, namely, chiefly through the substance of the bone itself, where it can flow safe from all injury and free from the action of the superincumbent brain. . . .

625*m*. *The mass of blood which approaches the brains is thus re-made and restored by the essences of the brain, in the same order in which it is deprived of these essences in the cortical and cineritious substances, and in the choroid plexuses.* The order in which the brain vivifies again, by its essences, the inert and sluggish blood of the sinuses which had been deprived of all its spirits, appears plainly from the insertion of the petrosal sinuses in the lateral sinuses, and from the manner in which the lympheducts out of the sphenoid bone are gathered together into the same sinuses. Into the very belly or trough of the lateral sinuses is discharged the very animal spirit [through the superior petrosal sinuses]. Below, where the lateral sinuses terminate in the jugular fossæ, there is emptied into them, through the inferior petrosal sinuses, a liquid endowed with little, if with any, spirit at all. Still further down, that is, into the jugular vein itself, or into the subclavian, is emptied all the lymph of the thoracic duct, as well as the recent chyle. All these ingredients are stirred up together in the whirlpool of the right heart; and thence they pass through the lungs, where they deposit everything incongruous, and all flatulent breaths, and where they imbibe instead volatile essences from the very air; and then at last they return into the arteries of the body. The spirituous lymph—the fluids of the first and second order—as said above, empty into the widened ends—the receptacles—of the lateral sinuses, so as to reanimate the whole mass of blood. For the purer and more subtle an essence is, the more swiftly a large volume of the same penetrates, tinctures and vivifies (as is well known from the experience of chemistry); for to the continuous, stirring action of the volume itself there is added here the action of the cerebellum, which expands and contracts in alternate periods. Presently there is introduced, through the inferior petrosal sinuses, a liquid which is less spirituous, and which is discharged immediately into the jugular fossæ, so that in these bony narrows, nothing of the previously disposed—that is, reanimated—blood, out of the receptacles of the lateral sinuses, is able to descend into the body without receiving a share of the liquid out of the inferior petrosal sinuses. At last, the blood, which has been prepared in this manner and made liquid, can become embodied, as it were, or can furnish itself with a body, through the chyle. For unless the chyle were infused into a blood previously vivified, there would result from that mixture a kind of sluggish viscosity. Wherefore, the grosser ingredients succeed in due order, so that the act of commingling may be successfully accomplished. In exactly the same order and according to the same procedure, the blood is deprived of its spirit in the cortex, and in the cineritious substance of the brain. For the genuine red blood, namely, that which is more soluble, and not so involved in its elementary, natural particles, is dissolved into its white blood, and enters the fibres. The very elements or ingredients of the red blood, however, are chiefly the so-called animal spirits, of which the white blood consists, and further a kind of subtle oily substance charged with volatile urinary matters by which the composition of the red blood is effected. When, therefore, the white blood enters the fibres, that oily and volatile substance is separated thence, and after it is mixed with an attenuated lymph, it enters into the interstices between the fibres, and constitutes the nervous juice—the cerebro-spinal liquid. This is the reason why the cortex of the brain on being torn exhales a kind of volatile urinary breath, and why it seems greased and anointed with an attenuated oily lymph, as is shown by the experience collected in the chapter on the Cortical Substance. Those two fluids, namely, that which circulates in the fibres, and that which percolates through the interstices between the fibres, are again set free in the lateral ventricles, and conjoin themselves there with the serum of the choroid plexuses. The ventricular liquid composed in this manner enters the infundibulum, and before it reaches the arch-gland, is resolved again, *first*, into the white blood, to which some of the nervous juice—the cerebro-spinal liquid—seems to be admixed; and *secondly*, into the remaining juice which is composed of the lymph of the choroid plexuses, and which also seems to be charged with nervous juice—cerebro-spinal liquid—and to occupy the integument of the gland. In that same order, therefore, in which the ingredients of the blood are separated, first in the brain, and afterwards again in the infundibulum, they are again recompounded. Still, these ingredients cannot be recompounded into red blood before a new volatile urinary substance is introduced again from the new chyle, and afterwards from the air in the lungs. To the conveyance and application of this volatile substance with its salts, nitres, and other elementary substances, the common water lends its aid, and in this manner constitutes the serum of the blood. Still the same quantity of spirituous essence which is expended upon the fibres of the cerebrum, cerebellum, medulla oblongata, and spinal cord, has to be supplied again to the blood through the pituitary gland, as well as through the remaining [lymphatic] glands of the body. But that quantity of the animal spirit which has been consumed in feeding the body, and which has become obsolete by inviscations and involutions in the tissues and liquids of the body, is replaced by the new spirit which is elaborated by the brains and the medulla oblongata and spinalis. The regeneration of this spirit goes on perpetually in that substance which is the parent of the animal spirit, as is proved from experience in the chapter on the Cortical Substance.

CHAPTER XXI.

THE RETE MIRABILE.

626. WILLIS.[1]—"As this plexus of vessels, called rete mirabile, in some instances, is found very large, in others very small, therefore the pituitary gland in the latter case receives fewer, and in the former considerably more branches; and in some animals it scarcely receives any shoots at all from the arteries. The varied proportion in the size of the 'rete' corresponds to a different distribution of the vessels. It is to be observed, therefore, that in some animals, especially in man and the horse, the rete mirabile is wanting altogether; and because in them both carotids are carried about in a roundabout way through the recesses of the cranial bone, in man one or two shoots, or none at all, are introduced from these arteries into the pituitary gland; while in the horse only a few branches enter the gland, which therefore becomes smaller in size. In most other animals, however, especially in those where the rete mirabile is present, many blood-vessels enter the gland; which can be proved by inspection, and also experimentally. For if a liquid dyed black be injected into the carotid with a syringe, the exterior part of the gland, which is interwoven with sanguineous vessels, will, for the most part, be imbued with a black colour. . . In those animals which have a larger pituitary gland, many foramina of considerable size are present in the bone underneath. Again I often noticed that vessels or canals are interiorly in these foramina. Upon injecting in the calf ink into one of the larger foramina in the bone, the blackened liquid at once enters the smaller veins under the bone, and penetrates thence into the jugular vein (pp. 29, 30).

[1] "Cerebri Anatome," etc., Cap. IV., VII.

. . . In the dog, fox, sheep, calf, deer, and most other animals, both carotids, while hidden away under the dura mater on the bone of the cranium, are divided into exceedingly small shoots, and these shoots interlaced with other vessels, that is, with veins and nervous fibres, constitute retiform plexuses. These plexuses extend on either side of the sella turcica, and fill the cavities which are found there. After all these vessels have thus been interwoven in various ways, some arterial shoots, which have become extricated from the rest and again reunited, coalesce in that carotid trunk which, after perforating the dura mater, ascends straightway into the cerebrum. The above-mentioned plexus is commonly called the *rete mirabile,* and indeed justly so, because nothing in the whole fabric of the animal body is more worthy of admiration. Besides the arterial branches which proceed from the two ascending carotids, venous shoots are met with in this plexus, although they are fewer; these venous shoots are derived from branches of the internal descending jugular vein. Both kinds of vessels, after becoming divided into minute shoots, like bundles of twisted silk-thread, are variously interwoven; this network of vessels, however, is sustained by nervous fibress which are supplied by the larger trunk of the fifth pair of nerves. The above-mentioned plexus of vessels, or the rete mirabile, in some animals is very much larger, and contains many more intertwisted vessels, than is the case in others; for in the calf, sheep, goat, and the rest which feed on grass, its compages is larger than in the dog, cat, and in other carnivorous and hotter animals. It must further be observed that where the rete mirabile is larger, the plexus of one side is inosculated into that of the other side, and that from either plexus very many shoots of vessels enter the pituitary gland; so many indeed, that if you inject a blackened liquid into the trunk of any artery below the cranium, the vessels or plexuses of both sides are imbued with the dye, and the blackened humour will flow out of the trunk of the opposite artery that has been cut. Often also we witnessed the following experiment. Let the carotids be laid bare on either side of the neck, so that their little tubes are exposed to the sight to the length of about one inch and a half; then let a dyed liquid, contained in a large syringe, be forced upwards through the carotid trunk of one side; and after one or two injections you will see the dye returning on the other side through the trunk of the opposite artery. Nay, if said dye is injected very copiously in the direction of the head, it will thence flow back through the artery of the opposite side, below the diaphragm, and will finally reach the lowest part of the body; and meanwhile little or nothing at all of the injected dye will flow back through the large, external, jugular veins. If afterwards the head is opened, it will be found that all the arteries before their ingress into the head, and all their attendant veins, are imbued with the colour of the injected fluid. Some traces of the dye will also appear in the vessels which constitute the rete mirabile, and which cover the base of the brain (pp. 31, 32). . . . In this respect man, indeed, differs from most animals; namely, in this, that in animals the carotid artery, after being divided into thousand shoots, constitutes retiform plexuses (p. 54). . . . Most animals, differently from man and the horse, have the rete mirabile adjoined to the carotid artery; indeed, this is the case in so many species of animals, that common anatomy declares that it is present in all animals, including even man. In those animals where it is found, we notice that the carotid artery about to enter the cranial cavity is not carried over such a long circuit, but emerging near the sella turcica, is at once divided into little shoots, yet so that one small channel extends through the sella in a straight direction, and that through the same the blood flows placidly, crosses the same without delay, and is at once received in the cerebrum. Many little rivulets, however, are derived from the side of the sella in every direction, and into these the impetuous blood is easily diverted in its ascent. These little rivulets are partly ingrafted in the venous passages of the sella, and in the vessels of the other side, and partly they are carried into the pituitary gland; and partly also, after describing a circuit, they return into the former trunk of the artery. That this is so is proved by ocular inspection, and besides it may be demonstrated by the following experiment. If below the cranium a liquid of an inky colour be gently and gradually injected into the carotid, after passing through the straight passage, it is at once carried to the cerebrum, nor does it imbue the lateral vessels of the plexus with its colour; but if this liquid be squeezed in rapidly and impetuously, it runs at once into the plexus, and even into the side of the pituitary gland turned towards it, penetrating into its interior structure" (pp. 55, 56). Consult also the author's drawing of the carotid in the brain of a horse, and of the rete mirable in a calf's brain. In the former drawing it may be seen how the carotid of one side, immediately upon its entrance into the cranium through a great anastomosis, communicates with that of the other side, and then sends several branches into the pituitary gland.

627. VIEUSSENS.[1]—"While the carotid arteries are within the cavernous sinuses, they recline there twisted a little, and bent up in themselves. They send out many exceedingly slender shoots, lest they should touch immediately the anterior branches of the fifth pair of nerves and the sides of the pituitary gland; and some of these shoots tending in an anterior direction pass under the optic nerves. Others which verge towards the upper part of the cavernous sinuses, and adhere there, after breaking up into almost insensible shoots, are joined together in the form of an exceedingly small reticular plexus; others are carried towards the pituitary gland, and are inserted into it; still others aim towards the gangliform plexuses of the nerves of the fifth pair, where they terminate; and still others which are bent backwards are folded together a little, and then, in order that they may enter the substance of the sphenoid bone, after the dura mater has been pierced, said bone is perforated by very small foramina, which are driven into the posterior part of the same sphenoid bone, and into its sides, near the origin of the cavernous sinuses. After the carotid arteries, while they are still hidden away within the cranium under the dura mater,

[1] "Neurographia Universalis," Cap. VII.

have sent out the shoots mentioned above, on ascending towards the cerebrum, they perforate the dura mater, and prepare a way for themselves between the internal anterior processes of the sphenoid bone and the optic nerves, which they touch immediately. . . . As to the rest, while the carotid arteries in man, yea, even in the dog, horse and most other animals, during the sojourn of the same in the cavernous sinuses, send forth sometimes very few shoots, of which each is distinct from the other, or which are only a little interlaced—no one will consider it singular if I declare that in man, the dog, the horse, and several other animals, the rete mirabile is always either very small, or wanting altogether. Nor is it very small, or wanting altogether in these subjects, because no venous vessels enter the cavernous sinuses; but simply, because in these animals the carotid arteries send out fewer and smaller shoots than in those which are furnished with the rete mirabile of Galen, in the latter, both carotids, on their first entrance into the cranial cavity, pass off almost altogether into shoots, out of which this plexus is formed. Hence it is that the carotids of those animals in which the rete mirabile is large are always much smaller above than below the two retiform plexuses; while, on the contrary, in man, the dog, the horse, and in certain other animals, where the rete mirabile is either very small, or wanting altogether, the carotids are almost of the same calibre above as below this plexus, as appears from ocular inspection; so that it is plain that during their concealment within the cranial cavity underneath the dura mater, they generally send off few, and sometimes only a very few shoots. In the calf, sheep, and most other animals, however, the carotids pass off into almost numberless shoots, which, upon being interlaced, form on each side a considerable plexus, which Galen, on account of some similarity which it exhibits, called the rete mirabile. These shoots, also, upon meeting together are intertwined with one another in the most wonderful way, and pass off into loops which are not unlike the meshes of a net. Thence it is, as I say, that the rete mirabile is a plexus of vessels situated within the two cavernous sinuses, and composed purely of very many shoots of the carotid arteries, which are either twined around each other, or inclined towards each other, at the same time forming one network. This plexus, however, in some animals is very much larger, and the vessels of which it consists form many more loops than they do in others. In the calf, the sheep, the goat, and the rest which live on herbaceous food, the texture of said plexus is more ample and more complicated than in the cat, and other carnivorous animals which are more heated; and when the texture of the rete mirabile is very much larger, the pituitary gland receives thence many more arterial shoots. The rete on one side also throws shoots into the rete of the other side, by means of which these two plexuses are joined, and communicate with one another; as is proved by this experiment that when a blackened liquid is injected into the trunk of either artery below the cranium, the vessels of both plexuses are imbued with the same dye, and the blackened humour flows out of the trunk of the opposite artery which has been cut. Willis asserts in his 'Anatome Cerebri' that the rete mirabile consists of veins, arteries and nervous fibres; this great man, however, will pardon me, if in company with the most experienced Rolfink, I assert that both retiform plexuses consist simply of shoots of the carotids without any veins. This may be proved by ocular demonstration by the following experiment. Suppose you tie the carotids about the middle of the neck, and inject into their trunks near the sella equina some liquid of another than blood-colour. If then the cavernous sinuses are opened above, it will appear that every vessel of the rete mirabile bulges out manifestly from having received the injected liquid, and that nevertheless nothing, or at least only little of the injected liquid passes into the adjacent cavernous sinuses, and into the internal jugular veins. I say, 'or only little,' because it is possible that a small portion of the injected liquid which enters the cavities of the small arteries, scattered through the spongy part of the sphenoid bone, should be reabsorbed by the small veins which it meets on the way, and that through them it should be conveyed gradually, drop by drop, partly into those cavities in which the rete mirabile is hidden away, and partly into the four petrosal sinuses near the sella equina. If, however, both retiform plexuses really consisted of veins interwoven with arteries, which veins would terminate either in the four petrosal sinuses, or in the internal jugular veins, the liquid, which had been injected into the trunks of the carotids, would descend out of the retiform plexuses either into the above-named sinuses, and thence into the internal jugular veins. or else it would pass immediately into the jugular veins themselves, and, indeed, not gradually or drop by drop, but most swiftly and in a sufficient quantity" (pp. 44-46).

This arterial blood, when it is about to be discharged, Vieussens thinks tends towards the optic nerves, and in this way, through veins, enters into the lateral sinuses; through other shoots it passes into the pituitary gland; through others into the gangliform plexus of the fifth pair of nerves, and thus into the lateral sinuses; through still others into the spongy substance of the sphenoid bone, or into the inferior petrosal sinuses; or, again, this same arterial blood is diffused through the dura mater.

He says, "It is to be noted that when the shoots of both carotids are rinsed out either with water or spirits of wine, and examined within the cranial cavity, under the dura mater, and when they are uncovered, each at a time, some of these shoots appear smaller than the rest, and when not filled with blood they present some similarity to nervous fibres. This, no doubt, has induced Willis to believe that some nervous fibres enter into the composition of the retiform plexus of each side. That this, however, is erroneous every one may learn by investigating and uncovering the origins and insertions, both of the nervous fibres and of the supposed nerves, which enter the two above-mentioned retiform plexuses. For suppose it to be true that trunks of the motory nerves of the eye, and of the sixth pair of nerves, while they are hidden under the dura mater within the cranial cavity, did enter into the loops of either rete mirabile, still they would progress further, and would by no means be expended in the formation of these plexuses, as is the case with one shoot of either nerve of the sixth pair, which, while being contained in the cavernous sinuses, on its passage to the exteriors of the head, admits two shoots sent out from the anterior branches of the nerves of the fifth pair, and passes off into the great sympathetic nerve which, near its origin, bends itself back, subjects itself to the carotid artery, and creeping between its proper external, and its adscititious membrane, emerges out of the cranium (p. 47). . . . It is to be noted that although the rete mirabile in the dog, as in man, is either wanting altogether, or at least is very small, nevertheless, a single small sinus, filled partly with a cineritious and spongy substance, is found within the sphenoid bone, dug out below the anterior part of the sella turcica" (p. 48).

628. RIDLEY.[1]—"Notwithstanding the opinions of the late Wepfer, Willis, and of Vieussens too (which two last indeed, but only occasionally are willing to grant its existence in men, who, nevertheless, if the supposition of Willis be true, namely, that such cannot but be fools, had better be without it), together with almost all the ancients, as Vesalius, Columbus, etc., to the contrary, I have never found this rete wanting, or experienced any difficulty in discovering it in men. It has its origin from, and lies on the inside of each carotid artery, in that place of the circular sinus chiefly which looks towards the four inferior and superior petrosal sinuses on each side, between the pituitary gland and the carotid artery (p. 64). . . . The carotid trunk, which, above the dura mater in those creatures that have a rete mirabile, is very small compared to what it is below, whereas in men it is of the same size on both sides of this membrane—is divided into several channels, and these are not only reticulated and twisted, but also many of them, by their insertion into the pituitary gland, are attended with small veins issuing thence, whereby also some part of the burden is taken off (p. 65). . . .

[1] "Anatomy of the Brain," Chapters VIII., IX.

In brutes the rete mirabile is not only situate on each side of the pituitary gland, but runs quite under its posterior part, by which one side of the rete communicates with the other, a disposition of this part with which Vieussens was altogether unacquainted, whereas in man, inasmuch as that sort of structure does not exist in the one, *i.e.*, in the rete, therefore it is not necessary that it should be required in the other, *i.e.*, in the pituitary gland (p. 72). . . . The rete lies in a duplicature, as it were, of the dura mater, on each side of the posterior part of the sella turcica, as though one lamina of it was spread upon the subjacent bone, and the other over the pituitary gland; a disposition contrary to that in brutes, as we have already taken notice of" (p. 74).

629. HEISTER.[1]—"The rete mirabile is a retiform plexus of vessels and membranaceous fibres situated on each side near the pituitary gland, and under the dura mater, where the circular sinus is. In calves it is larger than in man, but its uses are unknown (Vol. I., no. 273, p. 139). . . . Not a few authors deny the existence of this rete in man, the sentiments of whom are collected by Nicolai.[2] I wonder that even Ruysch, who had at first described this rete in words and by an illustration,[3] should now class it among fables,[4] when yet the rete mirabile may easily be exposed to the sight of every one, by opening carefully the dura mater with a scalpel on either side of the pituitary gland. Morgagni states in his Epist. Anat. I., no. 91, that this plexus was first described by Varolius" (Vol. I. Note 49, p. 95).

630. LITTRE.[5]—"The rete mirabile is a reticular plexus situated on each of the two sides of the sella turcica. It consists of innumerable little branches of nerves and arteries which communicate with one another; the nerves with the nerves, and the

[1] "Compendium Anatomicum," Amsterdam, 1748.

[2] "Dissertat. de Directione vasorum," p. 43.

[3] "Epistola Problematica," XII., Plate 13, letter T.

[4] "Adversaria Anatomica," II., p. 45.

[5] In "Mémoires" of the Academy of Sciences, Paris, 1707; quoted in Manget's "Theatrum Anatomicum," Vol. II., p. 306.

arteries with the arteries. A part of them, which are detached from the remaining reticular body, pass off on both sides into the pituitary gland. The nerves originate from the sixth pair, and also from the anterior branch of the fifth pair; but the arteries from the internal carotid."

631. BIANCHI.[1]—"Filaments distributed in all possible directions run out, and are interwined in the cavities which are adjacent to the sella, chiefly in the lateral; this has given rise to the name 'rete mirabile.' The threads of this rete do not consist entirely of shoots of the carotids, as Vieussens seems to hold, but a part of them is contributed by solid and fleshy little cords, which in respect to size are proportioned to the little muscles fixed on both sides in the interiors of the heart, which little cords also, in an analogous form, are stretched from one wall of the cavity to the other; to these walls also they are firmly attached, and from these walls they are interlaced in various forms, and run out. There are no nervous fibres properly in these retiform collections, as Willis states; some veins, however, are intermingled, as Willis likewise maintains together with Ridley. Most of the tendinous little cords of the rete mirabile derive their origin from the tendinous septum of the lateral cavities, and upon this also they chiefly rest in their twistings and turnings. Other cords, both such as are larger and smaller, emerge from the internal surface of the clinoid processes, others again from the anterior surface of the petrous process, or immediately from the sides of the middle portion of the sella turcica. They emerge higher or lower down, interiorly or exteriorly, crossing in various directions, straight out, transverse, and oblique, and by being fastened together, interrupted, and terminated in various ways, they in this wise form a dense net, which is stretched out in every possible direction in the cavities of the membranous bag. Above the carotids, however, it is more conspicuous, and it is firmly connected with them by its various threads. We also meet with hard polyps in these

[1] "Demonstratio Anatomica F. M. Nigrisolio conscripta," 1715, in Manget's "Theatrum Anatomicum," pp. 342-349.

cavities, which protrude roughly over the surface of the walls, and which are due no less to retiform obstructions, than to simple twists in the cords, just as is the case in the ventricles of the heart, and in the longitudinal sinus."

MORGAGNI.[1]—"Among the things further written on the subject of the rete mirabile [viz., in Manget's 'Theatrum Anatomicum,'] I willingly approve and acknowledge this additional point; namely, that its vascular filaments are increased by many solid little muscles, as it were, which are produced mostly from the dura mater, which constitutes or lines the walls of the cavernous sinuses. On this account, also, I believe that Spigelius called this, our rete, 'a membranous plexus,' and that before him, Jacobus Berengarius[2] (who dissected, according to his own testimony, one hundred human heads almost solely for the sake of this rete) said, that at the sides of the pituitary gland, to the right and left, in a posterior direction, he often saw and touched, under the dura mater, something like a rete, and at the same time something intricate, and likewise under the dura mater, behind the 'foramen nuchæ,' towards the 'os laude,' and above the sphenoid bone. And he added immediately afterwards, 'because Galen says that the rete mirabile consists partly of the substance of the dura mater, I believe that the whole rete mirabile cannot be seen, because the dura mater is so interwoven with it, that one cannot be distinguished from the other.' And although Nicolaus Massa after him taught that it appears thence that the rete sometimes is a process of most subtle arteries in the shape of most attenuated villi, still Willis placed nervous fibres in it; yet the author of the above explanation has made it very plain, that Willis meant thereby real villi, and fibres properly so speaking, and not nervous fibres. Real villi, however, and tendinous and muscular fibres agree with the nature of the dura mater, whence, as I said, they are propagated. Would I could corroborate in the same way what this author further affirmed

[1] "Adversaria Anatomica," VI.; Animadversio, XXX.

[2] "De hum. corp. fabr.," Liber. X. Cap. 4.

in respect to the same rete mirabile, namely, that it is always present, no less in man, than in certain other animals. Nor do I say this for this reason only, because I have always been in the habit of declaring and of repeating constantly that I have not dissected any animals, and therefore do not know how this matter is circumstanced in any animal; but I say, it because I have noticed that scarcely any anatomist, among those who acknowledge that the rete mirabile exists in man, but has declared that it is less conspicuous in him than in many animals which they enumerate; so also in some human heads I have noticed some exceedingly slight traces of the same rete; which I find has also been noticed by many other anatomists" (p. 37).

633. JACOBUS BERENGARIUS CARPUS,[1] who confesses that he dissected more than a hundred human heads almost entirely for the sake of the rete mirabile, and yet is still in a state of uncertainty about it, says—"My opinion is that if there is a rete according to the position assigned to it by Galen, it must be admitted that Galen has been here totally in the wrong, for he says that as soon as the carotid arteries have ascended over the sphenoid bone, they are at once divided into least shoots, and compose a rete; and afterwards again, he says 'that out of all the branches of the rete, two branches of the carotid arteries are again made up, which perforate the dura mater, and climb up into the cerebrum.' And this is not true, because I have often introduced a small probe into the above-mentioned large branches of the carotids, as they ascend into the neighbourhood of the optic nerves, and I found that the probe, without meeting with any obstacle, penetrated right through these arteries into the very substance of the sphenoid bone. If, however, the aforesaid arteries had been interwoven and divided into least shoots above the sphenoid bone, as stated by Galen, the probe could never have penetrated down into the substance of the bone through the little arteries, without meeting with an obstruction. I conclude from this experiment that there is no rete mirabile

[1] "Commentaria com amplissimis additionibus supra anatomiam Mundini cum textu cjus in pristinum nitorem reducto," Bologna, 1521, 4to; p. ccccclix., *a.b.*

there; but I believe that the aforesaid ascending arteries, which are divided into least shoots in the pia mater, are sufficient for subtilizing the vital spirit, which afterwards in that refined form ascends into the substance of the cerebrum and is digested there; and which, from the substance of the cerebrum, passes into its ventricles, where it is afterwards digested. I, therefore, believe that the rete mirable is rather a creation of Galen's imagination than that he ever had a good look of it; and I believe that all others after Galen place the rete mirabile more on the strength of Galen's opinion, than because they have discovered it by their own senses."

634*a*. WEPFER[1] says,—"Galen places the rete mirabile under the dura mater where the pituitary gland is, namely, a little before this gland outside the dura mater, where he says it exists manifestly; that gland, he says, the rete embraces in a circular form, it touches the same far back, and it underlies almost the whole of its base. Afterwards he describes it as not being simple, but as if several nets were placed one on top of the other, so, however, that those in the middle are connected with one another, and cannot be loosened from one another, and torn off without being injured. Finally, he says that in a great measure the rete is formed of the arteries which tend from the heart towards the head; and, indeed, of the small shoots of those arteries which pass off into the neck, and the external parts of the face and head (p. 26). . . . He manifestly teaches that after the larger part of the carotid artery has been received into the cranium, and before it enters into the cerebrum through the dura mater, it is divided into a rete mirabile, and then afterwards, before its entrance, it again coalesces. Finally, he declares that the use of this rete consists in this, that the vital spirit abides there until it is sufficiently prepared and digested for the production of the animal spirit, and that then it does not only proceed at once into the ventricles, but is also communicated to the cerebrum; almost in the same manner in which

[1] "Observationes Anatomicæ ex cadaveribus eorum quos sustulit apoplexia," Amsterdam, 1681.

the arterial and venous blood is compelled to loiter in the vasa deferentia, until they are fitted to put on the nature of the semen."

[Modern Authors.

634*a*. Sömmering.[1]—" In oxen, sheep, goats, and other animals furnished with the rete mirabile, no artery is led into the brain through an osseous cranial canal, but in its place a branch of the carotid enters through a short foramen into the cavity of the cranium. In a like manner the cerebral trunk of the carotid also does not enter the cranial cavity through a long osseous canal, but through the shortest foramen. In the same place of the basilar bone where in man the cerebral carotid artery is found twisted and fastened to the bone, in these animals it is dissolved into the so-called rete mirabile, and after it is again gathered up into one trunk, without having given off any branches, and with the dura mater being added to it, it reaches the pia mater, whither it was tending—in the same way indeed as was described in an excellent manner by A. Bonn and B. S. Albinus. In a similar manner in man the ophthalmic artery penetrates through an osseous canal, while in the ox and sheep, on its way to the bulb, it is dissolved into a rete mirabile, and collected again, before it is subdivided into the ciliary arteries.

"In this manner, then, unless I am very much mistaken, by the aid of the 'rete mirabile,' the same equability in the flow of the blood is secured in certain kinds of brute animals, as is effected in man through the affixion of the blood-vessel to an osseous canal" (p. 64).

634*b*. Langer.[2]—" The *rete mirabile arteriosum*, in the

[1] Sömmering (S. Th.). "Academicæ Annotationes de cerebri administrationibus anatomicis, vasorumque ejus habitu." In "Denkschriften der Königlichen Akademie der Wissenschaften zu München für das Jahr, 1808," Munich, 1809.

[2] Langer. "Der Sinus Cavernosus der harten Hirnhaut." In "Sitzungsberichte," etc., Wien, 1885.

case of the SHEEP, is produced by the concurrence of several arteries, namely, of a branch of the arteria maxillaris interna which enters the cranium through the foramen ovale, and of a second branch which approaches the sphenoid bone through the sphenoid fissure. The 'rete' consists of a convolution of twigs representing a cylindrical body, and which is situated in a lower furrow corresponding to the sulcus caroticus in man, and extending as far as the orbit. In addition to the cerebral artery proper, there depart from this 'rete' several smaller twigs, which are distributed in the background of the orbit.

"Here also must be mentioned the well-known small triangular 'rete' in the orbit of these animals, which is formed by the ophthalmic artery above the fundamental muscle of the eyeball, exactly where the artery passes over the optic nerve. . . .

"Almost in a like manner as the cerebral and ophthalmic arteries, the corresponding veins of these arteries are also employed in the formation of retia mirabilia.

"The dense venous 'rete' which corresponds to the small twigs of the cerebral artery takes the place there of the sinus cavernosus. Like the arterial 'rete' it is likewise situated along the sides of the sella turcica, and indeed in the above-mentioned osseous furrow corresponding to the sulcus caroticus of man. It consists of short, winding, and closely interlaced tubules, into which the venæ ophthalmicæ are resolved. . . .

"Of the fact that the venous reticular formations, which in the case of the 'ruminantia' lie along the side of the sella turcica, correspond to the lacunous sinus cavernosus, there can be no doubt whatever; especially since the plexus cavernosus of the child presents a transitional stage of the reticular form of this sinus into its lacunous form. . . .

"The question how the two 'retia mirabilia,' the arterial as well as the venous, which are situated along the sides of the sella turcica, are related to one another topographically, is answered by casts obtained by corrosion [see above no. 621*e*] thus: that these two 'retia' are mutually interlaced into each other; consequently, that they are so inserted into one another, that they form a connected whole, the shape of which approaches that of a cylinder and which completely fills up the sulcus caroticus.

"The arterial 'rete mirabile,' which in the CAT is situated along the sides of the sella turcica, and which is made up of the cerebral artery and its ramifications, varies from the rete mirabile in the sheep, not only in this that the ramification is more scanty, but also that the little arterial branches are longitudinal, and arranged in almost parallel order, while in the sheep the twigs are winding and interlaced. The venous formation which, in the cat represents the sinus cavernosus, is likewise a 'rete,' the vessels of which anastomose in oblong meshes, and are inserted between the arterial twigs. The result altogether is the same, as in the case of the sheep, only the form is more simple" (pp. 317-320).]

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ANALYSIS.

635. The rete of Galen, or by way of eminence called the rete mirabile, is a ramification of the carotid artery, before it ascends into the cerebrum; for the greater portion of this artery, during its stay in the cavernous sinuses, is broken up into shoots, leaving only a small channel. The shoots, which are twisted together like little ropes, are entwined and supported by membranous fibres, as by a kind of cords; afterwards, however, they are reunited in a continuous channel. Galen seems to have extended this rete a little too far. There is also a kind of smaller rete or reticular plexus in the duplicature of the dura mater at the sides of the sella, near the circular sinus, threads of which are despatched into the pituitary gland. This latter rete is sometimes visible in human brains [see *Langer* above, in no. 621*x*]; but the former occurs exclusively in the brains of animals. The use of the rete mirabile in animals is threefold, but in man it serves only one purpose, which is identical with the third use in animals.

636. Its first use consists in breaking the impetuosity of the blood, and in changing its circulation; for the cerebrum claims its right over the blood, as soon as it approaches the boundaries of its cranium; as is the case also with the cerebellum, the medulla oblongata and the spinal cord, and, in short, with the whole of the highest region of the kingdom. For the alternate systaltic and diastaltic motion of these organs is synchronous with, or coincides with the alternate motion of the lungs, but not with that of the heart and the arteries of the body. In order, therefore, that the stream of the blood, which by continuous vessels is conveyed thither, at this turning point may change its motion, and that it may be initiated into the alternate

motion of the brain, it is necessary that so soon as the carotid enters the interior parts, it should be divided into threads, and that out of its fused or molten trunk, filaments, as it were, should be evolved, which upon being twisted together are formed into a plexus, called the rete mirabile. In this wise the carotid divests itself of the impelling forces of the heart, and submits itself to the brain. It is different in human brains. There the carotid artery is not dissolved into minute shoots, and becomes evanescent, as it were; but, on the contrary, it increases in volume, and in the cavernous sinuses swells into a certain arterial receptacle or sinus; and by wonderful flexures and modes of contortion it constantly rids itself of the yoke of the heart or of its body; first, at its very entrance through the cranium; afterwards, as it climbs over the dam of the posterior clinoids; again, in the cavernous sinuses, where it becomes tumid and ventricose,[1] and inflects itself into gyres; and, finally, during its very ascent into the cerebrum. In addition, it also lays aside its motory membrane which is continued from the muscle of the heart, and puts on a coating from the membrane of the brain; and, at the same time, it acquires a plexus of fibres from the root of the great sympathetic nerve. In animals, however, where the road is shorter, the artery is carried about less; there also the bones of the cranium are arranged differently, and the vessels are distributed differently

[1] Swedenborg makes this statement on the strength of WEPFER's observation, that in the cavernous sinuses, the carotid arteries "present the appearance of a kind of bladder placed at the sides of the sella turcica," and that they "exceed a nutmeg in size." See Vol. I. p. 330. Still other authors also have noticed a tendency in the arteries of the brain towards enlargement or dilatation. So PORTAL, in speaking of the cause of the movement of the brain, says, "The movements of the brain were known to the ancient physicians, and they attributed their cause at first to the action of the dura mater; yet without any foundation. . . . Other anatomists again sought for their cause in the motion of the arteries. But this hypothesis falls to the ground of its own accord, as soon as you consider that *an enlargement of the arteries* is of a much more frequent occurrence than a raising of the brain." (Cours d'Anatomie médicale," etc., Paris 1803; Tom. iv., p. 65.)

The whole mode by which the cerebral blood in man is emancipated from the motion of the heart is fully analyzed in the light of modern experience, in the Appendix, in Note vi., no. 50. —EDITOR.

through the cerebrum; and therefore the carotid artery must be broken up into shoots, and the impulses imparted to it by the heart have thus to be neutralized almost, as when a rushing stream is checked by a weir, which becomes pervious only when the flood-gates are opened.

637. The second use of the rete mirabile consists in this, that immediately upon its entrance into the cranium, the blood of the carotids, through the infinite number of anostomoses, between these vessels is equalized, so that the right trunk does not convey more blood to the cerebrum than the left trunk; or that both streams are made common to the whole cerebrum. For the intervening shoots in equal proportions communicate of the abundance of the one to the state of want in the other; since a liquid which is injected into the artery of one side penetrates into that of the other side, and the arterial vessel above the pituitary gland swells to the same size, and assumes the same diameter as the artery below [that is, before it has been dissolved into a rete]. On this account, in horses which are not furnished with a reticular plexus, there are simple and large anastomoses already at the first boundary, and below the place where in other animals this reticular expansion exists. It is different in man where the carotids are not like exhausted canals, but like receiving vessels at either side of the sella, representing large troughs full of arterial blood, upon which the cerebrum may draw for the supply required by each of its two hemispheres, and by every lobe, convolution, and cortical cluster, so that there is never any difficulty in summoning the requisite quantity and quality of blood. In animals, however, the whole cerebrum acts as one with each of its parts, and indeed simultaneously with them, and in a similar manner; for animals act only from causes outside of themselves, wherefore their brain demands blood in a like proportion from each of the carotids.

638. The third use of the rete mirabile, however, consists in furnishing blood to the intervening gland, thus providing for its motory fibres, and perchance also to the processes of the sphenoid bone; for little sanguineous plexuses are of occasional occurrence

where little bodies [in the present case, the pituitary gland], are to be moved by a muscle; since the quantity and quality of the motion, and a certainty in the effects result thence. It would be different were the motory fibres of the muscle provided with blood immediately out of the arterial trunk, without any intermediate "rete." This use of the rete mirabile man has in common with every animal; wherefore more or less evident traces of such a reticular plexus are said to have been discovered on either side of the sella, in the duplicature of the dura mater; or else these traces must be looked for in the gland itself.

639. It is very important that a thorough inquiry should be instituted why the internal carotids in all brute animals equalize their blood at their first entrance into the cranium, either by open anastomoses, or by the concealed ones of the rete mirabile; and again, why in animals the carotids are reduced and attenuated into such minute little channels, while in man the case is quite different; for in him these vessels enter into the cavernous sinuses, and pass out thence without any anastomoses and without any equalization; and during their stay in these sinuses they are enlarged and become swollen.[1]. The proximate cause of this phenomenon is a difference in the organization of the brains of animals, a more remote cause, a difference in their mode of action; but the most remote cause is their faculty of acting only from external causes, and thus from others, as it were, and not from their own internal causes. Every change and emotion of the animal mind (*animus*) demands a different quantity, nay, and even a different quality of blood. While the brain is incensed with anger, it is also agitated by a tempestuous flow of heated blood. When it melts with joy, the blood also is dissolved and spreads freely over it; and the contrary happens when the brain is moved by gentleness, fear, sadness, and also by the rest of the emotions, which are termed passions and affections of the animal or lower mind; so that there is not the least emotion but claims for

[1] See the footnote above, p. 201.—Editor.

itself its own share of blood. The human cerebrum, which is not only the general external, but also the internal sensory, proffers hospitality to the rational soul or to the intellect, so that it is able to think, analyze, judge, decide and will, or that from the end it is able to draw conclusions respecting the means, and from the means respecting the end, or that from the antecedents it may infer their consequences, from the causes their effects, and from the present the future. The cerebrum is stimulated into the ordinary motions of nature, not only by external causes or objects of the senses, and by causes insinuated into the blood from without, but almost at each moment it also kindles these motions from internal causes or from the ideas of its mind, especially when it burns with an end, a purpose, which is obstructed by the love of self. Scarcely a moment therefore passes when the cerebrum is not stimulated into some little motion, which demands a different quantity and quality of blood: for the above-named motions or affections of the animal mind (*animus*), that is, of the cerebrum in respect to its organical principle, are as many ardours or heats of life, and as many incitements to thought. As the cerebrum, therefore, as has been frequently remarked above, summons to itself its own blood, and as the human cerebrum, sometimes within fractions of a minute, demands another blood of a different nature, it is necessary that there should be some receptacle or reservoir of the same, as it were, with a full supply, so that there may always be some source where its wants may be supplied, and whence its ideas may be cherished and warmed with a certain assisting motion of the animal mind (*animus*), and thereby with blood. Again, in order that the human brain may be active as to any one of its parts, and thus capable of being divided, and again as to each aggregate of parts in either hemisphere, therefore its stream of blood is not equalized at the threshold; nor do the carotids fully coalesce beyond the sella turcica, and sometimes by a transverse branch, as in brutes; nor again do they, before their coalition, send out branches into the nearest lobes. The case is different in the cerebra of brute or irrational animals, which are excited simultaneously and congruously by external causes; wherefore I doubt whether those who, among the human family, are furnished with the rete of Galen, which, by way of pre-eminence, is called the rete mirabile, are really rational.

640. The preposterous conclusion is thence drawn that the organism alone, or the quantity and quality of the coursing blood, imparts to the soul itself the faculty of thinking sublimely or distinctly in accordance with its own nature; for such as is the nature, perfection and eminence of the soul, such also is the quality of the organism, or such is the form of the cerebrum, by whose ministry it receives objects from the external senses, and applies them to the internal; which power is lost as soon as the organism and the pathway of the blood is destroyed; whence there arise insanity, delirium, weakness of the intellect, nay, the temperaments, and so many differences among the individuals in the human family alone; although the soul of every one of them, even of the insane, nay, of embryos and sucklings, considered in itself and in its own ideas so-called, is as wise as the soul of Plato. Still the modes of the operation of the soul in the body, and those of its communication, flow through the organic way, and demand for themselves help and assistance from the blood. It follows hence that the soul of a brute animal can by no means think in the human cerebrum, even as the human soul cannot think in the cerebrum of a brute animal; but such as is the soul, such is the formation of the cerebrum; and such as is the cerebrum, such is the communication, or such is the representation, and the likeness of the eminent operations of the soul itself. This, however, we only touch upon here on passing.

APPENDIX TO CHAPTER XXI.

AN EARLIER ANALYSIS OF THE RETE MIRABILE.

640*a*. Argument.—The rete mirabile may be looked upon as of three kinds, for the formation of which the carotids are broken up either much or little, before they ascend into the brain; and indeed for this purpose that they may furnish twigs to the pituitary gland, as well as to the bone underneath, for the conveyance of the spirituous juice. And again, that they may emancipate themselves from the action of the heart, and prepare the blood for the brain. In man, however, there is no such breaking up of the carotids into little branches, nor is there required any anastomosis below the brain, as in the case of the animals, namely, neither for the pituitary gland and its spirituous juice, nor for the action of the heart. The human brain, indeed, is so organized that it can summon the requisite quantity and quality of blood from the arteries. These arteries, being left undisturbed, so that the organs of its lower and higher degrees, as exigency requires, may act either apart or conjointly; and that man consequently may enjoy the use of reason and of freewill, and arrange all things for the purposes which the soul intends.

640*b*. *The rete mirabile may be looked upon as of three kinds; for the formation of which the carotids are broken up either much or little, before they ascend into the brain.* For there is *first* that "rete" which *par excellence* is called "mirabile," and also the "rete Galeni," although this author seems to have extended it too far. This species of "rete" is made up of the carotid, which is almost entirely broken up into branches, only one small canal being left, into which the branches are reunited before the carotid perforates the dura mater, and ascends into the cerebrum. This kind of "rete" is conspicuous in the cavernous sinuses, where it is intertwined with, and supported by little membranous tendons or cords, and is made up of small vessels woven in a net-like texture—according to the description of the authors, and especially of Willis, who delineates cleverly and carefully this kind of "rete" only, which is found in the calf, sheep, goat, fox, cat, and others. The *second* kind of net occurs where the carotid indeed throws out numerous shoots, yet does not lead them about in the cavernous sinuses, but places them underneath the duplicature of the dura mater, chiefly along the posterior side of the sella turcica; namely, near the circular sinus and the beginnings of the petrosal sinuses; likewise, along the sides where the carotid presses against the pituitary gland, perchance, also, on top, as Vieussens insists. This kind of "rete," when it is distinctly offered to the sight, usually also exists between the gland and the sella, and according to Ridley, in the surface of the former, in the dog, horse, and perhaps also in some human brains. The *third* "rete" exists when there are no traces of any "rete," or only such as are not conspicuous between the productions of the dura mater, and near the posterior part of the gland—but when merely a few shoots are taken from the carotid, and inserted in the gland, where this "rete" consequently is alone visible. These three genera of the "rete" differ from one another as to more and less; for, since by an examination of the larger "rete," we may be instructed respecting the smaller, it appears that the purpose of all of them is the same. The difference is simply that in one species of animals the brain calls for an almost entire breaking up of the artery; and in another species only for a partial or an exceedingly small division. For the brain derives thence its power of acting, on the one hand, that it may be in a condition to watch, and provide, and rule over its body, and its members and organs; and, on the other, that thence, as from a storehouse, it may summon blood, the purer essence of which it transmits into fibres, providing thereby for the nerves, and at the same time for the new blood;

wherefore if an observer is keen-sighted, it seems that from the appearance of the carotids, as they thus tarry near the threshold, he may draw conclusions as to the faculty of action of the brain.

640*c*. *That the carotids may furnish twigs for the pituitary gland*—either many or fewer, larger or smaller ones, and again, either immediately, or mediately through the retiform plexus. For chiefly towards the pituitary gland does the carotid send out its shoots, and both the first and second species of the "rete mirabile" concentre themselves in the direction of the gland, so that it may be looked upon in a certain sense as their centre. The office of the "rete," consequently, is to furnish the pituitary gland with blood. For the first kind of "rete," which is led about in each of the cavernous sinuses, has a channel of communication around the gland; and the second also communicates under the production of the dura mater, as well as in the pituitary fossa. The third species enters the gland from the carotid on either side. For this purpose, indeed, that the muscle of the gland may always be in a condition of acting, and may never be deprived of blood which enters into it from so many points, into which also it may flow back—although a part of it passes likewise into the little veins. The retiform plexus outside of the gland, or between the gland and the wall of the sella, is productive of a similar result; for when the gland, by means of the blood, is expanded, the intervening little branches also swell, and *vice versa;* by which circumstance the gland also is able to act upon the liquid which is contained on the outside of its surface. The muscular action of this gland also is strengthened through little branches of the fifth and sixth pairs of nerves, which almost at the same place, where they apply themselves to the sides of the gland, press against the carotids; for this purpose, indeed, that they may be able to accompany each shoot into the gland itself, by pressing in a similar manner upon the surface of the shoots, and thereby causing their constriction, which takes place whenever the carotid expands itself. For from the carotid when it is expanded, a living force redounds to the nervous fibres which accompany the shoots of the same; for these fibres constrict every least vessel, and direct its blood either back into the artery which is then expanded, or they urge it into little veins —altogether as is the case with the muscle of the heart, when the aorta together with the right auricle is expanded, and thus acts upon the cardiac plexus. For from the living motor force of the nervous fibres arises the contractile force, which again, by the inflowing blood, causes the expansile force; all of which, together with the ratio and the degree of the same, may be proved and known from every muscle of the whole body. This seems to be the reason why the above-named pairs of nerves cast themselves upon the artery; and this seems to be the manner in which the fibres of the nerves effect an entrance, namely, with a view of acting upon the blood they press upon the surface of the vessels. For the remaining filaments which are noticed in the "rete mirabile," are not nervous fibres, but, according to Morgagni and many others, they are simply membranous cords. Those filaments, however, which, between the gland and the sella, appear as fibres, are often little canals for the spirituous lymph. Meanwhile, a greater number of arterial shoots enter the pituitary gland in animals; for with them there is a greater quantity of spirit and liquid, and at the same time a grosser quality of the same, both within and around the gland. The greater, however, the quantity, and at the same time, the grosser the quality, the greater the force of action which is required; for a liquid of a purer and better quality is propelled with the slightest possible force to its destined places, even the most distant. All things thus correspond with their measures, weights, and powers of resistance.[1]

640*d*. Since the subject under discussion here is the nervous or filamentous coating, by which the trunk of the carotid, from the point where it enters into the cranium, is accompanied into the cavernous sinuses, a fit subject of discussion seems to be

[1] The whole subject of the motion of the pituitary gland which is caused by the contraction and dilatation of the arterial vessels is discussed in the light of modern experience, in Appendix, Note vi., nos. 5-10.—Editor.

here, whether the nervous fibres, between the proper coating of the artery, and that which it has borrowed in the place of the muscular coating which it has lost, arise from the great sympathetic nerve, or from the fifth and sixth pairs of nerves; whether the sympathetic nerve, consequently, has its origin at its own highest cervical ganglion, and through the mediation of the carotid, like the accessory spinal nerve, pursues its way upwards into the cranium, or whether it descends from the above-named cranial nerves. From the grounds which have been adduced in the third Transaction, it appears that the great sympathetic nerve, from its own ganglion, extends itself over the carotid, and terminates only in a reflex manner in the two cranial pairs of nerves, or in one of the two, namely, for this reason, lest during the expansion of the carotid, and while the nervous threads are in a state of tension, without such an insertion, these threads should burst, which is prevented by their reflex inosculation.

The great sympathetic nerve is chiefly placed over the liquids of the body, and thus superintends the distribution of the animal spirit, the nervous essence, through the fibres of the remaining nerves, and it likewise governs the areas over which the blood is supplied, so that all these parts shall undergo an alternate period of motion in harmony with the animation of the brain. In order, therefore, that this nerve may carry on its function, it is necessary that it shall encompass the carotid, and accompany its branches into the pituitary gland, and likewise into the osseous passages into which the ramification, that is, the shoots of the rete mirabile are continued. But whether the sympathetic nerve transmits into the pituitary gland separately any nervous fibres which have become loosened from its trunk, so that afterwards they may become attached to the blood-vessels in the gland—this will have to be decided by experience. I, for my part, entertain very strong doubts whether any fibres enter the gland at all from the sixth and fifth pairs of nerves, and I am rather of the opinion that they are dispatched thither from the carotid plexus.

640*e*. *That the carotids may supply twigs also to the bone underneath for the conveyance of the spirituous juice.* This is rendered evident by the experience of Willis and Vieussens, as well as by autopsy. For when a blackened humour is injected into the carotids, the substance of the bone is dyed thereby, and the dye collects in drops in its little crypts. Willis also seems to assert that the little arteries enter likewise into the small orifices themselves which are open in the bottom of the sella turcica. And Vieussens maintains that little branches of the carotid or of the "rete" enter the substance of the bone in the neighbourhood of the four petrosal sinuses; further, that the caliber of the upper cerebral trunk of the carotid is considerably smaller than that of the trunk below; for so much of its ramification cannot be expended simply on the ganglion of the fifth pair and on the optic nerves, that a sensible diminution would result thence; and the portion of the carotid blood which enters into the pituitary gland, for the most part, is returned again into these arteries, with the exception of a small quantity, which possibly may escape into the veins. Wherefore, most of the branches which do not return into the trunk seem to be expended upon the bone; and, indeed, for this reason, that these arterial twigs may constantly deliver and sprinkle blood upon the spirituous lymph. This action of the carotid blood is but a continuance of its action in the interior of the gland. In those subjects, therefore, where there is a large "rete," or in which the passages through the bone are larger, and the spirituous lymph more plentiful and grosser, there also a larger number of branches is expended upon the bone, and there the upper cerebral trunk of the carotid is reduced in size.

In order that the blood may thus be sprinkled upon the spirituous lymph which is expressed from the pituitary gland, it is necessary that nervous fibres should apply to those shoots of the "rete" which enter the substance of the bone, even as these fibres accompany those shoots which enter the gland. For this purpose, indeed, that at the same moment when the carotid is expanded, or when the spirituous lymph is expressed from the gland, the blood shall be sprinkled upon the spirituous lymph which passes through the lympheducts in the bone. The same also seems to be the case with that spirituous lymph, which, in the dura mater which is spread out under the gland, or wherewith the pituitary fossa is lined, is conveyed into the little transverse and circular sinuses. Into these sinuses there are derived, not only the small veins of the gland, but also arterial vessels of the "rete;" altogether in the same way in which the arteries of the dura mater are also derived into the longitudinal sinus. Perchance also the same thing occurs here; namely, that small arteries of the "rete" do not immediately enter into the above sinuli, but are associated first with little veins, even as has been observed above in connection with the longitudinal sinus.

640*f*. *And again, that the carotids may emancipate themselves from the action of the heart, and may prepare the blood for the brain.* For in brute animals which live exclusively under the government of their blood, and suffer themselves to be acted upon in accordance with its changes, a different arrangement is required, so that the heart shall not continue its action into the very brains. For this purpose the carotids are almost entirely broken up into branches, and in this manner the impetus of the heart is checked. This also seems to have been Galen's idea where he says that the uses of the rete consist in the vital spirits being confined there, and in their being compelled to tarry there, just as the arterial and venous blood is compelled to do in varicose enlargements in the body. This appears very evidently from the constriction, namely, from the diminution in size of these vessels; for as soon as they enter the cranial cavity under the posterior clinoid processes, they are almost entirely broken up into small branches, with the exception of a small canal which continues its way, and with which the other small branches again become associated before it ascends into the brain. Fibres of the great sympathetic nerve, moreover, embrace the carotids; and from their trunks these fibres are transferred altogether to their shoots; and these shoots they follow, so that if the nerve is unable to coerce the carotid trunk as a whole, it is able to subdue its individual parts and branches. And the nerve does not allow these branches to rejoin the small trunk which is left, until the intervals of their motion are reduced into harmony with the motion of the nerve itself. This same result also seems to be brought about through the membranous cords, of which Bianchi says that they are like tendons and robust ropes; but Morgagni, that they originate from the dura mater which either constitutes or lines the walls of the cavernous sinuses. According to these authorities, therefore, the "rete mirabile" of Galen seems to be rather of a membranous than of a sanguineous nature. The effect produced by these provisions seems to be the same which the dura mater also brings about at the very threshold, where it supplies the carotid with a coating—namely, that the arteries, by the help of the dura mater, and also by the force of the nerve by which they are embraced, are brought under the dominion of another ruler. To the above there is added still another mechanism, by which the heart is altogether deprived of the power of extending its action beyond, and which consists in this, that the rete mirabile of one side or of one cavernous sinus, communicates with that of the other side, and that there are frequent anastomoses between them. For the economical administration of the blood seems here to be identical with that which prevails in the whole brain, according to which all vascular branches and trunks are expanded, that is, undergo their diastole at one and the same moment, and likewise their systole; or that their expansion and constriction is simultaneous, and not successive as in the body; consequently, that the intermediate and communicating little branches are expanded at the same moment as their trunk. For this purpose it is necessary that they shall be tied together like cords and fasciæ, and that in accordance with the description given of them, they shall be rolled and twisted together: so that they may unroll and untwist, that is, open themselves, when the little trunk by a force acting upon it from without is expanded, and *vice versa*. The arrangement hence is, that when the heart sends its blood thus far, and acts in the interior of the vessels, and when the action of the sympathetic nerve and of the productions of the dura mater does not agree therewith, these little branches rather contract and contort themselves, and thus repel the blood, instead of transmitting it. Wherefore, this "rete" is said to be so wonderfully woven, that, according to Willis, there is nothing more wonderfully done in the body. There is thus confirmed here, what we inferred in our second Transaction, namely, that the action of the heart terminates at this threshold, and that its action is taken up by that of the brain. For presently the little branches, after they are reunited, commit their trunk, which has laid aside its dural coating, and at the same time its network of nervous fibres, to the pia mater, and submit it altogether to the same. This also is the reason why in Willis' experiment, who injected a liquid into the carotid outside the cranium, that same liquid passed into the trunk of the opposite side, namely, through anastomoses, above this disruption into little branches. This liquid, indeed, passed through the little canal [in the middle], leaving only insignificant traces of the blackened humour in the rete mirabile, and none whatever in the cerebrum and its cortex. Much of the liquid indeed flowed back through the other carotid; which is an evident sign that the heart is deprived here of its power of action. In the horse, dog, and the remaining animals in which such a rete mirabile is not perceived, there still exists a communication between the carotid of one side and that of the other side, through sufficiently large canals, namely, before these vessels enter the cavernous sinuses and again pierce the dura mater. This arrangement produces a similar result, namely, it retards and breaks to a great extent the impetus of the cardiac blood. In these animals, also, according to Willis' experience, the blood passes through several bends and windings, and is carried over more space than is the case in those animals which possess the rete mirabile.

640*g*. *In man, however, there is no such breaking up of the carotids into little branches, nor is there required any anasto-*

mosis below the brain, as in the case of the animals which are either altogether destitute of a rete mirabile, or in which some faint traces of such a rete are found in the duplicature of the dura mater near the pituitary gland. These traces are more numerous and more marked in proportion as the juice which is expelled through the gland is more copious. This is in accordance with the variety in the genius of each. For we are justified in believing that those persons who live more in a state of obsequiousness to the incitements and desires of their blood, have also more of such a rete, because they approach nearer to the nature of animals. There are reasons, therefore, why in man the carotids are never broken up in such a manner.[1]

640*h*. *Such a breaking up of the carotid into branches is not required in man for the purposes of the pituitary gland, nor for its spirituous lymph,* which is to be transmitted through the osseous substance; in the first place, because this lymph is not required in such great plenty, and because it is of a purer quality, and requires only the slightest force for its propagation. For this same reason, also, the openings in the bone are scarcely conspicuous in man; and according to Vieussens, can be perceived only in fresh crania; while in the calf they are fairly gaping open.

640*i*. *Nor is it required for the action of the heart,* which is checked through several curves during the passage of the carotids, both in the bone of the cranium, and upon reaching the interior of the skull in the cavernous sinuses. This same result also is obtained by a double perforation of the dura mater; further by the coating which these vessels borrow, and by the insertion of the sympathetic nerve between this adscititious coating and its own coating. All this suffices for the purpose that man shall not be governed by changes in the blood, as is the case with animals.

640*j*. *The human brain is so organized that it can summon the requisite quantity and quality of blood from the arteries when they are left undisturbed.* This subject is discussed in

[1] The methods resorted to in man for the purpose of emancipating the carotid blood from the motion of the heart, are discussed in the light of modern experience in the Appendix, Note vi., no. 50.—EDITOR.

Transaction II.; and this could not be done unless the trunks of the carotids were left undisturbed in the cavernous sinuses. For if these trunks were broken up, according as the exigencies required it, the brain would have to draw even upon the blood of the external carotids, and the nasal artery, and thus upon a more distant source; when yet for every state which the brain puts on, when it is pondering reasons, it requires a most present blood. For thought and imagination move the animal mind (*animus*) at one time less, at another more, frequently in a different way within the space of a single hour. At one time, therefore, it requires the presence of the blood in one part of the brain, and at another time in another part. And it would be unable to obtain the same, if in man there were an anastomosis of the blood below in the cavernous sinuses, as there is in the horse. Still man thence becomes subject to various kinds of illnesses, such as hemiphlegia, special attacks of paralysis, with headache so called, etc.

640*k*. *For this purpose that the organs of the higher and lower degree, as exigency requires, may act either apart or conjointly,* namely, when a change in the blood, and in the desire thence arising, and when at the same time the force of the objects which, through the organs of the body, incite and excite the blood and the ideas, penetrate as far as the sphere of the rational mind, and determine the will without a previous intuition of causes. Lest this take place, the organism of the human brain differs altogether from that of the animals in this, that the former is able to dispose itself in such a way, that whilst it collects and examines its reasons, the blood cannot irritate it; and if it does excite the brain, still the power is reserved to it to govern this excitement, under the advice of reason.

640*l*. *So that man, consequently, enjoys the use of reason* which consists mainly in an analysis of matters and things, and in the faculty of drawing conclusions from the present and the past in respect to the future, and from antecedents in respect to consequences, . . . and that *he may enjoy the freedom of will, . . . and may arrange all things for the purposes which the soul intends. . . .*

CHAPTER XXII.

THE FUNCTIONS OF THE BRAIN, AND ITS CHYMICAL LABORATORY IN GENERAL.

641. There are three functions of the brain, just as there are three principal operations in the animal microcosm, namely, *sensation*, or perception by the senses of whatever takes place in the world around, and, indeed, a perception of these things within the microcosm itself, whenever it becomes affected thereby by contiguity; *motion* in a fit and suitable manner, whether it be natural motion like that of an animal, or rational motion like that of a man; and, finally, *the production and elaboration of essences and juices*, by means of which the animal microcosm may exist, subsist, grow and live by sensation, as well as by motion. According to the same principle there are three functions of the brain, namely, sensation and perception, determination and action, and again the conception and bringing forth of the animal spirit and blood. But since the brain sways the sceptre of the kingdom, and governs and administers it from first things or principles and from laws, from those which are its own, as well as from those which belong to nature, it therefore exercises a general, and at the same time a most particular supervision and care over all things. Wherefore the brain must be looked upon as the universal and general sensory, and at the same time as the universal and general motory organ of the body, and finally as the universal and general laboratory of the animal spirits and the blood, or of the essential juices of life. But wherever there is a universal, singulars or least particulars must needs be present, and wherever there is a general, there must be parts or

particulars. The universal and the general derive their whole from the singulars and the parts: such consequently must be the case with the brain, so that it shall be what it is, and that it shall perform distinctly and appropriately its three functions.

642. In order that the brain may be the universal and general sensory, there must be least sensories to serve it in the capacity of singulars and of parts. Of these least sensories there are as many as there are cortical, and also cineritious substances; for all sensations flash from the organs of sense, in the direction of, and following the guidance of the fibres even to their beginnings or principles; because sensations cannot stop except in the termination of each fibre, that is, in the cortical substance of the cerebrum and cerebellum, as well as in that of the medulla oblongata, and of the spinal cord: for the cortical substance serves the fibre in the place of a beginning and an end. From the situation, form, connection, mutual respect, harmony and quality of all these singulars and parts, or from their external and internal state, results what is attributed to the cerebrum and cerebellum as peculiarly their own, namely, their capacity of sensating and perceiving in the most singular and particular manner whatever is transacted and takes place outside of themselves in the surrounding world, and also in its own kingdom; for their thousand little organs and sensories sensate and see more on the principle that several eyes see more than one eye. Sensation pursues almost the same course in the animal microcosm, as modification does in the microcosm; for it runs from each single fibre which has been set into activity, as from so many centres of motion, towards the circumferences; and thus following the flux of the fibres, it runs from the extremity of every fibre which has been touched and modified towards the two beginnings of the medulla oblongata, that is, towards the corpora striata and the optic thalami, and thence sensation speeds away into the cortex of the brain, and at the same time into the first and ultimate point of its organism. This function of the cerebrum, however, belongs to our psychology, where it will be discussed.

643. In order that the brain may be the universal and general motory organ, there must be little motory organs which are its singulars and parts. Of these there are also as many as there are cortical and cineritious substances. The motory organ, however, is voluntary as well as natural. Its voluntary part belongs to the cerebrum, and its natural part to the cerebellum. The medulla oblongata and the spinal cord, on the other hand, are disposed in harmony with the conatus and the active forces both of the cerebrum and cerebellum, and they are in readiness to act according to the beckoning of each. The first termini of motion must be where the first termini of the fibres are, for the fibres are so many pathways of determinations, through which there is poured forth, from their first little springheads, as from so many little hearts, the animal spirit which, upon coming to a stop in the motory fibres of the muscle, produces there the action which the cerebrum, as the general sensory and intellective organ represents, intends and orders for itself. Where the cerebrum sensates, perceives, and thinks, there also it wills, and determines actions; for the will is the ultimate terminus of its understanding. From the very same origins, and thus the very same substances, by means of which the brain perceives the modes or modifications of the senses, it marks out and starts its motions; still these motions begin only at those particular origins which correspond to each of the motory fibres of the muscle. The cerebrum expends scarcely more than one half of its fibres upon its voluntary acts, the rest it utilizes in its chymical operations, or in the organs of its laboratory. The cerebellum, however, devotes the whole of its fibres to the production of motion, yet only of such motions as do not reach our consciousness; the medulla oblongata and the spinal cord offer their ministrations and assistance to either organ. This function of the brain, however, like the first function discussed above, belongs to the psychological part of our work, where it will be treated of more fully.

644. In order that the brain may be the universal and general laboratory of the animal spirits and of the blood, and hence of the essential liquid juices of life, there must be little

laboratories, to serve it in the place of singulars and parts. Of these also there are as many as there are cortical and cineritious substances, both of the cerebrum and cerebellum, and of the medulla oblongata, and the spinal marrow. These substances, therefore, may be defined as so many little laboratories, glands, or least brains. For there where the principles and heads of the fibres are, which are rivulets of animal spirits, there also are the little fountain-heads from whence these spirits spring; for there the brain conceives and brings them forth, and from thence it sends them out, so that they may be of general use to the kingdom. These spirits themselves are the purest, inmost, the highest and most universal essences of the blood; for the blood itself lives from its spirit, as the spirit from its soul. The blood also is the basis and seminary of everything in its kingdom; and upon its nature, constitution, determination, continuity and abundance depends the fate and condition of animal life. On this account also the blood is the parent and foster-mother of all kinds of juices in the body. While thus the brain cares for the blood, it provides at the same time in a universal manner for every liquid essence, or for every juice in the body. On this account the brain has fitted out its laboratory with a most illustrious chymical apparatus, that it may thus serve as a model and ideal for all the laboratories of the body, of which there as many as there are glands. All these glands must be regarded as its likenesses and types, and indeed on a large scale.

645. In so far as the cortical substance is situated in the beginning or centre of the actions of its body, and as it contemplates these actions underneath itself from on high, it is necessary that every individual part of the system of the body shall correspond to this substance, as effects correspond to their causes; wherefore everything in the whole kingdom, which performs any kind of an office, must pre-eminently be ascribed to the brain, which thus must be defined as the purest sensory organ, as well as a gland; nay, as a microcosm, the whole body being called a macrocosm.

646. As many glands as there are, so many laboratories are there fitted out with chymical organs; for by extraction, filtration and commixture, chyles, milk, salivæ, biles, exudations, and the remaining lymphs which owe their origin to the blood, are elaborated, and thence excreted in the glands for the uses of life. The large laboratory, however, or the gland of the cerebrum collects, separates, and transmits into the ultimate receptacles of the sinuses those simple essences, those principles and individual parts which are to form ingredients of blood-corpuscles, or blood-cells. This large gland is constructed according to the plan of the purest and most perfect glands, of such as are glands in a supereminent degree; namely, according to that followed in the construction of the cortical substances which are miniature likenesses of the brain; for in them is generated the animal spirit which imparts their inmost and chiefest essence and nature not only to the blood, but also to the remaining fluids which are created out of the blood, and are animated by it.

647. Upon its organical apparatus or laboratory, however, the cerebrum expends only one half of its forces; the rest of its fibres it despatches at once through the medulla oblongata into the sensory and motory organs of the body. The cerebellum, on the other hand, does not derive one particle into the above-mentioned laboratory—and therein it is joined by the medulla oblongata and the spinal cord—but it expends itself wholly, through the nerves, upon the higher and lower provinces of the kingdom of the body, and indeed upon the arterial and venous vessels, as well as immediately upon the blood; and thence, that is, by the way of the blood it is derived into the glands of the viscera of the body, of which there are myriads.

648. Only the softer, lighter and more liquid blood is conveyed and propelled towards the cerebrum and cerebellum through the carotid and vertebral arteries. The purer and spirituous essence of this blood is reabsorbed by the cortical substance, and together with the newly-elaborated spirit is committed to the fibres; so that only the grosser, harder, the

more inert, and merely corporeal part of the blood remains, which is rejected into the longitudinal, the lateral, and the straight sinuses. This blood, upon being deprived of its better life, becomes sluggish and dark, and is urged into the widened ends or receptacles of the sinuses and towards the jugular veins. Unless it were animated there by a new spirit, and thus revived, it would be unable to flow and would clog up the orifices; its bulk then would be increased, and after accomplishing a few rounds in its circulation, the blood would transgress its limits, and flood the whole brain, which is the court and council-chamber of the body. It would thus deprive the brain altogether of its sensory and motory functions, thus of its providence, omniscience, and of its power in its little world, and hence would put an end to the kingdom. In order to escape this danger the brain establishes its laboratory, which it furnishes with a vast array of organs, and thither it sends its spirit through fibres, both that spirit which it has recently elaborated, and also the old spirit which it has received back from the body, in order that this spirit may restore and vivify the dying blood,—the supply of spirit being always proportionate to the exigencies of the case. In this wise the blood, which but a short while previously was lifeless, is re-animated, and after being made liquid again, it returns into the body, where it describes and perpetuates its circles. On this account the petrosal sinuses originate at the very sella of the pituitary gland, and they burst out thence as from a prison; and on this account they empty their contents in due order into the widened ends or the receptacles of the lateral sinuses, and into the jugular veins themselves. After the blood on its return journey has been imbued with spirit, it is received by the new chyle, or in its stead by a most refined lymph, which are conveyed into the subclavian vein by the thoracic duct. Into this chyle or lymph the blood is at once introduced, and presently it is carried into the general whirlpool, or agitator, that is, into the right ventricle of the heart. Afterwards it is dispersed through the pulmonary tubes and vesicles, and imbibes the purest nitrous substances and the saline elements conveyed thither by the atmospheres; whence it becomes of a more lively and ruddy colour, and returns into the other chamber of the heart, from which it is expressed into the arterial, and thence into the venous vessels. In the capillary vessels the blood which has been generated in this manner is freed by excretion from all that is antiquated and obsolete, and also from all useless and urinous serosities which are cast out. Such is the use for the sake of which the apparatus of the chymical organs in the brain has been established.

649. Lest, therefore, the effect should betray the cause, and lest in its progress it should be brought to a stop, both petrosal sinuses are carried across the petrous and spongy temporal bones, where the ear with its tympana, fenestræ, tubes, and cochleæ which are hollowed out of the bones, is hidden away, and whither the auditory nerves likewise penetrate. These sinuses are thus carried across the whole of an area which is tremulous, and in a perpetual state of vibration from the sonorous modes of the internal ear; for the whole of this area, like an island, is enclosed by three sinuses, as by boundary streams. And, lastly, the jugular veins also, which contain the same blood, are carried towards the larynx, and they run down along the trachea, which is likewise in a tremulous condition; and the whole of this arrangement is for this purpose, that the highly elastic fluids, carried by the petrosal sinuses, which are already interiorly in a state of vibration and exhilaration, may also, by external adventitious causes, germane to their nature, be propelled towards their final goal, and be thoroughly commingled.

650. How sublime the chymical process of the brain, and, at the same time, its apparatus of organs is, and by what intrinsic art of nature it is stirred into life, appears only from a more thorough exploration and a closer scrutiny; for the more we examine the interiors of nature, the denser becomes the darkness and stupor into which we are thrown by its arcana; and at last we are compelled to acknowledge that nature does not take the least step without having respect to that end, which, in its minutest singulars, as by so many means, ever conspires

with the general, and at last with the one and only end; and again, that whatever the moral world in nature intends, its physical world, as a servant, produces most obediently as its effect; that, therefore, in the interior bosom of nature all science resides as it is in itself, and if we scrape off anything from its surface and crush it, mere diminutive drippings, and muddy at that, issue, as it were, from the immense lake. As nature teaches us the science of optics in the organ of sight, and acoustics and music in the ear, so in the organs of the brain, and in every glandule of the body, it instructs us in the most hidden art of chemistry; how the animal spirits are to be combined, filtered, solved, rectified and refined for every particular use, and how the laboratory is to be fitted out with the most elaborate alembics, phials, worms, and receivers; and how these are to be sealed with bladders and membranes, and to be warmed in baths.

651. Let me mention only one thing. As the brain in its laboratory, from the operations of combining and condensing fluids, passes to that of mollifying and separating the same, it likewise passes through degrees of cold and heat. In the first receivers, that is, in the lateral ventricles where vital essences are wedded to more inert serosities, there prevails a comparatively cool temperature. This temperature, however, abates and is rendered milder in the middle or third ventricle, for the veins of the lateral ventricles, and of the choroid plexus, cling to its bottom, and pass through it. A still milder temperature and a gentle tepid warmth begins in the infundibulum, the ventricose enlargement of which is encircled by the communicating branch of the carotid and vertebral arteries, and irrigated by innumerable arterial shoots and plexuses. The heat becomes intensified in the subjacent pituitary gland, against both sides of which press the swelling carotids which breathe out heat, and in addition this gland is flooded on all sides by motory fibres and little arteries. The temperature, however, is hottest in the cavernous sinuses, underneath which there is an oven, as it were; for these receptacles are not only filled by the

carotid arteries, but two sinuses also, and as many ample veins pass through the same, as well as some newly-born and most active nerves. We are therefore quite justified in calling the lateral ventricles cooling chambers, and the cavernous sinuses hot stews and baths.

652. Into its laboratory the cerebrum despatches its fibres and pours out its spirit; it also causes in it an alternate systaltic and diastaltic motion, while the corpora striata and optic thalami, or the beginnings of the medulla oblongata, the wells of the brain, furnish obediently the requisite water. The cerebellum, on the other hand, pours in blood or the serum of blood, for the choroid plexus is mainly constituted of the arteries of that organ, namely, of the vertebral arteries. A certain marriage-union is thus celebrated there, the cerebrum being the bridegroom, and the cerebellum the bride; the latter gives herself away in the thalami or marriage chambers of the former, and the corpora striata lend their help, and serve in a ministering capacity at the consummation of this marriage. The cerebellum acts also upon the isthmus formed by the corpora quadrigemina, and opens and closes the doors to the inner sanctuary; it likewise governs and rules the whole mass of the blood, and casts it into the jugular veins; it tightens, too, and relaxes the extreme ends of the tentorium which are extended as far as the cavernous sinuses and the sella turcica, and in this wise the cerebellum constantly stimulates the pituitary gland to pour out new life into the blood. It appears hence that the offices are so distributed between the cerebrum and the cerebellum that each claims a part in the regeneration of the blood.

CHAPTER XXIII.

A COMPARISON BETWEEN THE LARGE GLAND OF THE BRAIN AND THE SMALLER GLANDS OF THE BODY.[1]

633. NUCK.[2]—"The glands, usually reckoned conglomerate or racemose, are such as are composed of a congeries of lesser glands, and surrounded by a common coat; and each of the lesser glands puts forth an excretory duct, and these ducts again form a canal through which a certain liquid flows, either into some considerable cavity, or to the outside of the body.

Of this kind are the glandulæ innominatæ, the parotid glands, the pancreas, the glands of the mammæ, etc., which, with all the others of this description, are nothing more than a texture of very minute vessels composed of the smallest arteries which carry blood laden with various particles, and terminate in two orders of vessels, of which some are venous and admit venous blood, and some excretory, as we observed before. To get a clear view of the latter vessels, they must be made the subjects of certain experiments. When the membrane, investing a conglomerate gland, is removed, and any liquid injected through its excretory ducts, or its arteries, we then observe the lesser

[1] A large portion of this chapter was introduced by the Author in Part I. of the "Regnum Animale," where it constitutes Chapter viii. under the title "The Glands Generally;" for this reason it is crossed out in the original MS., and a portion of the anatomical quotations has been lost. As the analysis of the present chapter, however, differs very much from that printed in Part I. of the "Regnum Animale," we consider it useful, and even necessary, to introduce here the whole of the crossed-out chapter. The latter portion of the anatomical quotations we supply from Part I., and for the whole of the quotations we adopt the excellent translation of Dr. J. J. Garth Wilkinson.—EDITOR.

[2] "Adenographia Curiosa," Lugd. Bat., 1692.

glands receding from each other, their little vessels turgid with injection, and the glands themselves all rising up (*De glandulis in genere*, chap. ii., pp. 8, 9). . . . Having obtained a mamma, the nipple of which was perforated by many excretory ducts, I pressed out of it all the milk, and, selecting one of the largest orifices, I injected my mercury into it with as much dexterity as I could command, and immediately I had the pleasure of observing, not only that the lactiferous ducts were beautifully filled and presented an arborescent appearance, but that several of the lesser ones had so far admitted the mercury that it had passed into certain anterior vessels, continuous with the lactiferous ones (*Ibid.*, pp. 12, 13). . . . The [conglobate or lymphatic] glands have two membranes, an exterior and an interior. The exterior is the thinner membrane, and encloses the whole gland, and adheres in general so firmly to the membrane underneath it that it cannot be removed without laceration, although, in some cases, its connection is looser, and it may be separated more easily. It consists, for the most part, of circular fibres without either beginning or end, except about the entrance of the vessels where the circular arrangement is usually disturbed. . . . Upon removing the exterior membrane, we come to another thicker and more compact membrane immediately covering the substance of the gland, and which is perforated throughout by both the afferent and efferent vessels. Its pores, however, are so minute, that air does not ordinarily escape through them, notwithstanding it is forcibly driven through the vessels, a result to which the exterior membrane contributes in no slight degree. It is furnished with various fibres, longitudinal, circular and oblique, which touch each other in innumerable places, but are arranged quite irregularly. It is also supplied with both afferent and efferent vessels, arising from the same ramifications as the vessels of the exterior membrane (*De Glandulis Conglobatis*, Cap. I., pp. 27-29). . . . Besides the investing membrane, I found that the glands have also a fibrous tissue, consisting of a number of fibrillæ of different species and figures, and all united together. The exterior ones, placed immediately under the internal membrane (to which also the fibres were firmly connected) by their extremities, which represented so many little heads, were connected to the membrane in a certain regular order, so that the intermediate spaces, being ordinarily filled with lymphatic juice, rendered the coat uneven, and dotted with great numbers of little hemispherical tuberosities. The fibres immediately under these, and which were turned inwards towards the gland, formed various angles, some being hexagons, some pentagons, and some of different other figures, according as best suited the other part of the fibrous texture. The rest of the fibres, as far as the centre of the gland, still followed the other arrangement, but kept the same irregular order, some being larger, some smaller, some longer, some shorter than others, but always firmly connected together, and nearly resembling the moss on a tree, wherefore the conglomerate glands might not inaptly be called glandulæ vasculosæ, and the conglobate glandulæ muscosæ. After a careful examination I have never been able to find canals in these fibres; the whole of them, excepting the blood-vessels, are destitute of cavities. And here it may be observed that the compages of the glands was not the same in all subjects, but more lax in some, more tense in others, according as the glands were distended by a greater or lesser quantity of lymph. The glands vary also greatly in colour; some being grey (which is the usual colour), some yellowish, some blackish, and others again variegated. These glands, indeed, are naturally full of a certain transparent and limpid fluid; but this is often changed into a viscid humour; and I have seen the interstices of the glands filled and obstructed with tartareous and sabulous matter; and in some instances I have extracted as many grains of sand as there were cavities between the fibres, and occasionally have found the whole gland in a calculous state (*Ibid.*, Cap II., pp. 35-38). . . . Besides the fibres already mentioned, I have also seen various others, extending from one side of a conglobate gland to the opposite side; some being nearly rectilinear; others departing from the right line, and forming obtuse angles. . . . Having often previously observed that each gland receives at least one, frequently two, and not seldom three or four branches from the neighbouring arteries, hence I selected one of these branches for injection with mercury; which, finding a ready passage, made the little artery with its various ramifications conspicuous through the tissue of the gland; nor were the corresponding veins wanting, divided into a number of lesser twigs; but the blood-vessels were greatly exceeded in number by the nerves, which kept along their sides (*Ibid.*, Cap. III., pp. 39, 40). . . . I admit that these glands cannot be the origins of the lymphatics; for more than once I have observed so close a connection between the lymphatics and the arteries, that when a little artery was inflated, the lymphatic of some gland was inflated at the same time, and its lymph seemed often bloody, like the washings of flesh. A lymphatic sometimes puts forth lateral twigs, its principal branch only lying on the gland, and taking up again the returning twigs. No lymphatic can possibly finish its course, without being obliged to salute the glands in some part thereof; as we see particularly in those parts where there appear to be no glands, and yet where there are lymphatics; which latter, in such case, by ways hitherto unnoticed by anatomists, and as it were, by secret or blind paths, seek out some gland, and discharge into it their lymph; there to be mingled with some other lymph proceeding from a different source; and thence propelled by the common efferent vessel, towards the receptaculum chyli, or some other destination (*Ibid.*, Cap. III., pp. 47-49). . . . I have seen the lacteals still turgid with chyle in perhaps a hundred places (which, however, only very seldom we are able to see in the human body); and the glands of the mesentery full of a certain juice: and being desirous of knowing what intercourse there was between the lacteals and these glands, I injected mercury into one of the vessels proceeding from the intestines, and which was conspicuous on the outside for the number of its valves; and I had the unexpected satisfaction of observing, that not only was the lacteal filled by the injection, but the gland, to which it went straight, assumed a new figure and appearance; changing from flat, even, and smooth, to globular, rough, and tuberous (*Ibid.*, Cap. II., pp. 31, 32). . . . The conglobate glands of horses, oxen, dogs, and of other animals of the same kind were the subjects of investigation in our theatre, and everywhere the mercury by its course discovered the same order, and the same way. The glands sometimes, as has been the case in human subjects, changed their figure and surface (*Ibid.*, p. 33).

654. MALPIGHI.[1]—"There are many species of conglobate or lymphatic glands, differing from each other in their exterior configuration and internal structure, as well as in the quality of the juices they excrete, and in their excretory vessels. The gland with which the palate, the œsophagus, the intestines, and other similar parts are plentifully furnished, is the simplest of all, and the model of the rest of the glands. It consists of a membranous follicle or loculus, which is sometimes oval, sometimes round, and sometimes lenticular or oblong. Around this loculus or follicle, blood-vessels and nerves ramify, and we may conjecture that it is also surrounded by fleshy fibres, or at any rate covered by a muscular extense, something like what we see in the stomach and œsophagus. Next in order to this simple gland are glands consisting of a number of loculi; as those in the face, in the lips, in certain parts of the skin, about the pudendum, and the palate ; in which the excretory vessel (which is sometimes oblong) has numbers of membranous loculi appended to it, which open into it, and are surrounded by ramifications of nerves and blood-vessels. The conglobate glands are situated in the axillæ, in the groin, in the fat, in the mesentery, and in almost every other part of the body. They are covered externally with a very dense membrane, which is supplied by lateral branches from the blood-vessels. Under this are placed circular fleshy fibres, which penetrate the body of the gland horizontally. This

[1] "*Dissertatio de glandulis conglobatis*," London, 1689 ; Leyden, 1690 ; contained also in his *Opera Posthuma*, London, 1697. The references above are made to the Leyden edition of 1698.

membrane is also frequently studded with multitudes of minute, round tubercles, caused by the turgid corpuscles contained within the gland. . . . The follicles of the gland are full of a certain cinereous humour, which is but little transparent in the natural state. . . . The loculi are appended to the blood-vessels which pass over the fasciculi of the fleshy fibres, and form the areolæ; wherefore the body of the gland is composed of various layers of areolæ and spaces of the kind placed one upon another. The blood-vessels, that is to say, the arteries and veins, enter these glands by many branches, mounting over their sides; and in some of the larger glands which are connected to the trachea, the vessels enter the belly of the gland, or the concavity formed by the doubling in and approximation of its two ends. After entering, the larger branches form a network, and their last twigs appear to terminate on the loculi and parietes of the areolæ. The glands have many nerves, and sometimes a single nerve enters their substance. And although in the interior of some of them there is a reticular tissue resembling a thin membrane, yet the filaments of which it is composed are not all nervous, but are frequently portions of the fleshy fibres, and of the fimbriated membrane which covers the gland exteriorly. The conglobate glands certainly have lymphatics appended to them, and which communicate with their inmost substance; so that a single lymphatic penetrates the smallest glands, and very frequently many enter the larger ones; thus we may declare that every conglobate gland is supplied with glands. . . . So great is the abundance, and such is the minute division of the lymphatics in the spleen, as to admit of neither description nor representation. Their trunks pass out about the thicker portion of the spleen, where the blood-vessels have their ingress and egress (*Opera Posthuma*, pp. 139-142). . . . In the fat and the interstices of the muscles, and within the conglobate glands themselves, we frequently find little glands, not bigger than vetch-seeds, and of a red colour; these when laid open are seen to contain coagulated blood, extravasated from the loculi. . . . With respect to the glands called renes succenturiati, I have clearly made out that they are supplied by a beautiful network of vessels, and particularly with vast numbers of white nerves, reticularly interwoven; whence it seems probable that a further separation is carried on by the nerves in the cinereous substance of these glands, or rather that this substance is an appendage to the excretory vessels and their extremities; inasmuch as it is immediately connected to a broad and capacious duct, which passing lengthways, opens externally, and discharges itself into the emulgent veins; while at its other extremity it gives off copious branches, whereby it receives the humour separated by the glands and tubuli. This duct or cavity is lined by a fine membrane, which is studded with innumerable foramina of irregular figures; whence it is probable that great numbers of excretories open into it, and that there is a passage from it into the foramina, as we see exemplified in the kidneys. I have often noticed an analogous structure in certain glands situated in the intestine that adheres to the fleshy stomach in hens and chickens (*Ibid.*, pp. 144, 145). . . . When the membranes of the conglobate glands are removed, or what is better, when a longitudinal section of the gland is made with the scalpel, and the part is well macerated in water, we meet, on a careful examination, with the following phenomenon. In the first place, transverse fleshy fibres proceed from the investing membrane, but they do not lie parallel, but slant and cross each other; and by their inosculation, or at any rate, their interweaving, they form numerous, and indeed almost innumerable reticular areolæ, generally roundish, though sometimes angular, and of different sizes. In the middle of each areola there is a glandular locus or follicle, which is either round or oval; and larger or smaller according to the larger or smaller quantity of substance which it contains. It is composed of a soft white membrane which collapses when the humour is evacuated; and if it be cut a cavity is seen. These loculi are very similar to the glands of the spleen. But when the glands are handled, the loculi are emptied, and become contracted and indistinct; and hence it is not always easy to see them, and for a long time, both my mind and eyes were puzzled by this circumstance. At length, however, I found what I wanted in diseased oxen, and other animals of the same kind; where the glands were sometimes increased to a hand-breadth, and their loculi so full of a tartareous substance, that a slight examination was sufficient to show them. In this obstructed gland the membrane of the follicles was more solid and thick than in the normal state, and near the glands were unusually large varicose and reticular productions of blood-vessels such as I have sometimes observed in the larger and redder loculi. But in order to see the loculi in all the glands, the exterior portion of the latter must be examined, for corresponding swellings are caused on the outside by the turgid loculi within, and when the gland is laid open we find rows of loculi, surrounded by areolæ of fibres, under the membrane itself. The follicles of the gland are full of a certain cinereous humour, which is but little transparent in the natural state; but when the animal is diseased they contain other matter, generally tartareous and mucous humours, or concreted juices. . . . After entering, the blood-vessels form of their larger branches a network, and their last twigs appear to terminate on the loculi and parietes of the areolæ (*Ibid.*, pp. 139-141). . . . Elsewhere we have pointed out that nature makes use of the same method in the composition of the viscera as of the glands, and that the liver, the cerebrum and the kidneys, are glands: the compages of follicles in them appended to the excretory vessels clearly proves this to be the case. . . . The glandular nature of the cerebrum, made up as it is of membranous follicles, is forcibly shown by the remarkable case of a girl which Wepfer relates, where the cranium was entirely filled with a congeries of almost innumerable vesicles, from which arose fibres that passed towards the base of the skull. In more than one instance a large vesicle had supplied the place of the brain" (*Ibid.*, pp. 145, 146).

655. BOERHAAVE.[1]—"Some of the glands are simple, others

[1] "*Institutiones Medicæ*," etc, Leyden, 1708, etc.

are compound; the latter commonly consisting of the former, aggregated and enclosed in a common membrane. The simple [lymphatic] glands discharge a peculiar humour through their lymphatic ducts, either into the chyle or the venous blood; or exhale it from the exterior of the skin, or from the surface of the free membranes that are found in all parts of the body. The compound [racemose] glands, on the other hand, discharge their humour (which is prepared in every part of the gland) through little canals belonging to each part, into a larger canal, and through this common excretory duct into the great cavities of the mouth and intestines, or else out of the body, for particular uses. The first kind are called conglobate, and the latter conglomerate glands. The simple glands are composed of a thin external membrane, and of an internal one which closely adheres to it. The first, composed of elastic circular fibres, entirely surrounds the glands, and contracts and compresses them; it chiefly consists of a contexture formed by the small vessels which enter into and pass out of the glands. The internal membrane is thick and more dense, being formed of fibres passing in all directions, and of an interlacement of vessels; and serving almost for the same uses as the external membrane. These glands are furnished with arteries, the branches of which are supported by, and distributed in, the membranes in a firm and regular order, and so accurately conveyed to every minute particle of the gland, that if wax or quicksilver be injected into the small arteries, it increases them and compresses the other vessels to such an extent, that we might thereby be led to the false conclusion that the whole fabric is arterial. They are also furnished with veins, which are distributed much in the same manner as the arteries. They have more and larger nerves than any other part of the body of the same magnitude; and these are so divided in the gland, that they seem to be present in all parts thereof. They have also lymphatics, which go to, and return from them. Their arteries are tubes—conical, curved, branching, elastic, and convoluted; at the extremities, cylindrical, no longer branching, but now changed into veins; but before they suffer this change, the small arteries communicate with one another by numberless anastomoses, in various positions, and at innumerable angles; so that their extremities are distributed in various ways in the different glands. The arterial blood, therefore, when driven into the glands, experiences rapid motion; strong resistance and compression, pressure of its parts against each other; oblique pressure, perpetual change of the points of contact; application many times, and in every direction, against all the minutest points of the canals, momently varying rotation in every particle; squeezing together of particles; onward and backward movement in the tubes, attenuation, attrition, preservation of fluidity, solidity, polish, secretion, and thorough mixture. Now as the branches which arise from an artery are generally narrower than the trunk from which they rise, so in these minute vessels the last branches are less than the last trunk. The last trunks convey the red, thick part of the blood, and pour it into the beginnings of the veins; the narrower branches receive the finer, more fluid, and pellucid parts, which are less in diameter than themselves, and which have been pressed by a strong, oblique, opposite force. But this thin humour, thus separated from the grosser part, is no longer blood, but another fluid, and that, too, various,—as sweat, perspiration, matter in the pores, tears, fatty wax, cerumen, mucus, saliva, sputum, linimentum, lymph, serum, bile, semen, oil, milk, fat, etc. Therefore the last branches, ceasing to be named arteries, are differently called, according to the nature of the humours they carry; and as they often again put on all the properties of arteries, they must have also their smaller branches and their veins; hence the arteries and veins are as much vehicles of serum, lymph, water and spirit, as of blood; nor do we know where these vessels terminate, but hence, at least, we see the origin, progress, termination and office of the lymphatics, which not only consist of veins, furnished with valves, and which, by reason of their thinness and transparency, are invisible. This we learn by the artificial means invented by Ruysch. Yet the branches, perhaps, of every such artery, now no longer branching, but straight, and distributed in the delicate little membrane of the finest glandular follicle, discharge their humour by open mouths into the common cavity formed by that membrane, where, being collected from all quarters, it, in a manner, stops, and constitutes the glandular lymph there prepared and reposited. It is by no means improbable that the nerves of the glands also discharge the spirits into them by a similar apparatus, mixing the spirits with this lymph, and thus supplying it with the requisite qualities. And the lymphatic arteries frequently bring their lymph, discharged into their valvular veins—a lymph which we call vascular—to those glands, and after a different manner pour it into the same follicle, and, mixing it with the spirits and the glandular lymph, they subtilise it afresh. When the abdomen of a healthy, living animal is opened, the lymph tends rapidly from all parts thereof towards the receptaculum chyli; and even after death, when the lymphatics are wounded, it tends to pass out of them, a contraction of the body taking place from the cold of death. Then this compound liquid, passing out through the lymphatic veins, is driven by the contractile power of the fibrous membrane by the motion of the artery and the pressure of the muscles into other glands there to undergo the same alterations, and thence into the receptaculum chyli, the thoracic duct, or the sanguiferous veins. And these seem indeed to be the universal conglobate glands of the body.

656. "But in other glands the case is different, for the follicle directly expels the liquid it receives by its emissary vessel into a common cavity, as into the frontal sinuses, the osseous cavities of the superior maxilla, the cells of the sphenoid bone under the sella turcica, the recesses of the spongy bones, the cavities of the nares, the lacunæ of the tonsils, where the mucus secreted is deposited, collected and altered. This is the case with the mucous glands of the mouth, of the posterior part of the tongue, of the exterior and interior of the epiglottis, of the internal nares, of the meatus auris, of the fauces, the larynx, the trachea,

the bronchia, the œsophagus, the stomach and the intestines, which glands may be called simple excretory glands. Others again, in the same way, discharge the humours they have prepared to the external surface of the body through peculiar emissary ducts arising from a cavity, as in the meatus auditorius, the pinnæ nasi, the exterior of the nose, the beginning of the internal nares, in the face, the neck, the axillæ, the scapulæ, in the areolæ of the mammæ, the areola of the umbilicus, in the nates, the perinæum, the pubes, the mons pubis in both sexes, in the scrotum, the integuments of the penis, in the labia vaginæ and the knees, the glands of which are now styled sebaceous glands (nos. 241-252). . . . But the simple glands already described, or others similar to them, when united together by common vessels, and connected and enveloped by a common membrane, generate certain compound, or, as they are called, conglomerate [or racemose] glands. These have usually one common excretory duct, which receives the humour sent into it by emissary ducts from all parts of the gland, and, collecting it, pours it into some larger cavity. The glandula innominata of the eye, the parotid gland, the pancreas, etc., are glands of this description. Moreover, the excretory duct of the common receptacle just mentioned—(1) often changes into a kind of arterial, sinous vessel which alters the humours, and then, by its arterial apparatus, discharges them into some open channel, as in the testis, the ductus Highmorianus, the epididymis, the vas deferens, and the vesiculæ seminales; or (2) discharges the humours direct into some common emunctory. Hence we know, with certainty, that water, lymph, thin serum, and salts, spirits and the most subtle parts of oils mingled therewith, are separated by means of the glands from the arterial blood, and that all these are either collected, altered and accumulated in certain places, or else driven through the small vessels into the minutest parts of the body, there to serve for motion or nourishment, whence they either return through the proper vessels to the heart, or else are exhaled, and, lastly, that the part of the blood which remains in the arteries after this process is concluded passes by degrees into the larger veins to be mixed with similar blood, diluted with lymph, and returned to the heart (nos. 257, 259). . . . Other glands again seem to be of a different structure. In these, the artery, which conveys the humours, communicates the grosser blood to its accompanying vein through anastomoses between it and the vein, and then, proceeding alone, and wreathing and gyrating, discharges from its extremity, into some common receptacle, a peculiar humour prepared from the blood, though differing from it in nature. If we consider the stomach as a glandular cavity, the small intestines as a continual excretory duct, further altering, refining, secerning and mingling their contents, and the large intestines as also an excretory duct, and if we apply the same to the testis, the epididymis, the vas deferens, the vesiculæ seminales, the urethra and the prostate gland, we shall not perhaps be supposed to question that similar operations may go on in even the minutest parts of the glands. Who shall say what is accomplished by the elaborate structure of the cortex cerebri, cerebelli and medullæ spinalis in their invisible initiaments?" (no. 262). See also Sylvius, Steno, Wharton, Graaf, Bellini, Borelli, Peyer, Leal, Cowper, Ruysch, Heister, etc.

ANALYSIS.

657. It is not my intention to treat upon the organization of the glands of the body, the method of their operation and their uses; for this work far exceeds my powers. Whoever attempts this will scarcely go beyond the threshold; and everywhere he will find the door closed to the larger halls, and still more to those hidden recesses where nature is sitting at her hearth-fires, and near her chymical apparatuses. And if perchance he should be allowed to take a glance into the interiors, it will appear to him like an abyss, in which the rays of his intellectual vision are not terminated but extinguished. If, however, I stop short in the threshold, I may perhaps lay down a few things, which may serve as a guiding torch in the hands of those who are willing to pursue their investigations further.

658. (1) The blood is the storehouse, complex and seminary, of all things in its bodily microcosm; for the blood-globule contains, besides the spirit which inhabits it, the first elements, the leasts, and the determinate unities, from which the fluid as well as the solid parts of the whole kingdom of the body may be compounded, and so subordinated and co-ordinated, as to be able to be resolved again into their component units; in such a manner, indeed, that the blood-globule, by dint of a hidden, chemical art, is able to produce whatever is capable of existing from the first things or principles. Hence an infinite variety of fluids and solids arises from one single source, namely, the blood. In the very nature of things, therefore, there is no compound more fertile, more perfect and more simple than the blood, because it comprehends mere simples.

659. (2) The blood, therefore, above all other fluids in the body, must be furnished by the cerebrum, cerebellum, the medulla oblongata and spinal cord, with its spirit, which is its chiefest essence and life; and likewise with saline principles which are either individually by themselves, or in a combined form; or, again, which are either simple or compound. By these principles the spirit is to be invested and compressed into little globules, and, indeed, through the common way of natural food, and also by special other ways which escape ocular vision. On this account the lymph which, when impregnated by various salts is called serum, goes to meet the blood; and thanks to this lymph as a means of conveyance—each blood-globule about to be born is furnished with this medium of conjunction and this nourishment or food.

660. (3) The genuine blood during every round of circulation is resolved into its constituent elements, and from these elements and others recently acquired is again recompounded: the cerebrum and cerebellum being especially clamourous for their spirit which they, together with that which has been newly created, commit to the fibres, while the rest, together with a more refined lymph, they send off between the fibres, and also between the smaller fascicles of fibres; so that the entire blood-globule, after having been resolved in the brain into its constituent elements, returns into the body by distinct paths through the nerves. After these parts have again been collected in vessels and glands, they are introduced afresh into the blood which is about to be reborn, while that portion of it which has accomplished its use, and is unfit for any other purpose, is excreted and exterminated.

661. It is, however, especially cared and provided against, lest any of the noble essence of life or of the spirit shall escape, transpire or perish; on the contrary, infinite care is taken so that after it has once been set free from the blood or any other juice it shall again flow back to its fountain-head, and perform its appointed uses. This is the cause of the creeping forth of innumerable lymphatic vessels, turgid with a most refined moisture, which carries the enclosed spirit; thence comes the

certainty with which they pass both mediately and immediately from every viscus into glands, into the thoracic duct, or into veins. Thence also is the circulation of humours of every kind which partake of life in proportion as they derive anything from this spirit. The very fibre, also, upon being but lightly touched with a sting, contracts, and closes up its delicate approaches, as though it were conscious of the precious burthen which it bears. Lest this lymph, enriched by such an abundant supply of spirit, should wholly expend itself, and become drowned in the fluids proper to each viscus (for they all have each appointed to them their own peculiar humours); lest therefore this lymph should be absorbed by the greedy stomach, the œsophagus, the intestines, the pancreas, the liver, the womb, the testes, the prostate glands, and by the remaining organs, conglobate or lymphatic glands, so called, are strewed over them, which, being stirred into alternate motions, may not only summon the meandering streams of this lymph, and claim and assert for the blood its due, but which may also provide against the viscera consuming more of it than is just, and required by their necessity and use. On this account also the lymphatic glands pour over the organs a similar lymph which they express from the arterial vessel and the fibre which terminates in it. Such also is the use of that large gland, called the spleen. In this manner the blood, the chyle, the milk, the bile, the saliva, and the semen have each granted to them what they require.

662. The conglomerate or racemose glands are so constituted that they do not select, separate, sift, commingle and excrete from the blood and its serum any other parts than such, as from a pre-established end of nature, agree with the juice and menstruum which is to be elaborated: wherefore the structure of each of these glands is various, and must be specially and individually examined and investigated. The following general statement only occurs to us now, namely, that every one of these glands claims to itself and appropriates from the universal store so much blood and of such a quality, as is demanded by its own necessity and use. The cerebrum and cerebellum

claim and abstract thence a large share, and indeed of a better quality; the liver attracts only what is effete, gross, black, and hard; the kidneys make a requisition for urinous, saline and stale serum. The testes and the genital organs demand a prolific and nutritive blood, teeming with spirit, untouched by the neighbouring kidneys, and refined from impurities; and thus each of the remaining viscera craves its own peculiar supply. Upon the cessation of the use, however, the effect also is at an end. A moderate use arranges the tributary streams in due order; an immoderate use causes confusion in and among them, and too scanty a use clogs them up; which is proved by the sucking of milk, by the incitements of various lusts whereby they are either relaxed or restrained, by the stimulation of the bile, by the retention of the chyle through fasting, and other habits which become constitutional, as it were, or natural. It hence follows that as the glands invite only such blood, serum, or lymph as agrees with their own character, the blood in every artery and vein, and in each of their branches, is different and distinct.

663. But let us pass to a comparison of the cerebrum and its functions with the glands of the body, where, as in types, an effigy of the former may be discovered.[1] [The CEREBRUM is proximately covered and surrounded by two membranes—the arachnoid, a thin membrane,[2] and the pia mater, which is somewhat thicker; the *glands of the body* likewise are covered by a thin common membrane, and by a thicker one underneath it. The CEREBRUM has its peculiar artery—the internal carotid—which enters it by two trunks; the *glands of the body* likewise have for the most part two arterial branches and two venous ones. The ARTERY OF THE CEREBRUM, dividing into twigs, winds and branches between the two membranes, and penetrating their folds, is dispersed about, and ramifies through the

[1] The portion in brackets is supplied from "*Regnum Animale;*" Part I., no. 190, where the subject under discussion seems to be more precisely and accurately stated.—EDITOR.

[2] Concerning the arachnoid membrane, see Vol. I., p. 422.—EDITOR.

recesses of the viscus; the *arterial branches of the glands*, and their twigs likewise, are entirely expended in forming the body of the glands. Indeed, the ARTERY OF THE CEREBRUM, dividing at last into the minutest threads, enters the very cortical glands or spherules, grows to them, weaves their substances, and seems to vanish or terminate there in extreme tenuity. The *arteries of all the glands of the body* likewise are entirely expended, and in a manner consumed in their minute conglomerate or miliary seeds or corpuscles.] The CEREBRUM is formed of an infinite number of little glands, or the beginnings of glands which are called cortical, and which occupy partly its circumference, and partly its interior substance; thence arise unequal eminences, protuberances and convolutions; the same is the case with *the glands of the body*. The CORTICAL GLANDS OF THE CEREBRUM, from the last twigs of their arteries, extract a certain purest and spirituous essence, which they increase by a new essence elaborated in their own bosoms. The case is the same with the *glands of the body* which, out of the contents of the arteries and the fibres, by various modes of filtration, cohobation and commixture, elaborate a new juice unlike the former which they send abroad. The CORTICAL GLANDS, like so many little hearts, represent as many active forces, and they excite their aggregate organ, that is, their cerebrum into alternate systaltic and diastaltic motions, exactly in the same way in which the motory fibres stimulate *the glands of the body*. The CORTICAL GLANDS OF THE CEREBRUM put forth many fibres, which, when collected into fasciculi, make up its medullary globe; these fibres, however, are primitive, and generate all the rest, wherefore they must be called fibres *par excellence*. The same is the case with *the glands of the body*, for their primitive and more simple glandules, or glandular forms, likewise put forth fibres, which compose the body of the glands, and constitute a kind of a medullary part; these fibres, however, in our following pages we shall call corporeal fibres. The FIBRES OF THE CEREBRUM are most attenuated little tubes, pervious to the animal spirit; the *fibres of all the glands of the body*, which are originally derived from the cerebrum or cerebellum, are likewise pervious to those juices which the lesser glandules, as so many fountain-heads, pour forth, send out abroad, and with which they are teeming. The CEREBRUM here and there gives rise to larger and smaller cavities which are called its ventricles; *the glands of the body* also have their follicles of which one is usually general or common, while the remaining loculi receive the humour as it trickles down through the fibres. The VENTRICLES OF THE CEREBRUM are furnished with foramina by which they intercommunicate; such also is the case with the follicles and loculi of every *gland of the body.* The CEREBRUM introduces not only fibres, but also sanguiferous vessels into the larger ventricles, and forms there the so-called choroid plexuses; *the glands of the body* also weave similar plexuses and retiform areolæ from the shoots of vessels which are interwoven in their follicles, and they join them into one texture; the networks even seem to cross transversely and horizontally, as in the cerebellum. From the ventricles of the CEREBRUM a canal or tube, its infundibulum, is put forth, which terminates in a slender process; from the cavities and follicles of *the glands of the body* a similar emissary duct is sent out, which extends outside their bodies. The CEREBRUM introduces and inserts the final appendage of its tube or infundibulum, its process or beak, into a certain subjacent gland, called commonly the pituitary gland, and there it ramifies in every direction its emissary fibres, and dispenses wisely through its outlets the liquids which have been conveyed thither; just as is the case *in the body with those glands which are called conglobate or lymphatic,* for by these not only the fibres, but also the lymphatic vessels which they receive, are arranged into forms; they receive both in their little bodies and pour forth their essences as required; for they receive animal spirit from the fibre, lymph from the interstices between the fibres, and also another more sluggish lymph in association with the serum of the blood, just as is the case with the pituitary gland of the cerebrum. The PITUITARY GLAND discharges the refined spirits which are sent down from the cerebrum, and despatches them by distinct ways into the nearest veins, into the sinuses which press against it, and also by channels which are hidden from view; in the same way *the conglobate or lymphatic glands of the body* despatch their liquids into the lymphatic vessels which burst out thence, and likewise into the veins which immediately depart thence, and finally through pores which have not yet been discovered. The CEREBRUM, by means of its pituitary gland, empties the various orders of its fluids into a certain general receptacle, namely, into the two lateral sinuses, and thence into the jugular veins, and lastly, into the subjacent left subclavian vein; in a like manner *the lymphatic glands of the body* send their fluids away towards the receptaculum chyli, and into the common thoracic duct, so as to enter likewise into the same left subclavian vein; they thus go to meet the most refined lymphs of the cerebrum which convey the spirit of life, and hence the liquids of both sides salute one another in the same goal with open lips, as it were, and with embraces, and, on looking backwards, they each acknowledge their origins from little glands.

664. The cerebrum is therefore a conglomerate gland which secretes and excretes into a smaller conglobate or lymphatic gland, the pituitary gland, the essences which it has elaborated, as is even the case here and there in the body. The cerebrum, however, is a model of all the glands, and its pituitary gland is a model of the conglobate or lymphatic glands, wherefore it also deserves the name of arch-gland. For the cerebrum derives all principles out of itself, and its very spirit also it does not conceive and procreate out of a pre-existing spirit; the fibres, likewise, it puts forth out of itself as its own. The glands of the body, however, are formed of the fibres of the cerebrum and cerebellum, and the juice which they extract from the blood they imbue with the spirit of the cerebrum, and thus revive and refine it. That the cerebellum itself also, in a certain measure, bears a similarity to a conglobate, that is, a lymphatic gland, will be pointed out in what follows.

(The fibres, of which the organical tissues are formed, are fourfold, according to their origin, nature and use: they are thus of a fourfold order. The first is the fibre of the cerebrum, which in the body becomes the nervous fibre; the second is the artery and the vein of the body; from these two is born the third or motory fibre; the fourth is the fibre which is born of the least glands, and which is called a duct, a filament, or a thread. The gland is composed of the fibre of the brain, a vasculum or little vessel, and the motory fibre. The simple glands produce the fourth fibre. Thus the conglobate or lymphatic glands, though formed of vessels and fibres, are still glands; and indeed glands in a more eminent degree than the conglomerate or racemose glands; for they are as many little laboratories which prepare the vital essences, and humours of various kinds. Size and dimension do not alter the case, nor is it altered if the gland sometimes changes its name. The smaller gland is a gland in a more eminent degree than the large one; but whatever is more eminent is not called thus, except by way of eminence.)

CHAPTER XXIV.

THE CEREBELLUM, ITS SUBSTANCES AND FORM.

665. All the gyres and sulci of the cerebellum are surrounded with a general, elastic and cellular membrane [the arachnoid membrane], uniting together the duplicature of the subjacent pia mater. If this membrane be raised from the one underneath by the use of the blow-pipe, there appear in great beauty and exact order the discriminations formed between the gyres. At the same time, little arteries are exposed to view which hasten away, and which, following the course of the interjacent pia mater, conceal within it their capillary heads and extremities, and at other times dip down into out-of-the-way clefts and folds; and at last, they transmit their wearied blood, bereft of its spirit, in a transverse, oblique and parallel direction, into larger vessels, and thence into general sinuses. The pia mater itself, with the blood accompanying it, lets itself down, generally in a falciform manner, in one place to a small depth, in another to a middle distance, and in another to a still greater depth. This is exhibited plainly to the sight, when the upper portion of the cerebellum is bisected horizontally, as far as the vermiform processes [median lobes]: the very duplicatures which dip down are then exposed to view, and it becomes manifest how in one place they unfold and expatiate in the form of small interstices, while in another they are more intricate and constricted, and so closely brought together, that the very junctures as it were disappear. The duplicatures or interstices, according as they are dissected more obliquely or transversely, or more or less vertically, appear cleft asunder to a greater or lesser distance, and in the plates are marked with shady lines. These

duplicatures, again, in the interior recesses of the cerebellum, branch off laterally or obliquely into smaller folds, and terminate only where the eye begins to lose the power of further tracing them, or where the use of optical instruments fails. Thus it is that the attenuation and expansion of the pia mater and blood-vessel, insinuating itself into the most recondite recesses, proceeds to an unassignable extent, so that it must be considered as a compages having throughout, from the surface to the innermost recesses, connection and continuity, forming such a wicker tissue as to present a labyrinthine, and to the anatomist, completely inextricable knot, unless nature, while living in this her intricate abode, teaches him how to unravel her tissue in the same order in which she herself composed it. Wherever the pia mater, with its sanguineous vessels, penetrates into recesses either visible or impervious to view, there also it is accompanied by the perfectly mobile, cortical or grey substance which is attached to it; so that whatever may be the implication, configuration and order of the foliated pia mater, the same order or form belongs also to the cortical substance, From this substance, again, as from a parent, is derived everywhere the white medullary substance, which, procreated from the former, occupies the interior of the cerebellum. If, therefore, its compages be dissected through the middle down to the fourth ventricle, the form of a small tree, called by some *arbor vitæ*, makes its appearance. And if the dissection be made obliquely in the direction of the vermiform process, or if the organ be removed by ablation, it displays similar boughs or branches. In this case, the medulla, which is hidden away in the interiors, is laid more open to view, because the trunks inosculate with the branches farther in. The aspect of the arboreal formation therefore changes, as the dissecting knife, whereby the cerebellum is laid open, is held in a more or less oblique direction. Three considerable medullary stems become visible [in a section made through the vermiform process], which inosculate into the trunk just as it passes into the cerebellar peduncles or crura. The highest with its branches is simple.

The middle arises of two stems to which other branches belong which are inosculated in a like manner. The lowest stem in a like manner grows out of two stalks near the "centrum medullare," and is luxuriously furnished with a number of conspicuous branches; so that there are as many arborescent trunks as there are processes or peduncles, besides innumerable smaller trunks which are implanted in the larger in regular order. If a horizontal section be made, the arboreal appearance is destroyed, and that of variegated marble is assumed. Little diverticula of blood also come into sight, scattered like stars in all directions, and red in hue. If the knife be passed farther into the substance, and if the little nests of cortex and pia mater are dug out on either side, then a spacious medulla is exposed to view, without any intervening striæ of grey substance [with the exception of the corpus dentatum]. The medullary trunk itself keeps near the medulla oblongata, buries itself, as it were, in its own soil, and, by making an arched bent, leaves a hollow almost over the middle of the fourth ventricle; for where the trunk is about to enter the medulla oblongata, it unites in one the medullæ of the stems, branches and twigs. It then separates, as it were, into roots or processes, from which it sends a larger one towards the tract of the corpora quadrigemina; another it despatches in an opposite direction into the pons Varolii, and when it approaches this organ, after leaving its arborescent source, it arranges its fibres for use in the most beautiful order, and intertwines them with those which come from the cerebrum; so that the ramification of all the processes or peduncles is equally charming to the sight as the arborescence in the interior of the cerebellum. A third peduncle it sends from the same cerebellar forest towards the spinal cord. Thus the cerebellum envelopes the medulla oblongata on both sides with its peduncles, and engirds it therewith in a wonderful manner. But the utmost skill is requisite on the part of the anatomist, to find the direction whither the peduncles incline, and to tell by what process of involution their fibres dip into those which, starting from the cerebrum, pursue their way into the spinal cord; and further, what particular fibres of the cerebrum are brought into contact with these cerebellar processes, and in what manner. Meanwhile, if the medullary trunk of the cerebellum be laid open in such a manner that its branches are folded back towards the edges of the organ, a medullary space is brought into view, with rhomboidal nets passing through it, which by Vieussens is called the "centrum medullare" of the hemispheres of the cerebellum; also a lesser tract which passes around the fourth ventricle, and is called the "centrum semi-circulare."

666. As the cerebrum is divided by a membranous septum derived from the dura mater into two hemispheres, so also is the cerebellum. The before-mentioned mater, by making an inflection, thus enters into it slightly, distinguishing its right portion from the left. The upper part of the cerebellum, which lies immediately under the posterior lobes of the cerebrum, is in consequence more depressed and flatter, but the posterior and two lateral parts, turning suddenly anteriorly and inferiorly, narrow into a rounder, and almost globular shape; while superiorly under the tentorium, they are drawn out more sharply. Otherwise the dura mater is superinduced over the cerebellum, beneath which, in immediate contact with this organ, is the arachnoid or cellular membrane and pia mater. If we lay bare the cerebellum down to the pia mater, we then expose to view the surface and order of the circular laminæ, with which the surface is ridged. In the superior plane of the hemispheres these divisive ridges or furrows are more distant from mutual contact, and more uniformly observe parallel lines. But on reaching the sides, with a view of being continued anteriorly on their way to the bottom of the cranium, they draw nearer to each other, and other fissures are added, which, like roots of the upper furrows, are more closely connected and enfolded, preventing thereby the upper furrows from gaping so far apart as to make the interstices wider than they really are. These roots, as it were, of the circular laminæ or gyres, after making wonderful inflections and contortions, at last

terminate round certain protuberances slightly elevated, whereby the furrowed surface is made to assume a certain lobular appearance. In these lobes, protuberances or subdivisions, a different arrangement and order of the furrows prevails; an order frequently running in a contrary direction to that of those that extend from the general surface of the viscus to its margins. But still in each protuberance by itself, they seem gradually to approach to a certain parallel arrangement. Such is the arrangement of the sub-divided surfaces of the cerebellum on each side round the medulla oblongata, the borders of which several of its subdivisions closely embrace. Of these protuberances or subdivisions, however, there are chiefly three pairs;[1] one of them, which is larger [the biventral and slender lobes] is on either side of the corpora olivaria, and pyramidalia, where the nerves of the eighth pair [nervus vagus] issue out, and also between the nerves of the ninth pair [the hypoglossal nerves]. Into this protuberance the general gyres from the upper surface inflect themselves; and those from below wreathe very deeply, and do not appear to preserve any conformity to the parallelism of the general gyres of the upper surface, except in the interior of the cerebellum itself. The surface of this protuberance or subdivision is ploughed by sulci which proximately apply themselves to the caudex of the medulla oblongata, and the nearer they approach to it, the more they recede from the circular shape, and follow the longitudinal course of the above caudex. The fellow of this protuberance, on the right side [in Duverney's plate] is in a manner differently subdivided from the other, and on its further limit is marked with tortuous spires, and through intermediate articulations, it is, so to speak, furrowed in a manner differently from the other; and this seems to be a means by which it is connected with the general order or root of the gyres. The second protuberance or appendage of the foliated laminæ of the cerebellum [the antero-superior and

[1] In his account of these "protuberances" on the inferior side of the cerebellum, Swedenborg bases himself on the very superior plate in Duverney's "Traité de l'organe d'ouie," Paris, 1683, 12mo.—EDITOR.

quadrate lobes] comes into view higher up when some portion of the cerebrum with the tentorium is removed; it is situated near the pons Varolii, where the fourth and fifth pairs of nerves issue from their fibres of origin; the gyres apply themselves to the borders of the above-mentioned pons Varolii in a form accommodated to its figure, and they flow into it obliquely compared with the general sphere of the gyres. On either side between the latter protuberances, a smaller lobe or subdivision [the flocculus or subpeduncular lobule] projects, having lines observing the same order and direction as the former, namely, in the place where the pons Varolii ceases, and the pyramidal cauda of the medulla oblongata begins; or again where the seventh and the sixth pairs of nerves [the facial motor, the auditory, and the abducent ocular nerves] emerge. This last protuberance is smaller than the rest, and it is like the second subdivision, but a transverse vermicular process [in Duverney's plate] runs across all its sulci, with a depressed fold passing all around it, whereby there is imparted to it the faculty of folding and unfolding with the neighbouring contiguous parts (except where the furrows are too deep), and thereby the protuberance with its furrows is raised up a little higher. But these particular subdivisions of the cerebellum, with several others which are formed by the gyres and encircling laminæ, are not equally conspicuous in every subject. For when the brain is in a state of collapse, or when it is pressed down by its weight, as is the case in dead brains, the folds or corrugations are often unfolded and their discriminations obliterated, just as when a napkin, twisted into spiral folds, is again unfolded, or as the forehead, when contracted and wrinkled, is again smoothed down and wears an even and serene aspect. Unless, therefore, the folds of the pia mater are traced with the finger, and unless the divisions are carefully noted, the junctures will remain out of sight. The case is different with regard to the cerebrum; for even when it lies dead, it has the appearance of still furrowing itself, twisting and tying itself into knots, as if it were still in the act of drawing conclusions. We would observe, however, that the cerebellum is such an articulated modulation, such an intricate compages, as to baffle the research even of the most skillful anatomist, and not unless you convolve and twist it in a variety of ways; nay, and again unless you liberate it from all circumpressure, will you be able to survey it from its inmost principles, or to perceive from what particle of its grey substance the force and freedom of its animatory motion proceeds, in what manner it folds itself into its members and parts, and unfolds itself from them, beginning in these parts. Some figures of its folds are given by Willis, *Cerebri Anatome*, fig. 1, 3, 7, 8; in Morgagni's *Animadversiones*, vi., Tab. i., fig. 3; and especially in Ruysch's plates, *Epist. Anat.*, xii., Tabs. xiii., xv., and in those of Duverney's in his treatise on the ear. The cerebellum, however, although it seems discriminated on the surface into figures apparently so various, each with its own particular system of circular laminæ, still its general gyres or laminæ are knotted into a simple process called the vermiform process. The upper part of this process is approached by the gyres or furrows of the upper surface, its lower part by those of the anterior surface; whence it follows that this appendage or process is double; that there is an upper or superior process which is larger, and also a lower or inferior one which is smaller. By this intermediate, though more compressed stratum, both hemispheres are bound together, as it were, by a concatenated series and system of gyres. These vermiform processes or median lobes receive the gyres of the whole cerebellum; for in them are concentrated the gyres or furrows from every quarter of its entire compages; wherefore like hinges, with very small spaces left between the furrows, and with numerous vessels passing between them, they are furrowed transversly. From these vermicular processes other laminæ or gyres are sent down obliquely, which are similar, and climbing upwards form, as it were, little bridges, so that the gyres arising from either hemisphere, through a continuous connection, may proceed [to the opposite side] where they creep up wavelike, obliquely and from the sides. Before, however, this general gyral system of the furrows of the cerebellum becomes involved in these vermiform processes, it seems at first to insinuate itself into certain poles, not far from the sides of the vermis; for when this general gyration reaches the shores of this process, it meets in a certain centre, and by spiral windings, and without any difficulty, it enters the pole or umbilicus, out of which through the intervening substances it passes into the veriest vermes themselves; so, indeed, that the centre of the sphere of activity, or the cynosure of each hemisphere, does not lie in these vermiform processes, but [in the great horizontal fissure near by or underneath the flocculus] at the two sides. This may be seen in Eustachius, *Tabul. Anat.*, Tab. vii., and in the plates of the other anatomists.

667. WILLIS.[1]—"Below the corpora quadrigemina succeeds the cerebellum. Its shape, like that of the cerebrum, is somewhat globose; it is also marked by gyres and certain convolutions, and thus appears uneven. The furrows and sulci of these convolutions are covered with pia mater, which binds together their summits and lines the interstices in the deep, into all of which it sends out vessels and enters deeply into them. Nevertheless, the cerebellum by its gyres and convolutions is variegated in an uncertain manner differently from the cerebrum; its folds, however, are arranged in a certain orderly series, for its exterior compages seems to consist of laminæ or gyres contiguous to one another, and interlaced with one another, and which, in a certain parallel order, extend throughout the whole of its surface. Both regions of the cerebellum, the anterior and posterior, terminate in the vermiform process. Near these termini, as in twin-poles, these gyres are shortest; thence, on ascending towards the summits [on either side], they gradually enlarge as in parallel spheres. These gyres, or spherical laminæ, are cortical exteriorly, and medullary interiorly, and the medulla of every one of them passes into two large central spaces, which, in the cerebellum, seem to serve the same purpose as the corpus callosum in the cerebrum. In certain

[1] "*Cerebri Anatome*," Cap. III., XV.

animals the cerebellum consists of one single compages, and its gyres or laminæ, all of which are arranged in a like parallel order, preserve this arrangement throughout. In other animals, however, certain other bodies, like protuberances or smaller superficial spheres, furnished with lesser gyres, are attached to the cerebellum as to their primary sphere; these lesser bodies, being eccentric in respect to the cerebellum, have often folds or laminæ running in a different direction to that observed in the cerebellum itself. This latter organ, however, whether furnished with these tubercular accretions or not, is found almost in all animals, of the same shape and proportion, and also organized of the same kind of laminæ. Those animals, where the cerebrum is differently constituted from man, as in birds and fishes, and, among quadrupeds, in rabbits and mice, whose cerebra are destitute of gyres or convolutions—these animals have a similar kind of cerebellum, with a similar arrangement of folds, and with the remaining component parts alike. . . . As the cerebrum within its cavity has its own choroid plexus, interwoven in various ways of arteries and veins, and most densely interspersed with glands, so also the cerebellum has similar plexuses of vessels which are furnished with the same kind of glands, but more numerous and larger than in the choroid plexus of the cerebrum. When the pia mater, which covers the posterior part of the cerebellum, is removed, this assemblage of plexuses and glands is plainly visible; for there, on either side of the vermiform process, they creep upwards, as it were, in two branches; each receives an arterial branch from the vertebral artery which is situated under the base of the medulla oblongata, and venous ducts which are sent out from the lateral sinuses. . . . Meanwhile, in order to describe the situation and the attachment of the cerebellum, we have to observe that it is situated over the medulla oblongata, to whose sides it seems fastened, as it were, by two crura. Between these crura on either side, with the cerebellum overhead, and the caudex of the medulla oblongata underneath, there is a cavity which is commonly called the fourth ventricle.

In each crus, which sustains the cerebellum, three distinct medullary processes or peduncles are discovered. The first of these, which is sent out from the corpora quadrigemina, ascends in an oblique direction; the second, which descends in a straight direction from the cerebellum, crosses the former, and encompasses the medulla oblongata; the third process, which descends from the posterior region of the cerebrum, is inserted in the medulla oblongata, and increases its trunk as by an additional strand (Cap. III., pp. 21-23). . . . In order that the three distinct medullary peduncles, which constitute each crus of the cerebellum, may be exhibited more fully to the sight, and in order that the inmost compages of the cerebellum may be examined, it is necessary that its whole globe should be dissected in the middle through both globes, that is, through the vermiform processes. Then it will appear plainly that in each hemisphere there is contained a large central space, in which medullary branches, like a tree, extend in every direction, and press against the cortical substance of the cerebellum which is diffused in all directions; further, that the three distinct peduncles which compose each caudex or crus of the cerebellum are inserted in the central space of each hemisphere (*Ibid.*, p. 24). . . . The cerebellum is situated in the very occiput below the corpora quadrigemina, where, being attached by its two crura to the caudex of the medulla oblongata, it appears in an almost spherical form. Its upper arched surface, with the pia mater intervening, adheres to the edge of the cerebrum itself, so far as its surface is concerned; yet with the cerebrum itself it is by no means conjoined, nor is there any immediate intercourse between these two organs and their parts" (Cap. XV., p. 98).

668. VIEUSSENS.[1]—"The cerebellum is that portion of the brain, taken in a larger sense, which is united to the medulla oblongata below the corpora quadrigemina. It is situated above it like a large tuber or bulb; and lies below the posterior edges of the two hemispheres of the cerebrum, being separated

[1] "*Neurographia Universalis*," etc., Cap. XII.

from it by the tentorium. From this it appears manifestly that the cerebellum is situated in the posterior region of the cranial cavity. The cerebellum is of a somewhat globular shape. Its external surface is irrigated by a great number of vessels, and whether it be covered with pia mater, or freed from the same, it becomes plain that it is divided by many transverse sulci; and when these are a little drawn apart from each other, it appears that the whole cerebellum is divided into laminæ. Its sulci, however,—different from the gyres of the cerebrum which are like convolutions of small intestines—do not follow an uncertain and oblique direction, but are rather drawn transversely, and its laminæ are arranged in a certain orderly series: for its exterior compages seems to consist of foliated laminæ contiguous to one another, and folded together, and which in a parallel order seem to pass over its whole surface. The middle region of the cerebellum, both on its anterior and posterior surface, terminates in the vermiform process; so that there are two vermiform processes which are made conspicuous when the cerebellum at one time is inclined a little forward, and at another backwards. In the two vermiform processes, as in a twin pole of the cerebellum, its gyres are shortest, and thence, in proportion as they ascend towards the summit, as towards an equator, they gradually grow wider as in a parallel sphere. When the brain is inverted, there appear, near the end of the fourth ventricle, two parts of the cerebellum [the flocculi], which are adjacent to the posterior vermiform process, and which, like this process, are marked with small and short gyres. The cerebellum, like the cerebrum, consists of two distinct substances, a grey or glandular substance which is visible on its whole exterior surface, and a white or medullary substance which occupies its interiors. When the cerebellum, denuded of its dura mater, is reclined backwards, a membrane of an ashy grey colour is discovered, which is somewhat thick and soft. This membrane [the valve of Vieussens] is a production of the pia mater, and is interwoven with a glandulous substance, not unlike the cortex of the cerebrum. A transverse medullary tract enters in front into this membrane, which adheres and is united to the inferior vermiform process, and to the peduncles which extend from the cerebellum to the corpora quadrigemina, as well as to the posterior part of the pons Varolii. Thence it appears that this membrane lines the anterior part of the cavity of the fourth ventricle, and closes up the posterior part of the aqueduct of Sylvius; wherefore we maintain that it performs there the function of a valve. . . . When the cerebellum is cut piecemeal in an antero-posterior direction, it appears that its grey substance is mixed with white substance in such a manner that both seem folded up together, and variegated like marble; at the same time also the valvula major of the cerebrum [the valve of Vieussens], and both vermiform processes are clearly exhibited to the sight. If the whole cerebellum, however, is dissected through the vermiform processes, as through twin poles, the white substance of this middle region is seen divided into several tracts, which spread out in every direction like the branches of a tree. These medullary tracts are imbedded in the grey substance which is diffused in every direction. At the same time also the peduncle which extends from the cerebellum towards the corpora quadrigemina, and likewise that other peduncle which is continued from the cerebellum towards the spinal marrow, together with the cavity of the fourth ventricle, come into sight (pp. 74-76). . . . After the cerebellum has been dissected through the vermiform processes, so that its interior parts are exhibited to view, and after the order and series has been recognized, in which its medullary fibrils are disposed, we dissect it again on each side through the middle, and then fold it back partly upwards and partly downwards. When this is done we notice in the central space of each hemisphere a certain grey or glandular substance [the corpus dentatum] which, on account of its being divided into parts of a certain rhomboid form, we at one time call the rhomboid substance, and at another the rhomboid bodies of the cerebellum. Underneath these rhomboid bodies all the medullary fibrils, of which each hemisphere of the cerebellum consists, meet together, and, being gathered up into a certain common centre, they pass off on either side into a medullary and spongy body, as it were, which we call the centrum medullare of the hemispheres of the cerebellum. Six peduncles, three on each side, which consist of the medullary fibrils coalescing together, are led forth from the above-said centrum medullare of the hemispheres of the cerebellum, and through their mediation the medulla of the cerebellum communicates with the posterior part of the 'centrum ovale' [of the cerebrum], with the white tracts which are produced from the middle region of the same 'centrum ovale,' and with the spinal marrow. Of these peduncles, those which tend towards the corpora quadrigemina we call the processes from the cerebellum towards the corpora quadrigemina, [superior peduncles or crura ad testes]; those which incline towards the medulla oblongata we call the processes from the cerebellum towards the medulla oblongata [the middle peduncles or crura ad pontem]; and those which terminate in the spinal marrow we call the processes from the cerebellum towards the spinal marrow [inferior peduncles or crura ad medullam] (pp. 78, 79). . . . Before the white medullary fibrils of each hemisphere of the cerebellum terminate in the above-mentioned processes or peduncles, they pass off into large medullary trunks or crura by which the whole mass of the cerebellum is supported as by a double foot or basis, wherefore Willis called them the peduncles of the cerebellum" (p. 81).

669. RIDLEY.[1]—"The cerebellum has three processes, which, joined together on each side, make up, as it were, two fair roots [or crura], by the ancients called the posterior roots of the medulla oblongata, and by the moderns, peduncles or stalks, by which this organ grows to the medulla oblongata. The first of these processes ascend from the cerebellum to the corpora quadrigemina; the second from the cerebellum to the medulla oblongata, and these, meeting together on its lower side, make up that large protuberance called by Willis the annular process, and by others, after the first author describing it, pons Varolii.

[1] "Anatomy of the Brain," Chap. XIV.

. . . The third process descends from the cerebellum backwards, upon the upper side of the medulla oblongata, like two prolonged thick cords on each side, making the medulla look somewhat thicker and broader in that place, and not unfitly styled the restiform process. These crura, when they meet at the other end [in the cerebellum], make up the central space (*meditullium*) or the corpus callosum of the cerebellum" (pp. 135, 136).

670. WINSLOW.[1]—"The cerebellum lies enclosed under the transverse septum or tentorium of the dura mater. It is broader laterally than in its antero-posterior direction. It is flattened on the upper side, and gently inclined from one side towards the other, answerable to the tentorium which serves to it as a kind of tent or ceiling. On the lower side it is rounder, and towards the back part it is divided into two lobes, separated by the falx minor of the dura mater. It is made up, like the cerebrum, of two substances, but has no circumvolutions on its surface. Its sulci are pretty deep, and disposed in such a manner as to form thin, flat strata, more or less horizontal, between which the internal lamina of the pia mater insinuates itself by a number of leaves, as it were, equal to that of the strata. Under the tentorium it is covered by a vascular tissue which communicates with the choroid plexus. In its front part it has two middle appendages called vermiform processes, of which one is inclined towards its anterior, and the other towards its posterior surface. . . . They are termed vermiform from their resemblance to an earth-worm. Besides the division of the cerebellum into lateral portions or into two lobes, each of these lobes seems to be likewise subdivided into three protuberances, one anterior, one middle, and one posterior; but they are not in all subjects equally distinguished, either by their convexity or limits; but they may always be distinguished by the direction of their strata, those of the middle and anterior protuberances being less transverse than in the posterior (Sect. X., nos. 92-95). . . . The strata of both substances of the cerebellum are not always of the same extent in the same portions or protuberances

[1] "Anatomical Exposition," etc., Sect. X.

of each lobe. This appears by merely viewing the convex or outer surface of the cerebellum; for there we see at different distances some cortical strata shorter than others, and likewise that the extremities of the short strata diminish gradually in thickness till they are quite lost between the two long ones. If we make a small hole in the external lamina of the pia mater over one of the lobes of the cerebellum, without touching the inner lamina, and then blow into the cellular substance by which these two laminæ are connected, through a small tube introduced into the hole, the air will gradually swell the substance, and separate the strata more or less equally from each other, through their whole extent, and we shall see at the same time the disposition of all the membranous septa or duplicatures of the internal lamina of the pia mater, with the numerous distribution of the fine blood-vessels which run upon it, especially after a successful injection, or in an inflammatory state of these membranes" (*Ibid.*, nos. 100, 101).

671. MORGAGNI.[1]—"What Ridley writes concerning the cerebellum, namely, that 'it differs from the cerebrum in its cortical structure, inasmuch as its interstices are here elliptical, or pieces of imperfect circles'—all this is very true. It must, however, be added that if, by the gentle insertion of the handle of the scalpel into those interstices, the circles are drawn apart from one another, it will be found that some of them are produced to a depth which is more or less shallow, while others penetrate very deeply into the very mass of the cerebellum. If, of those circles or strata which penetrate most deeply, we inspect that face which is turned towards the face of the nearest circle or stratum, we shall find that the whole of it is likewise furrowed by many interstices of other circles, as it were, some of which are parallel to one another, others are wonderfully interlaced with one another, or produced from one of their surfaces into another, and that hence arise not inelegant segments; so however, that those observers who do not draw apart these deeper interstices, perceive only the smaller portion

[1] "*Adversaria Anatomica*," VI.

of those circles or strata, into which the whole surface of the cerebellum is divided, and thus remain ignorant of by far the greater, and incredible part of its surface, and consequently of the extent of the cortical substance of the cerebellum. Further, between each of these cortical circles or strata, particular medullary circles or strata, though very much thinner, are enclosed, which are arranged in the same order as the cortical circles. From this method in its structure, it results, that when the cerebellum is dissected perpendicularly through its middle, the sections of the medullary circles produce an appearance of white arbuscles; the sections of the cortical circles, however, an appearance of leaves, as it were, thrown around these same arbuscles. While penning the above, I read Heister's description of the wonderful structure of the cerebellum which was recently published, where he pays particular attention to those sections which we have just mentioned, and which we call 'leaves,' but he little 'lobules;' and what we regard as the extreme twigs of the little arbuscles, following the example of Malpighi, he describes, as it were, as little excretory ducts, of use to each of these little lobules. The sections of the deeper circles or strata, however, together with the sections of the other circles into which they branch out sidewards, upon due examination he calls 'lobes,' and he points out the use of his structure. Besides, he represents all these sections as constituting a most elegant form, and explains the method by which, during the space of almost a single night, the cerebellum may be so prepared that all its interstices, each by itself, may be drawn apart. This experiment, on account of the ease with which it may be instituted, deserves our greatest praise. My hearers, however, are well aware how often I have previously demonstrated to them all that I have described above, without making use of this experiment" (Animadversio XI., pp. 13, 14). Our author also presents in a plate (Fig. III., p. 133) one "hemisphere of the cerebellum, drawn apart in two or three places, where the circles or strata descend more deeply, so that other segments of circles into which the surfaces of these former circles open, are exhibited to view."

672. Heister.[1]—"The cerebellum is like a small cerebrum, because it is almost six times smaller. It is situated under the posterior lobes of the cerebrum, and under the posterior processes of the dura mater in the lower part of the cranial cavity. By these processes [the tentorium and the falx minor] the cerebrum is prevented from compressing it. Its figure approaches a globular one, a little compressed. Its surface is less anfractuous or gyrated than that of the cerebrum, but it is furrowed, as it were, and divided into almost parallel laminæ. These laminæ are largest [and hence the furrows deepest] in the middle, but from thence they gradually grow smaller on either side, describing so many segments of circles, until they terminate on both sides in what is called the inferior and posterior vermiform processes. If the cerebellum is divided by the knife into a right and left part, it appears that its substance is both cortical and medullary, but the cortical part is much greater in quantity than the medullary part; this represents, in a very elegant manner, a kind of shrubs or little trees, the trunks of which constitute what are called the crura of the cerebellum. Though the cerebrum has several cavities, the cerebellum has none. The lobules of the cerebellum adhere in clusters, in the manner of leaves on trees, to the medullary shrubs or arbuscles already mentioned; they appear very beautifully on dividing the cerebellum. These lobules or little leaves, however, when the brain is not cut, constitute the laminæ or strata of the cerebellum, clothed with pia mater; of these the whole cerebellum consists. The crura of the cerebellum consist of three medullary processes. The first ascends from the cerebellum towards the corpora quadrigemina, and forms the valve of Vieussens. The second forms the annular prominence of Willis or the pons Varolii, and the third descends to the spinal marrow" (no. 271).

Examine also Heister's very elegant figures [Vol. II., Plate IV., Figures 16, 17, pp. 171, etc.], besides the plates of Willis and Vieussens, and especially the one of Duverney[2] in

[1] "Compendium Anatomicum," Vol. I.

[2] Duverney, Guichard Josephus. "Traité de l'organe d'ouie," Paris, 1683, 1718. It was inserted by Manget in his "Bibliotheca."

his treatise on the ear, which is most skilfully engraved. There the cerebellum is represented inverted, that is, with its anterior or inferior face with the protuberances called by Willis "episphæria" [*i.e.*, the flocculus], on which a certain vermicular process is placed transversely. There it may be seen how the general furrows of the upper surface of the cerebellum terminate below in the particular furrows of three protuberances [the biventral and slender lobes, the antero-superior or quadrate lobe, and the flocculus]; so that at last, after various inflections, they converge in the vermiform process. The lower surface of the cerebellum is represented like a napkin twisted into folds.

The Bloody Spots in the Medullary Body of the Cerebrum and Cerebellum.

673. It is well known that nothing is of a more frequent occurrence than that drops of blood, out of some nooks and receptacles in the brain, ooze out around the fingers and the edge of the instrument used by the operator; this is affirmed by Morgagni. The interior structure of the cerebrum indeed, as well as of the cerebellum, is variegated by many drops of blood like stars, as appears from Vieussens' Plates VI., VII., XII., XIII., and also from Ridley's Plate V., where arteries of considerable size are also represented within the cortical and medullary substances of the cerebrum. Concerning those sanguinary spots, says Vieussens, "I noticed, in the lowest as well as in the highest portion of the medulla, several arteries of this kind of considerable size, which penetrated that substance for the purpose of reaching the grey portion of the corpora striata. . . . None, or only very few of these arteries, were noticed in the parts nearest to the sinuses, or immediately below the cortex; few only in the fornix; not many in the medullary substance of the posterior edges of the cerebrum, which constitutes the upper part of the lateral ventricles. A few were observed in the whole external surface of the medullary substance of the cerebrum and cerebellum immediately

under the cortex, but at a greater distance therefrom many were discovered, as in that substance which constitutes the walls of the latter ventricles, and in that which immediately embraces the medulla oblongata. . . . If, after tying the carotids about the middle of the neck, spirit of wine, dyed of saffron colour, is repeatedly injected in either of the carotids, the grey substance of the cerebrum, and also the white substance are imbued with a saffron colour from the vessels which penetrate the medullary substance" (*Neurographia*, etc., pp. 39, 40).

[MODERN AUTHORS.

673*a*. QUAIN.[1]—"The cerebellum consists of a *body* and of three pairs of *crura* or *peduncles*, by which it is connected with the rest of the cerebro-spinal axis. . . .

"It consists of two lateral *hemispheres* joined together by a median portion called the *vermiform process*, which in man is distinguishable only as a small though well-marked part below, named the *inferior* vermiform process, and a mere elevation above, called the *superior* vermiform process. In birds, and in animals lower in the scale, this middle part of the cerebellum alone exists; and in most mammals it forms a central lobe very distinct from the lateral portions. . . .

"The *peduncles* are named superior, middle and inferior, and connect the hemispheres of the cerebellum with the brain, spinal cord, and with each other. The *superior peduncles*, crura ad cerebrum or processus ad testes, together with the valve of Vieussens, a lamina, stretched between them, connect the cerebellum with the cerebrum. The *inferior peduncles*, crura ad medullam, are the upper extremities of the restiform bodies. The *middle peduncles*, or crura ad pontem, much the largest, are the lateral extremities of the tranverse fibres of the pons Varolii. They connect together the two halves of the

[1] "Quain's Elements of Anatomy," etc. Eighth Edition. Two Vols. London, 1876.

cerebellum inferiorly. All these peduncles pass into the interior of the cerebellum at its fore part.

"FOLIA.—The cerebellum, at the surface, and for some depth, consists of numerous nearly parallel laminæ or folia, which are composed of grey and white matter, and might be compared with the gyri of the cerebrum, but are smaller and without convolution. These laminæ are separated by slightly-curved grooves or sulci of different depths.

"FISSURES.—One principal fissure, or sulcus, named the *great horizontal fissure*, divides the cerebellum into an upper and a lower portion. It begins in front at the entrance of the middle peduncles, and passes horizontally backwards round the outer border of the hemispheres. From this primary fissure, numerous others proceed on both the upper and under surfaces, forming nearly parallel curves, having their concavities turned forwards, and separating the folia from each other. All these furrows do not go entirely round the hemisphere, for many of them coalesce one with another; and some of the smaller furrows have even an oblique course between the others. Moreover, on opening the larger fissures, many folia are seen to lie concealed within them, and do not reach the surface of the cerebellum.

"LOBES.—Certain fissures, which are deeper than the rest and constant in their position, have been described as separating the cerebellum into lobes, which are named as follows. The *central lobe*, situated on the upper surface, consists of about eight folia, immediately adjoining the anterior concave border. The *superior and anterior* lobe, sometimes called *quadrate*, and the *superior and posterior* lobe, are placed between the central lobe and the great horizontal fissure. On the under surface are seen successively the *inferior posterior* lobe, the *slender* lobe, or lobulus gracilis, the *biventral* lobe, the *amygdala*, and the *subpeduncular lobe* or *flocculus*. This last-named lobule projects behind and below the middle peduncle of the cerebellum. It is connected by a slender pedicle of white fibres to the rest of the hemisphere; but its exposed surface is grey, and is subdivided into five or six small laminæ."

This division into lobes was originally introduced by *Reil.* He also distinguished the vermiform process into the following parts: (1) the *lingula* on the valve of Vieussens; (2) the *lobulus centralis;* (3) the *monticulus,* between the two quadrate lobes; (4) the *lamina transversa superior;* (5) the *laminæ transversæ inferiores;* (6) the *pyramid;* (7) the *uvula;* (8) the *nodule* which projects into the fourth ventricle, and is called the *laminated tubercle* (Malacarne).

673*b*. ARNOLD.[1]—" Formerly it was universally supposed that the medullary processes of the cerebellum in the direction of the cerebrum enter into the substance of the corpora quadrigemina, on which account these processes were called ' crura cerebelli ad corpora quadrigemina' [or ' ad testes']. I was the first who showed (' Bemerkungen,' etc., p. 40) that this is a mistake, and that these medullary processes pass under the corpora quadrigemina with a view of reaching the ' tegmentum ' of the crura cerebri. Stilling (' Ueber die Brücke,' etc.) confirmed my observation " (p. 720).

673*c*. MEYNERT.[2]—" A ' processus corporis quadrigemini ad cerebellum ' certainly exists, probably made up of fibres from the brachia after their decussation; although this designation is by no means deserved by the tract to which it is usually given—the ' processus cerebelli ad cerebrum ' [formerly ' ad testes ']. It properly belongs to the frænulum of the valve of Vieussens, which consists demonstrably of two similar halves, and which runs by way of the valve of Vieussens into the superior vermiform process of the cerebellum " (p. 700).—" The valve of Vieussens, the prolongation of the frænulum veli medullaris, is the part that, as Arnold has shown, really deserves the designation of ' processus cerebelli ad corpus quadrigeminum ' which has been wrongly applied to the ' processus cerebelli ad cerebrum ' (p. 713).

[1] Arnold (F.). " Handbuch der Anatomie des Menschen," Vol. III., Section ii. Freiburg, 1852.

[2] Meynert (J.). " The Brain of Mammals," translated by James J. Putnam; in Stricker's " Manual of Histology," American edition, New York, 1872.

"The *nuclei dentati* discovered by Vieussens are situated near the lower, medullated surface of the cerebellum, which roofs over the fourth ventricle. This body consists of lamellæ of grey substance 0·3mm. in thickness, which in man are thrown into intricate folds; and each of them is provided, on its lower and inner surface, with a hilus through which nerve-fibres find admission. . . . The *nuclei tegmenti* of Stilling are two rounded masses, which, in the human cerebellum, lie beneath the central lobe of the superior vermiform process. Seen from above, they have a rhomboidal shape. They measure 5mm. in length and breadth by 2mm. in thickness. . . . They are made up of large elongated nerve-cells, 60μ. in length by 15μ. in breadth (p. 754).

"*Fibræ propriæ.*—What we know of the course of the nerve-fibres in the cerebellum is but fragmentary and general. . . . Still it is established beyond question that there exist, within the medullary substance of this organ, systems of *fibræ propriæ*, that is, fibres which have their origin and termination within the cerebellum itself, besides the systems of fibres which belong to the peduncles which pass to different regions of the caudex.

"*Burdach, Arnold,* and *Stilling* have all taken cognizance of the fibræ propriæ in general, that is, bundles of fibres passing festoon-like, from convolution to convolution, along the surface of the cortex, disposed in delicate laminæ. *Stilling* describes further certain comprehensive special systems of fibræ propriæ, which unite together more distant regions of the cortex cerebelli. He designates them as median fasciculi. An anterior division of these, split into two parts, by the shortest path underneath the *nucleus tegmenti,* runs directly from the anterior regions of the superior vermiform process to the lobuli of the inferior vermicular process, that is, from the *lingula* to the *nodulus.* Another division of these median fasciculi, likewise divided into two parallel parts, the course of which is concentric with that of the first division and embraces the same, at first runs backward in a curve, the convexity of which is directed upwards towards the superior vermiform process, and then bends forward again in order to terminate in the most anterior of the convolutions of the inferior vermiform process, thus bringing the latter for the second time into connection with the most anterior convolutions of the superior vermiform process, though by a very circuitous route. Besides these systems of fibres, the cerebellum encloses also a considerable mass of *transverse commissural fibres*, which, like the corpus callosum of the cerebrum, probably unite together exactly symmetrical regions of the two hemispheres (pp. 754, 755).

"The *pedunculi* or *processus cerebelli.*—So far as these tracts lie within the limits of the cerebellum, the *processus ad pontem*, and certainly a large part of the *corpus restiforme* (outer division of the *processus ad medullam*) follow a very simple course. Their component fibres decussate, before reaching the cerebellum itself. Having entered the cerebellum, up to the moment of their entrance into the cortical substance, they remain confined each to its own side; although, no doubt, in so far as they enter into connection with the median regions of the cortex, a part of their fibres run inwards as if about to decussate. The relative position which the peduncles occupy within the cerebellum itself is determined by the situation of the masses of grey substance, in which they respectively terminate. The *processus ad pontem* and the *corpus restiforme* enter into connection solely with the cortex; while the *processus ad cerebrum* becomes connected primarily with the nucleus dentatus; and the *inner division of the processus ad medullam* with the nucleus tegmenti.

"Now, since the cortex occupies the most external position of all the grey masses, while the nucleus dentatus lies more centrally, between the cortex and the nucleus tegmenti which is the innermost of all—it is evident that the medullary substance of the cerebellum must be divided up among the different peduncles in such a manner that its *outermost* regions are occupied by the processus ad pontem and the corpus restiforme, its *central* regions by the processus ad cerebrum, its *innermost* regions by the inner division of the processus ad medullam "(p. 755)]

ANALYSIS.

674. Although the cerebellum seems to be a more compact body than the cerebrum, it is, nevertheless, just as capable of motion; for it has the capability of expanding and of approaching the fossæ and walls of the occipital bone, and again of receding therefrom, and thus of becoming constricted. The dura mater, which is attached to the bones of the cranium, does not offer any obstruction, for it is loosened from the pia mater underneath, and at some distance from it. The interior lamina of the dura also is slippery and polished, as though smoothed by the cerebellum constantly pressing against it, and again receding from it. Nor can any glutinous humour of whatever kind, that is, a humour of the kind which sometimes infests the surface of the cerebrum, clog up the intervening space: for as soon as it begins to collect from any cause whatsoever, it is discharged at once through the foramen magnum of the occipital bone. That the cerebellum is as active as the cerebrum, and swells in alternate periods, appears from its cortical substance; for this substance is more abundant in the cerebellum than in the cerebrum, and is implanted, and, as it were, inosculated in its least subdivisions and folia. Now, inasmuch as the cortical substance is the principle and beginning of every motion in the cerebrum, it is so likewise in the cerebellum; wherefore, since this organ is capable of motion and expansion in each of its parts, it must possess this capacity also as a whole. This is the cause why the cerebellum is divided into perpetual sulci, circles and ridges, almost down into its very innermost parts; and this circumstance consequently imparts to it the faculty of being folded together, and of unfolding; for its medulla is scanty, and besides is interlarded with frequent little spaces and

nooks for the blood. These little spaces are exhibited clearly to the sight in the plates of the author, by an appearance of shading between the branches of the [medullary] tree. From these and other similar forces a full faculty of expansion and constriction seems to be derived to the cerebellum.

675. But let us treat of the mode in which the cerebellum seems to be able to unfold itself in every direction, in breadth as well as in length and depth, that is, in accordance with every dimension of its body, preserving all the while its shape, except at its base where it presses upon the caudex of the medulla oblongata, or where the protuberances [*i.e.*, the parts around the horizontal fissure,] and the vermiform processes are situated. The most general gyres or strata of the cerebellum, the furrows of which are drawn over its superior and posterior convexity, distinguishing it in this wise, can be drawn apart, and can meet again only in one simple way, namely, as far as their parallel circles or strata extend; but when they converge towards the anterior side of the organ, they insinuate themselves into other gyres which run obliquely, and finally they follow a transverse direction, with a view of constricting themselves into their vermiform process, yet still observing a parallel arrangement. The protuberances which are there fastened to the organ, and of which three are manifest to the eye [*i.e.*, (1) the biventral and slender lobes; (2) the antero-superior or quadrate lobe; and (3) the flocculus], fold into one another and are articulated mutually, so as to wind themselves in a suitable manner into the general sphere, that is, into the mass of the whole organ.

This is also shown by the plates of the authors [especially Duverney's], where this side of the cerebellum is represented exactly like a napkin twisted into folds, or like a wrinkled forehead which ordinarily exhibits a smooth surface. From such a configuration of its surface there results a like faculty of all the parts, and from the faculty an action. For the production of this result, this lower side of the cerebellum is subdivided into these protuberances or "episphæria," and it is also constricted into the two vermiform processes. Poles also are described in addition, and from the poles there are spiral transits into these worms or vermiform processes; and neither of these transits is furrowed and cut in exactly the same manner as the other. On this account also certain rhomboid bodies [the flocculi], like regulators of the expansion, are thrown across diagonally.

676. The cerebellum thus is rendered capable, throughout its length and breadth, not only of unfolding its own organ and its whole mass, lobes, and laminæ, but also of determining the sphere of its activity into every stem, branch and twig soever of its medullary tree, and consequently into the fibres of every nerve soever which springs from its medulla. This determination results entirely from the power it has of varying its form. By means of this faculty also the cerebellum disposes aptly all little arteries whatsoever, which, in the form of plexuses, creep through the surface of its pia mater, and flow through its laminated interstices, so that the blood in a sure direction is carried to every particle of the cortex, and that not even the very inmost particles of the latter are destitute of their supply, and that each particle has thereby imparted to it the power of acting upon the fibre which is attached to it.

677. When a motion, however, is given, the direction of the motion is likewise given; and, indeed its direction into the essential parts of its body, that is, not only into the arteries and into the cortex, but thence also into every fibre which proceeds from the cortex, and consequently into the medullary trunk of the cerebellum which is cleft on either side into three processes or peduncles. All this variety of form which exists on the surface of the cerebellum is thus determined into a common medullary trunk, and thence into the derivative peduncles and nerves. In order, therefore, that the peduncles may be extended in a becoming manner, and again retracted, they are planted in a certain cleft, that is, in the edges of the fourth ventricle. These edges by the intervening cavity, according to their nature, are able to be drawn apart and again to be compressed. Without a cavity which may be thus stretched apart, and without such

an irradication of its peduncles in its edges, the mass of the cerebellum could not by any means be expanded and constricted; for should it attempt such a motion, no active force would result thence. The peduncles also, near the point where they are inserted [in the ventricle], are a little drawn apart, so that by the expansion of the ventricle they are pulled apart in a suitable manner; as appears from the plates of the authors which are drawn from nature.

678. The cerebellum can be expanded and constricted only at those periods when the cerebrum also undergoes the same motions: for the cerebellum and cerebrum are so conjoined, and again distinct from each other, that the one communicates its motion to the other; unless one against its own will is unable to act with the other. This is made evident from their mutual connection. The only thing intervening between them is the septum called tentorium, which is robust and quadruple, so that it is able to approach either organ. The posterior part of the cerebrum only is recumbent upon it; and it is attached in some places to the surface of the cerebellum, but not to its fibres. The lateral sinuses also, which receive the blood of the cerebrum, as well as of the cerebellum, intervene between the two organs; but they are gradually being subjected to the government of the cerebellum, which in the end governs altogether their widened ends or receptacles. The straight sinus too is intermediate between the two organs; but it is mainly attached to that process of the dura mater which belongs to the cerebellum. The artery of the cerebrum, that is, the internal carotid, also intercommunicates by its trunks and branches with the artery of the cerebellum, that is, the vertebral artery: for, on approaching the triple choroid plexuses, through anastomoses in the compages of the cerebrum, they mix their blood. Both organs are also consociated by fibres in each of the processes or peduncles, namely, in the first which ascends from the cerebellum towards the corpora quadrigemina; in the second which builds up the pons Varolii; and likewise in the third or restiform process which descends into the spinal marrow. They are consequently

consociated in the two general medullæ, the medulla oblongata, and the spinal marrow; and thus in every one of the nerves which are diffused thence through the lower provinces of the body. The fibre of the cerebellum also seems to cross over into the very region of the cerebrum, or under this region into that which belongs to the thalami optici; without mentioning the valve of Vieussens, which is the common barrier between the jurisdiction of each. From all this, that is, from the septa, arteries, veins, and fibres, and at the same time from the isthmus which intervenes between the two organs, it appears very plainly that the two brains are conjoined, although separated at the same time, and that their conjunction is such that one cannot be expanded and constricted except synchronously with the other; or again, that in instituting the periods of their motion they never collide. Nevertheless, this mutual arrangement is such, that the cerebellum is bound to act when the cerebrum sees fit; although from the necessity imposed upon these organs by their conjunctions, the cerebellum seems to extend the sphere of its activity to the members and organs of the cerebrum, and to its chymical labaratory.

679. This applies in respect to the periods of the motion, but in respect to its quality, the cerebellum is more constant in the observance of these periods, and it accomplishes its motion in a form more accommodated to the state of the body than the cerebrum. For this latter organ, especially when in a state of wakefulness, and when intent upon anything, is wont to display great inconstancy; at one time, namely, it rises higher and transgresses its limits, and at another it breathes more tranquilly, and, as it were, tacitly; at another time again it swells only slightly beyond the outer covering of its surface [viz., the arachnoid membrane]—altogether according to the impulses and affections of the lower animal mind suggested by the ideas of the intellectual mind. For in anger the cerebrum seethes and strikes against the walls of the sinuses, but in sadness and grief it is compressed, and lies, as it were, prostrate on the ground; thus it is in the remaining states which either

stimulate or retard its motion. An image of the animations of the cerebrum is presented to the life by the respirations of the lungs; for these two organs agree not only in the times, but also in the degrees of their motion. The cerebrum may be compared to an ocean lashed by an angry wind and raised into fierce waves, but the waves of which are anon smoother, or laid by a gently blowing zephyr. With the cerebellum the case is different, for although it is so leagued with the cerebrum that it can move only synchronously with the latter organ, still it preserves more evenly the degrees of its expansion, and does not rise any higher nor subside any lower, except when urged by a natural necessity. This is also confirmed by the mutual relation existing between them, for when the cerebrum awakes, and becomes intent, and when it opens the roads for the reception of impressions received by the senses, it raises itself, as it were, higher; and that part of the tentorium, which belongs to the cerebrum, this latter organ draws nearer to itself; it abandons, so to say, the lateral and the straight sinuses, and consigns them to the government of the cerebellum; it submits the vertebral artery to the auspices of the cerebellum only; and as to the fact of the cerebral and cerebellar fibres being conjoined, this does not impose upon either brain the degrees of motion of the other, for these conjunctions are without and outside the cerebellum. The extreme edges of the cerebrum, however, which rest upon the cerebellum, seem to make a common cause with the cerebellum, for the cortical or grey substances in these edges are not expended on the senses; the same method, indeed, is followed in the arrangement of these substances in the outlying parts of the cerebrum, which is followed also in the cerebellum; nor are these parts arranged into tori, clusters and convolutions, surrounded with anfractuous folds almost ad libitum; they are unable to accelerate, and then again to retard their movements, as is the case with those cortical substances which are in the convex circumference of the cerebrum. On this account also these edges of the cerebrum have their places assigned to them over the cerebellum, so that they may perform their motions evenly and constantly, as does the subjacent cerebellum.

680. The cerebellum eannot help feeling and becoming thoroughly sensible of everything that ever takes place in the body and in its minutest parts, for it is furnished with an abundant grey substanee distributed in a most regular order, and it is the cortical substance itself which feels and determines actions. Three nerves chiefly originate from the medulla of the cerebellum, namely, the nerve of the eighth pair of Willis or nervus vagus [that is, the pneumo-gastric nerve], the intercostal or great sympathetic nerve, and the nerve of the fifth pair [*i.e.*, the trifaeial or trigeminal nerve], which are the most general nerves, and are called sympathetic. There are also three principal branches which make up the trunk of the *arbor vitæ;* and, again, there are three processes or peduncles into which the medullary trunk is divided. That the above nerves are nerves proper to the cerebellum eannot be shown from the eourse of the fibres, but from the offices they perform in the outermost parts, that is, in the body. These nerves are inserted in every one of the most simple parts and connections of each viscus, muscle and gland of the body, and they weave and construct the very inmost textures of the same; wherefore nothing whatever ean happen therein which does not creep up at once through the fibres of these nerves, and also through the rest of the fibres with which the cerebellum is conneeted, even to the principles, that is, to the grey substance of the eerebellum, in order to report there the condition of the ultimate or outermost things in the least and greatest parts [of the body].

681*a*. As soon as this eortical or grey substance beeomes aware of the state of the ultimate parts, and the changes wrought therein, it immediately puts on, as it were, a corresponding analogous state and complexion, and disposes itself in agreement therewith; for the perfection of the purer substances eonsists in this, that they are able to undergo and to put on innumerable ehanges of state whieh result in sensation, pereeption and many other operations, concerning which we shall treat in our Rational and Experimental Psychology. According to the quality of the state, therefore, which is put on by every individual, cortical substance, is also the quality of the universal state which is induced upon the cerebellum, for the universal derives its state from the singulars, or the general from the parts. It has been pointed out above that the cerebellum is able to change its state in a variety of ways by a change in its form; consequently, by this same faculty it lends its aid to the singulars, that is, to the individual parts in the body, namely, through a determination of its operation into corresponding fibres whereby it preserves them in a state of integrity, remedies their prostrate condition, and does all those things which are usually attributed to the beneficent action of nature. All these things, however, do not reach our consciousness, wherefore we know nothing respecting them; consequently, also, they do not depend upon the judgment of our mind or upon our will. The acts of the cerebellum are therefore called natural, and those of the cerebrum voluntary. Still, in what way the acts of one brain follow nature as a leader, and those of the other the will; or, again, how it is that the acts of the one are hidden from sense, even from the most interior, while those of the other are open and manifest—this cannot be investigated nor demonstrated intelligibly, except by instituting an accurate comparison of the two brains, and unless we anticipate some things from our psychology and introduce them here.

681*b*. The cerebrum is differently formed from the cerebellum, for it consists of innumerable glomes or conglomerated cortical corpuscles. These glomes are mutually connected, and, as it were, concatenated, whence there arise clusters, convolutions, forms like those of the intestines, anfractuosities and a gyrated surface. Each conglomerate corpuscle of this kind, or each glome which is, as it were, a link in that chain, represents the cerebellum in a lesser form, for it is such in a smaller form as the cerebellum itself is in a larger form, so that each of them deserves to be called a diminutive cerebellum, or a likeness of the cerebellum. For every one of them is separated in a certain measure from the rest, and is situated within its own little space, or enjoys its own compartment—yet being still consociated with the neighbouring glomes, and through them with those which are more remote. It is surrounded by its own membrane which is soft, dense, reticular and vascular, and consequently it is kept asunder by its own septum or little tentorium. It is also provided with its own little artery which, like a little sinus, is enclosed in its membrane. Upon being dissected, it exhibits to the sight a little tree or grove just like the large cerebellum; consequently, it is divided into similar laminæ or folia. It likewise determines its medullary portion into certain peduncles, whence there proceed at once composite fibres. It is distinguished from neighbouring glomes by an intervening space and clefts, so as to enjoy its own sphere of activity. Many and innumerable such glomes are mutually concatenated with each other, their conjunction being not unlike that of the cerebrum with its cerebellum; whence it follows that each glome of this kind is able to act upon the grey envelope of the cerebrum—especially around its frontal prominences (*umbones*)—both individually or each by itself, or again in conjunction, that is, in consort with the neighbouring glomes, wherefore the cerebrum is organized of a great many little cerebellula.

682. Now, inasmuch as in the one cerebrum there are conglomerated so many little cerebellula, and as they are mutually adjoined to each other so as to form serpentine tracts, it follows thence that each of them is able to vary its forms, and change its state in exactly the same manner as the large cerebellum, and indeed more perfectly and more simply, because the cortical substances, of which it is organized, are scattered over a larger space—although the connections, outward form, and smaller protuberances of these cerebellula or glomes, together with their pivotal places and poles, have not yet been observed and discovered. When, therefore, it is demonstrated that each single object of the senses, its forces, modes, and forms through fibres

penetrates thither, and strikes the cortical substances of these fibres, inducing thereby upon these little cerebellula an analogous corresponding variation and change of state; and if it is further demonstrated that these little cerebellula are able to undergo and to put on innumerable changes of state, and to reproduce them by habit and training, and thus to run through an infinite number of them, and that those ideas which are called material, and which correspond to the objects of the senses, exist therefrom with all their variety—then I believe we are also able to demonstrate that the cerebrum possesses the power of sensating, noticing, and representing to itself, by imagination, things that had previously been objects of the senses, and again, that it has the power, by running through states with which it has once been imbued, of reproducing similar ideas, that is, remembering them, and finally determining actions which correspond to these ideas. From thence it follows that the acts of the cerebrum are voluntary; while those of the cerebellum, which is one such large glome, and which has no power of expansion unless the cerebrum consent, are natural. This subject, however, I was compelled to touch upon here only lightly and partially, because it belongs to Psychology. Meanwhile we learn from the cerebellum how the cerebrum, by the changes of state of its parts, is able to sensate and to determine; and from the nexus of the parts in the cerebrum, how it is that the cerebellum is unable to make manifest any of those exceedingly pure ideas with which it is affected.

683. From all this it appears very plainly why it is that a cerebellum is always adjoined to a cerebrum; for acting from the will, and acting from nature, are two distinct, and very often discordant things. The will, indeed, sometimes runs counter to the order of nature and to its laws, for no other rules and truths enlighten its path than such as had previously been acquired by the way of the senses, that is, *a posteriori* from the ultimate things of the world, from effects and phenomena which are often fallacious and disguise the truth. When these things are considered more profoundly they give birth to principles

which are regarded as so many truths. From these principles follow the order, and also the laws of the order, which the will observes when its actions are being determined. When such a fatuous light enlightens the path of the will, it can very easily be concluded of what character the government of the body would be, should it be administered under the lead of the will, and not under that of nature; especially since the understanding, and thence the will from itself, does not know the most simple laws of nature which are established and co-established in itself, and also in its body, but is in doubt even in respect to the most general and ultimate things, and holds controversies respecting them. Wherefore, in the government of the purest organisms, and thus in the administration of its own kingdom, the will would be blinder than a bat. Unless, therefore, a cerebellum were adjoined to the will, that is, a second brain which takes cognizance of every singular thing in the body, without, however, the mind becoming conscious of it, and which constantly, but silently and quietly, acts according to the order of nature, and the tenor of its laws, all would be over in a moment with its kingdom.

APPENDIX TO CHAPTER XXIV.

THE CEREBELLUM. (EXTRACTS FROM OTHER PARTS OF THE AUTHOR'S WRITINGS.)

I. From an earlier Treatise on the Brain.[1]

683*a*. The cerebellum is a single, largest glome or torus of grey substance, and it acts in one single and only mode upon the muscles which it approaches through its nerves, namely, through the nervus vagus, the great sympathetic nerve, and all those which in due order are procreated out of its restiform process [in the spinal cord]. And, as from the cerebellum we are able to see the quality of the particular force with which each glome or torus in the cerebrum acts upon its fibres, we thus see that the cerebellum expands and constricts itself in each direction, namely, in one direction from its upper or posterior surface, and in another direction from its lower or anterior surface, altogether in the direction in which its gyres or ridges flow, and in which they preserve their parallel course. The gyres of its upper part run out transversely, those of its lower part longitudinally, and thus in an opposite direction to the former. The gyres in each part terminate in the vermicular process belonging to each. One course of gyres, however, insinuates itself in a wonderful manner into the other course, and in either hemisphere they are gathered up in a pole, and thence are continued into the vermicular processes; so that the cerebellum, in a spiral manner, folds itself into a knot, and again unfolds itself: so, indeed, that it does not touch and move the medulla oblongata, which is attached and subjected to it, in any other manner

[1] Codex 65.—Photolithographed MSS., Vol. IV., pp. 161-163.

than is required by the ratio ot its compression. This ratio, however, consists in this, that anteriorly it only folds itself together, but does not raise or expand itself; while posteriorly it not only folds itself together, but also expands and elevates itself. This same effect also the cerebellum communicates to the spinal cord.

Still the whole of the sinuous constriction of this large glome or torus is directed interiorly into one general medullary trunk, and thence into the processes or peduncles into which it is cleft; for every eyelet or bud has respect to its twig, every twig to its branch, and every branch to its stem which is threefold; but the three stems have respect to their trunk: every cortical or grey particle, therefore, has respect to its fibre, and all grey particles together have respect to their fibrous trunk, which the cerebellum pulls up, that is, attracts to itself, whenever it undergoes its constrictive motion. With this faculty of attraction the cerebellum is predicated; for its medullary trunk passes into the medulla oblongata about the middle of the fourth ventricle, which yields on either side. The processes or peduncles, besides, are spread apart in such a manner, that each, when pulled, suffers itself to be attracted. The first of these processes then constricts the medulla oblongata under the corpora quadrigemina; the second process produces a similar effect upon it in the pons Varolii—nevertheless it rather pulls the medulla oblongata downwards [towards the spine] than upwards [towards the isthmus], lest the anterior surface of the spinal cord, which arises from the corpora olivaria and the pyramids, should be pulled up as well. The third process of the cerebellum draws the lowest part of the fourth ventricle upwards towards the cerebellum; and this produces a corresponding effect upon the posterior surface of the spinal cord. To this action apply themselves the vermicular processes, which are furrowed in a like manner, and thus they apply themselves to the upper part of the fourth ventricle, to which they are affixed.

2. *From "The Economy of the Animal Kingdom."*

683*b*. "The brain in the intricate conglobation of its simple and primitive substances is an exemplar and effigy of all the compositions and derivations to be found in the body, and hence also the effigy and exemplar of all the glands. A *spherule of cortical or grey substance*, composed of vascular threads of infinite minuteness, and endowed with recesses from which fibrules or permeable lines proceed, is not a gland except in an eminent sense. The spherules and porules of this kind are conglomerated into nuclei, nodes, or cerebellules, which, in the Part treating on this subject we shall call *cortical tori or glomes*, and which, both in their smaller effigy, and in their appearance, altogether resemble the 'cerebellum,' such as it is in its larger effigy; and, when overlaid with their own proper membrane, compose another degree of cortical spherules, which nevertheless cannot be called glands, except by way of analogy. From these again, connected together in the form of a spiral, and discriminated into separate convolutions, all overlaid and bound together with a double or triple tunic or meninx, the *cerebrum* is produced; and thus has the character of a great or principal gland, whose larger cavities are the lateral ventricles, the third ventricle and the aqueduct; its passage are the foramina called foramen anterius or Monroi, and the foramen posterius; its excretory is the infundibulum, which in the human subject is, together with the pituitary gland, employed to discriminate the humours which flow into it. . . .

"Of these several degrees of glands, *the cerebellum belongs to the second*, because it is homogeneous to the second degree of glands, or to the cortical tori or glomes of the brain, with which it corresponds" (i., no. 164).

683*c*. "By natural instincts I mean all those operations which do not come within the consciousness of the mind, or to its intuitive knowledge or perception: such, for instance, as the economical and chemical operations of the animal kingdom, among which we may enumerate the systole and diastole of the heart and arteries; those laws of the commixion, discrimination, separation and elaboration of the blood which are recounted in no. 199; and an infinite number of other things which follow in their train. Of these operations the *cerebellum* appears to be the conductor; and it acts all at once or undividedly out of the Gordian knot of its structure, and moreover it is an organism of the second degree (no. 164). But not so the *cerebrum*, which is discriminated into innumerable cortical tori or glomes, and its organism carried to the third degree of composition (no. 164), all the voluntary operations of the body being therefore under it. The soul, as a formative substance, is bound by necessity to adjoin the cerebellum to the cerebrum; so that the greater part of the economical functions and exercises of the body may be referred to the cerebellum, lest by any chance the cerebrum, when intent on its own concerns and reasons, should allow the republic to fall into inactivity and ruin, or distract and destroy it by insurrectionary motions, or by allurements and cupidities" (i., no. 269).

683*d*. "All the fibres of the cerebellum, or all the nerves arising from its fibres, such as the great sympathetic and the pneumo-gastric nerves, are so distributed to the viscera of the body, that while the cerebellum distends them by its spirituous fluid, and, as it were, maintains them in the equilibrium of general pressure, the causes, arising on the part of the body, excite the muscles depending upon these fibres and nerves into the motion which is called spontaneous, their natural motion being called involuntary. For the cerebellum, unlike the cerebrum, cannot animate particularly, since it has no cortical tori or glomes capable of being elevated; hence it cannot animate from a will distinctly determined, but has only a general action, and inspires all its fibres simultaneously" (i., no. 506).

683*e*. "The cerebellum seems to be appointed to the office of the general administration of the functions in the animal economy (while the cerebrum is employed in watching over the affairs proper to its own system), and to perform its animatory functions more slowly and silently. . . .

"Moreover, the cerebellum furnishes the heart itself, that is to say, its ventricles and auricles, the large arteries and veins, and for the most part, also the minutest arteries and veins of the body, with nerves sent out from its medulla, namely, the great sympathetic and par vagum, which are the offspring of the cerebellum. . . . But although the cerebellum is all in all in the heart and larger vessels, yet it is only the remote cause of their pulsation, for it only produces the action of the blood, which is itself the proximate cause.

"To the cerebellum it is owing that all things in the body exist, subsist, and are capable of motion, not that they are put in motion by any act of the cerebellum, but that when put in motion, they are by its act continued therein" (i., nos. 558, 559).

683*f*. "Since the cerebellum, with uninterrupted constancy, performs its animatory motion in the only manner proper to itself, and nevertheless transmits its fibre into all the viscera, each of which is moved in a manner different from the other, as, for instance, into the auricles and ventricles of the heart, it is consequently necessary that the proximate causes of their action should proceed from the body, and that the office of the cerebellum should consist only in preserving its nervous fibre whole and living. For the fibre dies, together with the motion of the viscus into which it enters, as soon as the cerebellum ceases to animate, or as soon as it is compressed, deprived of its blood, cut in pieces, or otherwise injured" (i., no. 561).

683*g*. "It is the common opinion of the learned that the cerebrum presides over the voluntary actions of the body, and the cerebellum over the natural, or, as some of them call them, the involuntary actions.

"But that the general or common animation of the cerebellum is equally voluntary, when that of the cerebrum is voluntary, is evident from this, that the cerebellum is abundantly endowed with similar cortical substances or principles of nervous fibres. Still it differs from the cerebrum in this, that it is capable of elevation as a whole or in general, while the corresponding masses of the cerebrum, and which as minute types represent the grand mass of the cerebellum (Ec. ii., no. 150), are elevable one by one or in part. So that the cerebellum enjoys determinability over the reciprocation of animation, just as much as the single masses of the cerebrum. And hence it is that the cerebellum also animates synchronously with the respiration of the lungs. For whenever the cortical substance is so fitted into its organ as to be expansible with it, there determinability is enjoyed according to the same will. There is, therefore, a voluntary animation of the cerebellum in general, when there is a voluntary animation of the cerebrum, as during the day, whenever there is good reason that the will should be carried forwards into act by a general aid. But at night, when no particular action of the cerebrum subdistinguishes and gives perspicuity to the general action, or when nothing comes from the external organs to its distinct consciousness and intuition, it appears as if all voluntary determination had ceased in both these viscera. But there is a want in all parts of the animal system—which want, in fact, is one of the causes determining the will—that necessitates the carrying round of the spirituous fluid (in which the life of the whole consists), and consequently necessitates alternate animation. Wherefore at night, the brains—unconscious of the common operations of the inferior body, as they are not then subdistinguished by any particulars—draw deeper, slower and more equable breaths, acting in obscurity, and from the principle of necessity" (ii., no. 162).

3. *From the Present Work on the "Brain."*

683*h*. "At night, while the will lies asleep, the cerebellum takes up the sceptre, and chiefly institutes the movements of animation; and as these flow from the source of nature, they are more constant and deeper; and since the cerebrum is then forced by the cerebellum into similar movements, the cerebellum sometimes labours with difficulty, and with a struggle, as may be seen from the state of the respiration" (i., no. 104*g*).

683*i*. "In general all fibres are either motory or sensory. The motory fibres, however, are either voluntary or involuntary; the former have their origin in the cerebrum, but the latter in the cerebellum. The sensory fibres also may be distinguished into such as are conscious and unconscious. The conscious fibres, in a like manner, derive their origin from the cerebrum, but the non-conscious, or those which are unconscious of changes, from the cerebellum. The fibres of the medulla oblongata and of the spinal cord, on the other hand, are of an auxiliary kind, and promote both motion and sensation.

"The *conscious* fibres are properly those which are called sensory, because every modification, impressed upon the organs of sense by their means, reaches the consciousness, or the knowledge of our mind in the cerebrum, or that same principle, whence originates the will. For where there is an understanding, there also is a will; nay, such as is the understanding, such also is the will.

"The *unconscious* fibres, however, properly so-called, are those which report the universal and the singular [that is, the least particular] state of the whole body, as well as the very modifications, even the purest ones—to the cerebellum, which at once feels the changes impressed upon the parts, and determines the natural motions in harmony therewith. Hence there are so many species and varieties of instinct; hence are those hidden and wonderful operations of nature, and hence the welfare of the whole animal republic: for where there is a determination of motion, there also is a similar or analogous principle which becomes aware of changes; both in this case being natural, and neither reaching the consciousness of the mind, and passing thence into the will" (i., no. 870).

683*j*. "The cerebrum of birds is uniform, and does not contain any convolutions. It appears hence very clearly that their cerebrum, so far as its cortical substance is concerned, is simply a purer organism which produces distinctly in acts, whatever nature advises, and what it excites them to do. For their cerebellum—of the operations of which neither the birds nor the remaining species of animals are rendered conscious—from a certain blind sensation, and from a principle assumed thence, instructs and orders them, that, in accordance with the order of nature, they must act so, and not otherwise. The cerebrum, however, produces the very acts; for the cortical substance of the same resides where it may be expanded and constricted in its individual parts, or whence all the motions in the body may be distinctly excited. . . .

"The office of sensating, and of producing proper animal motions, cannot be assigned to the cerebellum; yet, although the cerebrum [of animals] produces these motions—both the beginnings and ends of these motions are nevertheless natural, and the animals do not notice them, until they are made aware of them by the acts themselves, which they perceive by their senses" (i., nos. 900, 901).

683*k*. "In respect to the breathing of the lungs, the pulsation of the heart and arteries, the operations of the viscera and glands, the progression of the chyle through the lacteals,—all these are functions of the cerebellum, and not of the cerebrum"(i., no. 943).

"The cerebellum feels the smallest changes of state in its body, and yet it does not follow thence that the cerebrum becomes conscious of these sensations. Still the cerebellum, by such a sensation and information, is so arranged and disposed as to care for and to be of assistance to every part of its bodily system" (i., no. 946).

683*l*. "The cerebellum is a single and, at the same time, a largest torus or glome of grey and medullary substance, which, by the forces of its animation, pours a copious and perennial stream of spirits, and indeed constantly and in an individual manner, into all its nerves, and thereby into the organs, glands, and muscles. It is different with the cerebrum, which consists of many tori or glomes, that is, little cerebellula, conglomerated in the same manner. Wherever there is a fibre, and the origin of a fibre, namely, a cortical substance, there the animal juice is in a state of commotion; for all the fibres are little tubuli or canals, and the cortical substances as many little laboratories and glands by supereminence which exclude spirit, and transmit the old spirit brought back by the arteries" (ii., no. 240).

4. From the "Animal Kingdom."

683*m*. "The cerebellum has the general cognizance of those affairs in the kingdom of which the mind is unconscious, and it is the general ruler, regulator, and mover of the ordinances of nature.

"Through the pneumo-gastric nerve, as a general informant, the cerebellum is made aware of everything that happens or goes on within the boundaries of its kingdom, (the cerebrum being cognizant of whatever happens without them) in order that it may dispose, recruit, and reform all things by the constant laws of nature" (English Edit., i., no. 43, and footnote *dd.*).

683*n*. "Every fibre carries with it, wherever it goes, the animus or affection of its parent cerebrum or cerebellum; . . . consequently, different kinds of love, desire, hatred and loathing —longings and antipathies, and all their ever-various states.

"The cerebrum and the cerebellum produce, and, as it were, continue and unfold themselves in the body, by the fibres; consequently, both the brains are universally present in the body by means of the fibres. This is very conspicuous from all our sensations and actions. . . . Nothing is more certain than that the brains are the organs which wish or desire, and that the affections arising in them flow into the universal body" (*Ibid.*, i., no. 156, and footnote *h.*).

683*o*. "*The proper essence of the body* is the blood which is determined by the vessels—by the arterial vessels particularly, but also by the venous vessels.

"The *determinations*, therefore, are the organs or viscera, which are designed and formed by the blood-vessels, and which are the objects of the science of anatomy.

"*The motions of the essence so determined* are natural, voluntary and mixed; the natural organs are those of the organs or viscera, and are excited by the fibres of the cerebellum, particularly by the fibres of the great sympathetic nerve, and of the par vagum: the voluntary motions are those of all the muscles, which form the circumference of the body particularly, and its appendages, as the arms, the loins, etc.

"*The source of natural motion* is the cerebellum; but [the source of the motion] of the blood itself is the great heart of the body, with its arteries and branches, which latter correspond to the heart as the head of these motions.

"*The source of voluntary motion* is the cerebrum, and as allied and associated with it, the lungs: although the lungs are not only the source of the voluntary motions, by their association with the cerebrum, but they are in a manner the source of even the natural motions, by their association with the cerebellum; consequently, their sources of motion are, properly speaking, mixed,—one source ruling in the day-time, the other during the night" (*Ibid.*, i., no. 382, footnote *f.*).

683*p.* "All the nerves, with the exception of the par vagum and the great sympathetic nerve, and perhaps with the exception also of those sent by the restiform process of the cerebellum towards the genital members, are subject to the will of the cerebrum; such is the case with the twelve costal and the other nerves that descend from the medulla oblongata and medulla spinalis. This, however, as we all know, applies only to the waking state; for during sleep the same nerves act under the auspices and government of nature. The cerebrum rules in the day-time, and excites itself at will to general and particular animations, and with it the cerebellum, and medulla spinalis. The cerebellum, on the other hand, takes up the reins at night, and obliges the cerebrum itself, and the two medullæ, to follow its own reciprocal acts of animation. The government is thus alternated and divided between the cerebrum and cerebellum, that is, between will and nature.

"The circumstance of our breathing with the lungs more deeply and fully during the night than during the day arises not only from the energy of the cerebellum, (which is a small mass compared to the cerebrum, with the whole of its own medullary appendages, and those of the great stems proceeding from it), but also from the state of the lungs in sleep; but in the day-time, the lungs, with the cerebrum being awake, are almost constantly half expanded, and their vesicles half open" (*Ibid.*, ii., no. 394, footnote *b*.).

683*q*. "Since two principles of action exist in one body—to wit, nature, that is, the soul, in which this nature dwells, and the will—it is necessary that there should be two brains; one of them to be subject to the empire of nature, the other, to the empire of the will. Were there only one, then either nature alone would rule, in which case there would be no need of external organs for instruction; for the life, under whose auspices nature acts, is infinitely superior in wisdom to our inmost sensitive life: or else the will alone would rule, in which case all things would go to wreck, and perish in less than a moment. Therefore nerves proceed separately from these two brains, by which nerves operations are determined, and which dividedly administer the government of the kingdom" (*Ibid.*, ii., no. 457, footnote *l*.).

683*r*. "The cerebrum and cerebellum not only dwell under distinct septa and tents, and live without familiar intercourse within the bony walls of the skull, but they have their separate provinces beyond these boundary walls in the body also, whither they put forth their fibres. The cerebrum, or the fibre of the cerebrum, occupies the very ultimate boundaries or the muscular and sensorial circumference of this kingdom, but the fibre of the cerebellum has for its lot the whole interior field circumscribed by these boundaries where the viscera of the thorax and abdomen live. The fibre, propagated as an offspring by derivation from its parent cerebrum or cerebellum, when sent out to its goals, and determined to uses in the extremes, carries with it only that character, breathes only that power, and exercises only that force which it has obtained from its parent; thus the fibre sent out from the cerebrum involves whatever the mind of the cerebrum appoints to be executed in ultimates as a matter of choice or will, but the fibre from the cerebellum involves whatever its mind or soul deems advisable to be done as a matter of nature. The former takes the reasons of its choice or will from the sensoria disposed in the boundary of the kingdom; the latter, the reasons of its administration from the papillæ set within the viscera. In this way we see that the kingdom is divided between the cerebrum and cerebellum, or between the will and nature, and this, in such a wise, that nature, which manages the domestic, intimate and secret affairs of the kingdom, is environed and beset by the will which attends to the external business that is common to the body with the surrounding world, to the end, that the one may flow wonderfully into the other, as it were, in gyres, and flow back or turn, as it were, on hinges. Wherefore, as soon as ever the objects of touch have gone inwards, (for instance, from the surface of the body towards the peritonæum and the pleura, from the tongue into the pharynx and œsophagus, or from the nares into the larynx and trachea), they instantly escape us, and are rolled down, as it were, into dark ignorance, and manifest their qualities to the consciousness of the soul only, and to its auspices alone submit themselves. For there are two grand pairs of nerves, namely, the eighth pair of Willis or par vagum and the great sympathetic, which succeed and come on exactly at the places where the motorial and sensorial fibres of the cerebrum cease. These nerves, by their fibres, construct the viscera of the abdomen, the well-frequented kitchens of the body, and generate the little papillary or villous sensoria projecting from their innermost coats.

"It is evident that the eighth pair of nerves or the par vagum, and the great sympathetic nerve, are nerves of the cerebellum or nature, and not of the cerebrum or will; for of this we are assured, not only by tracing them to their origin, but also by the character and properties which they bring with them from their parents' house, in that they are insensitive, administer the innermost things, and do not live in the light of our senses, but withdraw whatever they do from our general sensorium, and communicate nothing beyond some silent effect by means of their connection with the neighbouring fibres of the cerebrum, or afterwards some ultimate effect to any of its organs" (ii., no. 527).

5. From the Work entitled: "The Senses and Sensation in General."[1]

683*s*. "Every sensation is carried to the cerebellum as well as to the cerebrum; each organ must partake of the same. For the cerebrum feels or sensates the modes, and manifests or gives forth affections; but the cerebellum induces suitable changes of state upon the affection. Wherefore the cerebrum as well as cerebellum send forth a nerve to each organ of sense. The fifth pair of nerves [nervus trigeminus] is a nerve belonging to both brains, the cerebrum as well as the cerebellum; for it approaches all the organs of sense and joins them to both brains. This also may be seen from its portio mollis. The very organs themselves, that is, the external sensory organs, do not feel anything from themselves; but are simply formed in accordance with the quality of the objects, so as to receive and forward [their impressions]—they are instrumental causes. It is the cerebrum which feels, and also the cerebellum, but the sensation of this latter organ does not reach the consciousness of our rational mind, but passes to the soul. These two brains which are formed in accordance with the order of the soul are the first causes of sensation. Although the soul is everywhere, still it cannot feel or sensate everywhere; it cannot, unless it forms for itself organs capable of receiving. Although, therefore, there is but one force, still the character of a function or use arises from its form and organization. Thus in the brain, and nowhere else, are organs fitted for the reception of sensations. Every organized form, therefore, is derived from the one soul; but the soul operates differently according to the character of the organization" (p. 23).

[1] "*The sensu, sensatione et affectione in genere*," edited by Dr. J. F. I. Tafel as "Regnum Animale, Pars iv." Tübingen, 1848.

683*t*. "Every sensation is carried to every cortical substance, whether in the spinal cord, medulla oblongata, cerebellum or cerebrum. There are therefore congeries of particles in the spinal cord, as well as in the brain, which undergo this change; perhaps the whole medullary and cortical brain is affected. From the change, which is thus induced on the cortical substance, there results sensation. The cerebrum is discriminated into larger and smaller particular congeries or clusters: these are [affected and] changed by the grosser sensations. But the particular modes and ideas of touch affect every individual or least substance. There are corresponding divisions in the spinal cord; but they are beyond our power of observation, as, for instance, in insects.

"Whatever reaches the spinal cord, as a matter of course, passes on to the cerebellum; for thither leads the royal road, and the spinal cord is an appendix of the cerebellum and cerebrum. The cerebellum, which is a single torus or glome, feels the very individual moments of touch, which do not reach the consciousness of the cerebrum: nay, it takes notice of many things, of which the cerebrum does not become aware. Unless this were so, the states could not be changed in a suitable manner, for this comes from the cerebellum. When many papillæ are touched, many nerves undergo modification, and the state of many principles in the brain is changed, etc. (p. 46).[1]

6. *From the Work entitled: "Generative Organs."*[2]

683*u*. "*Fibres are supplied to the testicles, not only by the great sympathetic and the par vagum, but also by the lumbar, and the great crural and ischiadic nerves, and, moreover, a particular branch is sent from the sacrum; thus the supply comes at any rate from all those nerves which carry the largest*

[1] From the photolithographed portion of the above work, in Vol. VI. of Photolithographed MSS. of Swedenborg, entitled: "Miscellanea Anatomica et Philosophica," etc. Stockholm, 1869.

[2] "The Generative Organs." A posthumous work of Emanuel Swedenborg, translated from the Latin by J. J. Garth Wilkinson. London, 1852.

amount of spiritual essence. The great sympathetic and the par vagum or eighth pair of nerves are the largest and most general nerves of the body; after which comes the ischiadic nerve, which is the biggest of all the trunks, not to mention the peculiar nerve from the sacrum, which Vieussens figures and demonstrates in his 'Neurographia.'

"*If we well examine these several nerves, it will be very evident that all the fibre that flows into the testicles descends from the medulla of the cerebellum, but not from that of the cerebrum: hence that the innermost and vital essence of the seed owes its origin, not to the cerebrum, but to the cerebellum.* In Chapters xxxvi. and xxxvii. of the present work, (see 'Economy' etc., i., nos. 478-486, and nos. 489-497) we prove that the great sympathetic nerve and the par vagum are nerves of the cerebellum, and not of the cerebrum. The ancient anatomists, with Hippocrates, were aware of this fact. This same remark respecting origin may be made of the nerve from the sacrum, delineated by Vieussens (*Neurog.*, tab. xxix., n. 14, 15), and which runs to the testes; for the whole residual fibre of the cerebellum, at the end of the spinal canal, comes forth at last in the sacrum: see the chapters on the Spinal Marrow. A nerve, moreover, proceeds from the great crural, and comes into close relations with this nerve from the sacrum, and, after a long contact therewith, at last leaves it. It is doubtful whether this nerve is the offspring of the cerebrum or cerebellum, for the great ischiadic nerve, which springs from the lumbar nerves, is spent on the muscles of the loins, legs, and feet; and therefore is of cerebral origin; but it does not run immediately to the testicles, but on the other hand comes into contact with a nerve that is determined thither, but afterwards again quits it; and thus only communicates to it the abundant spirit which it carries. Besides which a part of the fibres of the cerebellum also goes to form the above-mentioned great crural nerve. Moreover, the plain fact proves, that the fibre of the testes comes from the cerebellum, for the testicles are nowise under the dominion of the will, and cannot be called into activity at the will or disposal of the cerebrum; their excitation arises entirely from a kind of natural spontaneity and instinct. Furthermore, if the conception of this seed and of its first virtue depended on the will, *i.e.*, on the cerebrum, all this faculty would go to wreck after the briefest exercise, and the very purpose of nature, in the earliest age, would be quite frustrated. It follows then from the fibres themselves, from the facts of the case, and from the reasons, that the cerebellum is the butler and steward of the inner seminal essence.

CHAPTER XXV.

THE MEDULLA OBLONGATA.

684. WILLIS.[1]—"From the cerebrum we have come to its caudex, to which, indeed, the cerebrum itself and the cerebellum are attached as large tubers. This part is commonly called the medulla oblongata, under which name we understand the whole of that substance which stretches from the inmost cavity of the corpus callosum—*i.e.*, the third ventricle—and from the place where it is joined together in the base of the cranium, even to the foramen magnum of the occipital bone, where the same organ is continued farther, and terminates in the spinal marrow. Although the surface of the medulla oblongata is rendered uneven by certain protuberances, still it is not marked by any gyres and convolutions, as is the case with the cerebrum and the cerebellum, nor is its exterior, superficial substance of a grey colour, and its interior substance medullary and white, but its whole compages is in a certain measure medullary, without, however, appearing pure and shining, but being rendered quite dull and opaque by fibres and villi which protrude thence in various ways, and pass in various directions. For its fibres, which in different places are configurated according to a different plan, are here striated and progressing like rays, while in other places they are produced in a straight direction and drawn out lengthways, and in still other places they are found to be circular. In shape the medulla oblongata[2]

[1] "Cerebri Anatome," Cap. xiii.

[2] It must be remembered that the medulla oblongata, according to the older anatomists, includes the crura or pedunculi cerebri; nay, it is made to include even the optic thalami, which are styled by Willis and others the "crura" of the medulla oblongata.—EDITOR.

is bifurcated, and, like the Parnassus of the poets, exhibits the form of the letter Y; for its crura, or the thalami optici, arise in the anterior part of the cerebrum from both hemispheres, and inclining towards one another they coalesce in one trunk near the centre of the cranium; by drawing a line through the middle, this trunk, however, seems to be composed of two stalks which can be distinguished throughout the whole extent of its course. The medulla oblongata seems to be the broad, and, as it were, royal road into which the animal spirits constantly pour in from their twin sources, the cerebrum and cerebellum, in order to be conveyed thence into all the nervous parts of the whole body (p. 81). . . . But in order to explain all things which have any connection whatever with the medulla oblongata, we shall examine it from beginning to end, treating of all its various stations, halting-places and crossways. Where the corpus callosum is supposed to terminate, the medulla oblongate begins, since the medullary substance of the cerebrum near the frontal extremities (*umbones*) of both hemispheres is thickest, and under the appearance of a body of a whitish colour, but a little dark, and striated like ivory, coheres on either side with that central organ [*i.e.*, the corpus callosum]. These two bodies [the corpora striata] are the extremities or apices of the crura of the medulla oblongata, that is, of the thalami optici; between these and the cerebrum there are close and very intimate communications. Each of these bodies [*i.e.*, the corpora striata] appears shaped like a cylinder, rolled about into an orb; as they, however, constitute the summits of the crura of the medulla oblongata, *i.e.*, the thalami optici, they are not of a spherical, but of an oval shape, and in their direction backwards are a little curved. The ampler part of this organ or ganglion is joined with the medullary substance of the cerebrum; some portion of it, however, is free from this cohesion with the cerebrum, and constitutes an eminence by itself; it also causes that eminence which bulges out in each of the lateral ventricles. If these bodies, throughout their whole length, are dissected in the middle, they appear marked with medullary striæ almost in the form of rays. These striæ have a twofold affection or tendency, namely, some of them descend from the summit of this body [*i.e.*, the corpus striatum] as though they were tracts from the cerebrum towards the medulla oblongata, while others ascend from the parts below, and meet with those which have just been mentioned as though these corpora were highways for the spirits from the medulla oblongata into the cerebrum. And it is worthy of observation that no other part of the whole body appears striated in a similar manner. . . . All nerves, therefore, even those which have respect to the interior organs of the senses, originate near these corpora striata. The optic and olfactory nerves, indeed, by a long tract and roundabout ways, creep over the surface of the cerebrum, in order to be finally inserted below the portion of the medulla oblongata (pp. 81-83). . . . While dissecting some time ago the bodies of some persons who had died of paralysis of long standing, and of a most grievous dissolution of the nerves, I always noticed that these corpora were less firm than any other in the brain; they were discoloured like the first juice pressed out of olives, with their striæ very much obliterated. Further, in recently born pups, deprived of sight, and which also otherwise perform with difficulty their motions and their functions of sense, these striæ appear scarcely fully formed, and in a crude form.

"Near the obtuse and larger angles [in front], where the corpora striata are inclined towards one another, these corpora are almost contiguous; nothing but the fornix with its double roots intervenes between them. Nevertheless, where the two roots of the fornix, in a straight direction, are inserted in the corpus callosum, a medullary transverse tract [the anterior commissure], similar to a large nerve, which reaches out from one corpus striatum into the other, conjoins them, as it were, and causes them to communicate with one another. . . . Under these conditions the corpora striata are found constantly in man, and in quadrupeds of every kind and shape, and in every one of them they are striated or streaked in a similar manner;

they are also, as it were, like internodes by which the cerebrum coheres with the medulla oblongata. Nevertheless, in birds and fishes, the cerebra of which are similarly organized, though different from man and quadrupeds, things are a little different; for in birds the corpus callosum is wanting. Its equivalent, however, is found in the medulla oblongata, namely, near the optic thalami two ventricles protrude which are vaulted with a white and medullary substance, which is like the corpus callosum in man and the quadrupeds.

"On the other hand, again, the corpora striata, or those parts which are in their place, do not, in the customary manner, form a part of the medulla oblongata, but enter the cerebrum itself; for near the fissure of the cerebrum, two membranes, marked with medullary striæ, distinguish both hemispheres of the cerebrum, and line its ventricles; the striæ of both membranes descend like rays, and after being concentrated near the base of the cerebrum, they meet in a medullary process inserted on both sides in the medulla oblongata (pp. 84, 85). . . . Where the corpora striata cease, the medullary substance succeeds on either side, and after pursuing its way for some distance under the appearance of a brownish colour, it is distinguished from the neighbouring parts by a peculiar acclivity. This was called by Galen the 'thalamus nervorum opticorum,' for the optic nerves emerge here on either side in their uppermost part, and after being carried downwards with some enveloping substance, they are united near the infundibulum. . . . These nerves are inserted into the medullary caudex, like the branches of a tree into its trunk. . . . Meanwhile this interior compages of the medulla oblongata is the common duct both towards the eyes, and also towards the remaining nervous system, which takes its rise in a more posterior region" (p. 86).

685. VIEUSSENS.[1]—"The medulla oblongata is that part of the brain taken at large, which is contained partly within the enclosure of the centrum ovale, and partly is subjected to the cerebellum; so that it extends from the foremost region of the

[1] "Neurographia," etc., Cap. xiii.

lateral ventricles to the end of the fourth ventricle, where it passes over into the spinal marrow.

"All those parts, which are in the upper region, both of the cerebrum and the medulla oblongata, and also those which have respect to the cerebellum in particular, have been accurately explained in what precedes. In order that we may now lay open fully and to describe those parts which are discovered in the base of the brain taken at large, and of the medulla oblongata, after the cerebellum by a transverse cut has been removed from its peduncles, the brain is inverted, its convex portion having been previously sliced and ablated. After it has thus been inverted there come into sight the trunks of the vertebral and carotid arteries cut transversely, and their shoots which irrigate the exterior parts of base of the brain; further, the ten pairs of nerves, the infundibulum, the corpora albicantia, which are placed near the infundibulum, the two processes from the cerebellum towards the medulla oblongata, which pass off into the pons Varolii, the corpora pyramidalia, the corpora olivaria, and the spinal nerves which are accessory to the par vagum" (p. 82). See his Plates iv. and v.

The beginnings of the medulla oblongata or the corpora striata have been treated of above [in Chaps. xii. and xiii.]; the fourth ventricle, the corpora pyramidalia and olivaria, and the pons Varolii which are members of the medulla oblongata will be discussed below, as well as the nerves.

686. RIDLEY.[1]—"The third part of the brain taken at large, according to the foregoing method, is called the medulla oblongata, all whose parts on its foreside having already been spoken of, there remains in the next place that we take notice of what is on its other side where are most worthy of consideration its crura, as they are called; further the pons Varolii; and finally the corpora pyramidalia and olivaria, together with more on which we shall treat hereafter" (pp. 139-141).

687. WINSLOW.[2]—"In the name medulla oblongata is

[1] "Anatomy of the Brain," Chap. xv.

[2] "Anatomical Exposition," etc., Section x.

embraced all that portion of the brain which occupies the middle portion of the base of the cerebrum from before backwards, and further the middle portion of the base of the cerebellum. It is like a distinct medullary base between the cerebrum and cerebellum, common to both, generated by the reciprocal continuity of their medullary substances, and separated from both by the transverse process of the dura mater, the tentorium. This common base lies immediately on that portion of the dura mater which lines the basis of the cranium. The medulla oblongata may therefore be justly considered as the third general part of the whole mass of the brain, or as the common production or united elongation of the whole medullary substance of the cerebrum and cerebellum. It is extremely difficult, if not altogether impossible, to examine or demonstrate it as we ought, in its natural position. But we are obliged to do both with the brain inverted. . . . However to prevent false ideas either in viewing ourselves, or in showing to others the medulla oblongata thus inverted, it is very necessary often to call to mind that what appears as superior or upper in this situation, in reality is below in the natural state. The lower side of the medulla oblongata, in an inverted situation, presents to our view several parts which in general are either medullary productions, trunks of nerves, or trunks of blood-vessels. The chief medullary productions are these: the large or anterior branches of the medulla oblongata, which have likewise been named crura anteriora, and peduncles of the cerebrum; the transverse protuberance, called annularis, and likewise pons Varolii; the small or posterior branches called crura posteriora, and peduncles of the cerebellum; further, the extremity or cauda of the medulla oblongata, with two pairs of tubercles, called the corpora olivaria, and the corpora pyramidalia; and to these we must add a production of the infundibulum with two mamillary protuberances [the corpora albicantia]. The great branches of the medulla oblongata mentioned above are two very considerable medullary fasciculi [the crura cerebri] the anterior extremities of which are separated, and the posterior united, so that taken both together they represent a Roman V. These fasciculi are flat, much broader before than behind; their surfaces being composed of several longitudinal and distinctly medullary fibres. Their anterior extremities are beginning to disappear at the lower ends of the corpora striata, and it is for this reason that they are looked upon as peduncles of the cerebrum. . . . The other extremity or the cauda of the medulla oblongata is a certain contraction of that organ; for it is diminished in size until it reaches the foramen magnum of the occipital bone, where it terminates in the spinal marrow (nos. 102-106, 109). . . . The arachnoid membrane or the outer lamina of the pia mater appears to be distinctly separated from the internal lamina, in the interstices of all the eminences of the medulla oblongata, that is, of those on its lower side, without any visible cellular substance between them. The internal lamina adheres or is, as it were, agglutinated to, the surface of the interstices, as well as to that of the eminences; and it is equally stretched out between those of their portions which run out, to which it is closely attached. Among these eminences there must also be included the cornua of the optic nerve. In general it must be observed, concerning the eminences of the medulla oblongata, that some of them are outwardly medullary, and inwardly cortical, or partly medullary and partly cortical, so formed by a mixture of these two substances which remains still to be unfolded. From this common portion of the cerebrum and cerebellum arise almost all the nerves which go out of the cranium, through the different foramina in the cranium. It likewise produces the spinal marrow, which is no more than a common elongation of the substances of the cerebrum and cerebellum; and therefore the medulla oblongata may justly be said to be the first origin, and, as it were, the primitive source of all the spinal nerves, and thus of all the nerves in the human body" (nos. 116-118).

688. HEISTER.[1]—"The medulla oblongata is the lower and medullary part of the cerebrum and cerebellum, formed into a

[1] "Compendium Anatomicum," Vol. I.

kind of cauda or tail, and extended to the foramen magnum of the occipital bone, and giving origin to the spinal marrow and to the nerves of the brain. While taking the brain carefully out of the skull, there are discovered in its base the nerves of the brain which are usually called ten pairs, but are properly only nine, the ingress of the internal carotids into the cranium, the infundibulum and its insertion into the pituitary gland, and, finally, the accessory spinal nerve of Willis. After the brain is taken out of the cranium, we have to observe in its lower side the anastomoses of the carotid and vertebral arteries, the crura of the medulla oblongata of the cerebrum, and the crura or peduncles of the cerebellum, from which arise the medulla oblongata and the spinal marrow, the origins of the several pairs of nerves of the brain, the two corpora albicantia near the infundibulum, the annular protuberance of Willis or the pons Varolii, very ill drawn by Willis and others, but correctly by Ruysch; the end of the medulla oblongata, and, in this, the corpora pyramidalia and olivaria of Vieussens and Ruysch, and, finally, the arachnoid membrane which is very finely distinguishable in this part. On the upper side of the medulla oblongata, after the brain has again been turned up, we have to observe the fourth ventricle and the calamus scriptorius with its crena, all the other parts which have been already described as belonging to the third ventricle. The substance of the medulla oblongata is externally medullary; in its interior it contains some cortical or grey substance" (no. 272).

[MODERN AUTHORS.

688*a*. CARPENTER.[1]—"The Medulla Oblongata, or cranial prolongation of the spinal cord, which brings it into connection with the encephalic centres, is distinguished by the highly complex arrangement of its fibrous strands and of its nuclei of grey matter, and also by the peculiar distribution and endow-

[1] Carpenter's "Principles of Human Physiology," edited by H. Power, M.B., Lond., F.R.C.S. Ninth Edition. London, 1881.

ment of the nerves connected with it. The anatomical boundaries usually assigned to it are the pons Varolii above (from which it is separated laterally in animals by a broad band termed the Trapezium, but in man by a groove; the trapezium forming the posterior border of the pons) and the occipital foramen below; but these limits are purely artificial, and for physiological purposes the course of its fibres must be traced much higher. The part thus marked out has a bulb-like form, and presents, like the cord of which it is the continuation, a posterior and anterior median fissure. The former is deep and narrow, but suddenly widens out to form the space known as *sinus rhomboidalis* or fourth ventricle. The latter is wider and less deep; and its continuity with the anterior fissure of the spinal cord is interrupted by the decussation of the anterior pyramids, which is marked externally by the crossing of from three to five bundles of fibres from each side over to the other. This decussation may be considered as the physiological boundary between the medulla oblongata and the spinal cord. The surface of each lateral half is furrowed by grooves, which assist in marking out the several strands of nerve-fibres that may be distinguished on either side. The vesicular substance is aggregated into several pairs of ganglionic nuclei which form extremely important nerve-centres" (pp. 571, *et seq.*).

688*b*. QUAIN.[1]—"The term 'medulla oblongata,' as employed by Willis or Vieussens, and by those who directly followed them, included the crura cerebri and pons Varolii, as well as that part to which, by Haller first, and by most subsequent writers, this term has been restricted.

"The *medulla oblongata* is continuous below with the spinal cord, on a level with the lower margin of the foramen magnum. Its upper limit is marked by the lower border of the pons Varolii, into which it is continued above; its anterior or ventral

[1] *Quain's* "Elements of Anatomy," edited by *Allen Thompson*, M.D., D.C.L., LL.D., F.R.S., *Edward Albert Schäfer*, F.R.S., and *George Dancer Thane*, Professor of Anatomy in University College, London. NINTH EDITION. London, 1882.

surface rests in the basilar groove, whilst posteriorly it is received into the fossa named the 'vallecula,' between the hemispheres of the cerebellum, and there bounds the fourth ventricle. From its sides the seventh to the twelfth cranial nerves issue.

"It has the form of an irregular truncated cone, being expanded at its upper part both laterally and dorso-ventrally: its length from the lower part of the decussation of the pyramids to the pons is nearly an inch (20 to 24mm.); its greatest breadth is about three-fourths of an inch (17 to 18mm.); and its thickness, from before backwards, rather less (15mm). In its lower part, where it joins the spinal cord, its measurements are but little different from those of the cord.

"The *anterior* and posterior *median fissures*, which partially divide the spinal cord, are continued up into the medulla oblongata. The anterior fissure terminates immediately below the pons in a recess, the *foramen cæcum* of Vicq d'Azyr; it is partly interrupted below by the decussating bundles of the pyramids; the posterior fissure is continued upwards to about the middle of the medulla, where it expands into the fourth ventricle.

688*c*. "The structure of the medulla oblongata will be most easily made clear by tracing the several parts of the spinal cord upwards in their continuity with the parts of the medulla oblongata" (ii., p. 282).

"Posterior columns.—It will be remembered that in the upper region of the spinal cord a small portion of the whole posterior column is marked off from the rest by a well-developed pia matral septum, and is indicated in the surface by a distinct longitudinal prominence bounded laterally by a shallow groove. The portion thus marked off is the posterior median column, and the prominence, which is continued up into the medulla oblongata, becomes there still better marked, and is known as the *funiculus gracilis*. This, as it is traced upwards, especially as the fourth ventricle is approached, broadens out into an expansion termed the *clava*, and as the ventricle opens out, the clavæ of opposite sides diverge and form the lateral boundary to the ventricle in the lower part. Above, the clavæ are tapered off and soon become no longer traceable. The funiculi graciles, with their clavæ, are sometimes described as the *posterior pyramids.*

"Between the posterior median column and the postero-lateral groove, from which the posterior roots of the cervical nerves pass out, there is found in the upper part of the cord a single distinct column, viz., the posterior lateral column. This is also the condition at the lowest part of the medulla, close to its junction with the cord. But very soon there begins to be interpolated, between the prolongation of this column and the groove in question, another longitudinal prominence which is at first narrow, but soon broadens out into a considerable eminence known as *tubercle of Rolando.* The longitudinal prominence, which passes up into it, is therefore termed by Schwalbe *the funiculus of Rolando.* What may be regarded as the prolongation of the postero-lateral column also gradually expands as it ascends, so that it has a somewhat wedge-like form, and it is accordingly known as the *cuneate fasciculus.* On a level with the adjoining clava of the funiculus gracilis, the enlarged part of the cuneate fasciculus also, like that, exhibits a slight eminence, which is best marked in children, and has been termed the *cuneate tubercle* (Schwalbe). Beyond this the cuneate fasciculus passes the clava, and assists in forming the lateral boundary of the fourth ventricle.—The funiculus of Rolando is termed by Henle the lateral cuneate fasciculus: it is produced, as we shall presently see, by the approach of the caput cornu posterioris to the surface.

"In the upper part of the medulla oblongata, the cuneate fasciculus is concealed by a set of fibres (*external arciform* or *arcuate fibres*), which issue from the anterior median fissure, and, passing transversely outwards on the surface of the anterior pyramids and olivary body, turn upwards to join the restiform body. There is also a narrow strand of fibres marked by its white appearance, which crosses the line of the posterior roots from the lateral column, just above the level of the tubercle of Rolando, and joins this tract of oblique fibres. This is the '*lateral cerebellar tract*' [see below in no. 688*d*]. . . . These obliquely-crossing fibres turn upwards as they cross the funiculus of Rolando and cuneate fasciculus, and appear to blend with them to form a rounded prominent cord, the *corpus restiforme* or rope-like body which passes directly into the corresponding hemisphere of the cerebellum, constituting its inferior peduncle.

"The term 'restiform body' is sometimes made to include the whole of the posterior column of the medulla, with the exception of the funiculus gracilis, but with the addition of the lateral cerebellar tract, and the fibres which cross, as above noticed, from the anterior pyramids. By others again, the term is used synonymously with the posterior column. But it is more convenient to employ it in the restricted sense to indicate the tract of the medulla which passes up into the cerebellum, and this is mainly constituted by the arched fibres above mentioned, reinforced by the lateral cerebellar tract; the fibres in the cuneate funiculus and funiculus of Rolando being in all probability not continued up into the cerebellar peduncle as from the surface those funiculi sometimes appear to be.

"LATERAL COLUMNS.—The lateral column of the spinal cord appears on the surface to be directly continued upwards into the lateral column of the medulla oblongata. In reality, however, a considerable tract of the white fibres—that which in the spinal cord we have noticed as the 'lateral pyramidal tract'—is found, at the lower end of the medulla, to cross obliquely in stout bundles through the grey matter of the anterior cornu, and across the anterior median fissure to the other side of the medulla, where they form the medial and larger part of the pyramid The rest of the lateral column can be traced vertically upwards (with the exception of the 'lateral cerebellar tract' which passes, as already indicated, backwards into the restiform body) as far as the lower end of the olive where its longitudinally-coursing fibres become concealed by this prominence and by the arched fibres already noticed" (pp. 286-288).

688*d*. For the proper understanding of the terms 'lateral pyramidal tract,' and 'lateral cerebellar tract,' we introduce here the corresponding passage from the chapter on the 'Spinal Cord.'

"In the ANTERO-LATERAL COLUMN there are at least two tracts which can be traced not only along the greater part of the spinal cord but into or from certain parts of the encephalon. The two tracts in question have accordingly been named, from their upper connections, the *pyramidal tract* or *tracts*, and the *direct lateral cerebellar tract.*

"The *pyramidal tract* is directly traceable down from the anterior pyramid of the medulla oblongata. The greater number of the fibres, which compose the pyramid, cross at the upper limit of the spinal cord, down which they pass in the posterior part of the lateral column, as a compact bundle of fibres, occupying in a transverse section a somewhat oval area, which lies in the angle between the posterior cornu and the outer surface of the cord, but is in most parts separated from both by bundles of fibres belonging to other systems. This *lateral* or *crossed part of the pyramidal tract* can be traced as far as the third or fourth pair of sacral nerves, becoming gradually smaller below and approaching the surface of the cord.

"Some of the fibres of the pyramids of the medulla do not decussate at the upper limit of the cord. They pass down close to the anterior median fissure, which gradually diminishes as it is traced downwards, and ceases altogether at about the middle or end of the dorsal region of the cord. . . .

"The *direct lateral cerebellar tract* lies between the lateral pyramidal tract and the outer surface of the cord, occupying a somewhat narrow area of the transverse section, which in upper regions of the cord reaches to the tip of the posterior cornu, but lower down becomes more limited, and is separated from the cornu by the intervention of the adjoining pyramidal tract. It disappears at about the second or third lumbar nerves (pp. 277, 278).

688e. "The OLIVARY BODY, as its name implies, is an olive-shaped prominence, which lies in the upper part of the medulla immediately above the apparent termination of the lateral column, and extending nearly as far as the lower border of the pons, being only separated from this by the deep groove in which is sometimes a small band of arched fibres. The line of exit of the hypoglossal nerve-roots lies on its inner or mesial border, that of the accessory, vagus and glosso-pharyngeal roots along its outer side, but the latter are separated from it by a groove in which longitudinal fibres, prolonged from the lateral tract, can be seen. Sometimes there is a small longitudinal tract running along its inner border also, and in such case, with the arched fibres above and below, the olive appears to be entirely enclosed by a fibrous strand, which has sometimes been described as its capsule (siliqua olivæ). The longitudinal tracts, before and behind the olive, are often concealed in great measure by the arched fibres, which may form a complete superficial layer over the olive, and indeed over the whole anterior and lateral surface of this upper part of the medulla (pp. 288, 289).

"The NUCLEUS OF THE OLIVARY BODY, which, from its appearance in section, has been termed the *corpus dentatum of the olive,* is enclosed in the olivary prominence, and is therefore situated in the lateral area of the medulla, but the grey matter is not visible from the surface, being covered by both longitudinal and transverse white fibres. It takes the form of a thin wavy lamina, which is curved round at its edges so as to form an ovoid scalloped capsule. The open part or hilus of this looks towards the middle line and receives a considerable tract of white fibres which emanate from the anterior area immediately behind the pyramid, and pass into the hilus along its whole extent, forming the so-called *olivary peduncle.* Under the microscope the nucleus appears as a wavy band of neuroglia, with small multipolar cells imbedded in it. The fibres of the olivary peduncle diverge as they pass to the grey lamina. They partly terminate in the axis-cylinder processes of its cells, and partly pass in small bundles through the lamina, those which are more posterior turning backwards and coursing obliquely (as internal arcuate fibres) through the posterior part of the lateral area to join the restiform body, whilst the others have a more direct course through the grey lamina, and run between the longitudinal fibres which cover the olive. On reaching the surface they bend round and are continued as part of the layer of external arcuate fibres. Some may not reach the surface, but turn upwards and reinforce the longitudinal fibres just mentioned.

"Besides the main olivary nucleus, two smaller bands are generally seen, looking like separated portions of the chief nucleus. They are situated one on the dorsal, and the other on the mesial aspect of the chief nucleus, and are known as the outer and inner *accessory olivary nuclei.* They are traversed like the main nucleus by bundles of internal arcuate fibres going to the restiform body, and are frequently connected at one or two places to the main nucleus. The inner accessory nuclei are sometimes termed the pyramidal nuclei, for they lie immediately behind the pyramid (p. 295).

688*f.* "ANTERIOR COLUMNS. PYRAMIDS OF THE MEDULLA. —The anterior columns of the cord, although on superficial inspection they appear to be prolonged into the pyramids of the medulla, are so only to a small extent. For the 'lateral pyramidal tract,' crossing the anterior median fissure from the lateral column, is continued upwards close to that fissure, and unites with the comparatively small anterior pyramidal tract to constitute the prominence known as the *pyramid.* The prolongation upwards of the rest of the anterior column of the cord lies deeply, being altogether concealed from view by the pyramids.

"The PYRAMIDS are broader and more prominent above than below. They are bounded internally or mesially by the anterior median fissure, and externally by the olivary bodies, being separated from these by the groove before mentioned, from which the roots of the hypoglossal nerve issue. At their upper end they are constricted, and thus enter the substance of the pons, through which their fibres may be traced into the peduncles of the cerebrum.

"*The decussation of the pyramids* is the name given to the obliquely-crossing bundles of the 'lateral pyramidal tract,' which are seen in the anterior median fissure at the lower part of the medulla. The extent to which the decussation is visible varies considerably in different individuals; for in some the bundles take a deeper, in others a more superficial course. Further, in some cases a larger share than usual of the longitudinal fibres of the pyramids passes down in the 'anterior pyramidal tract,' and a correspondingly smaller share in the 'lateral pyramidal tract.' And since the anterior tract, which in the pyramid is external to the lateral tract, does not cross in the medulla, but merely passes obliquely at its lower end to attain the side of the anterior median fissure, the decussation in these cases is of less extent. On the other hand, in rare cases, the whole of the fibres of the anterior pyramid may cross over at the lower part of the medulla, and become 'lateral pyramidal tract,' in which case the anterior or uncrossed tract is wanting in the cord, and the medullary decussation is very well marked. All transitions are found between these two conditions (pp. 288, 289).

688*g*. "The internal structure of the medulla oblongata, like the external, is best understood by tracing its several parts upwards from the spinal cord. . . .

"The first changes are produced, both in internal structure and in the external form, by the passage of the fibre-bundles of the 'lateral pyramidal tract,' obliquely through the grey matter of the ANTERIOR CORNU, and across the anterior median fissure to the pyramid of the opposite side. By this abrupt passage of a large number of white fibres through it, the anterior cornu is broken up, and one part, the caput cornu, is entirely separated from the rest of the grey matter; whilst only the base of the cornu remains, as a small portion of grey matter, close to the antero-lateral aspect of the central canal.

"The separated portion of the anterior cornu becomes pushed over to the side by the development of the pyramid and the interpolation higher up of the olivary body between them, so that it comes to lie close to the remains of the posterior cornu [see below no. 688*h*]. The greater part of its substance is broken up into a *formatio reticularis*, *i.e.*, a comparatively coarse network of grey matter containing nerve-cells, intersected by bundles of white fibres; but a small part of the cornu remains for a time in the lateral column, near the surface, and is known as the nucleus of that column—*nucleus lateralis*—(pp. 290, 291).

"The FORMATIO RETICULARIS occupies the whole of the anterior and lateral areas of the medulla dorsal to the pyramids and olives respectively. It is thus named on account of the appearance which it presents in a transverse section viewed under a moderate magnifying power. This reticular appearance is caused by the intersection of bundles of fibres belonging to two sets which run at right angles to one another. Those of the one set are longitudinal, and these are intersected by transverse fibres which pass obliquely from the raphé outwards and somewhat backwards with a curved course towards the funiculus gracilis and funiculus cuneatus, and the olivary nucleus, and also in the upper part of the medulla through the restiform body.

"In some parts grey matter with nerve-cells enters into the constitution of the formatio reticularis. The cells are especially large and numerous in the reticular formation of the lateral area near the remains of the anterior cornu, and its grey matter is presumably derived in great measure from the latter. In the anterior or mesial area of the medulla, nerve-cells are absent from the formatio reticularis, and this is therefore sometimes distinguished as the *formatio reticularis alba* from the other or *formatio reticularis grisea*.

"The longitudinal fibres of the reticular formation of the anterior area, with the exception of those which occupy the tract nearest to the pyramids, are prolonged from the remainder of the anterior column of the spinal cord after the passage of the anterior (direct) pyramidal tract into the outer side of the pyramid. Those nearest the pyramids are derived from arched fibres which issue from the nuclei of the funiculi graciles and from the olives, and turn longitudinally upwards in this part. Those of the reticular formation of the lateral area are prolonged from the remains of the lateral column after the 'lateral pyramidal tract,' and the 'lateral cerebellar tract' have passed to their respective destinations. . . . According to Deiters, the axis-cylinder processes of the nerve-cells of the reticular formation all pass downward, while their branched processes are directed horizontally (pp. 296, 297).

688*h*. "Meanwhile [that is, while the substance of the anterior cornu is broken up into the *formatio reticularis*] the POSTERIOR CORNUA become gradually shifted laterally, simultaneously with an increase in size of the posterior columns of the medulla, so that in place of forming an acute angle with the posterior median fissure, they now lie almost at right angles to it. Moreover the caput cornu enlarges and comes close to the surface, where it presently forms a distinct projection, the *funiculus of Rolando*, which, a little higher up, swells into the *tubercle of Rolando*. At the same time the cervix cornu diminishes in size and like the anterior cornu is eventually broken up by the passage of transverse and longitudinal bundles of white fibres through it, into a reticular formation, which then separates the caput cornu posterior from the rest of grey matter, and joins the reticular formation derived from the anterior cornu. In the tubercle of Rolando the caput cornu is close to the surface, and its grey substance can readily be seen, but above the tubercle it lies deeper being covered by a well-marked bundle of ascending white fibres—ascending root of the fifth nerve—and by the oblique arched fibres which are passing over it to form the restiform body.

"The grey matter of the base of the posterior cornu undergoes a considerable increase as we trace it upwards in sections. For portions of grey matter are soon found to extend from it into the funiculi graciles and cuneati, forming the so-called nuclei of those columns. These nuclei are at first narrow in transverse section; but as the central canal approaches the posterior surface of the medulla, they appear as comparatively thick masses, which produce externally the eminences of the clava and the cuneate tubercle. Outside the nucleus of the funiculus cuneatus—which is often known as the restiform nucleus—a small accessory or external nucleus becomes formed.

"When the slit-like upper end of the central canal opens out into the fourth ventricle, the small remaining portion of the base of the anterior cornu comes to the surface of the floor of the ventricle, and as the sections are traced forward increases gradually in size, producing the eminence of the *funiculus teres*. In it, both in the lower part of the medulla where the canal is still closed, and above where it has opened out, a group of large nerve-cells is seen in the transverse sections representing a longitudinal vesicular column. From this column of cells the successive bundles of the roots of the hypoglossal nerve arise and pass obliquely through the substance of the medulla to leave it on its anterior aspect. The tract of nerve-cells is accordingly known as the *hypoglossal nucleus*.

"In the fourth ventricle the hypoglossal nucleus lies a short distance from the surface. Nearer to the surface of the floor and nearer also the median groove is a small group of cells continuous with those found in the raphé presently to be described, and known sometimes as the *nucleus of the funiculus teres*.

"At the base of the posterior cornu, in the lower part of the medulla, and near the central canal, a group of cells is seen in section, which seems to correspond with the hypoglossal group in the base of the anterior cornu. This, if traced upwards, is found to be pushed to the side as the central canal opens, so that in the floor of the ventricle it lies outside the hypoglossal nucleus. The group or column of cells in question corresponds to the prominence of the *ala cinerea* which appears on the surface, and it extends forwards as far as the *fovea posterior*. From it there arise successively bundles of fibres of the roots of the spinal accessory, vagus and glosso-pharyngeal nerves: those of the upper roots of the *spinal accessory* in the lower part of the medulla where the canal is still closed; those of the *vagus* beginning at the commencement of the ventricle, and arising along the length of the *eminentia cinerea;* and those of the glosso-pharyngeal coming for the most part from the upper part of the ala cinerea, and from the posterior fovea. The column of cells in question forms then, successively, the NUCLEUS OF THE SPINAL ACCESSORY, PNEUMOGASTRIC and GLOSSO-PHARYNGEAL NERVES.

"Towards the upper part of the medulla another tract of cells becomes developed outside the line of accessory, vagus, and glosso-pharyngeal nuclei. This tract corresponds to the lateral triangular area, which is seen on the surface outside the ala cinerea, and which passes into the *tuberculum acusticum* of Schwalbe. From it most of the fibres of the auditory nerve take origin, and it is accordingly named the PRINCIPAL AUDITORY NUCLEUS.

"The nerve-cells in the hypoglossal nucleus are larger than those in the spinal accessory, vagal and glosso-pharyngeal nuclei. Those in the nucleus of the funiculus gracilis are also of considerable size (pp. 292-295).

"Besides the collections of grey matter which are traceable from the grey matter of the spinal cord, portions occur in certain parts of the medulla oblongata, which are not represented in the cord. Of these the most important is the *nucleus of the olivary body*. . . . Other small collections of grey matter and nerve-cells are scattered in certain parts of the formatio reticularis, as well as one or two distinct tracts in connection with the external arcuate fibres, and a considerable amount in the median septum or raphé (p. 295).

688*i*. "The ARCIFORM or ARCUATE FIBRES of the medulla, which have more than once been alluded to, are the curved fibres which are seen in transverse sections coursing in the plane of that section. From their position they are distinguished into external and internal, or superficial and deep.

"The *superficial arcuate fibres* emerge, for the most part, from the anterior median fissure, and passing over the pyramids and olives, many of them go to the restiform body. They are added to the deep fibres which come to the surface partly in the groove between the pyramids and olives, partly after passing through the olives, as before mentioned. Traced back in the anterior median fissure, they are seen to enter the raphé and to cross over in it; after which it is supposed they may become longitudinal, but their further course is not certainly known.

"The *deep arcuate fibres* emerge from the raphé, and transverse the thickness of the medulla, tending towards the olives, the restiform body, and the nuclei of the cuneate and slender fasciculi. As we have just seen, those which pass through and in front of the olives are in continuity with the superficial arcuate fibres.

"Traced backwards into the raphé, the deep arcuate fibres appear to cross obliquely to the other side of the medulla, where in all probability they mostly become longitudinal, joining the fibres of the formatio reticularis alba. Others are said to turn upwards and become longitudinal before reaching the raphé. The cells of the formatio reticularis grisea are probably connected with some of the deep arcuate fibres.

"Amongst the superficial arcuate fibres, or between them and the subjacent columns of the medulla, small collections of grey matter with nerve-cells are here and there met with, which are distinguished as the *nuclei of the superficial arcuate fibres.* The principal group of cells lies superficial to the pyramid on either side. The nerve-cells of these nuclei are connected partly with the arciform fibres, partly with the fibres of the adjacent pyramid (p. 297).

688*j*. "The RAPHE or septum is composed of fibres which run in part dorso-ventrally (fibræ rectæ), in part longitudinally, and in part across the septum more or less obliquely. Intermixed among the nerve-fibres are a number of nerve-cells in grey matter. The fibræ rectæ are continuous anteriorly with the superficial arched fibres which emerge at the anterior median fissure; posteriorly with fibres from the funiculi graciles in the lower part, and from the nuclei of the funiculi teretes in the upper part of the medulla. The longitudinal are chiefly fibres which have passed into the raphé as fibræ rectæ, or as superficial or deep arcuate fibres, and in it have altered their direction and become longitudinal.

The obliquely-crossing fibres are the deep arched fibres which enter or emerge from the raphé. Others, however, near the dorsal edge of the raphé, seem to come from the nuclei of the nerve-roots, and these may pass more directly across as commissural fibres either into the formatio reticularis, or into the pyramid of the other side, in either case becoming longitudinal. The nerve-cells of the raphé are multipolar cells, those in the middle being chiefly spindle-shaped. The latter are connected with fibræ rectæ (Clarke), whilst the more laterally situated ones, at least those near the anterior median fissure, are connected with some of the superficial arcuate fibres (p. 298).

688*k*. "SUMMARY OF COURSE OF NERVE-FIBRES FROM THE SPINAL CORD UPWARDS THROUGH THE MEDULLA OBLONGATA.— Assuming for convenience of description the existence of three white columns of the spinal cord on each side, the various parts of these are continued upwards as follows:—

"The *posterior column* forms in the medulla oblongata the white substance of the three posterior funiculi: viz., the funiculus gracilis, the funiculus cuneatus, and funiculus Rolandi. The longitudinal fibres of the first two appear to end in the grey matter which forms their nuclei; and numerous deep arcuate fibres enter or emerge from the same collections of grey matter.

"The cuneate funiculus has been commonly described as passing up into the restiform body, but it seems doubtful if any of its fibres do actually take part in the constitution of that body, although from the surface the funiculus in question and the restiform body appear to be in continuity with one another.

"The large part of the *lateral column* of the cord, viz., the *lateral pyramidal tract*, passes into the opposite pyramid of the medulla, and ascends in this and in the ventral half of the pons towards the pedunele of the eerebrum. Together with the small part of the anterior eolumn of the cord whieh also enters into the eonstitution of the pyramid, it forms the *pyramidal tract of the encephalic isthmus* of Fleehsig (peduneular traet of Meynert). Some of the fibres of the pyramid, however, emerge as external arcuate fibres, and, joining the restiform body, pass to the cerebellum. A smaller part of the lateral column of the eord, the *direct lateral cerebellar tract,* passes at about the middle of the medulla obliquely baekwards to join the restiform body.

"The rest of the lateral column dips under the olives and forms the longitudinal fibres of the formatio retieularis grisea. These are eontinued through the dorsal part of the eneephalie isthmus towards the eorpora quadrigemina and optie thalamus.

"The *anterior column* of the cord in part is eontinued into the pyramid of the same side, but ehiefly dips under the pyramid and forms the longitudinal fibres of the formatio retieularis alba in the dorsal part of the mesial area. These pass upwards to the eerebrum. In the pons Varolii one traet of them beeomes eolleeted into a well-marked faseieulus (posterior longitudinal bundle), and most of the others form another traet (tract of the fillet) which terminates in the region of the eorpora quadrigemina. In the region of the medulla they are indistinguishable from one another in the adult, but in the fœtus they are found to develop at different periods, and are then readily differentiated (Fleehsig).

"A small bundle of fibres of the anterior eolumn of the eord was described by Solly as passing obliquely upwards below the olive to join the restiform body. This is not always present."

688*l*. MEYNERT.[1]—"The *pedunculi cerebelli inferiores*—proeessus eerebelli ad medullam—eonvey a eontribution of fibres from the eerebellum to the posterior eolumns of the spinal cord. Eaeh pedunculus eerebelli, aeeording to Stilling, is divided into an outer and inner division. . . . The *outer* division, the *corpus restiforme,* is a faseieulus of eonsiderable size, whieh emerges from the eerebellum at a point which,

[1] "Op. citat."

measured on the pons Varolii, corresponds to the regions between the origins of the superior and inferior roots of the facial nerve. . . . The *inner* division emerges from the cerebellum at about the same level with the corpus restiforme, and forms a tract of fine bundles of fibres which, on cross sections, appears as a four-sided surface, lying to the inner side of the oval surface presented by the former tract. . . . *Deiters* is not justified in denying that any portion of the fibres, which make up the inner division of the pedunculus cerebelli, are derived directly from the cerebellum (pp. 716, 717).

"The fibrous system of the *fibræ arcuatæ*—fibræ vel processus arciformes—plays an important part . . . in the structure of the posterior tract of the caudex cerebri, that lies between the level at which the decussation of the *processus cerebelli ad cerebrum* is completed, and that which corresponds to the lower extremity of the olivary body. The greater part of these transverse fibres are derived from the pedunculus cerebelli, and as emissaries of the latter they weave themselves among the fibres of the projection system. It is certain that the fibræ arcuatæ of the *superior* part of this region enter into connection with the clusters of the smaller nerve-cells, and through their agency, with the fibres of the projection-system, the future antero-lateral columns of the spinal cord. The *middle* system of fibræ arcuatæ is connected with the nucleus dentatus of the superior olivary body. . . . After having decussated at the median line, these fibres direct their course outwards . . . to reach the superior olivary body. By winding themselves spirally around the surface of their nucleus, they help to form for it a capsule of nerve-fibres, and then make their way transversely through its substance, entering undoubtedly into connection with its nerve-cells. Besides being united in this manner with the restiform body of the opposite side, the nucleus dentatus of the superior olivary body is further brought into connection with the cerebellum, by means of fibres that run directly into the latter, piercing on their way the inner division of the pedunculus cerebelli. The third or *inferior* system of fibræ arcuatæ from the pedunculus cerebelli lies in the region of the inferior olivary body. . . . The fact that the corpus restiforme, the outer division of the pedunculus cerebelli, progressively diminishes in size from above downwards, finally to disappear altogether, just at the same rate at which the *funiculi gracilis et cuneatus*, the posterior column of the oblongata, increase in size, justifies, and even forces upon us, the conclusion that the two tracts constitute in reality only different portions of one coherent system, the *posterior column* of one side having its origin in *the cerebellar hemisphere of the other side*" (pp. 722-724).

688*m*. "The fibrous tracts of the oblongata, from which the posterior columns are formed, may be divided into two groups, each of which follows a different course: 1. The *outermost* and *middle fibræ arcuatæ* from the restiform body . . . having their origin in the cerebellum, pass in part around and to the outside of the ascending root of the fifth pair and the olivary body . . . and in part they make their way through the root of the fifth pair as well as through the olivary body, although without entering into connection with the nerve-cells of the latter. . . . These fibræ arcuatæ then cross the median raphé of the oblongata . . . and make their way into the hilus of the olivary body of the opposite side, entering into connection with the nerve-cells. . . . This view is confirmed by the atrophy of one hemisphere of the cerebellum always occurring in connection with atrophy of the opposite inferior olivary body. From the cells of the olivary body, the fibræ arcuatæ (rather the posterior set of them) continue their course towards the *funiculi gracilis et cuneatus*, which form the posterior column of the opposite side from that hemisphere of the cerebellum in which they originated, to become finally a component part of these longitudinal tracts, after making their way through the nuclear masses of the same enclose. The bulk of the funiculi is thereby so much increased that they approach the median line from both sides behind the central tubular grey mass of the region, so as finally to come into apposition with each other, leaving only the posterior fissure between them. 2. . . . The most *posterior* of the fibræ arcuatæ . . . traverse the substance of *the olivary body of the same side*, but pass *behind the opposite olivary body*, after crossing the raphé, and having entered into connection with the large, scattered cells, they join the posterior column, their final destination. It is especially this set of fibræ arcuatæ that enter into connection with the large, irregularly-grouped cells of the motor district of the oblongata.

"Having reached their respective posterior columns, the collective groups of fibres, whose course we have been considering, lose themselves in collections of nerve-cells, within which they become organized anew into a sort of network which gives a peculiar flame-like appearance to cross-sections; and they separate, below the floor of the ventricle, into two groups that are fused together anteriorly, known as the *nuclear masses* of the *funiculi gracilis et cuneatus* respectively. The component elements of these nuclei are for the most part of small size (24μ by 6-9μ), only a small, but easily distinguishable semicircular group of the outermost, hindermost cells of the funiculus cuneatus, being made up of larger elements (30-36μ by 15μ).

"The various paths, followed by the fibræ transversæ from the pedunculi cerebelli, serve moreover to place these fibres in connection with the fasciculi of the projection system, composing the continuation of the tegmentum cruris cerebri. The two systems of fibres seem by no means merely to lie side by side without further connection, but to lie actually united with each other by means of the above-mentioned *clusters of small cells*, by means of the *olivary bodies*, and perhaps even by the *large scattered cells*.

"The *fibræ transversæ of the oblongata*, which pass over into the posterior columns, constitute manifestly a centripetal tract.

"*Deiters* regarded the longitudinal crural fibres, that stand in connection with the olivary bodies, as serving to prolong the posterior columns of the cord *into the cerebral lobes*. Such an assumption is, however, by no means justifiable, since those fibres that pass from the tegmentum into the olivary bodies proceed from tracts—the stratum lemnisci and the motor district of the tegmentum—that are continuations of the antero-lateral columns of the spinal cord" (pp. 724-727)].

ANALYSIS.

689. As soon as the fibres of the cerebrum, as well as those of the cerebellum, leave their paternal soil, they flow together in a common caudex or stem, which is called medulla oblongata, where they are also joined by new or recent fibres born from the caudex itself. As regards the fibres of the cerebrum, they are brought forth from its universal, cortical envelope, and, after being collected together they meet near the edges of the optic thalami, and of the beginnings of the medulla oblongata, which are called upper and lower, anterior and posterior corpora striata. Into these bodies—called central ganglia—the cerebral fibres immerse from all sides in a straight and oblique direction, rushing towards the anterior extremities of the same, where they thoroughly imbed themselves. Thence they pass through the medullary cylinder of the medulla oblongata, and, flowing down its anterior and posterior portions, they enter the spine of the back. The fibres of the cerebellum also, which first were consolidated in one trunk, and, subsequently, in their course, cleft again into three forks, enter this same caudex, where they interlace and enfold themselves with the fibres of the cerebrum, which flow towards them, namely, with its higher or upper fibres [those of the tegmentum] near the region of the corpora quadrigemina, or near the isthmus; with its lower fibres [those of the crústa] in the pons Varolii, and with the rest which tend towards the spinal marrow, through the fibres of the restiform process, not far from the foramen magnum of the occipital bone, or near the common cauda of the medulla oblongata. To these fibres are added those which are indigenous to, and native of, this medullary soil itself; for a copious grey substance is imbedded in its striated beginnings [in the corpora

striata and optic thalami], as well as in the remaining caudex, where, however, it is less copious. Wherever, indeed, there is any cortical or grey substance, there also are fibres; for these substances are the origins and beginnings of the fibres; wherefore these latter fibres must be attributed to the medulla oblongata. The fibrous medulla oblongata arises from the coalescence of this threefold progeny, and thus constitutes a common forum and halting-place of fibres of a threefold origin.

690. The living fountains, and the exciting causes of the motions of this body, are, however, only the cerebrum and the cerebellum; for they signalize, and watch over, its motions. The medulla oblongata does not start anything of its own accord, but is compelled to act with the two brains, that is, it suffers itself to be acted upon by the good pleasure of the two brains. Such an attachment to, and intertwining of, the fibres of the cerebrum with the fibres of this medulla, is very conspicuous in the tract bordering on the central ganglia—*i.e.*, the corpora striata and the optic thalami; for when the cortical cerebrum expands itself, its medullary fibre is lengthened out, and at the same time closely compressed; an opportunity is thus given to the cortex of the medulla oblongata [in its striated beginnings] of expanding itself in a similar manner, and of elongating its fibres, and *vice versa.* Without mentioning other modes of an ingenious nature for exciting the fibres of this organ to an action harmonizing with that of the fibres of the cerebrum and cerebellum; which modes are innumerable as well as inscrutable, for nature, when at work in its least things and in its centres, surpasses and transcends immeasurably the sciences and arts hatched out by human ingenuity, and also every intellect even of the most penetrating quality, bordering, according to the common acceptation, on the divine; meanwhile, from things seen and explored, it follows that the medulla oblongata is unable from itself to signalize and watch over any motion of the body, unless it be first excited by either of the two brains.

691. The medulla oblongata also has the power of unfolding

and expanding itself, for its striated beginnings—the central ganglia—as far as their backs are concerned, are exposed in the lateral ventricles, and they enclose also the third ventricle; they are besides engirded with a soft medullary border in a net-like form, [*i.e.*, the tænia semicircularis and the stria pinealis]. The pons Varolii is free and unobstructed as to its ventral surface, with which it looks towards the dura mater and the base of the cranium; such also is the case with the corpora pyramidalia and olivaria which are further down. On the opposite side, however, is the isthmus with its cavity [the aqueduct of Sylvius], the fourth ventricle and the calamus scriptorius, which, by their synchronous expansions and elongations, accommodate themselves thoroughly to the modes in which the [whole] medulla oblongata unfolds itself. It follows hence that the medulla oblongata has not only its periods of expansion and constriction, but that these motions also act synchronously with those of the two brains.

692. The fibres proper to the medulla oblongata are, therefore, a kind of auxiliary forces to the cerebrum and cerebellum, and whenever these organs decree any motion in the body, or receive any sensations from the body, the former fibres lend their assistance. By this means, indeed, there is an increase in the brain-forces along their course to any degree desired, whence there arises a certainty in the effect. This also is the reason why the corpora striata in pups and recently-born individuals, which are still destitute of the determination of motion and the reception of sensations, are tender and infirm, and the very striæ appear scarcely developed in them.

693. The medulla oblongata is the medium, uniting the determinations of the cerebrum with those of the cerebellum, for whatever unites the fibres is also a medium for uniting determinations, since all things in particular are determined by fibres and by the spirit of the fibres. The cerebrum acts from the will; the cerebellum, however, from nature; two leaders, who are rarely unanimous, are consequently placed over one kingdom. Apart from the medulla oblongata which unites

the fibres, and, consequently, the actions of both brains, and moderates them equably, this could never be accomplished, for perpetual discords would gradually arise, and the kingdom would be distracted even to death. How much the government is divided and mixed appears manifestly from the body, for while some parts, viscera and provinces in the body, are under the sole jurisdiction of the cerebellum, as arteries, veins, the heart, stomach, the small intestines, the liver, pancreas, spleen, the glands, etc., there are others which are subject to the rule of the will, as the muscles of the joints and articulations, and those which line the whole surface of the body, and there are still others which obey at the same time the rule of both nervous centres, as the lungs, the œsophagus, windpipe. The fibre of nature, however, or that of the cerebellum, must be present with, and at the bottom of, each single part, lest the will, which is a determination flowing from principles acquired from the ultimate world and the body, should be in conflict with nature, which is a determination flowing from principles derived from the inmost and first sources of law, and lest the will should thus deprive the soul of its sceptre, and cast it down from its throne. Chiefly on this ground there are adjoined to the two brains, the medulla oblongata and the spinal marrow, and in them the fibres are co-ordinated so as to regulate the supply of the administration of each nervous centre, and to provide for the necessity of life, and for those ends which conspire to the general good of the whole. Every individual nerve, therefore, is born from this medulla, and not a single one is generated immediately from the cerebrum or cerebellum, namely so, that the cerebrum, as well as the cerebellum, shall introduce their fibres, either into the nerves themselves by which the whole body is ruled, or into their roots, the object being that thus there may be effected, in the first threshold, what afterwards, by infinite anastomoses, is perfected, and over and over again wrought in the body itself.

694. The fibres of the cerebrum and cerebellum must also be associated together in a becoming manner in the caudex of the

medulla oblongata, [*i.e.*, in the medulla oblongata proper], and the peculiar fibres of the medulla oblongata must be attracted into their bond of union, lest any portion of the kingdom, that is, any part of the body, should be in want of its spirit, juice, and life. The cerebrum, by its own fibres and the associate ones of the medulla oblongata, sprinkles out this spirit at one time in a scanty, and at another time in a more profuse manner, altogether as its *animus* or natural mind is either exalted or cast down. The cerebellum, therefore, by constantly and perpetually contributing its spirit, must labour and strive, so as, on the one hand, to prevent losses, and, on the other, to restore losses. Thus the cerebrum, through sleep, is deprived, at alternate periods, of its government; that is, of motion and sensation, and thereby of those causes whereby the natural mind is excited.

695. Apart from the medulla oblongata, as the general collector and determiner of the fibres, the sensations also could not be conveyed distinctly, either to the cerebrum or the cerebellum, namely, five kinds of sensations with their various modes to the cerebrum, and purer and inmost sensations to the cerebellum. For all sensations are carried to the antecedents of the fibres, and all determinations of motion to the parts succeeding the fibres. Sensation, in accordance with the character of its fibre, is communicated to every contiguous fibre, and, like the rays of the sun, it flashes into the optic thalami and the corpora striata, which are the beginnings of the medulla oblongata; and thence from every point touched, as from a centre, it hastens to the whole cortical envelope of the cerebrum. The sensations are intensified on the way, while they are being carried along; for the medulla increases in size towards the corpora striata and the optic thalami, and by degrees becomes more striated, and more luxuriantly supplied with grey substance. The whole fibre of the cerebrum, which receives sensation, and diffuses it over its whole cortical substance, flows around these central ganglia. The very medulla of the cerebrum also consists of a perpetual reticular tissue with infinite anastomoses, so that all fibres, as it were, are there brought into contiguity with each

other. In this wise the medulla oblongata is a most fit vehicle for the conveyance of the modes of the senses. The fibrous course towards the cerebellum, however, is not laid out according to this plan. There is no such contiguity among the cerebellar fibres; their medullary trunk does not increase in size, nor does its grey substance become more copious; for the peduncles of the cerebellum are purely medullary, while the peduncles of the cerebrum, on the other hand, that is, the central ganglia and the crura of the cerebrum, are most abundantly interlarded with grey substance. Besides, the cerebellum is not organized for the reception of such modes, that is, it is unable to turn its attention to modes of this kind, to apply itself to their reception by turning its hinges, as it were, in a suitable manner, to vary its own forms, and change its states; differently from what is the case with the cerebellula of the cerebrum, which may be thus applied, and which, from infancy by culture, have been thus applied and disposed. Apart from the medulla oblongata, therefore, it is impossible for motion to be determined in a becoming manner, and for sensation to be distinctly received.

CHAPTER XXVI.

THE VALVE OF VIEUSSENS; THE FOURTH VENTRICLE, AND ITS CHOROID PLEXUS.

696. Inasmuch as the valve of Vieussens closes the anterior part of the fourth ventricle, and the choroid plexus lines both of its lateral borders, therefore these parts cannot be separated, and each be treated singly. It was thought also that the fourth ventricle should be discussed before the pons Varolii, because it is situated immediately under the cerebellum, and because the first process of the cerebellum towards the corpora quadrigemina environs it like a girdle.

The Valve of Vieussens.

697. VIEUSSENS.[1]—"When the cerebellum, denuded of its dura mater, is reclined backwards, a membrane of an ashy grey colour is discovered, which is somewhat thick and soft. This membrane is a production of the pia mater, and is interwoven with a glandular substance, not unlike the cortex of the cerebrum. A transverse medullary tract enters in front into this membrane, which adheres and is united to the anterior vermiform process, and to the peduncles which reach from the cerebellum to the corpora quadrigemina, and to the posterior part of the pons Varolii. From all this it appears that this membrane lines the anterior part of the cavity of the fourth ventricle, and closes up the posterior part of the aqueduct of Sylvius; wherefore we maintain that it performs the function of a valve. On taking into consideration its office, and its great importance, we

[1] "Neurographia," etc., Cap. XII., XVII.

call it 'valvula cerebri major,' so as to distinguish it from the membranous ligaments, which, within the cavities of the longitudinal and lateral sinuses, serve as smaller valvules, and perform their functions (p. 76). . . . It is to be noted that the aqueous juices, which are emitted from the pineal gland, and the little glands inserted in the choroid plexuses, are not able to penetrate through the aqueduct of Sylvius to the calamus scriptorius, because the 'valvula major cerebri' totally prevents such a course. This is proved by the following experiment:—I suppose the convex part of the cerebrum to be removed and its lateral ventricles opened; if then the third ventricle and the aqueduct of Sylvius are filled with water, and the same water is afterwards drawn out by a litttle sponge; and if afterwards the cerebellum is dissected through its middle from the front backwards, and opened out sidewards, the cavity of the calamus scriptorius is laid bare, where not even the least drop of water is found. Hence we maintain that admittance into the fourth ventricle is denied to those aqueous juices which are received by the aqueduct of Sylvius; and therefore they are compelled to direct their course towards the third ventricle, and to descend into its narrow cavity" (p. 110).

698. Ridley.[1]—"The valve of Vieussens, especially in human beings, is a thick medullary membrane, adhering anteriorly to the lower part of the posterior process of the corpora quadrigemina, a little behind that transverse medullary process, whence the pathetic or fourth pair of nerves arises. Laterally it extends to the process which ascends from the corpora quadrigemina to the cerebellum, and in its posterior expansion it reaches to the anterior vermiform process of the cerebellum. . . . By raising up with the finger the anterior vermiform process of the cerebellum, it rarely fails to come into sight, but if it does not, it is easily brought into sight by blowing into the foramen under the pineal gland. Its use, according to Vieussens, is to prevent any part of the water, which falls into the foramen posterius near the posterior corpora quadrigemina, from running

[1] "Anatomy of the Brain," Chap. xiii.

into the fourth ventricle, and, *vice versa*, from blowing out of the fourth ventricle into the aqueduct, or, again, from getting out on either side of the medulla oblongata. This last use is evidently most true, whether it be understood of water collected there preternaturally or accidentally, for I must needs confess that I could never find any water there any more than I could in the third ventricle, in subjects free from those diseases incident to that part. But with respect to the use of the passage from the cerebellum to the last or third foramen, I doubt the truth of Vieussens' statement, for many reasons, of which this is one; the fact, namely, that the choroid plexus, in the fourth ventricle, together with its adjacent parts, is of the same texture as the other choroid plexus in and about the lateral ventricles of the cerebrum, renders it as reasonable to suppose that water may be collected there just as in other parts of the cerebrum—nay, that this is so, Vieussens himself also allows as a matter of fact—this fact, consequently, renders it as necessary for the water to have a place of vent whenever it happens to gather there, as it is for that water which at any time collects in the other ventricles. And, consequently, in the next place, I do not see how this delicate membrane can at any time intercept a passage of so searching a body as water when it is forced against it; notwithstanding the supposed declivity of this part, which in man, by reason of the largeness of the subjacent prominent pons Varolii, is very considerable. For this forcing of the water against the valvula must needs happen by pulsation, whenever we suppose that cavity filled with it. And, in the last place, notwithstanding all the contrivance the aforesaid author has shown in having the gross part of water (which, as before noted, he grants may be, nay, constantly is deposited there from the glands of the choroid plexus situated here) conveyed out of this ventricle through the extremities of veins, I am inclined to think that, unless a speedier reductory passage were found out, very great mischief would frequently happen to the spinal marrow itself, and to the nerves springing from it; seeing that the extremity of the fourth ventricle called the calamus scriptorius is parted from the spinal marrow below only by pia mater, which, notwithstanding it is there double (even as it is quite down the whole spine, lest perhaps the water should fall down too readily upon the nerves arising from it), still upon an occasion like the present, may easily be supposed subject to violation, not to say anything of the high improbability of any such conveyance being accomplished at all by the veins, seeing that in a natural state they always are continuations only of arteries. It is true the fact of the passage under the corpora quadrigemina being so near at hand may prevent the water from lapsing into the fourth ventricle, when it finds its further passage that way obstructed by the interposition and resistance of the valve. And for the same reason, doubtless, it was that in Vieussens' experiment, which he adduces in proof of his opinion, no water was found in the fourth ventricle; because upon its non-admittance by the valve, it immediately found another passage where it was conveyed some other way, which, by reason of its declivity, was effected much more readily" (pp. 128-132).

The Fourth Ventricle, the Calamus Scriptorius, etc.

699. Bartholin.[1]—"That sinus or cavity, which Galen calls the ventricle of the cerebellum, others, the fourth ventricle of the cerebrum, when yet it is not in the cerebrum, we shall call the noble ventricle of the medulla. It is most solid, most pure and subtle, but very small, for, as Galen says, it possesses considerable forces and faculties. Inasmuch as behind a certain even duct or ventricle, it becomes enlarged at the sides, but afterwards is sharpened into a point, by some it is called calamus scriptorius. Another part of this ventricle, and indeed that half of it which forms, as it were, its ceiling, is constituted by the cerebellum, with which this medulla is conjoined, so that the whole of this cavity is situated between the cerebellum and the medulla oblongata; the greater part of the cavity, however, is below in the medulla. The use of this ventricle we

[1] "Anatome," etc., Lib. III.

declare to be to serve as a place for the generation and elaboration of the animal spirits. For this ventricle is most pure and subtle; its cavity is sufficiently large for the purpose; from this place, finally, the animal spirit may be diffused everywhere around into all the nerves; wherefore Herophilus justly declared this ventricle to be the chiefest" (p. 482).

700. WILLIS.[1]—"As the cerebrum within its cavity has its own choroid plexus, which, in various ways, is woven together of arteries and veins, and most densely interspersed with glands; so also the cerebellum has similar plexuses of vessels, which are furnished with the same kind of glands, but more numerous and larger than those in the choroid plexus [of the cerebrum]. After the pia mater which covers the posterior part of the cerebellum has been removed, this assemblage of plexuses and glands becomes easily visible; for there, on either side of the vermiform process, they are seen creeping upwards, as it were, in two branches. These plexuses on either side receive an arterial branch from the vertebral artery which is situated under the base of the medulla oblongata, as well as venous ducts which are sent forth from both lateral sinuses. . . . The cerebellum is situated over the medulla oblongata, to whose sides it seems fastened as it were by two peduncles. Between these peduncles on either side, with the cerebellum overhead, and the stem of the medulla oblongata underneath, for all these parts require to be separated from each other, there is a cavity which is commonly called the fourth ventricle (pp. 22, 23). . . . Since indeed it is very manifest that the animal spirits are generated within the cortical gyres or strata of the cerebellum, it does not seem worth while to place their laboratory in the ventricle which is underneath that organ. For that cavity is so large an empty space, because it is situated between the two peduncles of the cerebellum and the medullary caudex underneath on the one hand, and the gland of the cerebellum overhead on the other. A certain use, however, grows out of the existence of this ventricle, namely, that a serous humour, ooz-

[1] "Cerebri Anatome," Cap. III., XVIII.

ing out from the glands and plexuses of blood-vessels, rendered more liquid by that which descends from the substance of the cerebellum, trickles into this cistern. Prevented by a membrane from flowing into the origins of the nerves, this liquid is forced from the ventricle into a foramen of the aqueduct of Sylvius under the corpora quadrigemina. Thence it is received by the declivitous opening of the infundibulum, and despatched abroad" (p. 120).

701. VIEUSSENS.[1]—"If the whole cerebellum is dissected through the vermiform processes, as through twin poles, the white substance in this middle region is seen divided into several tracts. These tracts extend in every direction like the branches of a tree, and are imbedded in the cortical substance which is diffused in every direction. At the same time also the process, which reaches from the cerebellum towards the corpora quadrigemina, and likewise that other process, which is continued from the cerebellum towards the spinal marrow, together with the cavity of the fourth ventricle, come into sight. Besides the 'valvula cerebri major,' there is discovered in the posterior space of this cavity a choroid plexus. Willis maintains that this choroid plexus differs from those situated on the thalami optici in this respect, that the glands, with which it is furnished, appear more numerous and larger. We confess, however, that in the human brain we never found this distinction substantiated. After the 'valvula cerebri major' and the choroid plexus have been removed from the cavity of the fourth ventricle, two medullary tracts become visible with the help of the microscope, and in recently-dissected heads also without the help of the microscope. With these tracts there coalesce on either side certain white fibrils [the auditory striæ ?] running in a transverse direction, which emerge from the medulla oblongata, and which, near their origins, are distinct from each other, although in Plates ix. and x. they are represented as united, and present the form of one transverse medullary tract. The two medullary tracts, mentioned above, on either side pass

[1] "Neurographia," etc., Cap. XII.

over the proeesses running from the eerebellum towards the spinal marrow, and adhere to them, and afterwards terminate partly in the softer, and partly in the harder braneh of the seventh pair of nerves [aeeording to Willis]. Towards the end of the fourth ventricle there are notieed besides generally three, and sometimes four or five, medullary fibres whieh are derived from the proeesses of the eerebellum towards the spinal marrow; these, by eoalescing on both sides, form a short white traet, the lower part of which is sometimes divided into three, and sometimes into four fibrils, which pass off into the nerves of the eighth pair [aeeording to Willis]. Their upper part, however, after giving off eertain fibrils to the softer portion of the seventh nerve, is divided into two small trunks or branehes, the upper one of whieh terminates in the harder portion of the above-mentioned seventh pair of nerves, and the lower portion is instrumental in forming the sixth pair of nerves [aeeording to Willis]" (pp. 76, 78).

In Plates ix. and x. of this author, the fourth ventriele is exhibited as drawn apart, and in it appear blood-vessels running out from either extremity lengthwise, but branching out sidewards, without touehing one another. There are likewise seen eords of nerves [i. i.] or at least eords "that have the appearanee of nervous fibres, and which tend towards the upper part of the pons Varolii;" further, "two medullary traets [k. k.] whieh, proeeeding from the upper part of the medulla oblongata, terminate in the spinal marrow; eertain medullary fibres are adjoined to them on both sides;" yet in the Plate they are represented as if they entered the ventriele laterally on both sides. There also appear other "fibrils [m. m.] derived from the processes of the eerebellum towards the spinal marrow, to whieh there aeeede on both sides sometimes one, sometimes two thin medullary fibrils, arising from the upper portion of the medulla oblongata." In Plate xii., the fourth ventriele is represented as opened, together with the valvula magna and the ehoroid plexus; in Plate xiii. it is represented still more open.

[1] "Anatomy of the Brain," Chap. xiv.

702. Ridley.[1]—"The choroid plexus in the fourth ventricle begins to be glandular just under the eighth pair of nerves [according to Willis], whence it runs up on the side of the medullary caudex to the process from the cerebellum towards the spinal marrow, and from it enters the fourth ventricle which by Aurantius is called the cisterna spirituum. This ventricle, in accordance with what that author has observed (Anatom. Obs., p. 48), I always find broader than long, and double, though not divided by any intervening body, as is the case with the two lateral ventricles of the cerebrum. In this ventricle the choroid plexus does not lie loose, nor at its bottom, as the plexus does in the lateral ventricles; but, on the contrary, and which to my knowledge has not heretofore been noticed, it adheres closely to the top of this ventricle, that is, to the bottom of the overhanging cerebellum, and then running transversely just at the end of the calamus scriptorius, it becomes continuous there to the plexus of the other side, as has been observed in the case of the choroid plexus in the lateral ventricles of the cerebrum. This plexus arises from a ramification of the second or hindermost branch of the basilar artery, as does the second part of the plexus of the cerebrum mentioned above, and from another smaller branch of the said artery, about the place where it ascends from the vertebrals, which last branch turns into a reticular expansion first, and then a little further on meeting with the former, constitutes this plexus (pp. 133-135). . . . There are two or three fair medullary processes close to, and sometimes riding one over the other, a little on this side the fourth ventricle, or about the beginning of the calamus scriptorius, by which the two processes, which descend from the cerebellum to the medulla oblongata, are joined together; and there are two more, which, from that other transverse process behind the corpora quadrigemina, come down to these. These long medullary processes I never find wanting, though in different numbers, sometimes having seen two, and once I could find but one—though larger than ordinarily—and constantly, in what number soever, they terminate in the transverse processes at the afore-

mentioned beginning of the fourth ventricle. These long descending processes are just over against the corpora pyramidalia, on the other or under side of the medulla oblongata; and the transverse processes, at the beginning of the fourth ventricle last mentioned, are a little above the origin of the eighth pair of nerves [according to Willis], insomuch that without being circumspect, one may mistake them for the origin of that nerve, whereas in reality I find them to be the origin of the soft or hindermost branch of the seventh pair" (pp. 136-138).

In Figure vii. of this author is represented the superficial rima of this ventricle and of the calamus scriptorius, with the first process of the cerebellum, which runs towards the corpora quadrigemina, stretched out laterally; and with another transverse rima drawn laterally almost through the middle of the ventricle, the origin of which seems to be twofold, and its communication in the middle threefold; together with still another, which, near the sides of the ventricle, runs between the two transverse processes, uniting the same.

703. WINSLOW.[1]—"On separating the two lateral lobes or parts of the cerebellum, after having first made a pretty deep incision, we discover first of all the posterior portion of the medulla oblongata; and in the posterior surface of this portion, from the corpora quadrigemina all the way to the posterior fissure in the body, and a little under it, we observe a long cavity which terminates in the rear, like the point of a writing-pen. This cavity is what is called the fourth ventricle. At the beginning of this cavity, immediately behind the aqueduct of Sylvius, under the corpora quadrigemina, we meet with a thin medullary lamina, which is looked upon as a valve between that duct and the fourth ventricle. A little behind this lamina, the cavity grows wider both towards the right and the left, and then contracts again to its first size. It is lined interiorly by a thin membrane, and seems often to be distinguished into two lateral parts, by a kind of small groove running from the valve

[1] "Anatomical Exposition," etc., Sect. X.

of Vieussens to the point of the calamus scriptorius. This membrane is a continuation of that which lines the aqueduct of Sylvius, the third ventricle, infundibulum, and the two lateral ventricles. In order to see the fourth ventricle in its natural state, in which it is very narrow, it must be laid open, while the cerebellum remains in the cranium, and for this purpose the occipital bone must be sawed down very low. On each side of this ventricle is the medullary substance, which in the form of laminæ expands itself through the cortical strata of the cerebellum. These medullary laminæ are discovered according to their thickness, by cutting the cerebellum in slices almost parallel to the basis of the cerebrum; but if the cerebellum is cut vertically from above downwards, the medullary substance appears to be dispersed in ramifications through the cortical substance; these ramifications have been named the tree of life; and the two trunks, when these different laminæ arise, are termed the peduncles of the cerebellum (nos. 96-99). . . . The small branches of the medulla oblongata are lateral productions of the transverse protuberance, which, by their roots, seem to encompass that medullary portion in which the fourth ventricle, or the ventricle of the calamus scriptorius, is formed. These productions form, on each side in the lobes of the cerebellum, those medullary expansions, a vertical section of which shows the white ramifications commonly called the tree of life; and they may justly enough be called the peduncles of the cerebellum" (no. 108).

704. *Ruysch*, in a certain figure [in his Epistola Problematica, etc., xii., in Plate xiv., fig. 5] shows "some protuberances near the calamus scriptorius, and, indeed, in an infant, which," as he says, "can scarcely be called otherwise than the corpora pyramidalia and olivaria of the other side." I am not quite certain whether they are of the same kind as those mentioned by Willis,[1] whose words are as follows:—"Meanwhile, near the origin of the ninth pair of nerves which, in man, is found to be peculiar, and different from animals, the following is to be

[1] "Cerebri Anatome," Cap. XVIII.

mentioned:—In man, below the origin of the eighth pair of nerves, a certain protuberance is found attached on either side to the sides of the medulla oblongata. Four or five distinct fibres proceed thence; one or two of these entwine the vertebral artery which passes through here; all, however, coalesce in the same trunk, which is a nerve of the above-mentioned pair. When the pia mater is pulled off, this protuberance is easily seen, and it seems to be a peculiar storehouse of the spirit, destined for this nerve" (pp. 120, 121).

If the reader chooses he may examine *Heister's* plates where the fourth ventricle is represented with the arborescent ramification in the human brain, with still another representation of this ramification in the brain of a calf. Compare also Ridley's Plate vii., and Willis' Plates iii., vii. and viii. in his treatise on the Human Brain, as well as in his treatise on the Soul of Brutes.

[MODERN AUTHORS.

a. The Valve of Vieussens.

704*a*. Quain.[1]—"The *valve of Vieussens* (velum medullare anterius), stretched between the processus a cerebello ad cerebrum, is a thin layer of nervous matter, which lies over the passage from the third to the fourth ventricle, and, lower down, covers in a part of the fourth ventricle itself. It is narrow in front where it is connected with the quadrigeminal bodies, and broader behind where it is continuous with the median portion of the cerebellum.

"The valve is composed of white substance, superficial in its upper portion, but concealed in its lower half by a few transverse ridges of grey matter which appear as if prolonged from the grey laminæ of the cerebellum with which the valve is there continuous. Within it is some grey substance which constitutes the *nucleus of the roof of the fourth ventricle* of Stilling, and is supposed to connect the two dentate nuclei.

[1] "Elements of Anatomy." Eighth Edition. London, 1876.

"From between the posterior quadrigeminal tubercles a slight median ridge, named *frænulum*, descends a little way upon the valve, and on the sides of this, the commencing fibres of the fourth pair of nerves pass transversely outwards. The back part of the valve is overlapped and concealed by the superior vermiform process of the cerebellum" (ii., p. 552).

The following description of the *valve of Vieussens* is contained in the NINTH EDITION of Quain's "Elements of Anatomy:"—"The triangular interval between the two crura—the superior peduncles of the cerebellum—is bridged over by a lamina of white matter marked across with grey streaks. This is the *superior* (anterior) *medullary velum* or *valve of Vieussens*, and with the crura forms the posterior boundary of the upper part of the fourth ventricle. The white substance of which it is mainly composed is marked superficially by three or four flat transverse grey laminæ, with intervening sulci, which together constitute the so-called *lingula*. This is continued laterally and posteriorly into the grey cortex of the cerebellum, while the subjacent white substance of the velum is in direct continuity with the central white matter of the cerebellum, into which a pointed tent-shaped projection of the roof of the ventricle extends. This projection is bounded below by the *inferior* (posterior) *medullary velum*, which in like manner is prolonged from the white substance of the central part of the cerebellum. It is less easily displayed than the superior velum, being concealed by a part of the cerebellum, which is attached to its under or posterior surface" (ii., p. 304, *et seq.*).

704*b*. MEYNERT.[1]—"The *valve of Vieussens* is enclosed between the processus cerebelli ad cerebrum at that part of their course which lies between the corpora quadrigemina and the cerebellum, and together with these processus it forms, to use Burdach's expression, the *connective system* of the cerebellum. This valve of Vieussens, the prolongation of the frænulum veli medullaris, as has been shown by Arnold, is the part that really deserves the designation of processus cerebelli

[1] "Op. citat."

ad corpus quadrigeminum, which has been wrongly applied to the processus cerebelli ad cerebrum.

"In the velum medullare, three different systems of medullary fibres lie woven together: (1) the great mass of its substance is composed of the fasciculi of the frænulum; (2) at its anterior extremity the decussating fasciculi of the nervus trochlearis, which are of great thickness, intertwine themselves transversely among those of the frænulum; (3) the velum medullare further contains longitudinal fibres from the superior vermiform process of the cerebellum. These fibres decussate before quitting the borders of this latter organ, and after traversing the valve of Vieussens almost to the lower border of the corpus quadrigeminum they turn on themselves, and, describing curves which with their convexity look upwards, they join the inferior lamina of the lemniscus at its hindermost fasciculus, and pass onward with the latter, in the posterior division of the pons Varolii, to the spinal cord" (p. 713).

b. The Fourth Ventricle.

704*c*. Quain.[1]—"The space left between the medulla oblongata in front, and the cerebellum behind, is named the fourth ventricle, or *ventricle of the cerebellum.* The cavity of the ventricle is of a flat rhomboidal shape, being contracted above and below, and widest across its middle part. It is bounded laterally by the superior peduncles, and by the line of union of the medulla oblongata and the cerebellum. Behind, it is covered in above by the valve of Vieussens, which extends across between the superior peduncles of the cerebellum, and below by part of the inferior vermiform process of the cerebellum which projects into it. The upper end of the ventricle is continuous with the Sylvian aqueduct or passage (*iter*) leading up to the third ventricle" (p. 512).

704*d*.[2]—"The fourth ventricle is the space into which

[1] Quain's "Elements of Anatomy." Eighth Edition. London, 1876.
[2] *Do.* *do.* Ninth Edition. London, 1882.

the central canal of the cord, after becoming somewhat enlarged and cleft-like, opens out on the posterior or dorsal aspect of the medulla. The opening-out seems as if effected by the divergence of the funiculi graciles on either side at an acute angle, but the lateral boundaries of the ventricle curve round with their convexity towards the ventricle, and the latter rapidly broadens, so that opposite the middle peduncle of the cerebellum it has attained its greatest width. From this point its upper part again narrows, converging gradually above to be continued into the comparatively narrow Sylvian aqueduct. The ventricle is therefore irregularly lozenge or diamond-shaped, and is sometimes named *fossa rhomboidalis.* The pointed lower end of the ventricle has the shape of a writing pen, and is termed the *calamus scriptorius.* At its widest part the fourth ventricle is continued for a short distance on either side between the cerebellum and medulla, where these come in contact in the form of the pointed *lateral recess.* The lateral boundaries of the ventricle, in its lower or medullary part, are the clavæ of the funiculi graciles, the funiculi cuneati, and the restiform bodies. The roof of the posterior wall is formed by a simple layer of flattened epithelium covered by pia mater; but it is not quite complete, for there is a hole in it termed the *foramen of Magendie,* a little above the place where the central canal opens out into the ventricle, and there are two other apertures in the epithelial roof in the lateral recesses just mentioned. At the sides and below, this layer of epithelium passes into continuity with the epithelium covering the floor, but it is somewhat thickened by the addition of white nervous matter before reaching the lateral boundaries of the floor. This thickening is left as a slightly prominent and often ragged membrane, when the epithelium of the roof of the ventricle is torn off with the pia mater. It commences at the apex of the clava, and accompanies the lateral boundary for a short distance; then turns over the surface of the restiform body and terminates close to the place from whence the roots of the vagus and glosso-pharyngeal nerves issue. It is termed the *tænia* or *ligula,* and its upper transverse part forms the lower boundary of the lateral recess of the ventricle. Another thickening in the epithelial membrane is sometimes seen at the apex of the ventricle roofing over the point of the calamus scriptorius: this is named the *obex.*

"Two longitudinal vascular inflections of the pia mater, known as the choroid plexuses of the fourth ventricle, project from the roof into the cavity on either side of the middle line, covered everywhere, however, by the epithelium of the roof. Offsets from these pass also into the lateral recesses, from the apices of which they emerge, encircled by a duplicature of the ligula, which was termed by Bochdalek the *cornu-copia.* The epithelial layer of the roof of the ventricle follows all the convolutions of the choroid plexuses, but is nowhere pierced by them; it is generally described as the epithelium of the plexuses.

"The part of the floor of the fourth ventricle, which belongs to the description of the medulla oblongata, is marked off superiorly by some transverse white lines which cross the grey matter of the floor, and are known as the *striæ medullares seu acusticæ.* These arise close to the median line, and curve outwards over the restiform bodies to join the roots of the auditory nerve. They sometimes form a tolerably compact bundle; sometimes are more separate from one another, and occasionally are not to be made out on the surface, probably in these cases having a deeper course.

"This lower and smaller part of the floor of the ventricle is bisected by a slight median groove. A little on either side of this groove, and immediately below the striæ medullares, is a small triangular depression—*inferior fovea*—the apex of which extends only as far as the striæ, but the base is prolonged into two grooves, extending one from each angle. The inner of the two grooves passes with a slightly curved course towards the point of the calamus scriptorius, and thus cuts off a pointed triangular area which is bounded mesially by the median sulcus, and the base of which is turned towards the striæ acusticæ. This area is slightly prominent, and constitutes the lower end of what will presently be described as the *fasciculus* *teres;* in it is the prolongation of the tract of nerve-cells from which the roots of the hypoglossal nerve take origin.[1] The groove, which is prolonged from the outer angle of the fovea, passes downward with a slight outward obliquity nearly to the lateral boundary of the ventricle, and marks off externally another triangular area, the base of which is also directed upwards, where it can be traced into a prominence (best marked in children) over which the striæ acusticæ course. To this prominence Schwalbe has given the name *tuberculum acusticum,* since the main part of the auditory nerve arises in connection with it, and with the triangular lateral area behind.

"Included between the two grooves is a third triangular area, the apex of which is at the inferior fovea, while its base looks downwards and outwards. This area has a distinctly darker colour than the rest of the floor of the ventricle, and especially than the funiculi teretes on the inner side, which have a whitish-grey appearance, and it has accordingly been named the *ala cinerea.* Towards the apex it is somewhat depressed, but below it is elevated into a distinct prominence —*ala cinerea.* It contains the nucleus of the vagus, and superiorly, near the fovea, of the glosso-pharyngeal nerve" (pp. 290, 291).

"The floor or anterior boundary of the upper portion of the fourth ventricle, close to which the above nuclei [those of the cranial pairs of nerves, from the fifth to the seventh, hard and soft portions,] are for the most part situated, is marked in the

[1] This description of the *fasciculus teres,* as given on p. 293, is as follows:— "When the slit-like upper end of the central canal opens out into the fourth ventricle, the small remaining portion of the base of the anterior cornu [of the spinal cord] comes to the surface of the floor of the ventricle, and, as the sections are traced forward, increases gradually in size, producing the eminence of the *funiculus teres.* In it, both in the lower part of the medulla where the canal is still closed, and above where it has opened out, a group of large nerve-cells is seen in the transverse sections, representing a longitudinal vesicular column. From this column of cells the successive bundles of the roots of the hypoglossal nerve arise and pass obliquely through the substance of the medulla. . . . The tract of nerve-cells is accordingly known as the *hypoglossal nucleus.*" Compare above no. 688*h.*—EDITOR.

middle of each lateral half by a distinct, somewhat angular depression, in a line with the inferior fovea, from which it is separated by the eminence over which the striæ acusticæ pass. This depression is termed the *superior fovea*. Between it and the median sulcus is the prolongation of the fasciculus or *eminentia teres*, which is prominent opposite the fovea, but becomes gradually less so above and below. Extending from the anterior fovea to the upper end of the ventricle, where this narrows to the Sylvian aqueduct, is a shallow depression distinguished in the adult by its grey or slaty tint, which is due to a subjacent tract of pigmented nerve-cells—*substantia ferruginea*. It is known as the *locus cœruleus*.

"The lateral boundaries of this part of the ventricle are formed by the superior peduncles of the cerebellum. These pass gradually to the roof of the ventricle as they extend forwards and upwards. They are at first separated from one another by a tolerably wide interval, which, however, gradually narrows near the end of the ventricle, the two crura of opposite sides there approaching one another, and their margins coming in contact. The triangular interval between the two crura is bridged over by a lamina of white matter marked across with grey streaks—the *superior medullary velum* or *valve of Vieussens*"—[see above, no. 704*a*] (ii., p. 304).

704*e*.[1] "NERVE-NUCLEI IN THE FLOOR OF THE FOURTH VENTRICLE.—A continuous series of collections of grey matter, which extends from beneath the corpora quadrigemina downwards, along the floor of the fourth ventricle, and the centre of the medulla oblongata as far as the decussation of the pyramids, constitutes the nuclei of origin of the cranial nerves from the third to the hypoglossal. Those nuclei, contained in the medulla oblongata proper, give origin to the hypoglossal, the spinal accessory, the vagus, and the glosso-pharyngeal nerves. . . . At the point of the calamus scriptorius the prominence on each side of the median furrow indicates the position of the lower part of the *vagal* nucleus. A little higher

[1] Quain's "Elements," etc. EIGHTH EDITION. London, 1876.

up these vagal eminences diverge, and between them the *hypoglossal* nuclei come to the surface. A depression on each side of the vagal eminence separates it from the inner *auditory* nucleus. Beneath this groove, just below the striæ medullares, lies the nucleus of the *glosso-pharyngeal* nerve. The hypoglossal nuclei cease near the striæ medullares, but the eminence beneath which they lie blends with that of the vagal nucleus, and is continued upwards as the 'eminentia teres.' Beneath it, above the striæ medullares, lies the common nucleus of the *sixth* and *facial* nerves" (ii., p. 510).

c. THE CEREBRO-SPINAL LIQUID.

704*f*. COTUGNO.[1]—"Whatever there be between the dura matral sheath and the spinal cord, the whole of this space is *filled*, and indeed always. It is not filled with spinal marrow which is more swollen in living subjects; nor is it filled with a vaporous mist, as in this still obscure subject is supposed by some eminent men; but it is filled with a *water* which is similar to that contained around the heart by the pericardium; further, to that which fills the ventricles of the brain, the labyrinth of the ear, and in short the remaining cavities of the body, which are never to be approached by the open air (§ ix., p. 19).

"Not only the dura-matral tube, whereby the spinal cord is insheathed and the cord itself constantly engirded, is thus filled up by the water mentioned above, from the occiput down to the lowest part of the os sacrum—but this water abounds also in the very cranial cavity, filling up all the interstices between the brain and the enclosing dura mater. Some interstices of this kind always occur at the base of the cerebrum; and it is

[1] *Dominici Cotunnii*, Phil. et Med. Doct., "de Ischiade Nervosa Commentarius." Neapoli et Bononiæ, 1775.—Other editions of this now famous little treatise are as follows: 1. Naples, 1764; 2. In *Sandifort's* "Thesaurus dissertationum, programmatum et disputationum selectissimarum." Vol. II. Rotterdam, 1769; 3. Vienna, 1770; 4. An English translation published in London in 1776.

not at all an uncommon thing for a considerable interval to be found between the surface of the brain and the encompassing dura mater . . . (§ x., p. 19).

"The unreasonable method usually followed in the dissection of bodies is the cause why so great a collection of water in the spine, or around the brain, has hitherto escaped the attention of the anatomists. For those who are desirous of examining the brain usually sever the head from the neck. But when this is done and the dura-matral tube, which passes down through the cervical portion of the spine, is cut through, the whole of that moisture, which has collected around the brain and the spinal cord, flows out, and is heedlessly lost. When, therefore, the cranium is opened, all the interstices between the brain and the dura mater, which were heretofore filled with water, are then discovered to be empty . . . (§ xi., p. 20).

"In order, therefore, to observe manifestly the large collection of humour around the brain and spinal cord, the following directions have to be carefully followed. Let the head of a fresh body be raised up, and after the muscular covering has been removed, and the cranial bones have been laid bare, let the cranial roof be removed by a horizontal section. At this initial stage of the operation, great care must be taken, lest during the sawing of the bone, or during its removal from the dura mater, this latter membrane should be perforated anywhere. If, however, it has been preserved whole, and has been stripped off the bone, and if the body is that of an old man or of a cachectic person, wherever you make an incision, water will flow out; if it does not, the dura mater is filled up exactly by the brain. Let the dura mater now be dissected forthwith, and the brain laid bare, and then it will appear whether anywhere under the arachnoid membrane there are any air-bubbles, however small. If now the anterior cerebral lobes are raised up with the open hand, it will be noticed that the ethmoid bone on either side abounds with water; and if the rest of the brain be elevated, it will be found that all that part under the chiasma of the optic nerves, and at the sides of the pons Varolii, which is empty in those heads which are severed from the neck, is full of water. This water fills also the cavity in the sheath of the fifth pair of nerves, and the whole meatus acusticus. Around the caudex of the medulla oblongata every interval is filled with water. Let the caudex now be cut through, and the cerebrum and cerebellum be removed, and the whole body raised up, and it will be observed, that the dural tube, which encloses the spinal cord, is totally filled with water which surrounds the whole medulla. If now, after all this has been accomplished, the sides of some of the lumbar vertebræ are cut off perpendicularly, and an incision is made into the lower part of the dural tube which embraces the cauda equina, and which has been laid bare, a clear liquid will flow out. During this discharge, the liquid, which was visible around the upper part of the spinal column, gradually subsides, until at last the whole of it trickles out through the opening at the bottom. If, the head being left untouched, the lumbar vertebræ are opened, and an incision is made into the enclosed dural tube, a considerable quantity of moisture will be discharged. If, however, all that quantity, which of its own accord has made its way towards the place of incision, has been discharged; and if afterwards you raise the head of the body, and shake it, a new and more abundant flow of liquid, as if a new source of it had been unstopped, will be directed towards the open place. These experiments I repeated at different times in about twenty adult bodies, and I was able to draw freely from the cavity of the spine four, and sometimes as many as five ounces of water. This water was found perfectly limpid and clear in adults, although in some cases it had a slight yellowish tinge; in fetuses, however, which had been suffocated by a difficult birth, however small the quantity of the water, it was always found to be of a reddish colour and opaque (pp. 21-23).

"It seems to be beyond all possible doubt that the vapour of the spine, as well as that which moistens the remaining cavities of the body, constantly exudes from the extremities of the least arteries, and is again reabsorbed through the least veins by which it is inhaled. . . . I do not entertain, however, the shadow of a doubt, that presently there are commingled with these waters of the spine also those which are received by the fourth ventricle, either from the lateral ventricles of the brain through the third ventricle and the aqueduct of Sylvius, or from the cerebellum by an exhalation from its own arteries. The vertical position of the fourth ventricle, and the fact of the way thence into the cavity of the spine being sufficiently open, favour the conviction that there is a discharge of moisture thence into the spine" (§ xiv., p. 24).

704*g*. CRUVEILHIER.[1]—"There exists around the spinal cord a serous fluid, in quantity sufficient to occupy the interval left between the cord and the dura mater: this fluid is seated in the sub-arachnoid space. A similar fluid exists in the ventricles of the brain and in the sub-arachnoid cellular tissue, and fills the free spaces of the cranial cavity.

"The existence of the sub-arachnoid fluid was pointed out by Haller (*Elementa Physiologiæ*, T. iv., p. 87), and most explicitly and completely demonstrated by Cotugno (*De ischiade nervosa commentarius*), but the fact was neglected by anatomists, and the fluid regarded by some as the result of cadaveric exudation, and by others as that of a morbid action. The existence of this fluid has been again confirmed by M. Magendie, who, moreover, has clearly proved that it is seated in the sub-arachnoid tissue. . . .

"The objection that this fluid is found after death, but does not necessarily exist in the living subject, is overthrown by the following experiment:—If the posterior cervical muscles be divided in a living dog at their occipital attachments, the posterior occipito-atlantoid ligament will be exposed. The parts being well cleansed, the ligament must be cut away layer by layer, with a scalpel held flat against it. The ligaments will scarcely be cut through, before a small hernial protrusion, containing a fluid, will be seen; this consists of the visceral arachnoid [the arachnoid proper] raised by the rush of fluid. If

[1] "Descriptive Anatomy," in *Tweedie's* "Library of Medicine." London, 1842.

a crucial incision be then made in the occipito-atlantoid ligament by the aid of a director,[1] a fluid as limpid as distilled water will be seen beneath the arachnoid, which fluid is agitated by two kinds of motion, one of which is isochronous with the pulse, and the other with the respiratory movements. If the arachnoid be next punctured, the fluid will immediately escape in jets, and its quantity may be ascertained. . . .

"The sub-arachnoid fluid exists not only in the vertebral canal, but also within the cranium in which it fills up all the spaces between the brain and the dura mater. . . . The quantity of the sub-arachnoid fluid is in direct ratio with the progress of age; in aged lunatics, in whom the convolutions of the brain are much atrophied, the quantity of this fluid contained within the cavity of the brain is very great; none of these facts escaped the notice of Cotugno. The sub-arachnoid fluid in the cranium is not distributed equally around the brain, but is chiefly seated at its base. In order to show this fluid, it is merely necessary to raise up the brain carefully from before backwards, when it will be seen distending all the funnel-shaped prolongations formed by the arachnoid around the nerves, and it will escape as soon as the membrane is divided" (ii., pp. 920, 921).

704*i*. QUAIN.[2]—"This is a very limpid serous fluid which occupies the sub-arachnoid space. When collected immediately after death, its quantity was found by Magendie in the human subject to vary from two drachms to two ounces. It is slightly alkaline, and consists, according to an analysis by Lassaigne, of 98·5 parts of water, the remaining 1·5 per cent. being solid matter, animal and saline. In experiments made on the dog, it was found by Magendie to be reproduced in thirty-six hours after it had been drawn off, by puncturing the membranes at the lower part of the cord. When pressure is made upon the

1 "It is highly important to make the transverse incision very short, in order to avoid injuring the very large cerebral veins; for if these vessels be cut, the hemorrhage will be so abundant as to prevent the continuation of the experiment."

2 "Elements of Anatomy." EIGHTH EDITION. London, 1876.

brain, the quantity of fluid in the spinal sub-arachnoid space is increased, and conversely it may be forced from the spinal column upwards into the cranium" (ii., p. 575).

The literature on the subject of the Cerebro-Spinal Liquid will be found in the Appendix, at the end of Note vii.—EDITOR.

d. The Foramina of the Fourth Ventricle.

704*j*. KEY AND RETZIUS.[1]—"Magendie's description of the foramen at the lower end of the fourth ventricle is as follows:—He discovered a real, constant and normal aperture through which the cerebro-spinal fluid perpetually passes, in order to enter and to leave the fourth ventricle. This aperture is situated at the lower extremity of the fourth ventricle which, by the older anatomists, was called the calamus scriptorius. In order to convince yourself of the existence of this opening, all you have to do is to raise a little the edges of the inferior vermiform process of the cerebellum and draw them apart. Without tearing any of the tissues, whereby the vessels of this portion of the cerebellum are attached to the pia mater of the spinal marrow, you will then see an actual inlet terminating in the fourth ventricle. This is the anterior side of the foramen [turned towards the medulla oblongata]; its lateral, as well as its upper sides are formed by the choroid plexus and a medullary lamina, which is more or less extensive, and which is firmly inrooted in the lateral and in the prolonged extremities of the fourth ventricle. The shape and size of this foramen vary with different individuals, for they are proportionate to the quantity of the cerebro-spinal liquid. Sometimes, when this fluid is very abundant, the foramen is large enough to admit the end of a finger. Ordinarily, and when there is the normal quantity of this liquid, the diameter of the foramen in every direction is from two to three lines, and often it is divided into several compartments by vessels passing from the medulla oblongata

[1] *Axel Key* and *Gustaf Retzius*. "Studien in der Anatomie des Nervensystems und des Bindegwebes." Vol. I. Stockholm, 1875.

into the cerebellum. Sometimes the caliber of the foramen is reduced by one or both of the posterior arteries of the cerebellum passing in front of it. Magendie called this foramen the common 'orifice of the encephalic cavities'" (p. 12).

704*k*. "Luschka[1] affirmed the existence of the foramen between the fourth ventricle and the sub-arachnoid spaces, and called it after its discoverer—*foramen Magendii*. According to him, this foramen is of normal occurrence in man, but not in all animals. He says, 'As to the result of my investigations in the horse, I found, in agreement with Renault, that the lower end of the fourth ventricle in these animals is completely closed up.' . . . In addition to the foramen Magendii, Luschka discovered two additional foramina leading from the fourth ventricle into the sub-arachnoid spaces. His description is as follows:—'On either side, the outer angles of the fourth ventricle assume the form of a gutter leading outside, whereby the latter portion of the choroid plexus passes outside of the fourth ventricle, while the arachnoidea stretches freely over the place in question. The fourth ventricle, therefore, by its exterior angles, has an open communication with the sub-arachnoid space. The hiatus, where the pia mater passes over into the ependyma, meanwhile, through the lateral portion of the choroid plexus of the fourth ventricle, is so much contracted, that only a narrow slit remains, which is, however, sufficiently ample to furnish an entrance here, under the arachnoidea, to a liquid which is injected from below with a tubulus, the tela choroidea inferior still being fully preserved. This anatomical fact is of considerable importance, because in some animals, for instance, the horse, the lower extremity of the fourth ventricle is completely closed up, in which case the exterior angles of this cavity are the only means whereby a communication may be effected between the fourth ventricle and the sub-arachnoid space'" (p. 20).

704*l*. The results obtained by Key and Retzius themselves are as follows:—"As a direct proof of the existence of the foramen Magendii, we regard that furnished by injections.

[1] "Adergeflechte," etc. Berlin, 1855.

Such injections with congealing substances, namely, glue and paraffin, we made from the sub-arachnoid spaces of the spinal cord, as well as from the ventricles of the cerebrum. The injected mass was found in an uninterrupted state of continuity, and indeed in all stages of progress, from the 'cisterna magna,' pursuing its way through the foramen Magendii into the fourth ventricle; sometimes it extended into the ventricle simply in the form of a long bolt. . . . Once only we found the foramen Magendii closed by a thin membrane, which membrane seemed to be an immediate continuation of the tela choroidea" (p. 54).

Their own experience, in respect to the two lateral foramina described by Luschka, is as follows: "The existence of these lateral foramina under normal conditions is decidedly corroborated by the injections. Whether these injections were made from the sub-arachnoid spaces, or from the ventricles of the cerebrum, the congealed mass was found continued from the fourth ventricle through the lateral foramina, and in an uninterrupted state of conjunction with the mass in the sub-arachnoid spaces. When the injections were made from the direction of the aqueduct of Sylvius, with a mass of glue which quickly congealed, and when the injection soon after was interrupted, we succeeded in obtaining the mass issuing from the lateral foramina, as well as from the foramen Magendii, in the form of bolts which extended only a short distance outside. Such injections furnish very instructive preparations; they also show how easily a sluggish mass, almost in the act of congealing, passes outside of the ventricle through the lateral foramina, even when the foramen Magendii is open. Like the foramen Magendii, either of the two lateral foramina, or even both of them, may be closed. This was observed already by Luschka" (pp. 119, 120).

704*m*. QUAIN.[1]—"The sub-arachnoid space communicates with the ventricles of the brain by means of the foramen of Magendie, the opening into the lower part of the ventricle, through the pia-matral expansion (tela choroidea inferior) which closes it.

[1] "Elements of Anatomy." NINTH EDITION. London, 1882.

Two other openings through this membrane exist, one on each side, behind the upper roots of the glosso-pharyngeal nerve, in the pouch-like extension of the membrane beneath the flocculus" (ii., p. 376).

e. The Spinal or Central Canal.

704*n*. Henle.[1]—"By the improved methods of investigation of modern times, and especially by the microscopical examination of thin horizontal sections, it has been placed beyond doubt that the central canal, which formerly was considered as a formation peculiar to the fetus, and which in adults was allowed to exist only in the cervical portion of the spinal cord, is of regular occurrence in all vertebrata of all ages, and in every part of the spinal cord. A difference of opinions, however, still prevails on the question whether there are not more or less frequent exceptions to this rule. The following observers admit the absolute constancy of the central canal: Bidder, Owsjannikow, R. Wagner, Schröder van der Kolk, and Stilling, and they are of opinion that the non-discovery of this canal is due to a fault in the methods of preparation or of hardening. Foville maintains that this canal is constant in children, and easily demonstrable in their case, but not so easily in adults. Kölliker, on the contrary, firmly maintains that not unfrequently the central canal becomes obliterated, mostly in the cervical portion; in which case it is replaced by a cord of cells which partly contain several nuclei," etc. (p. 43).

704*o*. Quain.[1]—"Central canal.—Extending through the whole length of the spinal cord, in the substance of the grey commissure, there is a minute central canal which, in prepared transverse sections of the cord, is barely visible, as a speck, with the naked eye. Superiorly it is continued into, and opens out at, the calamus scriptorius of the fourth ventricle; and

[1] "Handbuch der systematischen Anatomie des Menschen," Part iii. Braunschweig, 1871.

[2] "Elements of Anatomy." Eighth Edition. London, 1876.

inferiorly, at the extremity of the conus medullaris, it becomes enlarged, shaped like the letter T, and extends backwards to the surface of the cord, being covered in only by pia mater and connective tissue. This canal, though minute, is an object of considerable interest as a typical part of the structure of the cord, it being the permanent remains of the cavity of the cylinder, formed by the spinal cord at the earliest period of its development. It is more distinctly seen in fishes, reptiles and birds, than in mammals" (ii., p. 496).

704*p*. CARPENTER.[1]—"The 'spinal canal,' which is continued downwards from the fourth ventricle, is about one-hundredth of an inch in diameter, and, according to Mr. Lockhart Clarke, is lined with a layer of columnar ciliated cells, whose attached extremities taper into delicate fibres, becoming continuous with the fibres of the connective tissue of the white column" (§ 481).

f. THE SUB-ARACHNOID SPACE.

704*q*. QUAIN.[2]—"The sub-arachnoid space—the space between the arachnoid membrane and the pia mater—is larger and more evident in some places than in others. Thus, in the longitudinal fissure, the arachnoid does not descend to the bottom, but passes across, immediately below the edge of the falx, at some distance above the corpus callosum. In the interval thus left, the arteries of the corpus callosum run backwards along that body. At the base of the brain and in the spinal canal there is a wide interval between the arachnoid and the pia mater. In the base of the brain, this sub-arachnoid space extends in front over the pons and the interpeduncular recess as far forwards as the optic nerves, and behind it forms a considerable interval between the cerebellum and the back of the medulla oblongata. In the spinal canal, where it surrounds the cord, it is of considerable extent. It is occupied, in both brain

[1] "Principles of Human Physiology." SEVENTH EDITION, 1869.
[2] "Elements of Anatomy." NINTH EDITION, 1882.

and cord, by trabeculæ and thin membranous extensions of delicate connective tissue, connected on the one hand with the arachnoid, and on the other with the pia mater. This tissue is most abundant where the space between the two membranes is least. It is dense in the neighbourhood of the vessels and is continuous with the tissue of their walls. In the sub-arachnoid space, at the base of the brain, in several places the arachnoid is separated by larger intervals than at other parts from the pia mater.

"The sub-arachnoid space communicates with the ventricles of the brain by means of the *foramen of Magendie*, the opening into the lower part of the fourth ventricle, through the pia-matral expansion (tela choroidea inferior) which closes it. Two other openings through this membrane exist, one on each side, behind the upper roots of the glosso-pharyngeal nerve, in the pouch-like extension of the membrane beneath the flocculus.

"A certain quantity of fluid is contained between the arachnoid membrane and the dura mater; but the chief part of the cerebro-spinal fluid is lodged in the sub-arachnoid space in the meshes of the trabecular tissue.

"The spinal sub-arachnoid space is divided by an imperfect fibrous septum on either side termed the ligamentum denticulatum into interior and posterior portions. . . . Sub-arachnoid trabeculæ also connect the nerve-roots with the inner surface of the arachnoid, and in the dorsal region fine membranous trabeculæ extend between the posterior nerve-roots, and the *posterior septum*—a sort of septum dividing the sub-arachnoid space at the back part of the cord. In most cases, however, the sub-arachnoid trabeculæ are far less developed in the spinal canal than in the cranium" (ii., p. 376).

g. The Lymphatic Spaces in the Peripheral Nerves.

704*r*. Cotugno.[1]—"There remains to us now to examine carefully whether the moisture of the spine, which has been

[1] "De Ischiade Nervosa Commentarius." Naples, 1775.

described above—the cerebro-spinal liquid—penetrates the sheaths of the nerves which originate from the spinal cord, so as to bathe and warm the nerves which descend into and are propagated through the body, even as it affords the same use to the whole of the medulla. The same dura-matral tube, by which the spinal cord is enclosed, receives also in a funnel-like appendage, and in a kind of loose sheath, the separate nerves which depart from the spinal cord. This same sheath attends the nerve freely, until at its point of departure from the spine it produces a ganglion. Now, inasmuch as the cavities of all those sheaths, which receive in themselves the nerves of the spinal cord, are continuous with the cavity of the dura-matral tube which encloses the spinal cord, and as these cavities are uninterruptedly filled with the very same vapour or moisture, it is evident that each nerve, as far as its ganglion, is warmed by the moisture of the spinal cord. For each of these dural sheaths, which had remained open so far, becomes now fastened firmly around the ganglion, and from thence it is dissolved into cellular laminæ, which partly embrace the nerve on all sides, and partly invest also the individual nervous filaments. The vapour thus seems to be debarred from passing beyond the ganglion, wherefore we were willing to prove whether a passage was afforded to mercury even as it was to air. For the air when driven in through a tube, which was applied to the open orifice of the sheath on this side of the ganglion, overcame the ganglion, and all the sheaths which invested the nerve were in this manner quickly puffed up on the other side of the ganglion. Mercury, when injected and squeezed, travelled the same way through the narrow defiles of the ganglion, and penetrated into the very cellular sheaths of the nerve beyond. . . . And although the passage of the air and of the mercury beyond the ganglion could not be effected without some pressure, still the pressure was light, or, at all events, not so great as to suppose the existence of an obstacle which the spinal moisture could not overcome in a living man of its own accord, and without pressure. If, however, the purity of the spinal vapour and its aqueous character is taken into consideration, whereby it is enabled to penetrate much more easily than air and mercury, and if due weight is attributed to the circumstance of the paths which are to be crossed, being much looser in a living subject, and of the liquid, which is to pass through, being rendered more penetrating by warmth, there is sufficient reason why the opinion of those should not be impugned, who maintain that the nerves enjoy the benefit of the spinal moisture even beyond the spinal ganglion" (xxiv., p. 39).

704s. WILLIAMS.[1]—From a summary on the uses of the cerebro-spinal liquid we extract as follows: "The following statements, some of which we know to be matters of fact, while others are in our present state of knowledge necessarily hypothetical, I venture to bring forward:—

"That the cerebro-spinal fluid occupies that space which exists between the inner layer of the arachnoid and the pia mater; and that, as pointed out by Magendie, the ventricles of the brain communicate with this sub-arachnoidal cavity. . . .

"That the intra and extra-cranial sub-arachnoidal tubes, surrounding the cerebral nerves, as they emerge from the cranium, communicate continuously and directly with the fluid in the large intra-cranial sub-arachnoidal spaces, and consequently also with the spinal sub-arachnoidal sac.

"That the filaments of the roots of the cerebral and spinal nerves may be seen floating in the cerebro-spinal fluid. . . .

"That the quantity of the cerebro-spinal fluid is infinitely greater than is usually imagined or described; and that it is not only rapidly secreted, but also rapidly renewed. . . .

"That the cerebro-spinal fluid actually comes into contact with what we believe to be most important portions of the cerebro-spinal mass; and that it also is probably distributed throughout the whole of the brain and spinal cord, and even the *minutest peripheric terminations of the nerves*. . . .

[1] Williams (Joseph, M.D.). "On the Cerebro-spinal Fluid." In "Lancet" of Feb. 18, 1860.

"That the cerebro-spinal fluid is probably secreted by the cellular portion of the cerebro-spinal mass, or by the pia mater, and that it is being constantly diffused throughout the whole of the nervous system.

"That the pia mater not only dips down into the convolutions, as usually described, but that it probably, as a highly vascular and delicately attenuated membrane, penetrates into every portion of the cerebro-spinal mass, wherever the arterial blood is distributed. . . .

"That the alternate rise and fall of the cerebro-spinal fluid does not synchronize with the pulsations of the heart, but corresponds with the movements of respiration, there being an alternate compression and exhaustion, and hence the dynamic power for sustaining the circulation of the cerebro-spinal fluid.

"That undulatory motions and currents exist in all the cavities of the brain and spinal cord. . . .

"That when this fluid is deficient, perverted, and desiccated, it may cause a partial or complete paralysis, as also atrophic wasting of muscles; *moisture being so essential for all nervous action.*

"Such are the opinions, I venture, with great diffidence, to submit, as to the uses of the cerebro-spinal fluid. Its importance has certainly not yet been fully recognised. Only recently, when conversing with a distinguished physiologist, he told me he considered 'it played but a very subordinate part in the animal economy.' I would now, however, fain believe that but few persons will read this synopsis without at least acknowledging that this fluid must play a most important part in the animal kingdom" (pp. 165, 166).

704*t*. QUAIN.[1]—"The nerves, as they pass from the brain and spinal cord, receive their perineural covering from the pia mater, and in addition, two looser sheaths, an outer from the dura mater, and an inner from the arachnoid. Upon the optic nerve these sheaths remain distinct and separate, so that the space which each encloses can be injected, the outer from the sub-

[1] "Elements of Anatomy." NINTH EDITION. London, 1882.

dural, the inner from the sub-arachnoid space. On the other nerves, the arachnoidal sheath soon ceases, and the single sheath eventually blends with both the epineurium and perineurium of the nerves. Accordingly, it is found that an injection, driven into either the sub-dural or the sub-arachnoid space, passes readily along the nerves even as far as the limbs. There thus exists a continuity between the ventricles of the brain, the sub-arachnoid space, the perivascular canals of the cerebral substance, and the lymphatic spaces within the nerve-sheaths" (ii., p. 377).

704*u*. KEY AND RETZIUS.[1]—An Abstract of the generation of the "neurilemma," or of the connective tissue which forms the system of sheaths by which the spinal nerves are enclosed, as this is delineated and described in the magnificent work of these authors :

THE SYSTEM OF SHEATHS OF THE SPINAL NERVE-ROOTS.—After leaving the substance of the spinal cord, the anterior and posterior roots of the spinal cord are embraced by pia mater; and this membrane besides enters into their interior structure, and collects into fascicles or funiculi the nerve-fibres of which the roots consist (ii., p. 5).

The nerve-fibres themselves are separated from each other by a scanty interstitial tissue, consisting partly of very thin laminæ, and partly of fibrillous tissue with nuclei of protoplasm (ii., p. 6).

On entering the sub-arachnoidal space of the spinal cord, the nerve-roots are enveloped by the membranous and trabecular tissue peculiar to this space. Portions of this tissue let themselves down between the fascicles of the root, establishing thereby trabecular and membranous connections between them (i., p. 90).

On approaching the outer wall of the sub-arachnoidal space, the anterior and posterior roots draw nearer together so as to leave that space in company; the arachnoidea and dura mater

[1] "Studien in der Anatomie des Nervensystems und Bindegewebes." Stockholm. Vol. I., 1875; Vol. II., 1876.

each furnishing a sheath to the departing spinal nerves (ii., p. 7).

The sheath which consists of sub-arachnoid tissue is likewise continued; and it begins to connect itself now with the arachnoidea by means of a trabecular network. By this connection of the two there is formed the *sub-arachnoid space of the nerve-roots* (*Ibid*).

On the outside of the arachnoid sheath, however, between the latter and the dural sheath, there is formed the *sub-dural space of the nerve-roots* which is connected immediately with the sub-dural space of the spinal cord: for the arachnoidea is not, as is supposed, reflected on the internal surface of the dura. This dural space is richly interspersed by trabeculæ whereby the arachnoidal and dural sheaths are connected (*Ibid*).

In this manner the nerve-roots are attended by an arachnoidal and a dural sheath until the nerves reach the spinal ganglia (*Ibid*).

Before approaching the ganglion, however, the nerve-roots are first broken up more and more into fascicles; and here the dural sheath plays an important part. In the first place a dural partition is always erected between the anterior and posterior roots after they are united in one nerve. The dural sheath itself is fortified in addition on the outside by a layer of connective tissue derived from the outermost integument of the spinal cord which is attached interiorly to the bony surface of the vertebral column. In the nerve-roots this exterior tissue works itself more and more into the substance of the dural sheath, so that at last the boundary line between the two is effaced. A similar process takes place interiorly between the dural and the arachnoidal sheaths; for trabeculæ in an increasing ratio pass from the dura into the arachnoidea. Besides, through the mediation of small membranes which are generated between them, these two sheaths become attached to each other over larger or smaller tracts, so that at last they can be separated only through artificial means (ii., pp. 7, 8).

The dura mater, besides, goes on forming additional partitions between the individual fascicles; and between the dural partitions and these fascicles themselves there is always some arachnoidal tissue. The farther, therefore, the nerve-roots retreat from the cord, the more are they sub-divided into distinct nerve-fascicles, each of which is encompassed by an arachnoido-dural sheath. The arachnoidal sheath itself, however, as well as the partitions which it lets down into the interiors of the posterior root between the fascicles, the farther they are removed from the cord, become of a more robust structure by the insertion into them of fibrillous trabeculæ (ii., p. 8).

In the vaginal tissue, which in this manner is developed out of the dura and the arachnoidea through the mediation of trabeculæ and membranes, another formation is noticed as the nerve approaches the ganglion. For the intervals between the trabeculæ and membranes are beginning to be filled up with cellular tissue, marked with nuclei of a roundish shape, in the meshes of which are small spaces and passages of a varied form. This tissue, which is situated in the partitions between the fascicle, Key and Retzius denominate "*preparatory tissue*," because in this tissue, which becomes more abundant as the nerve-roots pass into the ganglion proper, nests of ganglionic cells are by-and-by discovered (ii., pp. 8, 25).

704*v*. The connective tissue formations in the ganglia. —On examining the spinal ganglion itself, the dural sheath is found to be continued over the whole surface of the ganglion, after it has first entered into an intimate conjunction with the adipose tissue from the vertebral theca, whereby the nerve-roots had been attended. Under the dural sheath of the ganglion the arachnoid tissue is continued, that is, the arachnoidea proper and the sub-arachnoidal tissue, which consists of many cellular membranes lying close to one another. The dura and arachnoidea are joined together in many places, and many trabeculæ pass from the former into the latter, so that the boundary-line between the two is effaced (ii., p. 22).

In the interior of the ganglion the so-called "preparatory tissue," alluded to above, is found more abundant between the several fascicles, and nests of ganglionic cells are now discovered in this tissue. These ganglionic cells seem to exert a dissolving influence on some of the nerve-fascicles which enter the ganglion, especially on those which are in their immediate neighbourhood, for they break them up into smaller bundles, each of which is encircled by its own laminated sheath. The remaining fascicles, however, which also preserve their laminated sheath, draw nearer to one another, and gradually are bound up into a more compact nerve-trunk. The interstitial tissue, termed "preparatory," is also inserted into the sheaths of the smaller bundles and fascicles adverted to above, which sheaths form partitions between them (ii., p. 26).

The ganglionic cells themselves, as already stated, are imbedded in this interstitial tissue which at one time partakes more of the character of the so-called "preparatory tissue," and is more cellular and spongy in its nature, and at another seems to consist of more sharply marked, thin, homogeneous, little membranes, which are detached from one another to a certain distance, presenting thus a laminated and stratified appearance (ii., p. 47).

Such laminated membranes, covered with membranous cells, as in appearance are very much like the little sub-arachnoid membranes, form a mass of small compartments throughout the whole of the ganglion, and here and there they press more closely together, thus forming more robust partitions through the ganglion. These laminated partitions envelop the smaller groups of nerve-fascicles, and combine with the sheaths which these fascicles have derived from the arachnoidal tissue. The thicker partitions, however, which consist of a number of laminæ crowded together, proceed towards the surface of the ganglion, where they unfold themselves, and branching out apply themselves closely to the interior surface of the ganglion, forming there a concentric layer of laminæ, each of which has its continuation into the interior. This interior stratum of laminæ is styled by our authors *the perineurium of the* *ganglion.* As these laminæ draw nearer to the outer surface of the ganglion, they are covered with stronger, elastic nets woven of fibres; oblique clefts also open here and there between them. Thence arises *the epineurium of the ganglion*, as it is called by our authors. As the epineurium approaches the outer surface of the ganglion fat appears in its tissue; it becomes looser, and is finally attached to the outermost adipose tissue of the ganglion (ii., p. 48).—As already indicated, it must not be supposed that the perineurium and epineurium are new creations wrought in the ganglion. They are simply homogeneous, laminated transformations of the dural and arachnoidal sheaths, which through the nerve-roots have been continued from the spinal cord.

As the laminæ of the perineurium, however, extend likewise into the interior of the ganglion, where they form numerous laminated partitions between the several groups and fascicles of the nerve-roots, our authors term these interior continuations *the endoneurium of the ganglion* (ii., pp. 48, 49).

704*w*. THE EPINEURIUM, PERINEURIUM AND ENDONEURIUM OF THE PERIPHERAL NERVES.—We now translate from Key and Retzius directly:—"Every larger nerve, as is well known, consists of a number of fascicles, all of which are held together by a connective tissue, the so-called *neurilemma.* Every fascicle, however, appears surrounded by a special sheath, for which we thought it advisable to retain Robin's appellation *perineurium.* The term 'neurilemma,' which is so very liable to be misunderstood, we have dropped altogether; and all that connective tissue which extends inwards from the perineurium, and which is thus contained in the interior of the nerve-fascicles we denominate *endoneurium*; while the connective tissue, outside the perineurium, which holds together the entire nerve, we term *epineurium.*

"The *perineurium* of the peripheral nerves we found to consist of a number of thin laminæ arranged in concentric order, which can easily be separated, and which here and there are connected by a small number of trabeculæ. These laminæ or membranes bear some resemblance to the arachnoidal membranulæ, and are in fact continuations of the same. Each perineural membrane, in our estimation, is composed of three strata; its outer and inner surfaces being each covered by an exceedingly delicate cellular tissue, with an intervening fibrillous stratum more or less developed, but usually only very slightly perceptible" (ii., p. 68).

"Each nervous fascicle surrounded by perineurium is distinguished into a greater or lesser number of sub-divisions. These sub-divisions are caused by detached perineural membranes withdrawing from the perineurium, and entering into the interior of the nervous fascicle, sub-dividing the same at first into larger divisions. While pursuing their way in this manner, these membranes become richer in fibrils, than they were while continuing in the perineurium. From these partition walls, which consist of several laminæ, one membrane after another is observed to turn aside, in order to partition off and enclose a still smaller division or group of nerve-fibres of the fascicle. The blood-vessels, after penetrating through the perineurium in connection with these endoneural membranes, make their way into the interior of the fascicles. These vessels are engirded by one or two of those cellular membranes which abound in fibrils, and which are arranged concentrically around their sheaths" (ii., p. 69).

"Outside the sheath of Schwann, which belongs more especially to the nerve-fibre itself, there are obtained by teasing more or less numerous, delicate fibrils of connective tissue. . . . In successful preparations they are seen arranged around the nerve-fibre in regular order, and forming a membrane which appears more or less distinctly marked with streaks, which are due to fibrils. These fibrils therefore belong to an outer sheath which encompasses each single nerve-fibre in the shape of an ample tube or pipe. These fibrillous sheaths, however, are not independent formations, but like the other fibrillous membranes mentioned above, they are always covered by membranous cells; for on the outer side of this fibrillous sheath there are always nuclei surrounded by a small protoplastic zone which extends into the thin membranous formation. . . . An injection, passing from the perineurium, between the endoneural membranes, into the interior of the nerve, sometimes enters on the way into the interstices between the fibrillous sheaths of the individual nerve-fibres; yet without remaining confined there, it penetrates even into the interiors of these fibrillous sheaths, thus irrigating immediately the sheath of Schwann. It seems most highly probable that these are the real lymph-paths or lymph-spaces of the nerves; and that each nerve-fibre, bathed by lymph outside of the sheath of Schwann, or rather floating in it, is contained in an imperfectly closed, fibrillous sheath. Thence there is an open way for the lymph into the spaces of the perineural sheaths; and through their mediation it communicates with the lymph-spaces of the central nervous system" (ii., p. 71).

"The fibrillous sheaths, as well as the membranes which enclose the groups of nerve-fibres within the fascicles, we term *endoneurium*" (ii., p. 102).

"Immediately to the outside of each nervous fascicle is the *epineurium*. It consists of concentrically arranged fibrillous membranes of connective tissue. . . . On either side these membranes are covered by a layer of membranous cells. Under this layer, in the middle between it and the fibrillous layer, are noticed fine elastic fibres in greater or smaller numbers. Not unfrequently nuclei of a copious collection of protoplasms, sometimes extending to a considerable distance in the form of spindles, are seen inserted between the fibres. These membranes, therefore, are distinguished from the perineural membranes, especially by the greater abundance of fibrils in their central layer, and also in general by a greater number of elastic fibres. They are fastened together, although they may often be rolled off from the nerve-fascicle in layers. According to a similar principle is constructed the outermost, more robust sheath of the entire nerve which encircles all the fascicles. Its interstices are filled up with adipose tissue" (ii., pp. 71, 72).

The following points are proved by the researches of Key and Retzius:—

1. The dura mater, the arachnoidea, and the sub-arachnoid tissue are continued from the central nervous organs into the very end-bulbs of every single nerve-fibre.

2. The dura mater is transformed into the epineurium of the departing nerves; and the arachnoidea, together with the sub-arachnoid tissue, into their perineurium and endoneurium.

3. The interstices between the laminæ of the perineurium and endoneurium are continuations of the sub-arachnoid space.

704*x*. INJECTION OF THE NERVE-ROOTS.—"In our earlier papers we have shown that, from the sub-dural space of the brain and spinal cord, a liquid passes with great ease between the dural and arachnoidal sheaths as far as the ganglion, and we have further shown that from the respective sub-arachnoidal space a liquid penetrates within the arachnoidal sheath, and between the fascicles of the nerve-roots as far as the ganglion. Afterwards both liquids enter the ganglion itself. On injecting simultaneously both the sub-dural and the sub-arachnoid spaces, the respective liquids pursue for a time separate paths. In the neighbourhood of the ganglion, however, where the dural and arachnoidal sheaths begin to be more and more connected, the paths of the liquids also encounter each other here and there, so that the liquids also are able to commingle; and in the interior of the ganglion they encounter one another still more. Generally, perhaps, the sub-dural liquid remains within the dural sheath. Usually it runs also between its several laminæ, and now and then it makes its way between the laminæ of the arachnoidea, in order thus to get into the interior of the little trunk of the root. On making a sub-arachnoidal injection, the injected liquid also passes easily outside [the arachnoidal tracks]. If a solution of asphaltum in chloroform be used, the injection in this case passes from the interstices between the laminæ of the dura proper into the loose tissue wherewith the root of the nerve is invested on the outside, and there it spreads in many ways and various directions between its laminæ and trabeculæ as well as in its adipose tissue. Never, however, has the liquid been noticed to pass over into the lymphatic vessels which take their departure thence. In the arachnoidal sheath also the liquid pursues its way between the several laminæ, so as to get into the interior of the small nerve-trunks. From the laminæ of the arachnoidal sheath, and from the interior of the small trunks of the root, the injected liquid penetrates here and there easily into the sub-dural space and into the laminæ of the dura mater, and thence farther into the spaces of the above-mentioned adipose tissue wherewith the nervous root is engirded. Nevertheless, this is no reason why at other times the two different injections should not remain confined each to its own territory. The injection pursues its way farther in the direction of the partitions which are let down into the interior of the small nerve-trunks, between its fascicles: it flows there between their laminæ; and not unfrequently does it penetrate into the interior of the fascicles themselves, diffusing itself there between the separate nerve-fibres, so that each of the fibres floats in the liquid. If an injection be made into the root by puncture, in the direction of the cord, the liquids runs some distance into the spinal medulla between the individual nerve-fibres. In the anterior root also the injected liquids run for some distance separately in the sub-dural and sub-arachnoidal spaces, until gradually they become more and more commingled. These same two spaces, therefore, which, as has been shown elsewhere, are separated in the central organs, communicate with one another in the peripheral canals" (ii., pp. 8, 9).

704*y*. Injection of the spinal ganglia.—" In our description of the nerve-roots—see above, no. 704*x*—it was shown through what channels the liquids, injected from the sub-dural and sub-arachnoid spaces, reach the ganglia. On arriving there they either spread interiorly through the outer covering of the ganglia, or are conveyed into the interior of the ganglia through the small nerve-trunks. Both tracks also may be injected either simultaneously, or only one at a time. And again both may be injected either from the sub-dural, or from the sub-arachnoidal space alone. Generally, however, an injection from the sub-dural space remains more on the surface of the ganglion, while another, which is effected from the sub-arachnoidal space, penetrates more into its interior. Nevertheless, liquids injected from either of these places commingle in the ganglion, because their tracks meet there. In the circumference the injection passes all around the ganglion between its perineural laminæ, filling up the interstitial spaces which cohere with one another. Afterwards, as in the case of the very liquid solution of asphaltum in chloroform, the injection either passes outwards among the more irregular laminæ of the epineurium (wherewith the perineurium of the ganglion is lined on the outside), laminæ of which are attached in many places to the perineurium; or else it enters the endoneural spaces which are produced into the interior of the ganglion, and which ramify more and more, until at last the liquid penetrates into the interstitial tissue proper. Here it spreads through the fine passages and spaces of the tissue, forming in all directions copious finely-meshed nets and expanses, which communicate with one another, and which, in the intervals of the interstitial tissue, flow around the capsulæ of the ganglionic cells, irrigating the same. . . .

"The injection, which, on the other hand, enters the ganglion through the small nerve-trunks, pursues its way in a similar manner. It enters the ganglion partly between the laminated sheaths of the small nerve-trunks, and partly in the interior between the fine membranes which are there, or in the spaces around the separate nerve-fibres; and when these small nerve-trunks [in the interior of the ganglion] are broken up into smaller fascicles, the injected liquid passes, with these fascicles, into the interstitial tissue of the ganglion, filling there the same system of copious finely-meshed passages and spaces around the capsulæ of the ganglionic cells, which has been described above. . . .

"After the injection from the sub-dural, as well as from the sub-arachnoid spaces has penetrated through the entire substance of the ganglion, filling it completely, it collects again at the extreme end of the ganglion around the circumference, as well as in the interior of the small nerve-trunk, which is about to depart; it enters into its laminated sheaths and into their interior productions, or spreads around the individual nerve-fibres. In this wise the liquid passes into the peripheral nerve-trunks.

"If, instead of injecting the spinal ganglia from the sub-dural and sub-arachnoid spaces of the spinal cord, an injection is made into them by puncture, the copious lymphatic spaces in the ganglia are filled in the same manner, to a greater or less extent. Nets are thereby injected in the interstitial tissue, which communicate in various ways with one another; and also the passages which lead into the spaces around the ganglionic cells. . . . An injection made by puncture spreads also from the above nets into the spaces between the finer, endoneural laminæ, and thence it passes into larger spaces of the same kind, until at last it is continued into the laminæ of the perineurium. The injected liquid also passes between the membranulæ of the small nerve-trunks, and penetrates into their interior, where it travels either in a central direction towards the spinal roots, or is continued in a peripheral direction into the departing nerve-trunks. Here it circulates either through the perineurium, or its endoneural productions, or finally it pursues its way in the spaces around the separate nerve-fibres. The same system of spaces and passages is thus filled by injections from the spinal cord, as by injections made by puncture.

"No lymphatic vessels have we seen departing from the ganglion; the lymph-system of the nerves, consequently, does not stand in any immediate connection with the lymphatic system of the body; but, on the contrary, it is connected with the large serous spaces of the spinal cord on the one hand, and with the lymph-paths of the peripheral nerve-trunks on the other" (ii., pp. 49, 50).

704*z*. INJECTION OF THE PERIPHERAL SPINAL NERVE.—"It has been repeatedly stated above that, in making injections from the sub-dural and sub-arachnoidal spaces of the central organs, the injected mass has penetrated into the peripheral nerve-trunks beyond the ganglia, nay, that even under a low degree of pressure it has spread far beyond into the ramifications of the nerves. On examining nerve-trunks, injected in this manner with Richardson's fluid from the serous spaces of the central organs, especially horizontal sections of the same, it is found that the injected mass has permeated the nerves in a somewhat varied manner. As a rule, it made its way chiefly through the circumference of the individual fascicles, thus remaining confined to the *perineurium*. On making a more minute examination, however, the injected mass is found deposited between the laminæ of the perineurium, the blue liquid having separated the laminæ more or less from one another, and having filled the interstitial spaces between them to a greater or less extent. Sometimes, for a considerable distance, the liquid has continued its way only between a few, nay, merely between two of the laminæ; at other times, however, and indeed frequently, it has penetrated between several or even between all the laminæ of the perineurium. The fact of many of these perineural spaces having been filled simultaneously proves manifestly that these spaces communicate here and there. The perineurium of the separate nerve-fascicles of a single nerve-trunk is thus more or less filled to a great distance in a peripheral direction. Sometimes only a few of these fascicles are injected in this manner; at other times more. Should then, as is the case sometimes, the fascicles coalesce, or should they anastomose by branches, the liquid is transferred from one fascicle to the other through the perineurium of the anastomosing branches. If, however, the fascicles become divided, the liquid continues to flow through the perineurium of the several branches.

"An injection, made from the serous spaces of the central nervous organs, usually selects by preference for its paths those perineural spaces, which are the direct continuations of the corresponding spaces of the cerebro-spinal ganglia. Still the liquid does not always remain confined there. On the contrary, it spreads thence both towards the circumference and towards the interior of the nerve. In the former case it continues its way between the epineural laminæ, filling either one or many of the epineural spaces, and indeed not only the interior ones which are more concentrical, but also those which are situated nearer to the circumference, and which are irregular. A confused network of injected spaces and passages results thence, especially in those places where several fascicles meet. These epineural spaces are connected, in the direction towards the central organs, with the corresponding epineural spaces of the spinal ganglia. Epineural injections, however, are more frequent in the ganglia than in the nerve-trunks.

"The liquid often enters into the interior of the fascicle in such a way, that in those places where the endoneural laminæ are directed outwards, it abandons the perineural spaces and passes into those of the endoneurium. In doing so it usually becomes more or less diffused through the interior parts of the fascicles. At first it chiefly remains between the endoneural laminæ which are subdivided more and more, and in this wise it bathes the various groups of nervous fibres. The injected liquid, however, does not always remain confined in the endoneural spaces, but here and there it enters into the very groups of the nervous fibres. A peculiarity is noticed here, for the liquid does not remain in the spaces outside the fibrillous sheaths, nor does it simply pierce these sheaths, but it fills the entire space both within and outside of these fibrillous sheaths as far as the sheaths of Schwann. In inspecting a horizontal section of a nerve injected in this manner, the entire tissue appears filled with the liquid in the injected places, which thus have the appearance of a mass dyed with the blue liquid of Richardson. In this blue mass the nervous fibres, surrounded by the sheaths of Schwann, form a more or less crowded assemblage of small white islands. As the fibrillous sheaths never form a boundary-line against an injection, it is plain, as was observed above, that they do not present an impenetrable barrier, but that they are perforated in many places, thus affording a passage for liquids. The sheaths of Schwann, however, always keep off an injected mass, for we have never observed it in the interior of a nervous fibre. The groups of nervous fibres are thus so circumstanced that they may be permeated more or less copiously by the blue liquid which at one time affects more the central part of a fascicle, and at another keeps more in its circumference. On making a longitudinal section of an injected nerve, it appears that the injected mass is not introduced between the groups of fibres in a fascicle in the form of a reticular arrangement of meshes, but that it fills all the spaces between the fibres throughout the whole length of the nerve" (ii., pp. 109, 110).

"In order to test the results obtained by injections made from the serous spaces of the central organs in the brain and spinal cord, we made a great number of injections into the nerves by puncture, using for this purpose the liquid of Richardson, as well as a solution of asphaltum in chloroform. The same spaces were filled by this method of injection, as were filled also by the former method" (ii., p. 111).

Concerning the injection of CEREBRAL NERVES, our authors state that in the beginning of their formation they present a structural difference from the spinal nerves; but that the lymph-paths, in either case, are the same. They say, "On leaving the cranial cavity the cerebral nerve-roots are furnished with a dural and an arachnoid sheath, which presently pass over into epineurium, perineurium, and endoneurium. In the case of the cerebral nerves also, a liquid, injected from the subdural, as well as from the sub-arachnoid spaces, runs out in a peripheral direction. The individual nervous fibres of the cerebral nerves are constructed according to the same plan as the spinal nerves" (ii., p. 9).

704*aa*. WALDEYER.[1]—"Although four years have passed

[1] Waldeyer (Prof. W. in Strassburg). "Beiträge zur Kenntniss der Lymphbahnen des Central-Nervensystems." In "Archiv für Mikroskopische Anatomie." Vol. XVII. Bonn, 1880.

since the appearance of the voluminous work of A. Key and G. Retzius, entitled: 'Studien,' etc., no one, it seems, has hitherto tested thoroughly the results which are there laid down; although they are in part of the greatest importance, and a few are downright surprising. I therefore induced Dr. Fr. Fischer, second assistant of the Institute in this University, to undertake this work. About sixty bodies of human beings and animals were employed for this purpose" (p. 362). Respecting the method followed, Prof. Waldeyer says, that "in all essential matters it was identical with that followed by A. Key and G. Retzius." The outcome, however, of this test-examination, as stated by the Professor on p. 366 is, "The beautiful results of the Stockholm authors were fully confirmed, and in a few points supplemented by Dr. Fischer's experiments."

ANALYSIS.

705. The fourth ventricle, which, by some of our modern anatomists, is made of no account, or deemed of only slight importance, but which, by the old anatomists, was esteemed most highly, with Varolius deserves to be called the chiefest ventricle, with Aurantius a cistern of spirits; and Galen was fully justified in declaring that "it possesses a matter of considerable forces and faculties;" for thence, as from a principal, mediating cause, comes the power, as well as the exertive force of the motions of the whole encephalon, that is, of the cerebellum, medulla oblongata, spinal marrow, and, by connection therewith, also of the cerebrum and its chymical organs. Thence also, the spirituous lymph [the cerebro-spinal liquid] is dispensed almost throughout the whole nervous system. Should this cavity, therefore, happen to be cut, the patient would at once be consigned to a certain and speedy death, which is also proved by experience, a needle having been passed through it as an experiment.[1] This ventricle, like the upper ones of the cerebrum, has its periodical movements of expansion and constriction, whereby it imparts to the members, with which it is connected, and which are subject to it, the power of exercising their vital motions.

706. The cerebellum derives thence the power of its motion, that is, its power of expansion and constriction; for unless its

[1] This is fully agreed to by modern science, only it is expressed differently. Thus modern experimenters declare that a pigeon, hen, or guinea-pig will bear the removal of the greater part of their cerebellum, provided you do not meddle with the medulla oblongata underneath. But as soon as the medulla is wounded—or as our author would say, as soon as the fourth ventricle is violated—a certain death ensues. For the medulla oblongata cannot be reached without first passing through the fourth ventricle.—Editor.

medullary stems were attached to a cavity, or implanted in a soil capable of yielding, of being drawn apart and contracted, whenever they stretch themselves and relax again, neither the interior medullary, nor consequently the cortical grey substance, and hence the circular strata and segments of the cerebellum could be unfolded : for the outermost parts must conspire with the middle in the production of the same effect. But if the medullary stems and trunk are unable to stretch and contract themselves, their three processes or peduncles, and consequently the fibres, nervous roots and nerves proceeding thence, cannot enter upon their corresponding periodical movements. The machine of life, that is, the cerebellum, would then stop in its first threshold, and would labour under an impotence of action. The vermiform process also would be incapable of unfolding, by alternate motions, its furrows and knotted folds; for this process presses against and rubs the central rima of this ventricle from the valve of Vieussens; so that these parts must all necessarily tend towards and flow into the same determination of motion.

707. Thence the medulla oblongata also derives the power of its motion; for this organ encompasses and closes up this ventricle on all sides. The pons Varolii, and the corpora pyramidalia and olivaria press against and constitute the bottom both of the ventricle and the calamus scriptorius. The first process of the cerebellum towards the corpora quadrigemina, together with the posterior prolongation of the cerebrum, constitute its edges, and together with the rest form its walls; and the third process of the cerebellum towards the spinal marrow flows down along its sides. All these parts, and at the same time the primitive fibres and the roots of the nerves, originating therefrom, unless provided with a cavity capable of being distended, and of undergoing its alternate states of expansion and relaxation, would be deprived of their ability of unfolding, and of fulfilling their numberless bodily and animal functions; wherefore that auxiliary and mediating organ, that is, the medulla oblongata, would be stagnated by a deadly inactivity and waste; it would grow torpid, and would lie there

shunned by the remaining parts. In order, therefore, that the simple as well as the compound nervous roots may institute their local reciprocal motions in a becoming manner, they all have their places allotted to them in the most regular order around this cistern, that is, around its floor and walls; and thus, having received their determination, they flow in such a way that into each nervous root action results thence according to every disposition of things, in the middle, and also according to use in the circumference. This appears most manifestly from the fibres of the fifth, sixth, seventh, eighth and ninth pairs of nerves, which all in an appropriate manner either apply themselves to this ventricle, or cross it transversely, and in its neighbourhood, and under its base, unite and fold themselves together in a suitable manner. On this account this noble ventricle is as it were a balance-wheel and regulator of the motion, not only of the medullary caudex, but also of the roots of the nerves, entire phalanxes of which burst out in this neighbourhoood.

708. The spinal marrow, in like manner, would not possess the power of raising itself, unless a cavity were prefixed to it within the very cranial cavity itself. For the spinal marrow, just like the medulla of the head, of which it is an immediate continuation, alternately expands and constricts itself; since in addition to the extraneous fibres of the cerebrum, cerebellum and medulla oblongata, it is also furnished with its own fibres from an abundant supply of expansible cortex or grey matter within its own limits. Its power of expansion, or rather of extension and contraction, namely, in its posterior surface, depends, as upon a certain regulating lever, upon the intumescence and subsidence of this ventricle, or upon its capacity of yielding; otherwise this spinal cylinder, that is, the medullary shaft enclosed within the vertebræ would in vain strive to stimulate its numerous forces into action. And the same would be the case with the nerves which start from the spinal marrow on their way into the provinces of the body. In order that this vertebral medulla, and the grey substance enclosed within it, may enjoy the full power of relax-

ing their constituent parts (*tori*) in an appropriate manner, its posterior surface is not attached closely to the foramen magnum; and fibres, both of the cerebrum and cerebellum, press into it in crowds, and on their passage thither apply themselves to the wedge-like planes and walls of the fourth ventricle.

709. Besides, the expansile and constrictile motion of the medulla oblongata, which is continued even into the spinal marrow, by the regulating action of this ventricle, is directed and transferred from the front to the rear of this organ; and indeed for this reason, lest the roots of the nerves, by the elevation of the soil nearest to them, should be displaced and disturbed, as will be confirmed in the following chapters treating of the pons Varolii, the corpora pyramidalia, and the spinal marrow. This appears not only from the inflection of very many fibres in an antero-posterior direction, but also from the fact of the ventricle itself being established in this portion of the caudex, which is more capable of expansion than its other, that is, its anterior division. On this account also we attribute to this ventricle the regulation of motion.

710. Yet not the cerebellum, medulla oblongata, and spinal marrow alone are affected, but the cerebrum also carries on its motions, and especially the chymical organs of its laboratory accomplish their operations in harmony with this ventricle, for without the service and auxiliary function of this ventricle the cerebrum and its members would soon be seized as it were with a swoon, and would cease to act; because there is a continual nexus of all things, and indeed a certain chain and series from first to last things through the middle. If, therefore, either the cerebellum, or the medulla oblongata, or the spinal marrow, or if, going still farther, the lungs or the heart were struck with an inability of action, a similar effect would at once be communicated to the cerebrum. The cerebellum is so connected with its cerebrum as to expect from it a government and an alternate motion akin to its own. In the medulla oblongata, the fibre of the cerebrum reigns equally with that of the cerebellum; likewise in the spinal marrow; and the fibre of the cerebrum

which comes from its front part, descends into the medulla of the neck and of the back through the pons Varolii, in the closest proximity to the bottom, and the walls of this ventricle, while that which comes from its crown flows down the same way, through the isthmus, close to the edges of this ventricle. If, therefore, the alternate and reciprocal action of the ventricle should cease, that of the fibre, and consequently, that of the cerebrum itself would cease; for in order that the cortex may possess mobility in itself, it must have motion and action in the middle parts and in the extreme or end; because in its extreme or end resides the active force of its power, which must act the part of one and the same cause, in order that the cerebrum may have the power of motion.

711. The proximate cause why the organs or members of the large gland of the cerebrum would cease to act, if this ventricle should remain inactive, is as follows:—The fourth ventricle and the aqueduct of Sylvius are like a pair of scales, the vertical beam of which is the valve of Vieussens; for as soon as one of them rises, the other is as it were pressed down, since one acts upon the other through the medium of the valve, because their motions alternate. The moisture, which is injected into the aqueduct, presses against the valve, and bends and bulges it out in the direction of the upper and hence widest part of the fourth ventricle; but when the ventricle swells reciprocally and exerts a pressure, then the valve is driven into the aqueduct, and closes it up almost completely, urging its lymph through the foramen under the pineal gland into the third ventricle, and *vice versa*. This valve, great in use, but small in size, not only closes up in this manner the approaches, and shuts the door tightly, lest any liquid of the cerebrum should flow into the fourth ventricle, and *vice versa*; but it is also like the tongue of a pair of balances, like the pivotal point of a see-saw, or like an axis which is moved around by a wheel; wherefore it is also of a delicate structure, pliable, medullary, the grey substance with which it is interspersed co-operating with it. It is covered on all sides with a thin membrane which is con-

tinued into the fourth ventricle on the one hand, and into the aqueduct on the other, so as to apply itself to both; it rests obliquely or lies in a declivitous position, being attached to a certain process of the corpora quadrigemina, and to fibres sent out from the fornix as to a *frœnulum*, or as to the pole of a waggon, and likewise to the extremity of the vermiform process; perchance also to the fibres of the first process of the cerebellum towards the corpora quadrigemina. In this wise it is fastened to the fibres of the cerebrum, as well as to those of the cerebellum, accommodating itself to either part. It also remains secure; for it occupies a middle and central position, like the tongue of a pair of scales, and guards the equilibrium; and in addition it is protected by the vaults and walls of both cavities which rise up against it, and to which it applies itself, when pushed inwards. Its delicate structure and small size answer completely to the measure and force of the acting lymph; just as the semi-lunar valves of the heart correspond to the impulse of the sanguineous stream. It follows thence that without the reciprocal action of the fourth ventricle, and without its action upon the valve of Vieussens, and through the valve upon the aqueduct, the third ventricle would remain emptied and unsupplied with its desired lymph; and consequently also the lateral ventricles, the pineal gland, the infundibulum and the pituitary gland, and thus the organs and members of the chymical laboratory.

712. This fourth ventricle, on account of the actuality of motion which it secures for the circumjacent members of the encephalon, supplies also a noble and most highly gifted juice impregnated with spirit to the roots of the nerves, and hands it over for distribution to the medulla oblongata, and especially to the spinal marrow. This choicest serum and defecated lymph, which is expressed from the tender shoots and villi of the vertebral artery between the laminæ and inmost folds of the cerebellum, and which enters thence into the fibrillous interstices of its medulla, cannot escape or be discharged by any other way than by that of the medullary stems into the

subjacent ventricle, or into that cavity which is intercepted and closed up by the peduncles; for there is no other egress. Such also is the case with that moisture which does not penetrate the arborescent growth of the cerebellum, but passes through the folds under the pia mater, and through the duplicatures of the same, and which pursues its course until it finds an exit. This humour also cannot shower down anywhere else than under the membrane whereby the peduncles are lined, and through the vermiform process where this same membrane is attached to the valve of Vieussens. For the arterial blood may, indeed, enter into the interior recesses of the cerebellum, but its coarser part only is allowed to flow back into veins. Inasmuch as this ventricle cannot absorb the whole of that noble moisture which is collected in the whole medullary substance of the cerebellum, and in its laminated surface, it is pumped out by its alternate motion. The modus operandi, by which it accomplishes this result, appears also clearly from the way in which the peduncles, namely, their medullary portion, is irradicated or inrooted, and by which the enclosing membrane or outer covering is inserted in the edges of this cistern. That most refined lymph which is propelled through the reticular plexuses of the medulla of both brains, and through the interstices and pores of the nerves of the body, is not the animal spirit itself, but it is impregnated with spirit; as is the case generally with the lymph of the conglobate or lymphatic glands and of the thoracic duct, which upon being evaporated by fire does not leave any residuum behind. That such a lymph percolates through the interstices of the fibres, or passes between the fasciculated nerves, and that without such a lubricating liquid neither the fibres, nor the spirits of the fibres are able to execute their behests, but would speedily coalesce into a solid and inert mass, will be demonstrated by experimental proofs in Part II., Chapter ii., which treats concerning the medullary fibre of the brain, and the nervous fibre of the body.

713. The lymph, which, by the medullary stems, is conveyed

into this cistern, out of every cleft of the cerebellum, and out of the medullary branches of its arborescent organism, must needs be most refined and of a spirituous nature, and it cannot be a pituitous humour or feculent liquid, such as is found between the meninges, and sometimes in the anfractuous folds of the cerebrum. For the cerebellum goes through its alternate motions with constancy and tranquillity, in deep silence and with an ever-serene complexion. The cerebrum, on the other hand, very often displays in its motion inconstancy, impetuosity, and again inactivity, wherefore a grosser species of lymph is excreted there. The cerebellum also sends off the feculent portion of the serum into its larger-sized veins, and presently into the straight sinus. This most refined lymph of the cerebellum is soon joined by a lymph, endowed with fresh spirit from the choroid plexus, which lines both sides of the ventricle, and both of which portions intercommunicate by anastomoses. This plexus also serves to show that the same kind of lymph is instilled into this cistern, as into the lateral ventricles of the cerebrum; since its texture is similar, and it is interspersed with similar glands. On this account also the cerebellum seems to represent a gland, and indeed the chiefest among the conglobate or lymphatic glands; for through emissary ducts or peduncles it excretes a juice into a cavity, that is, into the fourth ventricle, and thereby provides for the subjacent roots of the nerves, while the gland of the cerebrum cares for the mass of the blood; wherefore, since the two brains differ in use, they differ also in structure. It seems, however, that the above cavity ought not to be called with Aurantius a cistern of spirits, but the cistern of a spirituous lymph; for no fibre, conveying the genuine spirit, empties into it.

714. In respect to the excretory duct of this lymph, it has, indeed, no outwardly visible duct of this kind, as is the case with the cavities of all the other glands. But from the fact of the connection of this ventricle with the double lamina of the pia mater being interrupted by clefts, it appears that this lymph is expressed and excreted between the duplicature, that is,

between the pia mater and the arachnoid membrane; for the interior lamina of the pia mater, *i.e.*, the pia proper, invests the ventricle itself, while the exterior lamina, [the arachnoidea,] passes around over it; and the duplicature appears remarkably thickset or crowded around the terminus of the calamus scriptorius, so that, according to Ridley's observation, in dropsical subjects it is found turgid with serum. It follows thence that the lymph of this cistern, and of the choroid plexus, is discharged into the duplicature between the pia mater and the arachnoid membrane, and that thence, through the continuous and customary ducts and follicles of the arachnoid membrane, it is derived especially into the posterior part of the medulla oblongata, where that membrane floats about quite thickly and loosely, and is thus distributed into every one of the roots of the nerves, or into the interstices of the fibres, as will be proved in Part II., in Chapter iii., where this membrane is treated of. For the arachnoid membrane is nothing else than a perpetual lymphatic duct, distributing this refined juice into the reticular tissues of the medullary fibres, and thence into the interstices of the nervous fibres. Whether there are still other channels for the discharge of the lymph, namely, whether such a channel opens immediately from the calamus scriptorius into the medullary portion of the spinal marrow, to my knowledge has not yet been discovered. For this purpose the fourth ventricle is contracted into the narrow form of a goose-quill; and for this purpose also there are present in infants, at either side of the calamus scriptorius, two olivary protuberances.

715. We are also obliged to discuss a little the cause and mode in which this ventricle is expanded and constricted. Ocular inspection teaches us that the medullary stems of the cerebellum are inserted on both sides in the edges of this cavity, and that, like the roots of a tree fastened into the ground, they embrace the ventricle in the middle in such a manner that underneath them, as under a ceiling, they form a crypt of equal breadth and length. It follows thence, that from the thrusting forth and drawing back of these peduncles, there results, as

from their efficient cause, the dilatation and constriction of this cavity. It appears thence that this ventricle is widened and spread apart in its middle when the superincumbent peduncles stretch themselves, and pour themselves out on all sides; but that the reverse happens when they draw themselves back. The diastole of this cavity accordingly happens, when the cerebellum stretches out its fibres, that is, when the cerebellum expands itself; but under a reverse condition the fourth ventricle has its systole. The very way in which this cavity runs, or in which it is notched, shows that its edges are unfolded and its floor cast up by the opposite medulla, *i.e.*, the pons Varolii, during that time [that is, during the diastole of the ventricle]. But when the ventricle is thus constricted [or flattened out by the clevation of its floors], the cnclosed lymph is driven out from its middle towards its extremities on either side, namely, against the valve of Vieussens which is above, as well as into the calamus scriptorius below; and thus it is expressed into the above-named duplicature [in the tela choroidea inferior]. When the lymph at such time impinges against the valve of Vicussens, the aqueduct of Sylvius, which is underneath the corpora quadrigemina, is comprcssed and emptied, and *vice versa,* so that the periods alternate. It was shown above that the aqueduct is filled and swollen when the lateral ventricles and the third ventricle are constricted, which happens when the cercbrum and cerebellum, and also the fourth ventricle are expanded. Thus this latter ventricle alternates with the aqueduct in its motions, as has been maintained above.

APPENDIX TO CHAPTER XXVI.

1. FROM AN EARLIER WORK ON THE BRAIN.[1]

a. The Fourth Ventricle and the Cerebellar Liquid.

715*a*. Argument. — The fourth ventricle and calamus scriptorius, like the remaining ventricles, is opened and constricted in alternate periods, yet in a peculiar maner. Without it the cerebellum could not carry on the movements of its animation, nor could the spinal cord undergo the changes of its motion together with the cerebellum. The fourth ventricle seems to receive in its bosom that spirituous liquid which the cerebellum breathes out between the two laminæ of its pia mater in the direction of the vermiform processes, and which it exudes at the same time out of its medullary substance near the place where its stems and trunk are divided into processes or peduncles. It seems also to express this liquid, through a cleft directed upwards between the pia and dura mater, and thence into the spinal cord, in order that there it may make its way into the roots of the nerves. To this liquid the fourth ventricle adds its own dew, which is distilled out of the choroid plexus. This ventricle also is subservient to roots of the facial, auditory and hypoglossal nerves, so that by a living action they may suitably act upon the muscles which they approach.

715*b*. *The fourth ventricle and calamus scriptorius, like the remaining ventricles, is opened and constricted in alternate periods.* This we infer not only from the fact of its being called a ventricle, and being hollow, but because it is

[1] Codex 65, as reproduced in Volume IV. of the Photolithographed MSS. of Swedenborg, pp. 376-387.

surrounded on all sides by those parts which expend upon it the force of their action; as by the cerebellum with its medullary stems and trunk, which are cleft into processes over its cavity, and applied in such a manner that the fourth ventricle is necessarily opened by the respiring cerebellum as it acts upon its nerves. It may be inferred also from the vermiform process, which is divided into ridges and gyres, and which, from the valve of Vieussens downwards, applies itself to the ventricle from above; for unless the subjacent cavity would consent to the contraction of this process, one would stop the other. But that the vermiform process is contracted along the ventricle appears from its situation and furrowed form, and also from the concentration into the same, as into an axis, of the gyres of the cerebellum. The same appears, further, from the fact, that the processes, both of the cerebellum and cerebrum, conspire for the purpose of opening and constricting the cavity of the ventricle, that is, for the purpose of raising, and at the same time widening the same; for the upper process of the cerebrum—the tegmentum—flows down near its sides; and its anterior process—the pes or crusta—seems also to inflect itself partly in this direction; at all events [through the raphé] to send some fibres towards the middle of the ventricle. That the first and third processes of the cerebellum—the crura ad cerebrum, and the crura ad medullam—act upon the fourth ventricle is plain to the sight. For the same reason also the upper edges or the upper circumference of the cavity is medullary and yielding; even as it is invested by a membrane which is capable of dilatation. To confirm and strengthen the alternate opening and constriction of the ventricle, there is added at its bottom, and along the lower parts of its sides, a copious grey substance, and, indeed, the whole of that grey substance which is in the medulla oblongata, as appears from the plates of Willis, where the caudex is shaved down to this substance. Finally, the alternate dilatation and constriction of the ventricle appears from the blood-vessels which pass through its cavity, and from the choroid plexus which extends along its sides; also from a number of other arguments, so that the above position is quite able to occupy the place of an unequivocal truth.

715c. *This ventricle, however, undergoes this motion in a peculiar way;* for by comparing all the circumstances of the case, this motion seems to be a kind of unfolding of the edges of the ventricle, and an elevation of its floor to such a degree, that if it contains any liquid at all, especially in the calamus scriptorius, it ejects the same superiorly, in a place where it is not covered up by a ceiling. This may be inferred from the fact of the medullary trunk of the cerebellum being cleft into its processes or peduncles almost directly over the middle of the ventricle; further, from the medullary, and hence yielding character of the edges of the ventricle, which are governed and impelled by the first and third processes of the cerebellum, and the upper process—the tegmentum—of the cerebrum which is tending downwards. Further, from the second process of the cerebellum—the crura ad pontem—which, in the body of the medulla oblongata, runs parallel with that same process, which, in the middle of the ventricle, runs transversely over its cavity. Again, from the groove which causes a division in its floor from the valve of Vieussens to its lower extremity; as is reported by Winslow. It appears again from the fact that all the action of the anterior or ventral surface of the medulla oblongata is reflected backwards towards the ventricle, and thus casts up its floor, and spreads its edges apart; for the corpora pyramidalia and olivaria are so formed, that they extinguish the motion of the pons Varolii through intervening notches or transverse grooves, and that through other means they are able to retreat sidewards; so, indeed, that the motion of the pons Varolii is directed backwards and solely into the fourth ventricle; whence it is that the anterior surface of the spinal cord is incapable of elevation, and that its posterior or dorsal surface determines all motion into itself. This same thing is also indicated by the blood-vessels, one of which is situated in the middle of its bottom, and the rest are stretched out along its sides, and not, as is the case in the third ventricle, united in the middle of the fourth ventricle, and mutually contiguous to one another. If, therefore, these vessels are expanded in alternate intervals, and at the same time are shortened, as is the case with all the rest, it follows that the bottom and at the same time the extremity of the pons Varolii is raised up. It thus seems that the calamus scriptorius, and also a part of the fourth ventricle, that is, the upper part of its cavity, unfold their edges by these means; whence it is that this latter part projects its liquid, if it contains any, into the calamus scriptorius, rather during the state when it is unfolded. This same also may be seen from the grey substance of the fourth ventricle, which does not occupy the roof or upper circumference of the ventricle, but its floor and the lower part of its sides; further, from the choroid plexus which runs out transversely about the extremity of the calamus scriptorius, and associates itself there with the plexus of the other side. . . . Finally, it appears from this that the pia mater at this same extremity presents a duplicature, so as to allow itself to be drawn apart there; nor is there any other foramen, into which the fourth ventricle could direct the force of its action, that is, the effect of its expansion.

715*d*. *Without the fourth ventricle the cerebellum could not carry on the movements of its animation;* for the effect of the expansion and constriction of its whole body is directed into its medullary trunk, and thence into its processes. Unless these processes in alternate periods were drawn towards the cerebellum, and again relaxed, there would be wanting a living action upon the fibres of the pons Varolii, which act upon the basilar artery; and again upon the fibres which run transversely across under the corpora quadrigemina, and which act upon the isthmus, and the portion of the chymical laboratory of the brain which is there; further, upon the fibres which act upon the spinal cord and its dorsal surface, which they raise up at the same time; and finally upon the fibres of the cerebellar nerves, namely, upon those which are sent into the nervus vagus and the great sympathetic nerves; which nerves, with their copious juice, tend towards the muscles. Suppose now the cerebellum should be deprived of its possibility of expansion, in this case the action of the cerebellum, or the extension of its action, would cease; this also has been proved by driving a needle into that ventricle. The same may be concluded from the vermiform process of the cerebellum, into which the action of the surface of the cerebellum is directed; for this process applies itself to the ventricle, and unless the latter acted in a state of obedience with it, there would result thence a recoil. Besides, the entire body of the cerebellum, with its ridged and gyrated surface, is superincumbent on the ventricle, to which it applies all its terminations in a peculiar manner. The same may be predicated from the processes of the cerebrum, which are directed into the spinal cord.

715*e*. *Nor could the spinal cord undergo the changes of its motion together with the cerebellum.* I pass by the medulla oblongata; for unless it were furnished with a cavity, into which its grey substance could respire, it would be deprived of the power of acting upon its nerves as well. But to return to the spinal cord. This cord depends so much upon the fourth ventricle, and together with it upon the restiform process of the cerebellum, that each time, whenever it contracts itself and its grey axis, it is at the same time elevated behind. This effect could never be attained without the conjoint support and assistance of such a cavity. If this conjunction were wanting, the dependence of the spinal cord upon the cerebellum would also perish; for it is chiefly through the mediation of the fourth ventricle that the cerebellum is able, through its fibres, to act upon the cord. In this wise also, and by no other means, can the anterior and posterior spinal arteries and veins be supplied with blood, and the grey substance of the axis live, and thus act upon the muscles of the respiratory field and upon the rest. For this same reason also it has been provided, that this ventricle shall never be clogged up by any pituitous humour, without ejecting it at once; lest all animal motions should at once be put to an end by its obstruction.

715*f*. *The fourth ventricle seems to receive in its bosom that* *spirituous liquid which the cerebellum breathes out between the two laminæ of its pia mater in the direction of the vermiform processes;* for the fact that the cerebellum expresses constantly a refined liquid from the little arteries which enter into its furrows and gyres, follows from the regular friction which all these vessels undergo by their alternate compression, extension and relaxation. The whole of this juice cannot be poured into the medullary substance itself of the cerebellum, but must be expelled towards the surface between the pia mater and the arachnoid membrane. Inasmuch as the pia mater is spread out quite loosely over the surface of the cerebellum, and nevertheless is determined into the vermiform processes, which are superincumbent over the ventricular edges, and apply themselves in a suitable manner, it follows that the whole of the liquid, conveyed thither through this general lympheduct, lapses into its unfolded cleft or opening [the foramen of Magendie]. On this account also, valves of considerable size are attached to the pia mater—the valve of Vieussens, or the velum medullare anterius, and the velum medullare posterius in the calamus scriptorius—which lie in the direction in which the liquid is to be expelled. These valves are likewise capable of contraction, and are irrigated by an abundant sanguineous stream. Only a juice of a better quality can be distilled between the folia of the cerebellum, on account of the constancy of its animation, and the regularity of its folds. It is different in the brain, which is hourly exposed to a change in its motion.

715*g*. *The fourth ventricle also receives at the same time that spirituous liquid which the cerebellum exudes out of its medullary substance, near the place where its stems and trunk are divided into processes or peduncles;* for the medullary stems of the cerebellum insert, and, as it were, ingraft themselves into the medulla oblongata exactly near the edges of its ventricle, but the spreading apart of the processes takes place almost above the middle of the ventricle. Should, therefore, the medullary substance of the cerebellum at any time be supplied with more liquid than it needs for the use of its fibres it would seem to exude the same into the ventricle also in that place; unless this discharge takes place between the arachnoidea and the pia mater; which last membrane is evidently duplicated below, with very loose meshes. This was observed by Ridley in a highly dropsical brain, where he saw the greater part of the lymph collected between the duplicatures of the pia mater around the calamus scriptorius.

715*h*. *It seems also to express this liquid through a cleft in its ceiling, between the pia and dura mater, and thence into the spinal cord, in order that there it may make its way between the roots of the nerves;* for when the ventricle expresses this liquid out of its drawn-up edges, an open course is left to it down the spinal cord. For in the foramen magnum of the occipital bone, the spinal cord does not adhere to the dura mater, nor is it united with it in the back and at the sides, but only in front. Now, since the whole of that liquid which is expressed from the cerebellum is harmless and spirituous, it is for this very same reason fit to enter into the roots of the nerves, which require such a humour. Without such a moisture, or without some interstitial juice, these busy nerves would be dried up and deprived of the faculty of attending to their duties. For all intermediate spaces, wherever there are any, whether in membranes or in nerves, require to be filled up with a suitable, appropriate juice, so as not to become sinewy. And as to the spinal cord itself, it cannot supply such a copious juice as would answer to the activity of the nerves, and to the continuous loss of the same; wherefore it seems constantly to be under the necessity of borrowing the same from the cerebellum. On this account also, the arachnoid membrane of the spinal cord, that is, its general lymphatic duct, is denser, and floats around it more loosely, and determines the juice which is confined under it towards either roots, the anterior as well as the posterior. We may presume, therefore, that this liquid is by no means injurious to the nerves, as is the pituita of the brain between the pia and dura mater, and also that which often collects in its medullary substance, and in its ventricles. In case this last humour should flow down through an open foramen, and unrestrained by any valvular bolt or bar, as sometimes seems to happen out of the region immediately above the isthmus, and from under the continuous expansion underneath the corpus callosum—it would do great harm to the nerves, unless it be excreted thence.

715*i*. *To the above liquid the fourth ventricle adds its own dew which is distilled out of the choroid plexus;* for this reason indeed, that it may pass into the interstitial spaces around the roots of the fasciculi of the spinal nerves. For, according to what has been stated above, there is the spirituous juice or white blood—the animal spirit—which permeates the very fibres; there is the nervous juice which passes through the interstices of the fibres; and there is a still grosser, but not phlegmy, humour which is intended for the interstices of the nerve-roots or fascicles. These three kinds of fluids, which correspond to the interstices or little canals, must needs exist. The first species, that is, the spirituous juice or animal spirit, enters into the fibres immediately from the cortical or grey substance; the second one, which is expressed from the little arteries, passes into the interstices of the fibres, which are interiorly in the fascicles or so-called nerve-roots; it passes into these interstices where the fibres begin to be collected into nerve-roots, consequently around their beginnings, whither the general duct, that is, the arachnoid membrane, directs this juice. The third species, however, that which is about to enter the interstices or the intermediate spaces of the nerve-roots or fascicles, when they apply themselves to one another mutually, and submit themselves to the dura mater, cannot be contained between the double lamina of the pia mater; for the pia mater and the arachnoidea invest the very nerve-roots or fascicles; nor can it be of the purity of that juice which courses interiorly in the nerve-roots between its fibres. Wherefore a grosser juice is here required; and in order that it may be suitable it must be mixed with the juice of the choroid plexus, so that, among all the liquids and all the canals which they enter, there may be a similar ratio; and that they may, in a suitable manner, according to the activities of the more simple and composite fibres, have mutual respect to each other. For the composition of this liquid, therefore, the secretion of the choroid plexus seems to be required; in the same manner almost in which, in the lateral ventricles, the spirituous juice—the animal spirit—requires to be mixed with the nervous juice, and this, again, with the secretion of the choroid plexus. That the liquid, which, from this ventricle, flows down between the pia and dura mater, is of this description, appears sufficiently from the transverse production of the plexus, near the extremity of the calamus scriptorius, where there is the beginning of the downward flow of the liquid; and also from the glandular character of the plexus itself, and its close application to the bottom of the ventricle. This plexus also is not subject to those changes to which the plexuses of the lateral ventricles are exposed, so that it constantly pours forth a homogeneous vapour. There is, however, this difference between the two secretions, that the analogous juice which is prepared in the lateral ventricles enters presently into the blood, but this latter juice into the nerves; and thence it betakes itself into the blood, through glands and vesicles in the body. From what has been said above, it follows that the dilatation of this ventricle, and the elevation of its floor, coincides with the contraction of the vermiform processes, with the spreading apart of the processes of the cerebellum, so that, through the mediation of the cerebellum, while the ventricle is being widened, it is also shortened; it further coincides with the contraction and elevation of the spinal cord, and the opening of the space between the dura mater and the pia mater of the cord in the foramen magnum of the occipital bone; even as it concides with the expression of the liquid out of the choroid plexus. From all of which follow the aforementioned conclusions.

715*j*. *This ventricle also is subservient to the roots of the facial, auditory and hypoglossal nerves, so that by a living action* *they may suitably act upon the muscles which they approach.* The case with these nerves is exactly the same as with the motor nerves of the eye, namely, with the third, fourth and sixth nerves, in respect to the aqueduct of Sylvius; which relation has been treated of above, wherefore it is unnecessary to repeat it here. For the above-mentioned nerves have their origin under the fourth ventricle. The seventh pair of nerves, that is, the facial and auditory nerves, besides supplying the small muscles in the cavity of the ear, approach almost all the muscles in the face, and the hypoglossal nerve all those which in the tongue are subservient to speech. The first cervical pair of nerves also seems to trace its origin into the neighbourhood of the fourth ventricle. Through the mediation of this cavity, from a voluntary there is thus born a spontaneous act. Now inasmuch as so many nerves originate under the floor of the ventricle, and at its sides, the expansion and constriction of this ventricle must be such, that it applies itself to all, lest one fibre should be attracted less regularly than another. It provides also for these nerves in this sense, that it instils the requisite moisture into them, namely, that which is constantly supplied from its cavity. Hence also may appear the important use of the ventricle which is so deeply hidden away under the cerebellum, namely, that with Aurantius it deserves to be called a cistern of spirits for the use of the nerves, while the triple ventricle of the cerebrum may be called one for the use of the blood. The moisture of the cerebellum is afterwards received by another cavity in the medulla of the neck, and at last by several additional cavities in the medulla of the spine; but whether these cavities are continuous I do not know, and I even hesitate to believe it (no. 173).

b. The Cerebro-spinal Liquid in general.[1]

715*k*. *A subtle liquid is distilled from the least arteries of the cerebrum between its anfractuosities as well as between*

[1] From Codex 65, as reproduced in Vol. IV. of the Photolithographed MSS. of Swedenborg, pp. 193, *et seq.*

the sub-divisions of the cortical tori or glomes; for, according to Leeuwenhoek, Ruysch, Pacchioni and others, the cortex of the brain is always polished, and, as it were, anointed with oil; and between the anfractuosities there appears an oily lymph by which the hinges are, as it were, lubricated; out of the same substance also there exhales a certain urinous element. I do not mean here the humidity of a diseased brain, nor the moisture of the interior lamina of the dura mater, but that liquid which bathes immediately the cortical substance, whether it be expressed from the winding little arteries by which it is interpenetrated, or whether it come from the pia mater which, upon being pressed, always yields some moisture, and since this is kept under the arachnoid membrane, it cannot rise upwards, but must necessarily flow downwards among the tori and the divisions of the tori. The arachnoid membrane also, by its pressure, contributes to this effect. Inasmuch as this liquid is obtained from the delicate, arterial threads which, by the constant animation, that is, the respiratory motion of the cortex of the brain, are pulled and again relaxed, and thus milked, it is quite possible that it contains also some spirituous elements. Meanwhile, inasmuch as this secretion is perpetual, it follows that nature has also provided excretory channels.

715*l*. *This liquid cannot make its way into the fibres, but still it is able to penetrate between the fibres in the fascicles or in the so-called roots of the nerves;* for this liquid which is secreted from the least arteries and the pia mater, and which, on account of the obstruction offered by the arachnoid membrane, cannot rise between the meninges, flows outside of the cortical spherules, wherefore it must betake itself between the fibres which, in alternate periods, are pulled and again relaxed, or which, in alternate periods, open their interstices for the reception of such a liquid. This fluid also is harmless, and, besides, the fibres require to be bathed by such a liquid, lest they should coalesce. For it is a matter of demonstration, that the veriest simple fibres are held together between one another by the most delicate membranes, which by revolutions are wound into spiral membranes, even as is the case with the muscular rings and the coatings of the arteries, or in the bronchial tubes of the lungs, as well as in other places. Hence these membranes must of a necessity contain a moisture, through the mediation of which the fibres may be kept in a condition in which they are able to act, and in which they do not become torpid as is the case when there is no fluid by which they are kept apart. For we must hold on to the fundamental proposition that all things in the animal kingdom are pervious, or, according to Hippocrates, capable of transpiration, and if they are pervious, they must be filled with a suitable juice. Thus there must be in the nerves minutest fibrules—the fibrules of the axis-cylinder—for the pure spirit; fibres less delicate—medullated and non-medullated fibres—for the animal spirit; further, the interstices between the fibres for the present liquid, and for the grossest liquid the interstices between the fascicles or nervous roots. An overabundance of this last juice, as we are instructed by the history of diseases, may do an egregious damage to the nerves.

715*m*. *When this liquid occurs in nerves, it is commonly called nervous juice.* Chemistry informs us that this is the same juice which is secreted in the brain. For either liquid evaporates most quickly; it does not thicken when exposed to the heat of a fire, but is noticed to pass off entirely into the air; while the remaining humours of the body, according to Boerhaave and many others, generally either coagulate by the action of the fire, or leave many residua behind. The origin of this humour is thus deduced from the brain, and by some it is thought to be the nervous spirit itself—this, however, is contained *within* the fibres. . . . When a nerve is cut horizontally, the spirituous juice, that is, the animal spirit, cannot exhale from the fibres themselves, nor can it be extracted thence chemically by any artifice; for the fibres then retract within their spiral coils, and thus close up every passage, so that only the present liquid has a chance of flowing out. The source of this liquid in the nerves cannot be anywhere else than where the newly generated fibres are gathered together; and this takes place as soon as they pass out of their formative substances. The above applies also to the cerebellum, and to both medullæ where there is any grey substance. In the cerebellum this liquid is secreted between its numerous folds which are perpetually rubbed and operated upon during the moments of the animation of the brain; wherefore there must needs be expressed thence a juice which can pass only into its white or medullary substance, and thence into its medullary trunk, and consequently into its processes and nerves. In a similar manner a like liquid is derived from the spinal cord, between the fibres, into the very roots of the nerves, which are presently invested with pia mater.

715*n*. *This nervous juice seems to differ very much from the animal spirit, which passes through the fibres;* for the animal spirit is almost purely spirituous; it is of a perpetual mobility, expansible, compressible, capable of division into the least possible parts, elastic. The fibre is most highly adapted to the animal spirit, and the animal spirit to the fibre, so much so, indeed, that no force can become lost therein. It is different with the nervous juice—that is, the cerebro-spinal liquid—for in this liquid there are also aqueous, oily, and subtle urinous elements, and perchance there is also some spirituous element which vivifies the rest; wherefore this liquid cannot be of a perpetual mobility, expansible, compressible, elastic, etc., except through that portion of it which it receives from the spirituous element admixed to it. This liquid, therefore, is comparatively inert, and possesses more of a passive than of an active force (no. 276).

c. The Arachnoid Membrane.

715*o*. The arachnoid membrane, which has borrowed its name from the spider (*arachne*), the delicacy of whose web it emulates, is superadded to the pia mater. Together with this latter membrane, and almost like another lamina of the same, it suffers itself to be drawn towards every external tract and fissure, be it high or low or evenly spread out in a plane; yet it does not enter the sulci and windings. When, therefore, the arachnoid membrane is removed, the quality of the cerebrum, and especially that of the cerebellum which is distinguished into folia or leaves, is revealed to the sight. This membrane is attached more closely to the underlying pia mater in the crown of the cerebrum, but more loosely at its base and over the cerebellum. Again, the connection between the two is more close around the eminences of the medulla oblongata than in its depressions; and it clings more closely to the anterior surface of the spinal cord than to its posterior surface, where it is suspended by the action of the ligamentum denticulatum. It encircles also the nerves in their roots (no. 280).

715*p*. Between the arachnoid membrane and the pia mater there are formed duct-like cells, through which the juice, which is expressed from the pia mater and the little arteries, is directed to those places where it may be derived between the fibres, as well as between the fascicles of the fibres, and into the very medullary substance of the brain; so that all parts, by being anointed with a suitable moisture, may accomplish their functions; while the superfluous juice is carried away through the ducts of the arachnoid membrane. Thence it appears that this membrane performs in the brain the same use which the lymphatics perform in the body (no. 284).

2. FROM PART II. OF THE PRESENT WORK.

The Cerebro-spinal Liquid and the Arachnoid Membrane.

715*q*. The moisture which is expressed from the vessels of the pia mater is directed by the arachnoid membrane between the fibres and laminæ of the nerve-roots or fascicles. For the nerve throughout its whole extent is like a filter, that is, it is perforated like a stalk, so that by separate channels it transmits distinct juices. The present juice, that is, the cerebro-spinal liquid, holds the sheaths of the fibres and the laminæ of the fascicles apart by anointing them; it also lubricates the roads. Nor do I believe that any one will call into doubt the ability possessed by such fluids of percolating through the porous network of the nerve, if he attend but slightly to the numerous phenomena presented by the nature of fluids, whereby we are informed that a humour, whether of an aqueous or oily nature, by invisible channels, is transmitted with the greatest ease and almost of its own accord from the bottom to the top, and also obliquely in every direction, as may be observed in stalks, branches, twigs and grasses, where the juices ascend from the roots to their highest tops (no. 493).

The forum or market-place, where the lymph, which is contained under the arachnoid membrane, that is, the cerebro-spinal liquid, flows together, is in the lowest or hindmost region of the medulla oblongata around the calamus scriptorius. Thither it flows from both brains, and thither it is conveyed from the whole circumference of the medulla oblongata, and thence, through the foramen magnum of the occiput, it descends towards the posterior surface of the spinal cord (no. 523).

715*r*. The lymph, which is contained under the arachnoid membrane, passes out between the medullary fibres of the brain and the nervous fibres of the body. . . . Without such a perennial source, and without a lymph flowing between them, the fibres would easily coalesce, whereby the individual or single forces of the nerves and muscles would run together . . . into such as are merely general, as is usually the case in persons where the motor fibres no longer yield obedience to the mind. Wherefore this lymph is like an ointment which oils, smoothes and lubricates the hinges (nos. 503, 509).

This same lymph is derived between the laminæ of the fascicles of the nerves. Every fascicle of fibres within the cranium and the vertebral theca is called a nerve-root, and is covered with a double or triple coating, the inmost of which has respect to the fibres, but the outermost to its associate fascicles in the nerve. These laminæ are kept apart and prevented from coalescing by a juice of a most subtle quality. This juice is none other than that which runs between the fibres, or which is also reserved for this use under the arachnoid membrane (no. 51).

The arachnoid membrane not only covers the cerebrum and cerebellum, but it accompanies also the roots of the nerves in the cranium, as well as in the spinal cord, as far as their outlets, thus sprinkling its noble juice between the laminæ of the nervous roots, as it also instils it between the fibres. . . . It appears as if the arachnoid membrane had chiefly the care of the nerves of the body under its charge (no. 512).

CHAPTER XXVII.

THE PONS VAROLII, THE CORPORA PYRAMIDALIA AND OLIVARIA.

a. The Pons Varolii.

716. The pons Varolii is the marriage-chamber or marriage-bed of the two brains, the larger and the smaller; for there the two like a married couple first embrace each other, and enter into a mutual covenant for the conception and the bringing forth of their nerves. The cerebrum moves thither from above with its active grey substance and its power of acting, and also with its medulla; the cerebellum comes from below with its medulla. For the medullary trunk of the cerebellum, which is collected from each leaf, twig, branch and stalk, after it has been divided into three heads or forks, in the immediate neighbourhood of the medulla oblongata, sends its chiefest parts forwards on either side into this annular protuberance or pons Varolii, as into a prolific soil; and after it has arrived there it at once breaks up into fibres, as the trees resolve themselves into roots. These fibres it throws out in a beautiful order and series, and through the surface insinuates them upwards, bent almost in the form of a revolving cycloid; and it does not cease its gyrations, until it reaches the middle of its diameter, where the fibre of one side meets with that of the other side. In the middle, where through these insinuations and gyrations a little groove is formed, the common trunk of the vertebral artery reposes, which, with its branches reaching out everywhere sidewards and inwards, is held fast in its place by the fibres. This second process of the cerebellum towards the pons Varolii, in addition to these roots

and large superficial fibres, submits also other more slender fibres disposed almost in the same order, which are underneath the former, and do not penetrate as far as the above-mentioned little groove, that is, the groove for the basilar artery; but at a little distance thence they enter the caudex, where they intertwine themselves with many fibres sent thither from the cerebrum as well as with such as are born or generated in the pons itself, and they direct themselves either towards the anterior surface of the spinal marrow, or enter into nerves.

717. WILLIS.[1]—"Several processes ascend obliquely into the cerebellum; and near them other processes descend in a straight line from the cerebellum, which do not seem to be inserted in the medullary caudex, but passing around constitute an annular protuberance, the pons Varolii. This annular protuberance is larger in man than in any other animal. I must remark further, that wherever the corpora quadrigemina above it are larger, the pons Varolii below is very small, and *vice versa* (p. 18). . . . As regards the pons Varolii, wherewith the medullary trunk in man, as well as in every quadruped, is engirded, it is formed in the following manner:—As soon as the second or middle process of the cerebellum, which descends in a straight direction to the medulla oblongata, touches its sides, it does not seem to be immediately implanted therein, but it increases into a broader mass, and, by a number of various circular fibres, encloses the surface of the same medulla; and after both processes of the cerebellum in this manner have descended on either side from the top of the medullary caudex to its base, they meet there and form this circular protuberance. Its compages is very much larger in man than in any other animal; in the hare, the rabbit, the mouse, and similar other animals, it is very small. . . . In respect to its size, the following observation applies constantly:—Where the corpora quadrigemina, in front of the cerebellum, are very small, this annular protuberance is very large, and *vice versa;* further, where these corpora are completely wanting, as in birds, this protuberance

[1] "Cerebri Anatome," Cap. II., III., XV.

also seems to be wanting. In most brute animals, but not so in man, near this larger protuberance, but a little lower down, another smaller protuberance, likewise circular, is situated, which also passes around the surface of the medulla oblongata. The root of this is a white and medullary line, which stretches out under the cerebellum, on the floor of the fourth ventricle. From the sides of this smaller protuberance the auditory nerves take their origin; but in man these nerves seem to originate from the extreme edge of the larger protuberance, and they also have for their root that white medullary streak which lines the floor of the fourth ventricle (p. 23). . . . The second process, which descends in a straight line from the cerebellum, embraces the medullary process, and, passing around it in this manner, it constitutes an annular protuberance, the pons Varolii, out of which the nerves of the fifth, sixth and seventh pairs derive their origins; in such a manner, indeed, that this protuberance seems to be the storehouse or reservoir of the spirits emanating from the cerebellum, whence these spirits are able to flow out, and to be drawn into, the ducts of the nerves situated at the sides" (p. 103).

718. VIEUSSENS.[1]—"The two processes from the cerebellum towards the medulla oblongata, which, by their coalition on the bottom of the medulla oblongata, constitute the 'annular protuberance' of Willis, or the pons Varolii, consist of exterior and thicker, and of interior and smaller medullary fibres. After the exterior medullary fibrils of the two processes which, from the cerebellum, pass towards the medulla oblongata, have reached the middle of the base of the medulla oblongata, they come into immediate contact with each other in a little groove, sometimes rather deep, which the basilar artery forms there in man. There also these fibres mix promiscuously, and engird the medulla oblongata in the form of a ring; on this account, also, without doubt, Willis called it the large annular process. Of the interior fibres, however, the extreme ends of which are distinct from each other, and which seem a little inclined down-

[1] "Neurographia," etc., Cap. XII., XIII.

wards, as may be seen in Plate xvi., some near the middle region of the base of the medulla oblongata are placed above some white tracts which emerge out of the middle of the corpora striata, while others are placed underneath them (see Plate xiii.); whence it is, that the above-mentioned medullary fibrils, and also the above-mentioned white tracts, intersect one another crosswise, as can easily be seen in the dissection of the brain. From the above it appears that the process from the cerebellum towards the medulla oblongata and the pons Varolii are essentially one and the same thing. This annular process, however, Willis calls the larger one, in order to distinguish it from a smaller one which is found in the cerebellum of certain animals, but never in the human brain (p. 80). . . . Where the above-said medullary tracts, which appear in the middle of the corpora striata, are continued towards the spinal marrow, before leaving the cranium, they climb over other medullary fibres of the pons Varolii; so that the medullary tracts, which emerge out of the middle of the corpora striata, and the medullary fibres of the pons Varolii, are crosswise interlaced with one another, nay, and intercommunicate with one another" (p. 87).

719. Ridley.[1]—"Where the two crura of the medulla oblongata, that is, the under part of the optic thalami come close together, the 'annular protuberance' or pons Varolii, made up of the second process of the cerebellum towards the medulla oblongata, begins to cover up the medulla oblongata for about the space of an inch and a half, after which this medulla oblongata, in one large trunk, is continued to the first vertebra of the spine, and so quite down to the end thereof" (p. 140).

Winslow.[2]—"The transverse annular, or rather semi-annular protuberance, is a medullary production which seems at first sight to surround the posterior extremities of the great branches of the trunk of the medulla oblongata, but the medullary substance of this protuberance is in reality intimately mixed with that of the branches of the above-mentioned medullary

[1] "Anatomy of the Brain," Chap. XV.

[2] "Anatomical Exposition," etc., Sect. x.

trunk. Varolius, one of the ancient Italian authors, viewing those parts in an inverted situation, compared the two branches to two rivers, and the protuberance to a bridge under which both these rivers met, whence it has the name of pons Varolii. Its surface is transversely streaked, and it is divided into two lateral parts by a very narrow, longitudinal depression which does not penetrate into its substance. The smaller branches of the medulla oblongata are lateral productions of this protuberance which by their roots seem to encompass that medullary portion in which the fourth ventricle and the calamus scriptorius are formed" (Sect. x., nos. 107, 108).

b. The Corpora Pyramidalia and Olivaria.

721. Willis.[1]—"It is further to be observed that near the lowest base of the medulla oblongata, as it were, two larger cords proceed from the pons Varolii, which pursue their way towards the spinal marrow in a straight direction, separate from the remaining medullary trunk, and after in their progression they have gradually become narrower, so as to assume a pyramidal shape, after proceeding for about an inch further they terminate in sharp points. Their extremities consist of that region whence the nerves of the par vagum derive their origin, and they cause a certain intumescence in the medulla oblongata. . . . So long as these corpora pyramidalia remain invested with pia mater, and lined with the plexuses of vessels, they do not appear so manifestly, but when the pia mater is torn off they become so conspicuous, especially in man and the dog, as to present the appearance of large nerves. In those animals, where the pons Varolii is a little larger, these processes are produced in right angles in respect to the same, and are broader and more conspicuous, and *vice versa;* in birds they are totally wanting (p. 24). . . . The corpora pyramidalia are continued from the pons Varolii on the medulla oblongata towards the spine, for this purpose, that the abundant supply of spirits

[1] "Cerebri Anatome," Cap. III., XV.

in that storehouse, by the elongation of these processes, may be able to flow out partly into the origin of the eighth pair of nerves, and partly into the cemmon tract of the medullary caudex" (p. 103).

722. VIEUSSENS.[1]—"Between the processes from the cerebellum towards the corpora quadrigemina, and the processes from the cerebellum towards the medulla oblongata, there are found two white bodies, one on each side, which are similar in shape and colour to nerves, or at least to nervous fibrils; two bodies of this kind, however, tend towards the upper part of the pons Varolii (p. 81). . . . The corpora pyramidalia, which are situated below the pons Varolii, are two white, pyramidal prominences which are discovered in the middle of the base of the medulla oblongata about its end, and which, although they coalesce, yet by the interposition of the anterior spinal artery, appear distinct from one another. The corpora olivaria are two white prominences of the shape of the kernel of an olive which are at the sides of the corpora pyramidalia" (p. 82).

723. RIDLEY.[2]—"There are also two white, long medullary processes called corpora pyramidalia both by Willis and Vieussens which arise just at the termination of the pons Varolii; these bodies run down upon the medulla oblongata for the space of an inch, ending some distance below the place where the nerves of the eighth pair begin, which have their origin between the corpora olivaria and the processes of the cerebellum towards the spinal marrow, partly on the side thereof; differently from Dr. Willis' account of them, who describes them as ending in pointed extremities, just where these nerves have their origin. On each side of these appear plainly the corpora olivaria, so called from their figure, as the former were called by Vieussens, which, with the corpora pyramidalia and the corpora albicantia behind the infundibulum, he calls 'conceptacula spirituum animalium,' the places of conception of the animal spirits" (p. 141).

[1] "Neurographia, etc.," Cap. XII., XIII.
[2] "Anatomy of the Brain," Chap. XV.

724. WINSLOW.[1]—"Four eminences first come into sight, of which two are named corpora olivaria, and the other two corpora pyramidalia. Immediately afterwards, the medulla oblongata is divided into two lateral portions, by two narrow grooves, one on the upper, and the other on the lower side. They both run into the substance of the medulla, as between cylinders, flattened on that side where they are joined together. On separating these grooves with the finger, we notice a cross-wise interlacing of many small medullary cords, which run obliquely across from the substance of one lateral portion into the substance of the other. M. Petit is the author of this discovery, by which we are enabled to explain several phenomena both in Physiology and Pathology. The corpora olivaria and pyramidalia are whitish eminences situated longitudinally near each other on the lower side, immediately behind the pons Varolii. The corpora olivaria are in the middle, so that the interstice between them, which is only a kind of superficial groove, answers to the inferior groove of the following portion. The corpora pyramidalia are, as it were, two collateral eminences depending on the corpora olivaria. . . . These four eminences constitute the lower half of the medulla oblongata; which observation I here repeat, so as to impress upon the reader that in all the figures and demonstrations these parts are represented as superior, which in their natural situation are inferior. So also these eminences are under the fourth ventricle, and under the peduncles of the cerebellum" (Sect. x., nos. 109-112).

725. In Willis' Plate vi. is represented the pons Varolii, like a circular area, and all around it, near its edges, are distributed the origins of several nerves; the same in Plate v. In Duverney's Plate, in his treatise on the ear, it is likewise represented very exactly; there also is marked the interstice or the transverse groove between the pons Varolii and the corpora olivaria. It is shown there that the fourth thin pair of nerves emerges near the upper edges of the pons Varolii; the fifth pair, however, which is quite robust, on either side of this

[1] "Anatomical Exposition," etc., Sect. x.

protuberance; the sixth pair from the top of the corpora olivaria; the seventh pair from the lowest portion of the pons; the eighth pair like a bundle on both sides, under the corpora pyramidalia—near the sides of which they burst forth; the ninth, however, from the middle of the lowest part of the corpora olivaria; and the tenth below, from the caudex itself. In Plate iv. of Vieussens, the pons Varolii [O O] is represented evolved like a cycloid with oblique superficial striæ; and also a certain fibrous and striated process above it [N N], which descends into the compages of the pons itself; further, the vertebral arteries [Q Q], which, upon being united, form the basilar artery [P]. This last artery is seen passing through the middle of the pons, and on both sides it sends out branches into it, and inserts them into it. It is also shown how the basilar artery, immediately beyond the pons, is dispersed into branches which communicate with the carotids; further, how the two trunks of the vertebral artery, together with a certain canal in the middle, pass through the middle of the corpora olivaria: the corpora pyramidalia [R R] are noticed leaning against the sides of the corpora olivaria [S S]. In his Plate v. the same annular protuberance or pons Varolii appears like a broad ring [M M], and the corpora olivaria [O O], and pyramidalia [N N], like inverted bottles; there also are represented the vertebral arteries and likewise the nerves. In Plates v., xiv., and xv., the same is represented, together with the groove which divides the lateral portion at the pons on the surface. In Ridley's Plate i. the whole is represented a little differently; there also are exhibited the pons Varolii, the corpora pyramidalia and olivaria, together with the junction of the vertebral arteries and their common trunk. In his Figure vii. is shown the exterior appearance of the pons; and in Figure vi. it is exhibited a little shaved off. Heister states that the pons Varolii was badly drawn by Willis and others, but well by Ruysch.

[MODERN AUTHORS.

725a. QUAIN.[1]—"The PONS VAROLII or *tuber annulare* forms a prominence marked by transverse fibres above and in front of the medulla oblongata, and between the lateral hemispheres of the cerebellum. Its ventral surface and upper and lower margins are arched, the superior much more so than the inferior; and at the sides its transverse fibres are gathered together into a compact mass, which passes into the cerebellum, and is named the *middle crus or peduncle of the cerebellum.* Along the middle of its ventral surface the pons has a shallow groove along which the basilar artery runs, and it is perforated by small branches of the artery. The pons consists ventrally of transverse or commissural fibres, between which the longitudinal fibres, prolonged upwards from the medulla oblongata, pass, together with a large admixture of grey matter. The superficial fibres of the ventral surface are transverse in their general direction, but while the middle fibres pass directly across, the lower set ascend slightly, and the superior fibres, which are the most curved, descend obliquely to reach the crus cerebelli on each side; some of the upper fibres cross obliquely the middle and lower ones so as to conceal them at the sides. When the superficial transverse fibres are removed, the prolonged fibres of the anterior pyramids come into view; these, as they ascend through the pons, are separated into smaller bundles, intersected by other transverse white fibres, which, with those upon the surface, are all continued into the middle peduncle of the cerebellum.

"At the lower part of the pons, behind the fibres from the anterior pyramids, is a special set of transverse fibres named the *trapezium*—so called because in most of the lower animals, in which the more ventrally situated fibres of the pons are not developed, and the pyramids are small, these transverse fibres partially appear on the surface between the pyramid-bundles

[1] "Elements of Anatomy." NINTH EDITION. London, 1882.

in an area of a somewhat four-sided shape. Laterally they curve round a collection of grey matter behind them, called the superior olivary nucleus, and probably many of them are connected with its cells. They then course outwards across the bundles of the facial nerve-roots, and in front of the upward prolongation of the substantia gelatinosa of the tubercle of Rolando, and the bundles of fibres belonging to the ascending root of the fifth nerve to join the middle peduncle of the cerebellum.

"Between the bundles of fibres of this ventral portion of the pons, grey matter with small multipolar nerve-cells is everywhere found (*nuclei pontis*). It is probable that many of the transverse fibres are connected with these cells, and it may be that a cell is connected at one part with a transverse or commissural fibre, and at another sends a process to reinforce the longitudinal fibres of the pyramidal tract ascending through the pons; but the same fibres do not appear to turn upwards, *for the transverse fibres are smaller than the longitudinal.* The interspersed grey matter seems to correspond to that which is found between the arcuate fibres of the medulla.

"The posterior or dorsal portion of the pons is chiefly constituted by a continuation upwards of the formatio reticularis, and of the grey matter of the medulla oblongata. As in the latter, there exists here also a median septum or raphé, which is similar in structure to that of the medulla. It does not extend through the ventral half, being obliterated, or nearly so, by the great development of the transverse or commissural fibres, except near the upper and lower borders, where the superficial fibres of the pons turn in at the median line; and especially on the upper border, where bundles of the same fibres encircle the crura cerebri as they emerge from the pons.

"In the reticular formation, in addition to the scattered and reticularly-arranged grey matter with nerve-cells everywhere met with, there are one or two important collections which lie imbedded in this formation, and from which nerve-fibres arise. One of these is the superior olivary nucleus, another is the nucleus of the seventh or facial nerve, and others give origin to portions of the fifth nerve.

"The SUPERIOR OLIVARY NUCLEUS is a collection of small nerve-cells which lies behind the outer part of the trapezium, in what corresponds—as indicated by the passage outwards of the roots of the sixth and seventh nerves—to a prolongation of the lateral area of the medulla. In man it is very much smaller than the inferior olivary nucleus, to which it does not present much resemblance. In some animals, however, it is larger, and has a distinct sinuous outline. From it, as above-mentioned, some of the fibres of the trapezium arise.

"The NUCLEUS OF THE FACIAL NERVE lies in a reticular formation just dorsal to the superior olivary nucleus, and at some depth, therefore, below the floor of the fourth ventricle. It begins to be visible in sections immediately above the medulla oblongata, and extends three or four millimetres upwards.

"The MOTOR NUCLEUS OF THE FIFTH NERVE (Lockhart Clarke) comes to view above that of the facial, but it is less deeply situated, lying a little below the lateral angle of the fourth ventricle. Both it and that of the facial contain large nerve-cells.

"The UPPER SENSORY NUCLEUS OF THE FIFTH NERVE lies on the outer side of the motor root. The cells are small and arranged in clusters separated by the fasciculi of origin of the nerve-root. This nucleus extends somewhat farther, both above and below, than the motor nucleus.

"The rest of the grey matter of the pons lies near the dorsal surface, and appears in the floor of the upper part of the fourth ventricle. Besides scattered nerve-cells, others are collected at certain parts into definite groups or nuclei from which some of the remaining cranial nerves take their origin. Like the similarly placed nuclei in the medulla oblongata, these also do not lie close to the epithelium which covers the surface, but are separated from it by a layer of gelatinous substance (neuroglia), free from nerve-cells, termed the ependyma of the ventricle.

"The INNER or PRINCIPAL NUCLEUS OF THE AUDITORY

NERVE, which lies under the tuberculum acusticum, is prolonged upwards underneath the striæ acusticæ into the pons. It is widest at about the junction of the medulla and pons, where it extends almost to the middle line; further up it rapidly narrows and becomes shifted towards the lateral boundary of the ventricle as the nucleus of the sixth nerve makes its appearance between it and the median sulcus. Its cells are small, and it is much broken up by the passage through it of fine transverse nerve-fibres.

"The OUTER OR SUPERIOR NUCLEUS OF THE AUDITORY NERVE (nucleus of Deiters, Laura) is characterized by the large size of its cells, and lies immediately on the outer side of the main nucleus. It does not begin to be visible so far down as this, but is continued as far upwards, rather increasing in size superiorly, whereas the main nucleus diminishes. It is much broken up by longitudinal fibres. The connection of this nucleus with the auditory nerve is called in question by Laura.

"The ACCESSORY NUCLEUS OF THE AUDITORY NERVE is represented in the upper part of the medulla by a collection of nerve-cells lying in the angle between the restiform body, and the two portions of the posterior root of the nerve. But the chief part of the nucleus is placed higher up in the region of the pons on the outer side of the anterior root. It is remarkable for the fact that its cells are enclosed like those of the spinal ganglia each in a nucleated capsule.

"The NUCLEUS OF THE SIXTH NERVE (common nucleus of the sixth and seventh of some authors) consists of a tract or column of large multipolar cells lying on either side of the median sulcus. It corresponds to the part of the funiculus teres which lies in front of the striæ acusticæ on the floor of the fourth ventricle. It has a close relation to the root of the facial which runs along its mesial side, curves round it eventually, and appears to receive some fibres from it, but it is somewhat doubtful if this is really the case (Gowers). Its cells are smaller than those of the facial nucleus" (ii., pp. 299-304).

Concerning "the upper portion of the fourth ventricle," see above, no. 704*d*.

725*b*. MEYNERT.[1]—"The bundles of fibres composing the *processus cerebelli ad cerebrum*, in the region of the crus cerebri above the corpora quadrigemina, are forced apart by the introduction of a mass of finely granular substance, containing nerve-cells of two general sizes (some 45μ by 15μ, others 15μ by 3μ), and are thereby made to form the centrum rubrum tegmenti. In the region of the superior corpus bigeminum this same process appears as a simple medullary tract, the circumference of which, by the absence of the granular grey substance, must manifestly be less than that of the centrum rubrum. . . . This medullary tract continues to contain large numbers of nerve-cells, and these remain scattered among its fibres even after its decussation.

"These nerve-cells, which are of great size (45μ by 15μ) are disposed in a striking and unusual manner, inasmuch as they lie parallel rather to the smallest arteries and the capillaries than to the nerve-fibres. They appear to be in the closest apposition with the walls of these vessels, are suitably bent to fit the angles made by their branches, and send out long and thick processes that run longitudinally along, and probably in, their walls. This peculiar arrangement is to be demonstrated even in the centrum rubrum itself, and from there onwards to beyond the point of decussation of the processus, and the processus itself does not free itself entirely of nerve-cells until it has emerged from the corpora quadrigemina.

"The processus cerebelli ad cerebrum is seen to approach very near the median raphé. The surfaces, which it presents on successive cross-sections, are never made up exclusively of the cut ends of longitudinal fibres, but even in the region above the lower half of the superior corpus bigeminum contain also a large number of transverse lines which correspond to such fibres of the processus as have left their longitudinal course to pass over to the opposite side of the tegmentum, decussating at

[1] "Op. citat."

the median line with those that cross in the reverse direction. . . .

"This decussation, and the subsequent process of reconstruction of the processus cerebelli ad cerebrum, takes place in the region of the lower half of the inferior corpus bigeminum and of the place of exit of the nervus trochlearis. . . .

"The processus of the two sides, taken together with the decussating fibres, come thus to have the form of a horse-shoe opening backwards, which encloses between its two branches the comparatively large area occupied by those constituent fibres of the tegmentum destined for the spinal cord which lie between the posterior longitudinal fasciculi and the stratum lemnisci. . . .

"The position of all the spinal cord fibres of this region is completely governed by that of the processus, which, in the course of their decussation, force their way among the former and push them aside in such a manner that, so long as the processus occupy a central position in the tegmentum, the remaining fibres lie to the outside of them, whereas, when the processus attain a lateral position, the other fibres appear on cross-section between them. . . .

"After having completed its decussation, which is undoubtedly complete, . . . each processus disengages itself superiorly and externally from the posterior division of the projection-system in which it was imbedded. . . . Opposite the greatest convexity of the pons it lies entirely free" (pp. 712, 713).

725*c*. "The basis cruris cerebri becomes split up into secondary fasciculi by the passage through it of the transverse fibrous tracts of the *processus ad pontem*.

"After these fascicles have still further divided into bundles of very small size, a certain number of their component fibres . . . enter into connection with nerve-cells (30μ in length and 12μ in thickness), which cells are in connection likewise with the fibres of the processus ad pontem.

"These nerve-cells are found along the borders of the districts occupied by the secondary groups of longitudinal fibres belonging to the crus cerebri, where the latter lie in contact and evidently in connection likewise with the fibres of the processus ad pontem. They lie further: (1) towards the more central portions of the secondary groups of longitudinal crural fibres, which indicates that these groups are everywhere penetrated by the fibres belonging to the processus ad pontem; (2) within the strata that contain the exclusively transverse fibres of the processus, viz., both the superficial and the deep transverse fibrous layers of the anterior division of the pons.

"We may divide the *transverse* fasciculi belonging to the processus ad pontem, as they appear on the surface of the pons obtained by cross-section, into (1) a superficial stratum; (2) those interwoven among the longitudinal crural fibres; (3) a deep-seated stratum" (pp. 714, 715).]

ANALYSIS.

726. The pons Varolii is the marriage-chamber, as it were, of the fibres of the cerebellum, as well as of those of the cerebrum and of those of the central ganglia, *i.e.*, the optic thalami and the corpora striata. The fibre of the cerebellum enters this chamber as a bride, for it bends and bulges itself around the surface. The fibre of the cerebrum, attended by, and adjoined to, the fibres of the central ganglia, which serve in the capacity of bridesmaids, flows into, and through this protuberance, and on its passage inserts itself in various places into the fibres of the cerebellum. From their mutual intercourse in the marriage-bed itself there arises a triple progeny, and further down in the protuberances below, an offspring still more manifold; nay, as many as six or seven pairs of nerves, have their birthplace there. But in what manner the fibre of the cerebrum and that of the cerebellum mutually embrace each other, and how the fibre of each is betrothed to that of the other, this escapes the sight of the eye, and hence also the scrutiny of the rational mind. So much, indeed, is very clear, namely, that each single fibre flows most distinctly, and that in this gathering of roadways, each fibre has respect to the end from the beginnings, and to the beginnings from the end; and that it never deviates one hair's breadth from its determination. Further, that here, in the pons Varolii, is the first station where the above-mentioned fibres of a threefold origin and quality establish a certain common meeting-ground, whence they launch forward into their field of action, institute their olympic games, and keep in sight their goals.

727. The fibres which, on either side in the form of a hemicycle, revolve around the surface of the pons Varolii, hold the

vertebral artery, that is, the united trunk of the basilar artery, tied and bound in such a manner that this vessel, according to every exigency, is expanded and constricted not only by a general, but also by a particular force, aid and summons. This work has been assigned to the fibres of the cerebellum which creep along the surface, and constantly act upon their own proper artery. On this account also these fibres are arranged in, and bent into, such a circular form that not only the general action of the pons, but also the particular one of its fibres by a suitable determination may enter into the fibres of the first as well as of the second order, or, into those of the roots of the nerves; again, that the general action of this organ may enter into the subsequent roots of nerves which are about to emerge out of the corpora olivaria and pyramidalia, and likewise out of the trunk of the spinal marrow itself, and, finally, that this action may be thoroughly accommodated to the surrounding members and cavities as well as to those that lie on the opposite side, namely, to the infundibulum, the corpora striata, the corpora albicantia, to the isthmus and its approaches, to the fourth ventricle, as well as to its own associate processes, namely, to the first and third processes of the cerebellum, and to the rest which are at a still greater distance. For in a unanimous series there is a continuous connection, as well of substances as of motions, from the first to the middle, and from the middle to the last or ultimate parts.

728. Without a previous knowledge and acknowledgment of the expansion and constriction of the body itself of the pons Varolii, we remain in deep ignorance as to the meaning of the inflected, wedge-like form assumed by its fibres. We know, indeed, nothing whatever, unless we look upon the axis of the pons Varolii as then in a state of circumrotation (*peritrochio*), or upon its spiral disk (*tympanum cochleatum*) as it were in a state of motion. So soon, however, as we cherish a faith in its reciprocal agitation, everything at once becomes transparent and comprehensible. When thus it is perceived that the cerebrum and the cerebellum, together with the corpora striata and

the optic thalami are moved in alternate periods, it follows that the pons, the annular protuberance, which is interposed here, is urged around by all these bodies, and stimulated into action by its own fibres as to its least or most singular parts; so that it is turned in conformity with the ratio of the forces received thence, and with the arrangement of the parts. It follows thence in accordance with the physical laws which have become known to us, and in accordance with rules purely mechanical, that the fibres which in a winding manner creep over the surface of this annular protuberance, interlace and inwrap in a sinuous manner the whole of its anterior surface; further, that these winding fibres by virtue of their circular inflection pull downwards, and at the same time constrict in alternate periods the circumference of this protuberance, while in the interior structure of the organ the fibres belonging to the cerebrum endeavour to pull this organ upwards in the direction of the origin of their movements. Hence there results a kind of reciprocal action of the surface, and of the internal structure of the pons, similar to that of a hand-mill, where grooves, running in an opposite direction, are chiselled into the millstones, which grooves act upon each other according to an opposite method of grinding, for while the cerebellum conveys thither the strata of its fibres in bends or inflections in the direction towards its peduncles, the cerebrum also leads forth its own strata, whence there arises a kind of contradictory system of rotation. It appears hence how the blood flows into the attracted and dilated [basilar] artery, and into the branch communicating with the carotid artery, and even into the shoots themselves, for it flows in altogether in accordance with the intensity of the motion. It appears also especially how through such a reciprocal action of the fibres, or through the kind of action and reaction there, the pons Varolii is deprived of the faculty of extending its expansile motion to the tract of the medulla oblongata which is lower down, and succeeds next in order, namely, to the corpora olivaria.

729. Lest, therefore, the expansile motion of the medulla

oblongata should be continued beyond the annular protuberance or pons Varolii as far as the corpora olivaria and pyramidalia, a transverse groove or fold, like a boundary ditch, is interposed between the part of the pons furthest down, and the part of the corpora olivaria highest up. This is a manifest indication that, if the pons should transgress beyond its ring or circle in that direction, its motion would turn back upon its course, and its impetus being checked in this way would be neutralized. The object of this is that the expansile motion may thus be shifted towards the posterior surface of the medulla oblongata where the fourth ventricle and the calamus scriptorius are situated, both of which are capable of expansion, and, consequently, towards the posterior surface of the spinal cord, on which account also the medullary caudex does not adhere to the hinder wall of the vertebral cavity, although it is closely affixed to its anterior wall. The final reason, however, is lest the roots of the nerves in the medulla oblongata itself, as well as in the spinal marrow, by the alternate motions should be pulled upwards and displaced, and thus drift about, whence there would result an uncertainty in their determination.

730. This is further confirmed by those diminutive folds and interstitial fissures, which are introduced between the corpora olivaria and the corpora pyramidalia below, but which run in the direction of diameters in respect to the higher transverse groove; for the pyramidal corpora, by means of these folds, can retreat a little towards the sides, whither the motion is directed, and thus are able to avert and repress inroads from above. Besides, if the situation of the parts in this lowest region of the medulla oblongata is carefully compared with the motion of each, namely, with the situation and motion of the fourth ventricle, of the calamus scriptorius, of the fibres which climb up the ventricle, of the roots of certain nerves, especially of the eighth pair; further, with the situation and motion of the lower vermiform process and of the pons Varolii—it will appear from this comparison that forms like those which are called olivary and pyra-

midal must needs exist there; and that these corpora are the very apices or genuine beginnings of the spinal marrow, although they have their origin within the cranial cavity; for in their neighbourhood the motion of the medulla oblongata ceases, and that of the spinal marrow begins.

731. I may be allowed to introduce here a conjecture; for whatever does not flow from evident marks, and whatever induction is based only upon the connection of parts, all this, I hold, must be relegated among hypotheses. The conjecture, however, is as follows:—The second process of the cerebellum, whence arise the fibres of the pons Varolii, and perchance also those of the par vagum, originate from the middle region of the cerebellum; but the fibres of the first process [crura ad testes] from its posterior region, and those of the third process [crura ad medullam] from its anterior region. That the fibres of the pons Varolii spring from the middle of the cerebellum may be concluded, it seems to me, from that middle stalk which terminates in the peduncular trunk of the cerebellum. Further, it may also be concluded that there proceeds thence the strongest and most constant action of the cerebellum, such as is wanted for the pons Varolii and the par vagum. Again, from the usage which is frequently observed, and according to which the fibres are everywhere connected by decussations, as is also the case here near the corpora olivaria and elsewhere, it follows that such also must be the case in the cerebellum, where, even as the highest parts tend towards the lowest, and the lowest parts towards the highest, so also the middle parts, which are formed from the two sides pressing together, will result in an inextricable knot, such as presented by the cerebellum. Yet this is written down simply *en passant*.

APPENDIX TO CHAPTER XXVII.

FROM AN EARLIER WORK ON THE BRAIN.[1]

a. The Pons Varolii.

731*a*. The pons Varolii consists of the fibres of the cerebrum which embrace those of the cerebellum, interlace themselves with them, and insinuate themselves into them. In the pons Varolii, again, the fibres of each of the brains intertwine themselves with, and insinuate themselves into those fibres which are proper to the medulla oblongata.

In this semi-annular protuberance, called the pons Varolii, we are able to see, more clearly than in the other members of the brains, those figures which arise from the inflexion of the fibres, because they visibly creep around that organ, and mutually incline towards a diametral line, where the basilar artery, about the middle of the organ, lies as it were hidden away, and imbedded in a certain groove. We remain profoundly ignorant of the meaning of these carved, wedge-like masses of fibres, so long as we do not know beforehand and acknowledge the animation of the adjacent bodies; and we are unable to understand the meaning of the arrangement of the whole texture, so long as we do not behold the machine in motion. But as soon as ever we have faith in the reciprocal agitation of this organ, all that is submitted to the sight in this organ becomes at once intelligible. As soon, then, as we perceive that the cerebellum and the cerebrum, with its corpora striata and optic thalami, that is, with the upper and lower beginnings of the medulla oblongata, swell and subside in alternate periods,

[1] Codex 65. Photolithographed MSS., Vol. iv., pp. 116-118.

just like the pulmonary bellows: it follows thence, that the intervening plane or annular tuber—the pons Varolii—driven around by them all, and moved in its most singular parts by its own fibres, is wound or turned about in conformity with the ratio of forces received, and with the arrangement of its own parts and lines. Thence it follows, in accordance with purely mechanical rules, and those physical laws which have come to our notice, that the fibres which in tortuous windings extend their course over the surface of this orbicular protuberance, constrict its whole anterior side in a sinuous manner; and indeed in the same way in which the first process or peduncle of the cerebellum, on the opposite side, is belt-like thrown around the medulla oblongata under the corpora quadrigemina; so that the constriction of the caudex shall be of the same character on the one side as on the other; with this distinction only, that in the pons Varolii the area, as well as its sinuous contexture, is larger. Again, it follows that the winding fibres, which occupy the surface of the pons Varolii, and which are those of the peduncles of the cerebellum, on account of their circular inflection, pull down and at the same time constrict the surface; while the straight fibres in the medullary stem, which are those of the cerebrum, draw the same up towards the origin of their motions: whence there arises in the pons Varolii a reciprocal action of the surface and of the interior of the medulla, and a certain likeness to the motion of a hand-mill, in the stones of which are wrought grooves which run in opposite directions and which act upon the substance to be ground by movements derived from opposite sources. For while the cerebellum pulls the strata of its fibres towards their sources and thus towards the peduncles, in accordance with their winding course, the cerebrum also pulls the cerebral fibres towards their sources; whence there arises a kind of turning into opposite directions. There results hence an action on either side towards the posterior surface of the medulla oblongata, where the fourth ventricle is situated, and where a deep cleft or fissure runs down to the spinal cord; and no action whatever is communicated to the anterior surface of the medulla through the corpora olivaria and pyramidalia, between which and the pons Varolii a little space is left, that is, an interstitial groove or fold is introduced.

b. The Peduncles of the Cerebellum, together with the Corpora Pyramidalia and Olivaria.

731*b*. Almost from the same place of insertion whence the cerebellum, for the purpose of forming the pons Varolii, sends out, from the trunk of its medullary tree, that process or peduncle which is called the second, it throws out two other processes. One of these on either side it dispatches towards the corpora quadrigemina. This process, called the first, encircles the caudex of the medulla oblongata, like a fasciated belt. The other, of a harder consistency, it sends downwards towards the spinal cord. This process is called the third or restiform. From the second process, the one first mentioned, which proceeds in a transverse direction, two medullary tracts are produced on either side towards the edge of the fourth ventricle, and these presently terminate in another transverse tract. This transverse lower tract runs parallel with the higher; it is wider in the middle with a division. At the sides it has a double front, like a cord cleft into two. Under this tract the restiform or third process of the cerebellum works its way, and gradually, as it approaches the foramen magnum of the occiput, runs in an oblique direction and becomes contracted, so as to enter the spinal cord.

731*c*. *The corpora pyramidalia* extend immediately below the pons Varolii for about an inch within the cranium; as though they were the topmost apices of the spinal cord, and the lowest extremities of the medulla oblongata. So far as their surface is concerned, they are whitish eminences, which are separated from the above-mentioned pons by a groove, not very deep, which runs transversely. By the anterior spinal artery which originates either from the right vertebral artery, or from the common trunk which is made up from the two stems, and which runs on the superficial groove of these corpora, they are distinguished slightly into two columns, as it were, or pyramids. They are crossed by striated and medullary planes which are sent out from the cerebrum and cerebellum into the spinal cord, and which by degrees approach nearer to the central axis, and, as has been observed by Petit, by oblique decussations pass over to the fibres of the opposite side.

The *corpora olivaria* are, as it were, affixed on either side to these pyramidal bodies in the middle. Their topmost extremities, however, terminate below those of the pyramidal bodies; from which they are separated by a slight lateral fissure. Both vertebral arteries pass over these bodies in an oblique direction.

Experience, however, has not yet informed us where the striæ and fibres of these four columns originate; how those of one column climb over those of the other; into which points of the surface, of the axis in the middle, and of the nerves of either medulla, they are derived; and, finally, which striæ of fibres are sent over to the cisterns and foramina of the opposite region. For the fibre is here so compacted and interlarded with grey matter, that it can be extricated and identified only when one stratum is most carefully removed or lifted from another stratum, and the eye at the same time is armed by the most powerful glasses, so that the distinctions are clearly seen. The fibres which are presented before the naked eye are usually so imbedded in wasted, collapsed, frail and straggling other fibres, that they can furnish only a delusive light for conjectures, wherefore experience in these regions is quite misty, as it were. And yet for all that it cannot be denied that a most beautiful order pervades the whole, and that through invisible passages, which constantly escape the sight, lymphs and juices find their way. If a passage be denied to liquids, because vision declares that it has not been observed, and cannot be observed, what then should we say of the ventricles analogous to those of man in the least brains, or in the spinal cord of animalculæ, which can scarcely equal in size the spaces in our fibres of the second order. And yet the lymphs and spirits, by which they grow and are nourished, course most expeditiously through their medullæ and nerves even as they are conveyed into the muscles and members. This we are justified in concluding from their crawling and flight, that is, from the extremely swift vibration of their wings which does not strike the eye except as a general modulation, and which first reaches the ear as a buzz. Besides, the entire little bodies of some are beyond the sphere of our vision. Now, as according to the microscopic experience of Leuwenhoek, several thousands of vessels and little pores perforate a particle as large as a middle-sized grain of sand, what must not be the case with the smaller particles through which there flashes a liquid still more refined, which immensely exceeds in subtilty the visible flow in the blood-vessels and lymphatics (no. 163).

NOTE VI.

THE CHYMICAL LABORATORY OF THE BRAIN.

F. Functions of the Infundibulum and the Pituitary Gland.

1. General Uses of the Pituitary Gland.

1. SWEDENBORG describes the pituitary gland as "the last of the organs of the whole chymical laboratory in the brain," and as "their complement and crown" (no. 592). He also points to the fact that "the whole of the brain, with its substances and membranes, its intermediate and ultimate integuments, its processes, arteries and sinuses, concentres in this one gland, as in a certain terminus of its work," and such being the case, he says, "it must needs be that the brain has in view and carries out here some sublime and grand work which concerns the whole kingdom, and on which its welfare depends" (*ibid.*). "That the pituitary gland, however, is of such intrinsic importance, and that its nature is such," he continues, "can never be known from the gland alone, but only when it is regarded in connection with the parts that precede and follow it, and thus when it is considered from them."

That the pituitary gland performs an important use in the animal economy is also universally admitted by the modern school of comparative anatomy and physiology. So *Virchow*[1] says, "If, amid all the uncertainty that prevails respecting the interpretation of the use of this enigmatical organ, you will call to remembrance that the pituitary gland—the hypophysis cerebri—is almost the most constant of formations in the whole series of vertebrata, and that it preserves its relations to the sphenoid bone with the greatest persistence, you will at least not entertain any doubt that it represents an essential

[1] Virchow (R.). "Untersuchungen über die Entwickelung des Schädelgrundes," etc. Berlin, 1857, 4to.

link in the development of this class of animals." *Wilhelm Müller* [1] sums up the results of his investigations into the development and structure of this organ in these words, "If you compare the form of the pituitary gland in man with that which it has in the remaining classes of vertebrata, the result shows that this organ, with its essential attributes, descends through the whole family of vertebrate animals. . . . The fully-developed gland exhibits essentially the same characteristics in all animals furnished with a cranium. From this circumstance I infer that the gland has some very definite functions to fulfil which are not dispensed with as the animal organisms become successively more perfect. For only under this supposition does the continued transmission of this organ through the order of vertebrata, with the retention of all its essential attributes, become intelligible." This opinion *Mihalkovics* [2] quotes from W. Müller as expressing his own view.

But as regards the actual state of natural science on the subject of the use of this organ, *Ecker* [3] expresses it in these words, "I refrain from attempting to interpret this enigmatical organ and declare its functions, since we lack the very first ideas on the subject. I rather confess my absolute ignorance in this connexion."

Another more recent writer, *Sapolini*,[4] says, "The functions of the pituitary gland are still unknown; it constitutes a problem, the solution of which we do not possess; in short, that gland for us is still a myth."

2. One observer, however, from Swedenborg's point of view, seems to be on the right track—namely, *Leydig*.[5] Speaking of the pituitary gland in some fishes, in the *Raja clavata*, he says, "In respect to its external form I have to mention, first of all, that it is grown fast to the base of the cranium; and that, in the form of a

[1] Müller (Wilhelm). "Ueber Entwickelung und Bau der Hypophysis und des processus infundibuli cerebri," in "Jenaische Zeitschrift für Medicin und Naturwissenschaft." Vol. vi.; Leipzig, 1871; pp. 334-425.

[2] Mihalkovics (Victor v.). "Entwickelungsgeschichte des Gehirns," etc. Leipzig, 1877, 4to; p. 90.

[3] Ecker (A.). The article "Blutdrüsen," in Rud. Wagner's "Handwörterbuch der Physiologie." Vol. iv.; Braunschweig, 1853; pp. 160-162.

[4] Sapolini (G.). "L'aire de la selle turcique," traduit de l'italien par M. A. Hubert, etc. (Journal de Médecine, de Chirurgie et de Pharmacologie, publié par la Société Royale des Sciences médicales et naturelles de Bruxelles, for 1879; p. 305).

[5] Leydig (Prof. Franz). "Beiträge zur mikroskopischen Anatomie und Entwickelungsgeschichte der Rochen und Haie." Leipzig, 1852; p. 12.

reddish-yellow welt, 7‴ in length, it extends symmetrically to the right and left. . . . The closed sacs of which it consists, throughout the whole extent of the gland, are encircled by very many blood-vessels, and what appears strange, in the lateral productions of the gland, which abound with vessels, and chiefly there, are found blood-globules in their various retrograde metamorphoses. You will notice there, in cells 0,00675—0,0135‴ in size, all the intermediate steps from the still yellow blood-globule to the blackish remnants of such globules. The final condition of these cells in the pituitary gland must consequently be described as marking a transitional stage on their part into clear lymphatic globules of 0,003,375‴. At least the intermediate members between the lymphatic globules and other globules of 0,006,75‴, which contain the sharply-marked fragments of blood corpuscles, are far too numerous not to give rise in the mind of the observer to this supposition."

From Prof. Leydig's observation it would appear that the function of the pituitary gland consists in converting the antiquated red blood-corpuscle into its antecedent state of a lymphatic or white blood-corpuscle, or rather the red-blood corpuscle is first reduced into fragments, and fragments of these red corpuscles are developed into lymphatic or white blood-globules.

According to Swedenborg, the pituitary gland receives from the brain through the infundibulum those ingredients which, when combined with the chyle supplied by the thoracic duct, result in the formation of the red blood. These various ingredients, chief among which are the elements of the pure, lymphatic blood, the immediate parent of the red blood, the pituitary gland refines and equalizes, and dispenses to the blood in that proportion in which they are wanted. The actual infusion of the lymphatic or pellucid blood into the red blood, Swedenborg is led to infer from the facts of his time, begins after the various liquids and lymphs which contribute to the formation of the blood have left the pituitary gland; but Prof. Leydig's experience seems to show that the instillation of a spirituous lymph into antiquated blood-cells, and hence the regeneration of the red blood, at least in the lower animals, commences already in the pituitary gland itself: and that, for this purpose, blood-cells arriving from the carotids, or from other sources, are first broken up into fragments, and each fragment, then, by the instillation of the spirituous lymph of the brain, is transformed into a highly-living, lymphatic globule. Several of these lymphatic globules, according to Swedenborg's theory, enter afterwards into the composition of one red blood-cell. The full bearing of Prof. Leydig's discovery on Swedenborg's theory will be examined more in detail below, in no. 22.

3. Swedenborg's theory of the blood, as stated by himself, is as follows: "The globule of blood [blood-cell] is of a three-fold origin, order, nature, and hence dimension. . . . If, therefore, we would lay open the nature of the globule, we must conceive that the spirituous essence [animal spirit] constitutes the *first* order; that the less compounded blood [the spirituous lymph, or lymphatic blood], the fluid consisting of plano-oval spherules, constitutes the *second* order; and, lastly, that the red blood constitutes the *third* order; which last thus enjoys in a manner a triple maternity" (*Œconomia Regni Animalis*, Part i., no. 92). And again he says, "There are two kinds of blood, a grosser blood, and a purer blood, and the former is red, the latter transparent. . . . This latter blood is actually the very lymph that the lymphatic vessels absorb, and carry back through the thoracic duct into the red blood. . . . In an absolute sense, indeed, the purer or pellucid blood is the animal spirit, which floats in its lymph, as the red blood floats in its serum; wherefore the purer blood or animal spirit is, in a like manner, beset and surrounded by a serum, but of the most refined and delicate character, and properly termed lymph" (*Regnum Animale*, English edition, Part ii., no. 510, *e*).

According to Swedenborg, the pituitary gland superintends the purveyance of the more spirituous ingredients necessary for the composition of the red blood. For it is the recipient, *first*, of animal spirit from the fibre of the medullary substance of the brain which is continued into the gland through the infundibulum, and terminates there; *secondly*, it is the recipient of the spirituous lymph, or of the lymph of a middle quality, which is identical with the purer or pellucid blood, and which consists of "animal spirit floating in its lymph, as the red blood floats in its serum;" and *thirdly*, the gland receives a grosser serum, which, when supplemented by the chyle from the thoracic duct, is instrumental in preparing the more composite red blood out of the former more spirituous ingredients.

The "lymph" which "besets and surrounds" the animal spirit is derived partly from the minute vessels of the choroid plexuses, and partly from the interstices between the fibres of the brain. The "lymph" derived from the latter source is identical with the cerebro-spinal liquid. This lymph is conveyed into the choroid plexus from the subarachnoid space, and is afterwards fortified and strengthened by the grosser lymph secreted from the blood-vessels in the choroid plexus itself (see Note vii., no. 4). The serum of the *third* order, which is on the level with the more composite red blood, is likewise derived from the choroid plexuses, and besides, it trickles down through the epithelium lining the vaults of the ventricles. On this subject we read in Swedenborg's "Memorabilia," "The large ventricles of the cerebrum are places where serosities trickle down from the interstices between the fibres, and from other sources. They are thus a kind of urinary bladder of the brain, where serum or lymph is mixed with spirit; and whence spirit and the better portions are again secreted" (nos. 830, 831).

In the liquid which is conveyed from the lateral ventricles through the third ventricle into the infundibulum, the purer spirituous lymph, which is distilled from the choroid plexuses, is thus mixed promiscuously with a serum of a lower order. The two are separated in the infundibulum, and enter into the pituitary gland by distinct channels.

The spirituous lymph, that is, the lymphatic blood which is separated from the grosser serum in the infundibulum, is still more refined in the pituitary gland, and then that portion of it which enters into the posterior lobe of the gland is surcharged there with fresh animal spirit received immediately from the medullary substance of the brain in the infundibulum; while the remaining portion of that lymph is received in the central cavity of the gland. There it is equalized and refined, partly by the addition of animal spirit, and partly by the infusion of an additional refined serum, which, when needed, is distilled from the carotid blood, in the anterior lobe of the pituitary gland.

That spirituous lymph which has been surcharged in the posterior lobe with animal spirit, according to Swedenborg, is carried at once from the posterior lobe into the sinuses in the immediate proximity of the pituitary gland; and thence it is emptied into the superior petrosal sinuses. But the remaining spirituous lymph, or lymphatic blood, which constitutes the greater bulk of that liquid, according to our author, is conveyed immediately into the jugular vein through lymphducts in the sphenoid bone.

The grosser serum, however, which is separated from the ventricular liquid in the infundibulum, is conveyed through special pores or tubes from the infundibulum into the posterior part of the gland, whence it distils into a receptacle under the posterior lobe. And during the expansion of the gland, this serum is squeezed through a duplicature of the dura mater into the cavernous sinuses.—These points we shall examine presently in the light of modern science.

4. From a general survey of the uses of the pituitary gland as laid down by Swedenborg, it appears that it is a place of exchange, a mart, where the medullary substance of the brain meets the tissues and vessels of the body, and where the spirit of the brain is finally prepared for a marriage with the lower essences of the body. All the powers of the brain thus concentre in the pituitary gland, and through its mediation the riches of the higher sphere of the brain are communicated to the lower sphere of the body.

In conformity with the uses which are carried on through its mediation, the pituitary gland would thus seem to be composed of brain substance on the one hand, and of tissues of the body on the other. The substances of the brain would thus descend into the pituitary gland, and the substances of the body would ascend into it. The fact of this being so, is confirmed beautifully by the history of the development and formation of the pituitary gland in the embryo and fetus. For there it is made manifest that the gland is the joint product of the brain on the one hand, and of an organic membrane of the body on the other; the brain giving rise to the posterior lobe of the gland, and a membranous production arising from the cavity of the mouth furnishing the elements for the formation of its anterior lobe.

On this subject we read in *Quain*,[1] "The formation of the pituitary body may be shortly described as consisting in the meeting and combination of two outgrowths from very different fundamental parts; one cerebral or medullary from above, and the other corneous or epiblastic (*glandular*) from below, in a recess of the cranial basis which afterwards becomes the pituitary fossa. The cerebral outgrowth, the posterior of the two parts, takes place by the formation of a pointed projection downwards of a portion of the lower medullary wall of the vesicle of the third ventricle, and its firm adhesion to the base of the cranium. This is the commencement of the infundibulum. Meanwhile, a little in front of the same place, there is projected upwards from below a part of the basilar surface of the cranium, so as to form a deep recess lined by the corneous layer from the back and upper part of the future mouth. . . . The flask-like outgrowth of the buccal epiblast, which gives rise to the hypophysis cerebri, is now gradually shut off from the corneous layer and cavity of the mouth, first by the constriction, and subsequently by the closure of its place of communication. There remains, however, for a considerable time, a longish thread of union between the two. The epithelium of the enclosed portion subsequently undergoes development into glandular cœca and

[1] "Elements of Anatomy." Eighth Edition. Vol. ii., pp. 736, 737.

cell-cords, and its internal cavity becomes gradually obliterated. This forms the anterior part or lobe of the pituitary body. The posterior part owes its origin to the combination with mesoblastic tissue, of a widened extension of the infundibular process of the brain, which is thrust in between the sac of the pituitary body and the dorsum sellæ. The nervous structure of this posterior lobe afterwards disappears in the higher animals, but in the lower it retains its place as a part of the brain."

From *Mihalkovics*[1] we add the following particulars: "The development of the anterior lobe of the pituitary gland is a little more complicated. It will be useful, therefore, to distinguish in its development the following stages: (*a*) the transformation of the epithelium of the buccal cavity into a pocket; (*b*) the pinching off of this pocket from the epithelium of the cavity of the mouth; and (*c*) the development of glandular productions in the shape of tubes or cœca out of the epithelium of the parietes of the pocket. . . . During the constriction of the little pocket, tubular formations of epithelium, from the inner wall of the pocket, shoot forth into the vascular connective tissue by which it is surrounded. . . . This formation of epithelial tubes is caused through branches of the interior carotids intertwining the little pocket in a net-like fashion; so that the epithelium during its increase is compelled to grow into tubular forms. These tubes are afterwards pinched off from their native soil by vessels; they ramify, and by their ramifications constitute the anterior lobe of the pituitary gland. The posterior lobe is developed out of the process of the infundibulum. It is a projection of the basis of the mesencephalon, which among the lower vertebrata continues its nervous structure into the adult stage, but among the higher vertebrata, by the intrusion and spread of tissues derived from the pia mater, is changed into an appendage of the central nervous system, consisting of connective tissue."

2. Motion of the Pituitary Gland.

5. The pituitary gland is enabled to carry on its multiform functions by an alternate expansion and constriction of its body, which is synchronous with the movements of the brain. Concerning this motion Swedenborg says, "The pituitary gland does not seem to be moved by

[1] "Entwickelungsgeschichte des Gehirns." Leipzig, 1877; p. 92.

an active principle, like the cerebrum and cerebellum, that is, by a certain cortex or cineritious substance. For it is outside the brain, and receives its fibres from thence; perchance also from the branch of some nerve, and it does not create its own fibre" (no. 594). The motion of the gland, he further states, follows, as a consequence, "from the cavities and follicles which are in the gland itself [the anterior lobe], and in its appendage [its posterior lobe]; likewise from the distance and space between the gland and the wall of the sella." Again he says, "It follows from the fact of the gland being attached with its roof to the dura mater, so as to be held suspended, and in the capacity of swelling" (*ibid.*).

Modern science fully agrees with Swedenborg's statement as to the fact of the pituitary gland being held suspended, and thus in the capacity of swelling. Key and Retzius[1] show in addition that the upper surface of the gland is attached to the dura mater only around the edges, while in the middle there is a subarachnoidal space left, which, in accordance with the motion of the gland, would alternately be either filled with, or emptied of cerebro-spinal liquid; thus assisting materially in the motion of the organ. Their language is as follows: "Just as the hypophysis—pituitary gland—on its upper surface has a subarachnoidal space completely filled with cerebro-spinal liquid, so at its lower surface it has a broad venous sinus—the inferior transverse sinus or sinus intercavernosus inferior (*Henle*)—which on either side passes over into the sinus cavernosus. . . . The fact of the hypophysis lying thus imbedded between a serous cistern and a venous sinus is no doubt a matter of interest, and it even seems to us to increase the peculiarity of this enigmatical organ." This peculiarity vanishes as soon as it is admitted that the gland has its regular movements of expansion and constriction, which movements are materially assisted by the displacement and rushing in of a liquid into the spaces mentioned. Modern science also has fully established and confirmed the fact of the existence of a central cavity or canal in the interior of the gland; which canal, with its various ramifications, has been most minutely described and delineated by *Peremeschko*, and also by *Sapolini*. (See below, no. 17.)

6. For the expansion and constriction of the pituitary gland, however, Swedenborg accounts in a twofold way. In his later work on the brain, he states that "from delicate arterial shoots there is born and produced a muscular or motor fibre which constitutes the greater

[1] Key (Axel) and Retzius (Gustaf). "Studien in der Anatomie des Nervensystems und des Bindegewebes." Stockholm, 1875; vol. i., p. 97.

part of the posterior lobe, and also some portions of the anterior lobe, and stirs its body into its own diminutive little motions" (*ibid.*).

In his earlier work on the same subject, he explains this motion by the expansion and contraction of the smaller arteries with which, like other glands, the pituitary gland is richly supplied. He says, "For the production of muscular action there is required an influx of arterial blood, and a reflux of arterial as well as of venous blood; further, there is needed a nerve with its fibres which adjoins itself to the little arteries. Both are present in the pituitary gland. Innumerable vessels flow in from the carotid which lies very near, and stretches along its shorter side. . . . That a few venous vessels depart thence into the membrane, which holds the place of a periosteum, and that afterwards these vessels are carried into the inferior transverse and superior circular [*i.e.*, the intercavernous] sinuses, and partly also into the substance of the sphenoid bone in the direction of the lateral sinuses, has been pointed out above. . . . But as regards the nerves, all authors confirm that the pituitary gland is approached by branches of the fifth and sixth pairs" (no. 602*i*). The *modus operandi*, however, by which the motion of the pituitary gland is brought about in this latter case, Swedenborg explains as follows: "When the cerebrum constricts itself, the little ganglion of the nerve [supplying the pituitary gland] acts upon the gland or its little arteries, constricting them, and also expelling the blood therefrom. For when the brain is constricted, the carotid is expanded, according to the general rule, that a reflux of arterial blood takes place into this vessel, when, that is, the muscle or the gland are deprived of this blood. On the contrary, however, when the brain is expanded, or the carotid is constricted, the blood is expressed into the gland and expands the same; and thus it fills with blood the vessels which, during the period of constriction, have been deprived of the same" (no. 602*j*).

7. That both sources of motion exist in the pituitary gland, the former in its posterior, and the latter in its anterior lobe, is capable of being proved by modern investigations. In respect to the former source of motion, Swedenborg says that "a muscular or motory fibre is produced from delicate arterial shoots" in the posterior lobe of the gland, and "constitutes the greater part of the same."

The muscular fibres in this case, we maintain, are those of "plain or unstriped muscular tissue," which, according to Quain,[1] "is made up of cells, named *contractile fibre-cells*." These fibre-cells, he further states, "may form fibrous bundles, and strata, or may be less

[1] "Anatomy," vol. ii., p. 118. EIGHTH EDITION, 1876.

regularly arranged, or mixed with other tissues in greater or less proportion. They are of an elongated fusiform shape, usually pointed at the end:" and "each has a nucleus, rarely more than one, which is always elongated, and either oval or rod-shaped." Fibre-cells of this description exist in great abundance in the posterior lobe of the pituitary gland, according to the testimony of W. Müller and others.

W. Müller[1] states as the result of his examinations, that in newly-born babes the process of the infundibulum, which is continuous with the posterior lobe of the gland "is uniformly formed, to a small extent, of roundish cells, and to a larger extent of *fusiform cells* with elliptical nuclei, 0,005 mm. in thickness, and 0,015 mm. in length. . . . These cells are collected into regular fascicles which decussate in many places, not unlike the cells in fusiform sarcomas, *i.e.* flesh-tumours. Vessels from the surounding pia enter into the part, forming a loose capillary net arranged chiefly in rhomboidal meshes." A similar state of things, only with the muscular elements still more developed, he found in adults. He says, "The bulk of the processus infundibuli [which is continued into the posterior lobe] in man, as well as in the pig and the dog, is formed of fibrillary connective-tissue, which abounds in round and fusiform cells, and partly also in ramified cells, which are strewn between. This tissue is gathered up into bundles; and these, as is the case in fusiform sarcomas, decussate in various directions."

These same "fusiform cells" are noticed by *Frey*[2] in the posterior lobe of the gland. He says, "In the smaller posterior part, which is greyish in colour, we meet, in a connective-tissue substratum, with fine isolated nerve tubes, cells resembling ganglion corpuscles, a quantity of sustentacular connective-tissue, with *fusiform cells* and blood-vessels, but no glandular tissue."

Peremeschko[3] says that "fusiform cells," of the kind which he defines as "fusiform connective-tissue cells," are contained in the posterior lobe in large quantity, and that "in teased preparations they appear collected in small heaps."

[1] Wilhelm Müller. "Ueber Entwickelung und Bau der Hypophysis und des processus infundibuli cerebri." In "Jenaische Zeitschrift fur Medicin und Naturwissenschaft." Leipzig, 1876; p. 410, etc.

[2] Frey (Prof. H.). "The Histology and Histochemistry of Man," translated from the fourth German edition by Arthur E. J. Barker, and revised by the author. London, 1874; p. 446, § 238.

[3] Peremeschko (Dr.). "Ueber den Bau des Hirnanhangs," in Virchow's "Archiv," etc., Bd. xxxviii. (Dritte Folge, Bd. viii.). Heft 3. Berlin, 1867.

8. These fusiform, *i.e.*, muscular fibre-cells exist only in the posterior, and not in the anterior lobe of the pituitary gland; wherefore, Swedenborg was at fault where he says that "these muscular fibres constitute also some portions of the anterior lobe." And yet the elements of muscular motion are not limited to the posterior lobe, but exist also in the anterior lobe. There, however, the second source of muscular action which Swedenborg suggested in his earlier work on the brain seems to be brought into requisition, which demands that arterial vessels shall institute a muscular action immediately from themselves, without the generation of any muscular fibre-cells.

For this purpose there is required first of all an abundant supply of strong arterial vessels. On this subject Swedenborg says, "Innumerable vessels flow into the gland from the carotids which lie very close to it and which stretch along its shorter side. All authors confirm this, except Willis, who instead of using the word 'innumerable' says 'very many.' Vieussens, however, proved experimentally, that there is such an arterial structure in all human pituitary glands. In animals where the pituitary glands are comparatively larger, and where they pour fourth a grosser, and, at the same time, a more copious juice, there is added on either side the rete mirabile, and, according to Ridley, also in front. Thence little arteries enter into the gland; and thither the reflux of blood takes place when the gland contracts itself. The body of the gland—the anterior lobe—on this account is quite reddish, and by Littre is called its red portion" (no. 602*i*).

Modern science fully bears out Swedenborg's statement as to the vascular character of the pituitary gland, especially of its anterior lobe. So *E. H. Ecker*[1] says, "The pituitary gland surpasses all parts of the brain and spinal cord, not only in the size and immense number of blood-vessels, but also in the size of their diameter. The vessels pass into the gland chiefly out of the infundibulum, and from the middle they direct their course into both lobes. Other central vessels pass into the anterior lobe, especially towards its circumference. The formation of an extremely dense net takes place in this fashion, that the single larger vessels wind themselves in a serpentine manner, and communicate with each other by simple anastomoses; only a few finer vessels are here observed."

The source whence the pituitary gland derives its supply of arterial blood is more precisely stated by *W. Müller* and *Luschka*, and

[1] Ecker (E. H.). "De cerebri et medullæ spinalis systemate vasorum capillarum." Trajecti ad Rhenum, 1853.—See also "Schmidt's Jahrbücher," etc., vol. lxxxix., p. 151.

especially by *Sapolini.* *W. Müller*,[1] like E. H. Ecker, maintains that the arteries of the gland "enter principally at the upper end of the organ," and that "they are derived chiefly from a very copious plexus which is situated at the bottom of the infundibulum, and is made up of branches of the carotids and the basilar artery." He further says, "The arterial branches in the interior of the gland pass over into a net of capillaries of 0,01—0,802 mm. in width, which entwines the glandular substance with meshes on an average of 0,03—0,04 mm. in width." Of the arterial supply in embryos he says, "The arteries by which the capillaries in the interior of the gland are supplied, arose partly from small branches entering the gland from the bottom of the sella, and partly from a group of arteries running in a parallel direction, which enter into the substance of the gland from the pia mater along the conical production which the gland sends out in the direction of the chiasma of the optical nerves."

Luschka,[2] on the other hand, declares that "a very large supply of blood is dispatched towards the anterior lobe of the gland through slender twigs of the internal carotid, which originate from it chiefly during its passage through the cavernous sinuses;" although he likewise admits that "almost invariably also a little twig departs from the carotid during its passage through the dura mater into the cranial cavity; which little vessel climbs up towards the infundibulum, and is divided into smaller vessels which partly descend into the gland, and partly ascend into the bottom of the infundibulum." And he further says, "Some blood also is derived to the gland from the delicate network which belongs to the pia mater of the infundibulum."

Sapolini[3] agrees on the whole with Luschka; but he is more precise and explicit in his statement concerning the arterial supply which the gland derives from the pia mater of the infundibulum, and he specifies also more clearly where and how the "pituitary artery" leaves the carotid in the cavernous sinus. Concerning the arterial supply through the pia mater of the infundibulum, he says, "Between the chiasma of the optic nerves and the pituitary fossa covered with dura mater, there is a very supple leaf of pia mater, in which three or four little arteries pursue their winding course. The little artery

[1] Op. citat.," p. 410, *et seq.*

[2] Luschka (H. v.). "Der Hirnanhang und die Steissdrüse," Berlin, 1860, 4to; p. 46.

[3] Sapolini. "L'aire de la selle turcique," traduit de l'italien par M. A. Hubert, etc. (Journal de Médecine, de Chirurgie, et de Pharmacologie, etc. Bruxelles, 1879; p. 202.)

which is most in advance of the others derives its origin from the ophthalmic artery, precisely at the angular bend which it makes when it springs from the cephalic carotid. The other little arteries arise from the cephalic carotid while it is still underneath the anterior clinoid process; but they depart from the vessel before it gives birth to the communicant branch of Willis. The three little arteries, while describing their winding course, approach towards the middle, that is, towards the process of the infundibulum, over which, covered with pia mater, they continue their serpentine windings; afterwards they climb up to the infundibulum. On observing these little arteries under a magnifying glass, you will see them subdividing into minute twigs; some of which terminate in the vascular membrane, while others penetrate into the process of the infundibulum. This membrane, however, is also continued into the gland. . . . The pia mater which encompasses the pituitary gland is covered with little winding arteries and veins. I was able to distinguish clearly the two kinds of vessels, by injecting into the arteries a solution of carmine, whereby the veins became enlarged and assumed a blackish colour. The numerous vessels which enter the pia mater, and leave that membrane, cause it to adhere very closely to the pituitary gland. About the posterior third of the gland the pia mater clings still more closely to the gland; by doubling, it forms a fold which corresponds to a furrow which is imprinted on the surface of the gland; for it is precisely this furrow which marks the division of the gland into a more voluminous anterior lobe, and into a posterior one which is smaller. This furrow is circular, that is, it runs around the gland, and describes on it a kind of meridian. It is deeper than you would suppose. The pia mater with its vessels passes under the margin of the larger lobe."

The pituitary artery, and its origin from the carotid in the cavernous sinus, Sapolini[1] describes as follows, "After the carotid has effected its entrance into the cranium, until it passes by the anterior clinoid process, it occupies a long space in the cavernous sinus, of which it forms, so to say, the base, or even the pavement. During this passage it keeps along the side of the pituitary gland, but occupies a lower level than the gland itself. . . . While there, it gives off two stems which are very remarkable; one of them rises almost perpendicularly from the bottom of the posterior clinoid process. . . . After a short perpendicular rise of about 2 mm., it divides into three, and sometimes into four branches. The three first branches are remarkable for their diameter as well as for their distribution, and for the constant nature

[1] "Op. citat.," pp. 202, 313, 314.

of their termination. These branches start like so many rays from a central point, on which account I call them *radiating arteries.* Let us now examine the various rays. . . . From the perpendicular stem there is detached the first artery which is directed forwards and inwards. This is the *pituitary artery.* It is worthy of being remarked here that this artery, from its beginning until it reaches the envelopes of the pituitary gland, does not give out a single collateral branch. . . . On arriving at the gland, it divides into two distinct arteries. The one glides under the body of the gland. The other pursues a very winding course—it is embraced by the fold of the pia mater, and places itself between the larger and smaller lobes of the pituitary gland. At last it penetrates into the gland itself, and ramifies in the furrow of the pituitary gland, under the edge of the larger lobe, which forms a kind of hood over the smaller. I think I am justified in affirming that this is the artery proper of the pituitary gland; and that the little arteries which pursue a winding course before entering into that organ, carry blood especially into the larger lobe of the gland. As this artery is constantly fed by the cavernous carotid, it is quite capable of giving out a secretion. The other artery enters into the pia mater, where it divides into several little arteries which enter into the pituitary gland from below. These arteries embrace the sides of that organ, and from what I have been able to observe, they seem to spread over the external reddish stratum of the large lobe."

9. Concerning the venous vessels which carry off the blood from the pituitary gland, Swedenborg says, "Venous capillaries, springing forth from the gland, pass out and in through a membranous way" (no. 598). And again he says, "A few venous vessels depart thence into the membrane which holds the place of a periosteum of the gland, and afterwards they are carried into the inferior transverse and the superior circular sinuses, and partly also into the substance of the sphenoid bone in the direction of the lateral sinuses" (no. 604*j*).

Modern science agrees as to the abundance of venous vessels whereby the blood is carried away from the gland, but different observers have noticed them in different parts of the gland. *Müller*,[1] speaking of the blood-vessels in embryos, says, "The veins into which the arterial capillaries pass over, empty into a dense plexus situated at the sides and also in the bottom of the sella." The same statement he reiterates when speaking of the pituitary gland of adults. He says,

[1] "Op. citat.," pp. 390, 410, *et seq.*

"The veins empty into a loose venous plexus which encompasses the gland, and they are discharged finally into the cavernous sinuses."

This statement is confirmed by *Langer*[1] who says, "The anastomotic veins between the cavernous sinuses, which are called *sinus intercavernosi*, are only parts of a net spread out flat, which lines the whole pituitary fossa, and which, basket-like, receives in itself the pituitary gland. This net consists of a thicker kind of little tubes separated from one another by small longitudinal clefts, and which closely adhere to the sphenoid bone, and receive from it a diploic venous twig. Fragments of more delicate little tubes point out the existence of vessels which enter into this net from the pituitary gland" (p. 312).

Luschka[2] discovered some venous vessels which, emerging from the interior of the pituitary gland, empty into the superior circular sinus. Speaking of these vessels he says, "The venous blood of the pituitary gland is mostly emptied into the sinus circularis Ridleyi, along the inner side of which there are seen a number of fine, roundish, little mouths, and on either side of the same there is one larger orifice which serves to discharge the blood into the sinus cavernosus."

Sapolini,[3] however, by the experiments which he instituted, proved conclusively the existence of a most direct intercourse between the arterial vessels of the gland which are derived from the carotid, and the venous receptacles, the cavernous sinuses at the sides of the gland. He says, "In order to give a better account to myself of the relations which exist between the venous and arterial systems of the organs in question—those which constitute the area of the sella turcica—I made a preliminary carmine injection of the carotid of one side after having taken the precaution of isolating it by tying the cephalic carotid and the communicating branch of Willis. I obtained the following results: the cavernous sinuses were filled with the bluish-black liquid which I had injected. . . . In the anterior portion of the circular sinus there was a slight quantity of the injected liquid which spread from the pommel of the sella turcica above the carotid ligament, and bathed the anterior wall of the carotid where it makes its last bend, and where it ascends in order to become the cephalic carotid. . . . The smaller, round lobe of the pituitary gland was bathed in a bluish-

[1] Langer (Prof. H. von). "Der Sinus Cavernosus der harten Hirnhaut." In "Sitzungsberichte der kaiserl. Akademie der Wissenchaften." Wien, 1885.

[2] "Op. citat.," p. 46, *et seq.*

[3] "Op. citat.," p. 209.

black liquid excepting in its upper part; in the middle of the posterior part of that lobe the injected liquid was present in a very small quantity; it was there in the same proportions as it was also in the anterior portion of the large lobe of the gland. . . . The pituitary veins discharge their blood into the circular and cavernous sinuses in the midst of which the pituitary gland is situated like a small island surrounded with blood."

As to Swedenborg's statement that some venous vessels "are carried also into the substance of the sphenoid bone in the direction of the lateral sinuses," this statement is confirmed above by Langer's experience, but the whole of this subject is examined more fully below, in nos. 18 and 19, in the light of modern science.

10. The entrance into, and the departure from, the pituitary gland of an ample supply of blood-vessels is thus abundantly verified from modern sources. It remains now to be shown that the muscular fibres in the posterior lobe, and the arterial vessels in the anterior lobe of the gland are regularly innervated by some nervous branches, whereby they are contracted and expanded in alternate periods, imparting thereby a like motion to the whole of the gland.

In his later work on the brain, as stated above, Swedenborg derives the motion of the gland from the muscular fibre-cells in the posterior lobe of the gland, which are innervated immediately by the brain, through animal spirit conveyed into the gland through the process of the infundibulum. In the same work he speaks very cautiously about the introductiou into the gland of nervous fibres through the mediation of some nerve. He says merely, "The gland receives its fibres from the brain, perchance also from the branch of some nerve, and does not create its own fibre" (no. 594).

In his earlier work, where he derives the muscular motion of the gland immediately from arterial vessels, he describes more minutely the channels through which these vessels in the gland are innervated, and on the basis of the anatomical experience of his day he says, "All authors confirm that the pituitary gland is approached by branches of the fifth and sixth pair of nerves, *i.e.*, the trigeminal and abducent nerves" (no. 602*i*). And the action of these nerves on the arterial vessels he describes as follows: "The muscular action of this gland also is strengthened through little branches of the fifth and sixth pairs of nerves which almost at the same place, where they apply themselves to the side of the gland, press against the carotids, for this purpose, indeed, that they may be able to accompany each shoot into the gland itself by pressing in a similar manner upon its surface, and thereby causing its constriction which takes place whenever the carotid expands itself. For from the carotid, when it is expanded, a living force redounds upon the nervous fibres which accompany the shoots of the vessel, for these fibres constrict every least vessel and direct its blood either back into the artery which is then expanded, or they urge it into little veins—altogether as is the case with the muscle of the heart, when the aorta, together with the right auricle, is expanded and reacts upon the cardiac plexus. For from the living motor force of the nervous fibres arises the contractile force which, again, by the inflowing blood, causes the expansile force, all of which, together with the ratio and the degree of the same, may be proved and known from every muscle of the body. This seems to be the reason why the above-named pairs of nerves cast themselves upon the artery, and this seems to be the manner in which the fibres effect an entrance; namely, with a view of acting on the blood they press on the surface of the vessels" (no. 640*c*).

This action, on the strength of the anatomical facts of his day, Swedenborg attributes to the fifth and sixth nerves, yet in a later portion of the same argument he strongly queries whether this action is really due to these two nerves.

Speaking of the nervous plexus, which attaches itself to the outer surface of the carotid at its entrance into the cranium, he doubts very much whether that nervous network is really derived from the fifth and sixth nerves, as held by the anatomists of his day, and he asks whether it is not rather derived from the great sympathetic nerve, thus whether the sympathetic nerve does not really derive its origin from the highest cervical ganglion, and whether, continuing its course thence upwards into the cranium, as is even done by the spinal accessory nerve, it does not in that case rather terminate in these nerves than *vice versa?* The connexion of the great sympathetic nerve with the two cranial nerves, viz., the trigeminal and abducent nerves, which is a matter of experience, he argues, would be for the purpose of preventing the nervous filaments of the sympathetic nerve from bursting, during a compression of the animal spirit, through the intumescence of the carotids; the excess of animal spirit in that case escaping from the sympathetic nerve into the trigeminal and abducent nerves. "The great sympathetic nerve," he continues, "is chiefly placed over the liquids of the body, and thus it superintends the distribution of the animal spirit, the nervous essence, through the fibres of the remaining nerves, and it likewise governs the areas over which the blood is supplied, so that all these parts shall undergo an alternate period of motion in harmony with the animation of the brain. In order, therefore, that this nerve shall carry on its function, it is necessary for it to encompass the carotid and accompany its branches into the pituitary gland. . . . But whether the sympathetic nerve transmits into the pituitary gland separately any nervous fibres which have become loosened from its trunk, in order that afterwards they may become attached there to the vessels in the gland; this will have to be decided by experience. I, for my part, entertain very serious doubts whether any fibres enter the gland at all from the sixth and fifth pairs of nerves, and I am rather of the opinion that they are dispatched thither from the carotid plexus."

In his later work, entitled the "Economy of the Animal Kingdom," from which we introduce, into the present work on the "Brain," the chapter on the "Great Sympathetic Nerve," he corroborates the statement just quoted in these words: "*Into* the fifth pair of nerves, and at the same time *into* the sixth pair, flows our great sympathetic nerve, but not *vice versa;* hence through the medium of these nerves the great sympathetic is able to communicate an abundance of its spirituous liquid to all the nerves of the head. . . . That the great sympathetic flows *into* the fifth and sixth pairs of nerves, but not conversely, may be inferred from the fact that it is not continued from these nerves, but flows into them at a very acute angle, being like a graft upon them" ("Brain," i., no. 878).

Among modern authors there are two, J. Engel and Sapolini, who still maintain that the sixth nerve, in conjunction with the sympathetic, sends fibres into the pituitary gland. *Engel*[1] says, "From the plexus-like unfolding of the N. abducens [in the cavernous sinuses] a delicate nervous thread starts towards the third curve of the carotid, where it meets with a nerve which has just left the cavernous plexus. After becoming united with it, the combined branch climbs over the above-named curve of the carotid, and pursues its course towards the upper surface of the pituitary gland." Here, however, the observer lost the nerve out of sight.

Sapolini[2] says, "The cavernous plexus is formed of small threads of the internal nervous branch which starts from the superior cervical ganglion. The threads of that plexus are intertwined with the threads of the carotid plexus, whence proceed the nervous filaments which pass along the pituitary arteries, and which, after having

[1] Engel (J.). "Ueber den Hirnanhang und den Trichter." Inaugural Dissertation. Wien, 1839.

[2] "Op citat.," p. 314.

embraced the surface of the pituitary gland, penetrate into the very tissue of that body, and preserve there the vegetative life. But a different order of nerves approaches likewise the pituitary body, and this I am able to affirm with certainty, because I have seen those nerves in my preparations, and have followed their course. The anatomists declare that from the external and internal branches of the superior cervical ganglion there are detached several nervous threads which anastomose with the nerve of the sixth pair, or the external motor nerve of the eye. This is very true; but it is also true that from this latter nerve there are derived nervous filaments which are about to anastomose with the two branches of the sympathetic nerve of which I have just spoken; and those nervous filaments do not terminate there, but they continue their ways, pressed against the pituitary arteries, and they provide for their intimate interstitial movements" (no. 640*d*).

Sapolini's testimony that nervous filaments, whether of the sympathetic or any other nerve, accompany the pituitary arteries into the pituitary gland, and provide for the "interstitial movements" of the arteries, and thereby of the gland, is very important: for he proves precisely what Swedenborg says is wanted for demonstrating the motion of the pituitary gland as a whole.

The nervous threads of the sixth nerve, Sapolini suggests (he does not say it positively), are required in order to cause the alternate expansion and contraction of a sphincter which he discovered in the basis of the processus infundibuli. The discovery of this sphincter, which we shall discuss in its proper place, is most interesting; but why the fibres of the sympathetic nerve should be sufficient for innervating the arterial vessels and causing their expansion and contraction, and why they should be insufficient for opening and shutting a sphincter; and why for the opening and shutting of a sphincter which is entirely independent of any voluntary action on the part of man, there should be required a *voluntary* motor nerve—all this seems to us somewhat incongruous.

A priori, therefore, we are, with Swedenborg, inclined to doubt that "any fibres enter the gland at all from the sixth and fifth pairs of nerves, but are rather of the opinion that these fibres are dispatched thither from the carotid or cavernous plexuses." Still, since Swedenborg himself adds, that "this will have to be decided by experience," we shall examine the particular experience of Engel and Sapolini in the light of the collective experience of modern science.

Swedenborg's strong surmise that all the nervous fibres which enter into the gland are derived from the great sympathetic nerve, and none from the trigeminal and abducent nerves, is corroborated by *Fontana*,[1] *Ribes*,[2] *Bock*,[3] and *Luschka*.[4] While others, as for instance, *Bazin*,[5] *Bourgery*,[6] *Hirschfeld*,[7] go so far as to regard the pituitary gland as the cranial or cephalic ganglion of the great sympathetic nerve. Bourgery does so expressly on the ground of the many nervous fibres which enter from the cavernous plexuses into the pituitary gland.

Still all this does not refute the very positive declaration of Sapolini that in addition to fibres from the sympathetic nerve, "a different order of nerves—fibres from the sixth nerve or from the external motor nerve of the eye—likewise approach the pituitary body." In order to settle this disputed point, *Rosenthal*[8] prepared portions of nerves from the cavernous plexus in a most careful manner for microscopical investigation; and the result of his observation is as follows: "So far as the connection of the sympathetic nerve with the abducent nerve is concerned, I found that from the interior, as well as from the exterior carotid plexus, fascicles of equal size associate with the above-named cranial nerve. Further, that a portion of these fibrous fascicles accompany the abducent nerve beyond the reach of the cavernous sinus; while the rest of these fibres, after a short course, separate again from that nerve, and indeed constantly, in order to seek the fibrous fascicles of the common oculo-motor nerve which is situated in a median position; and, in company with these fascicles, they likewise follow in an anterior direction." While, therefore, Rosenthal admits what is universally set forth in our text-books, namely, that there is

[1] Cfr. "M. Girardi, de Nervo Intercostali." (Ludwig, Scriptores neurologici minores, Tom. iii., p. 85.)

[2] Ribes (F.), in "Mémoires de la Société Médicale d'Emulation," vol. vii., p. 97.

[3] Bock (C. A.). "Beschreibung des fünften Hirnnervenpaares und seiner Verbindungen mit anderen Nerven, vorzüglich mit dem Gangliensysteme," Meissen, 1817, fol.; p. 66.

[4] "Op. citat.," p. 49.

[5] Bazin. "Sur le ganglion cephalique, dit glande pituitaire," etc. (Comptes Rendus de l'Académie des Sciences, Tome ix. 1839.)

[6] Bourgery. "L'origine crânienne du grand sympathique." (Gazette médicale de Paris, 1845.)

[7] Hirschfeld (L.). "Névrologie et Ethésiologie," etc. Seconde édit. Paris, 1886; p 108.

[8] Rosenthal (L.). "Ueber Nervenanastomosen im Bereiche des Sinus cavernosus." (Sitzungsberichte d. k. Akad. d. Wissensch., Wien, 1878; lxxvii., p. 96.)

an anastomosis between the sympathetic and the abducent and common oculo-motor nerves, he is very positive that the anastomosed nerves leave the cavernous sinus in an anterior direction, and do not turn aside into the pituitary gland. His microscopical drawings show this in a convincing manner.

Of all the anatomical observers quoted above, *Luschka* [1] is the only one who actually traced sympathetic fibres from the carotid plexus into the interior of the pituitary gland.

The minute account of his examination is as follows: "On the basis of a not inconsiderable number of investigations, I feel compelled to declare in favour of the views of those who maintain that nervous threads depart from the carotid plexus into the interior of the human pituitary gland, and indeed into its anterior lobe. The extremely delicate little twigs, which consist only of a few primitive tubes, make their way through some of those fibrous trabeculæ which run across the cavernous sinuses. The place of departure of the nerves from the carotid plexus I found to be almost regularly on the inner side of the third curve of the internal carotid. The threads always are only very few in number, not more than two or three on each side. . . . In some places, here and there, they produce sheaths very large in proportion for single primitive tubes, or for only a few such tubes lying loosely together. During the passage of the nervous tubes into the anterior lobe of the pituitary gland, these fibrous sheaths are first lost in the cuticular envelope, which is formed of a continuation of the endo-cranium [*i.e.*, of pia mater]; while the little nervous tubes themselves first of all enter into the membrane which encloses immediately the parenchyma of the gland, in order to undergo in it here and there a process of ramification which requires a division of the tubes. This immediate membranous coating of the parenchyma can easily be isolated in larger or smaller portions in preparations steeped in chromic acid, and when it is thus separated, it can be tested as to any nerves which it may contain. From this membrane the little tubes dip into the glandular substance proper, but on account of their small numbers they are difficult to find; only in a few lucky cuttings they can be traced for some distance into the sustentacular connective-tissue. In spite of all my efforts, I have not been able thus far to arrive at any certainty in respect to the termination of the nervous tubes, and I must so far content myself with this result, still worthy of notice, namely, that, at all events, nervous elements are introduced into the parenchyma of the gland."

[1] "Op. citat.," p. 49.

Henle[1] also confirms that "the mikroscope exhibited to him, in the reticular tissue which is stretched out between the carotid and the pituitary gland, fine fascicles of nervous fibres, the same of which Luschka declared that from two or three on each side dip into the anterior lobe of the pituitary gland."

If now we recapitulate the results of modern science concerning the nervous fibres, which enter into the pituitary gland, we learn that these fibres enter into the gland by two ways—(1) as shown by Sapolini, sympathetic nerves from the carotid plexus accompany the pituitary arteries into the interior of the pituitary gland; and (2) independent nervous fibres from the carotid plexus, as observed by Luschka, Henle, and others, likewise enter into the interior of the gland. According to Swedenborg, the object of these fibres, certainly of those which are carried into the gland through the instrumentality of the pituitary arteries, is to cause an expansile and contractile motion of the little arteries, which are distributed profusely through the anterior lobe of the gland, and thereby to cause a similar motion of the entire anterior lobe; while some of the independent nervous fibres perhaps are utilized in superintending the opening and shutting of the sphincter in the base of the processus infundibuli. The muscular fibre-cells in the posterior lobe of the gland, on the other hand, are innervated by the brain immediately through cerebral fibres entering the gland through the infundibulum. This will now be shown in the light of modern science.

3. The First Fluid excreted from the Pituitary Gland.

11. In his earlier work on the brain, in speaking of the various fluids which are excreted from the pituitary gland, Swedenborg does not yet distinguish, as to degree, between the fluids of the *first* and *second* order, that is, between the animal spirit and the spirituous lymph of the brain, which are despatched into the blood by the pituitary gland; but he classes them both indiscriminately under the latter term. In his later work on the brain only, in treating of the pituitary gland, he calls attention to the animal spirit, to the fluid of the *first* order, as distinct from the spirituous lymph, the fluid of the *second* order.

Again, in his first work, he derives all the muscular power of the

[1] Henle (J.). Handbuch der systematischen Anatomie des Menschen. Bd. iii., Abth. 2; die Nervenlehre; Braunschweig, 1873; p. 567.

pituitary gland from the fifth and sixth pairs of nerves, or respectively from the great sympathetic nerve; while in his second work he ignores almost altogether this source of innervation, and declares that the nervous force of the gland is obtained from the fibre of the brain which is continued into the gland through the infundibulum.

An uncertainty in facts naturally begets an uncertainty in the theory based on such facts. The facts of science, at Swedenborg's time, were by no means sufficient to enable him to settle definitely the source whence the pituitary gland derives all its nervous force; some of these facts, indeed, were actually misleading. So, for instance, the anatomical authors of his time maintained that nervous fibres from the fifth and sixth pairs of nerves entered into the gland; while Swedenborg, on rational grounds, declared that the gland could be innervated only by fibres from the sympathetic nerve—and this declaration of Swedenborg has since been verified. But in the light of the science of his day he was afterwards induced to look upon the whole of this theory as uncertain, and basing himself on other facts taught by the science of his day, he declared that all the spirituous or nervous force of the gland is derived immediately from the brain.

The anatomical authorities of Swedenborg's time, indeed, led him to suppose that the fibre of the brain "is abundant in the tumid belly of the infundibulum;" that this fibre in the processus infundibuli "is contracted into a slender beak, and then again becomes diffused through the pituitary gland." On the basis of these facts he considered himself fully justified in regarding the quantity of animal spirit conveyed into the pituitary gland through the instrumentality of this fibre as amply sufficient for producing the muscular motion of the gland, and at the same time for causing the animal spirit to be rated as one of the three fluids which are discharged from the gland. The amount of fibre which enters the pituitary gland from the brain has since been considerably reduced by modern science. For it shows that the constitution of the processus infundibuli differs materially from what, at Swedenborg's time, was supposed to be the case. Modern science, indeed, does not furnish any facts denying Swedenborg's statement that "the pituitary gland receives animal spirit from the brain through the fibres of the infundibulum," and that "these fibres do not again pass out of it, but terminate there, and deposit the spirit which they have brought thither;" nor has it discovered any facts whereby to oppose Swedenborg's statement that this animal spirit innervates the muscular fibre-cells—the fusiform cells—in the posterior lobe of the gland; but by reducing the quantity of fibres received from the infundibulum, it shows the necessity of accounting for the muscular motion of the anterior lobe of the gland by some other method, namely, by that which Swedenborg himself advocated in his earlier work on the brain, and which afterwards he gave up in his later work, on the ground apparently of insufficient facts by which to support it.

The facts of modern science enable us to show that Swedenborg was right, both in his first and in his second inductions, with regard to the method which nature follows in innervating the pituitary gland; only the plan, which in his first work he advocated for the innervation of the whole gland, has to be limited to the anterior lobe, and that, by which, in his second work, he accounted for the nervous action likewise of the whole gland, has to be confined to the posterior lobe.

The present case, therefore, is not one where modern science proves Swedenborg's theory to be wrong; but where, by reducing to their proper limits two theories which he proposed at different times for the solution of the problem concerning the innervation of the pituitary gland, modern science shows that in both theories Swedenborg lighted on essential and true principles—the entire truth consisting in a proper harmonising of these two principles.

We shall now discuss the introduction of cerebral fibres into the pituitary gland by the way of the infundibulum.

12. First of all we shall have to prove that there are actually cerebral fibres in the posterior lobe. For although it is universally admitted that this lobe is a cerebral outgrowth, and although in the lower vertebrata its nervous character is preserved throughout, it is nevertheless maintained that in the higher vertebrata, and in man, the nervous character of the organ is completely lost, and that it consists purely of connective-tissue.

Mihalkovics[1] says on this subject, "The posterior lobe among the higher vertebrata experiences an involution already during its fetal existence, and its nervous elements are crowded out in a great measure by connective-tissue. . . . The processus infundibuli preserves its embryonal character more in birds than in mammalia; for the connective-tissue tracts are less luxuriant in the case of the former, and remnants of the embryonal formative cells are still preserved in the meshes of those tracts. Among mammalia, and still more in man, the connective-tissue tracts are so predominant that the elements of the central nervous system disappear entirely. . . . Through these

[1] "Op. citat.," p. 89.

transformations the posterior lobe appears in the capacity of a connective-tissue appendage to the central nervous system."

The entire absence of cerebral fibres in the pituitary gland is likewise maintained by *Hannover*[1] who says, "I have been unable to discover any cerebral fibres in any part of the gland whatever." Further by *Grandry*[2] who declares, "As to nervous elements I have never been able to discover any among the vesicles of the pituitary gland, either in the form of nerve-cells, or in that of nervous threads." *Henle*[3] says, "Microscopical investigation shows that the stem of the pituitary gland—the processus infundibuli—is free of medullated fibres; if there are any at all scattered through the substance of the hypophysis, they are supplied to the gland not through its stem, but through twigs of peripheral nerves from the carotid plexus."

These statements, however, are directly negatived by A. Ecker, Virchow, Kölliker and Frey. *Ecker*[4] says, "Delicate, varicose nervous fibres, which enter into the gland through the infundibulum, pass through its posterior lobe in company with numerous fine blood-vessels," and further, "both lobes of the gland are connected with the infundibulum, which supplies nervous fibres to the posterior lobe." *Virchow*[5] expresses himself as follows, "In the interior of the infundibulum there is continued very decidedly the ependyma of the third ventricle which forms a soft, very frail mass rich in nuclei. This mass, in its outer surface, almost always gives evidence of a very scanty presence of nervous elements. Among these there are occasionally *dark-bordered nerve-tubes* which accompany the infundibulum from above downwards. Nevertheless, I could not observe nervous fibres in all cases. . . . As to the gland itself I noticed in the posterior lobe dark-bordered nervous fibres; but in the anterior lobe never." *Kölliker*[6] says, "The posterior smaller lobe consists of a

[1] Hannover (A.). "Recherches mikroskopiques sur le système nerveux." Copenhagen, 1844, 4to.; p. 27, etc.

[2] Grandry (Dr. M.). "Mémoire sur la structure de la capsule surrénale de l'homme, et de quelques animaux." In "Journal de l'Anatomie et de la Physiologie," etc., 1867. Quatrième année; p. 400, etc.

[3] Henle (Prof. J.). "Handbuch der Nervenlehre," etc.; in "Handbuch der systematischen Anatomie," etc., Vol. III., Section ii. Braunschweig, 1871; p. 291.

[4] "Op. citat.," pp. 161, 162.

[5] "Op. citat.," pp. 92, 93.

[6] Kölliker (A.). "Handbuch der Gewebelehre des Menschen." Leipzig, 1852, p. 297, sect. 117. Also translated into English in a somewhat condensed form under the title: "Manual of Human Mikroskopic Anatomy." London, 1860.

finely-granular substance, with nuclei and blood-vessels, and possesses also *fine varicose nerve-tubes*, which, like the vessels, descend from the infundibulum." *Frey*,[1] however, declares, "In the smaller posterior part, which is greyish in colour, we meet, in a connective-tissue substratum, with *fine isolated nerve-tubes*, cells resembling ganglion corpuscles, a quantity of sustentacular connective-tissue, with fusiform cells and blood-vessels, but no glandular tissue."

Luschka, while plainly admitting the existence of nerve-tubes in the posterior lobe, declares that these fibres are there in a state of dissolution and consequent disintegration; and herein he is supported by Henle, although that anatomist otherwise denies altogether the existence of nervous elements in the pituitary gland; that is, of such elements as are derived from the brain through the infundibulum.

Luschka's[2] statement in full is as follows: "The fundamental substance of the posterior lobe appears to be a certain molecular mass differing in quantity in different places, which mass is composed of immeasurably minute elements, and also of some which are a little larger. Said mass seems to be a kind of cement by which other formations of various kinds are kept in connection. Among these there are undoubtedly *nervous* elements, but they are very few in number. They coincide with the nervous elements noticed in the brain, but these elements are very much inclined to become varicose and to break up generally. These nervous elements consist mostly of *fine nerve-tubes*, which are found isolated, and, in a certain sense, forced apart or divaricated, and they are met with chiefly in the circumference of the posterior lobe." Concerning the nervous elements in the infundibulum, he makes the following statement, "Before the transition of the infundibulum into the posterior lobe of the gland, there is noticed in it only a most subordinate quantity of *fine nervous tubes*, and only very few, mostly bi-polar, ganglion-cells; which, besides, are undergoing a peculiar process of degeneracy."

This peculiar disintegration or degeneracy of nervous elements in the infundibulum and in the pituitary gland, as stated above, has also been noticed by *Henle*.[3] This anatomist says, "The foundation of the posterior lobe, and of the processus infundibuli belonging thereto, consists of filamentous or fibrous fascicles which in the processus infundibuli follow a parallel direction, but in the posterior lobe decussate and run in various directions. . . . These filaments or

[1] "Op. citat.," p. 446.
[2] "Op. citat.," p. 21, *et seq.*
[3] "Op. citat.," iii., 2; p. 293.

fibres cannot be classified under any of the tissues of the adult body; but they remind one of the embryonal stages of several fibrous tissues, especially of nervous fibres; and this also the history of their development indicates. Yet these fibres seem not only arrested in their growth, but also to have undergone a sort of retrograde metamorphosis. I conclude this from the presence of little portions of small-grained yellowish fat, which are distributed in an irregular manner throughout the mass."

This apparent dissolution and disintegration of nervous fibres in the processus infundibuli and in the pituitary gland, which is noticed both by Luschka and Henle, confirm in a remarkable manner Swedenborg's statement as to the final fate of the nervous fibres in those parts; for he says, "That fibre, namely, the cerebral fibre in the posterior lobe, does not again leave the gland, but it terminates there, and deposits its spirit there" (no. 595). Luschka declares, among other things, that these peculiar nervous fibres "are met with chiefly in the circumference of the posterior lobe." This also agrees with Swedenborg's statement; he says: "These fibres discharge their animal spirit nowhere else than in the outermost parts and circumferences of the pituitary gland, where the muscular fibre and an abundant artery prevails."

While speaking, on the one hand, of "nervous elements—fine nerve-tubes—which are very much inclined to become varicose, and to break up generally," and of "nervous tubes" and "ganglion cells," which "are undergoing a peculiar process of degeneracy;" while declaring, therefore, that in the pituitary gland, and in the infundibulum, there are cerebral fibres in a state of dissolution, Luschka, on the other hand, and also Henle, points out clearly in the posterior lobe of the glands the products of such a dissolution or disintegration; for *Luschka*[1] says: "Notwithstanding the small quantity of nervous tubes in the gland, at the edges of mikroscopical objects taken from the posterior lobe, by the addition of water and other reagents, there are discovered numberless drops and streaks of *myelin*, presenting all sorts of forms." This "myelin" seems identical with "the small portions of a small-grained, yellowish fat," which Henle saw "distributed in an irregular manner through the mass." Luschka, indeed, does not think that this medullary substance—myelin—is derived from nervous tubes and ganglion-cells by their disintegration; but we look upon it as a strong confirmation of Swedenborg's theory, according to which not only cerebral fibres terminate in the infundibulum and the gland, but also

[1] "Op. citat.," p. 21.

the contents of these fibres are discharged or set free in the gland. Nay, from the considerable quantity of myelin—medullary substance derived from nerve-tubes and ganglion-cells—observed by Luschka, we consider ourselves justified in concluding that the amount of animal spirit, of nervous essence, thus infused into the gland, is far in excess to what appears to be discharged through the comparatively few nervous tubes discovered by the observers. The amount of animal spirit, indeed, seems sufficient not only for innervating the muscular, fusiform fibre-cells of the posterior lobe, and of starting there the muscular motion of the gland, but also for charging even to overflowing with animal spirit that spirituous lymph which filters into the substance of the posterior lobe out of the infundibulum.

The whole of the spirituous lymph, the fluid of the *second* order received by the pituitary gland, and discharged thence, will now be discussed.

4. The Second Fluid excreted from the Pituitary Gland, likewise the Function of the Posterior Lobe of the Gland, and of the Central Cavity.

13. Of the above fluid we have to notice two species. *First*, that which in the infundibulum is secreted from the ventricular fluid, and which, when properly equalized, that is, furnished with a sufficient amount of refined serum, as well as of animal spirit, is discharged in that form from the pituitary gland; and *secondly*, that same fluid which, in the posterior lobe of the gland, is surcharged with animal spirit, and acts thus as the bearer of the fluid of the *first* order, from the pituitary gland.

The definitions which Swedenborg gives of the fluid of the *second* order are as follows: "The spirituous fluid in question is the real, white blood, capable of expansion and compression, elastic, divisible, and most light" (no. 581*f*). Again he says, "This kind of lymph we call a liquid or fluid of a middle nature; for there is the spirituous essence—the animal spirit—the liquidity of which is acknowledged by all; there is further an elementary lymph or a common water; and there is a lymph which, upon being mixed or married to the first essence, constitutes the liquid of a middle nature" (no. 596). In another place Swedenborg defines this fluid as "the white blood with which some of the nervous juice—of the cerebro-spinal liquid—seems to be commingled" (no. 625*k*).

This same fluid, in the lateral ventricles, is mixed with a serum of a lower order which "trickles down from the interstices between the fibres, and from other sources" (see above, no. 3). The ventricular liquid thus obtained, during its passage through the infundibulum, is separated again into its two constituent fluids, namely, into the fluid of the *second* order, or the spirituous lymph which is the "real, white blood," and into the fluid of the *third* order, which is a grosser serum.

The mode by which this separation takes place, Swedenborg describes as follows, "When the cavity of the infundibulum is constricted, and its beak—the processus infundibuli—erected, the enclosed moisture—the ventricular liquid—is expressed by two ways; namely, its lighter, purer and spirituous portion—the fluid of the *second* order—is pressed into the porous, bibulous, and medullary substance of its walls, and thence into the beaked process which is inserted in the pituitary gland; while the heavier, grosser, and earthy portion—the fluid of the *third* order—is urged into some lateral ducts and processes in proximity to the pia mater which acts as a lining, and thence it is expressed above, around, and below the pituitary gland. . . . The former fluid is instilled by a fibrous channel immediately into the substance of the gland; but the latter is relegated around the gland, between the sides of the sella turcica" (no. 576).

Again we read, "The spirituous lymph—the fluid of the *second* order—percolates between and around the fibres, and, therefore, must needs descend into the cavities and follicles of the gland. For a fluid which presses upon the interstices between the fibres, must necessarily be discharged into the clefts which are caused by the interstices themselves" (no. 596).

As to the *modus operandi* by which the separation of the two fluids in the infundibulum takes place, Swedenborg says further, "The cavity of the infundibulum is not invested by any membrane or meninx, but the fibres on their way into the interiors are interwoven in a net-like fashion, and afford everywhere passages. And again, when the cavity is contracted into a tube or slender duct, or when the infundibulum is extended, these fibres rise, occupy their respective places, and arrange themselves so as to afford a passage" (no. 577). And further, "The spirituous lymph—the fluid of the *second* order—is the real, white blood, capable of expansion and compression, elastic, divisible, and most light; wherefore it is separated instanter from the grosser liquid, so soon, indeed, as any active force is brought to bear on both" (no. 581*f*).

What has modern science to say to this?

14. Modern science shows, in the first place, what was known already at Swedenborg's time, namely, that the pituitary gland in reality consists of two lobes, the anterior and the posterior, and that between them there is a central cavity.

The anterior lobe, as was shown above, is originally an outgrowth of the epithelium of the mouth, and bears a strictly glandular character. According to *Mihalkovics*[1] it consists of "epithelial sacs or blind tubes with a stroma of connective tissue, rich in vessels," and "in front it sends off a narrow production to the infundibulum as far as the chiasma of the optic nerves."

The posterior lobe, on the other hand, is a prolongation or outgrowth of the substance of the brain, in which, however, the nervous substance is on the decline, and has its place in great measure taken up by connective tissue. In contradistinction from the anterior lobe, which consists of glandular ducts, the posterior lobe consists of *meshes*, and these meshes are continued into the infundibulum, or rather this mesh-like arrangement begins already in the infundibulum.

On this subject *Peremeschko*[2] makes the following statement: "The framework of the posterior part of the gland consists of *meshes* which can be proved best by sections of the gland of a calf which have been dyed and treated with oil of turpentine. In the infundibulum this arrangement is not yet so clearly defined. The inner stratum of the infundibulum presents a framework of connective-tissue fibres with many fusiform cells." These fusiform cells, as we have shown, bear a great likeness to muscular fibre-cells which, Swedenborg maintains, are generated in the posterior lobe of the gland. Peremeschko then goes on and describes how connective-tissue bundles are dispatched into the interior of the posterior lobe from the surrounding pia mater; and out of these bundles, through larger and smaller sub-divisions, there is at last formed a framework of meshes. In these meshes there is a finely granular mass, together with fusiform and pear-shaped cells, and also cells which Luschka describes as "epithelial cells with and without productions."

These epithelial cells, which are essentially for the purpose of straining and refining, *Luschka*[3] considers of so great importance in the posterior

[1] "Op. citat.," pp. 83, 88.

[2] Peremeschko (Dr.). "Ueber den Bau des Hirnanhangs," in Virchow's "Archiv für pathologische Anatomie und Physiologie," etc. Bd. xxxviii. (Dritte Folge, Bd. viii.), Heft 3. Berlin, 1867; p. 338.

[3] Luschka (Hubert v.). "Der Hirnanhang und die Steissdrüse des Menschen." Berlin, 1860, 4to.; p. 18.

lobe, that he defines the substance of that lobe, and more or less that of the infundibulum, as consisting essentially of a mass of "connective-tissue and epithelium." After describing the pear-shaped, and also the fusiform cells, which have been discussed above in no. 7, he says, "There are in addition a considerable number of formations which mostly prove to be degenerate epithelial cells, deprived of their cilia, with very long productions; the sharply-marked and dark-bordered stems or productions of these cells are sometimes continuous with the ramified processes of the above-mentioned cells. These epithelial cells are thoroughly identical with the better preserved [epithelial] forms which Gerlach has shown to exist in the aqueduct of Sylvius."

In addition to these epithelial cells which, according to Peremeschko, are contained in the meshes of which the framework of the infundibulum and of the posterior lobe consists, there is besides, according to *Mihalkovics*,[1] a stratum of epithelium, which is situated along the inner, central portion of that production which ascends from the anterior lobe of the gland, and embraces the infundibulum proper in front. He says, "Towards the centre"—and thus in the interior—"the production of the pituitary gland, which is attached to the processus infundibuli, consists of cylindrical epithelia."

15. Although the minute structure of the infundibulum and of the gland, as taught by modern science, differs vastly from the idea which Swedenbórg collected from his study of the anatomical authors of his time, nevertheless these modern facts are by no means opposed to the function which Swedenborg, on the strength of the facts of his day, assigned to the infundibulum. This function, as we have seen, consists in straining the finer, spirituous lymph contained in the ventricular liquid from a grosser, heavier serum.

According to Swedenborg this finer, spirituous lymph is drained off through the interstices which exist between the medullary fibres of which, as he supposed, the substance of the infundibulum consists. According to the facts of modern science, however, this straining is effected through a system of meshes derived from the pia mater, of which system the framework of the infundibulum (and also of the posterior lobe of the gland) consists, and the fluid, which is thus drained off, is further refined by passing through the epithelial cells which, according to Luschka and Peremeschko, enter largely into the composition of the infundibulum and of the posterior lobe of the gland.

The arrangement, however, of the epithelial cells in the infundi-

[1] "Op. citat.," p. 88.

bulum, as we have learned, is twofold. For in addition to the epithelial cells just mentioned, which are contained within the meshes of its posterior part, there is besides the stratum of epithelium which, according to Mihalkovics, is situated along the inner, central portion of the production which, from the anterior lobe of the pituitary gland, ascends to the infundibulum and closely invests the same in front. The lymph, percolating through this latter stratum of epithelium, would naturally pass into the central cavity of the pituitary gland, which is situated between the anterior and posterior lobes of the gland, and thus between that part which is generated from the infundibulum proper, that is, from the processus infundibuli, and between that other part from which ascends the production by which the processus infundibuli is invested in front.

In the infundibulum proper, however, and also in the posterior lobe of the gland, the spirituous lymph, which is strained off from the ventricular liquid, is in addition enriched with animal spirit, with the fluid of the *first* order, which is set free there by the dissolution or disintegration of those nervous elements which are continued into the infundibulum, and also into the posterior lobe of the gland from the brain (see above, no. 12). This animal spirit, it seems, is infused into the spirituous lymph through the agency of the epithelial and pear-shaped cells which are imbedded in the meshes of the infundibulum and of the posterior lobe.

The question now arises, what becomes, *first*, of that spirituous lymph which is enriched in the infundibulum and also in the posterior lobe of the gland with additional animal spirit, and which thus acts as a vehicle of the animal spirit, of the fluid of the *first* order, secreted in the infundibulum and in the pituitary gland? And what, *secondly*, becomes of that spirituous lymph—the fluid of the *second* order—which is simply strained off from the ventricular liquid, and collects in the central cavity of the gland? We shall first follow up the former species of spirituous lymph, namely, that which has received its freight of animal spirit?

According to Swedenborg, the spirituous lymph in question, namely, "the spirit of the fibres, or the animal spirit married to the purer blood, betakes itself, first of all, into the sinuses which are proper to the gland" (no. 598), namely, into the inferior transverse sinus of Littre, and the superior circular sinus of Ridley. From these little sinuses, he maintains, on the basis of the facts of his day, that this same spirituous lymph is infused into the superior petrosal sinuses, and by these sinuses it is finally carried into the jugular veins. For these latter sinuses, namely, the superior petrosal, he says, "have their highest heads and lips close to the circular sinus. . . . They are comparatively long and slender, and their tube-like bodies are completely adapted to the quickness and swift flashes of this fluid" (no. 623).

The science of Swedenborg's day connects also the inferior transverse sinus with the superior petrosal sinuses; but modern science shows that the inferior transverse sinus of Littre empties its contents exclusively into the cavernous, and not into the superior petrosal sinuses. Wherefore Swedenborg's statement that "the pituitary gland discharges the first, purest, or spirituous fluid into its own little sinuses, namely, the inferior transverse, and the higher circular sinuses," must be confined to the latter, to the circular sinus; and the inferior transverse sinus of Littre must be excluded.

With this limitation, modern science fully bears out Swedenborg's statement concerning the ulterior destination of the spirituous lymph in question, and it confirms that statement besides by important additional particulars.

In the light of modern science the spirituous lymph surcharged with animal spirit, it seems, is first of all committed to lymphatic vessels, which according to *Mihalkovics*[1] abound in the posterior lobe. He says, "With man the lymphatic vessels attain in the posterior lobe a high degree of development, and they are continued thence even into the anterior lobe." These lymphatics, according to the same author, begin already in the processus infundibuli; for he says, "In the lowest part of the process of the infundibulum, horizontal sections of wide lymphatics are visible" (p. 88). From this it would follow that the dissolution of nervous elements, and hence the discharge of their contents into the spirituous lymph percolating through the meshes of the infundibulum, and the final gathering up of this lymph into lymphatic vessels begins already in the infundibulum. This also is taught by Swedenborg; for he says, "The infundibulum abounds with little veins, lest the refined and defecated moisture, which does not transpire through the beak—the processus infundibuli—into the gland, should escape into the air; but, on the contrary, may be sipped up by the little mouths of the veins, and together with the vapour of the gland may be determined [finally] into the basilar sinuses" (no. 577).

The whole of the spirituous lymph enriched with animal spirit—the fluid of the *first* order—is thus conveyed into the circular sinus through the lymphatic vessels which have just been described. But the circular sinus, according to the description furnished by modern authors,

[1] "Op. citat.," p. 89.

consists of two semi-circles or branches, an anterior and a posterior one, of which the anterior is usually larger, and the posterior smaller.

The posterior branch seems to receive the lymphatic vessels from the infundibulum, while the anterior branch receives those lymphatic vessels concerning which Mihalkovics declares, "the lymphatics of the posterior lobe of the gland . . . are continued even into the anterior lobe."

The existence of vessels similar to those which, according to Mihalkovics, pass from the posterior into the anterior lobe of the gland, is fully confirmed by the Brothers *Wenzel*[1] in these words, "In adults, and those who are further advanced in age, if the examination of the pituitary gland be carried on with due care, vessels are distinctly and clearly visible between the two lobes.—*First* case: On dissecting the hypophysis of a lady sixty years old, by the aid of a lens we discovered, near the anterior part of the posterior lobe, several vessels of considerable size. We saw *striæ* which had the appearance of passing from one place into the other.—*Second* case: In the hypohysis of an old man which was dissected in a like manner, we saw in the same place the larger and smaller mouths of vessels which had been cut through, which almost presented the appearance of a kind of sieve.—*Third* case: The same conjunction of the posterior lobe with the anterior by the aid of vessels which passed from one place into the other, we saw in the case of a man twenty years old." After detailing these cases the authors continue, "Whether these striæ, about the presence of which in a natural state and condition there cannot be any doubt, are only little blood-vessels, that is, arteries and veins; or whether they are in part blood-vessels, and in part little canals destined for some definite use—this question, even after a most successful injection, can be decided only with difficulty; but without such an injection it cannot be decided at all." And again they ask, "Are these little canals only blood-vessels? or vessels which convey to their outermost and most subtle ends some kind of other liquid, destined for some sublime use? This conjecture does not seem devoid of reason." Mihalkovics settles this question by declaring on the basis of observation that "*lymphatic vessels* are continued from the posterior into the arterior lobe."

The further course of the lymphatic vessels after they have reached the anterior lobe is indicated by *Luschka*[2] in the following passage: "The veins which depart from the capillary network in the interior

[1] Wenzel (J. and C.). "De penitiori structura cerebri hominis et brutorum." Tubingæ, 1812; p. 220, *et seq.*

[2] "Op. citat.," p. 46, *et seq.*

of the gland, on either side of the same, are gathered together into one little stem, the lumen of which usually becomes visible in horizontal sections when accurately made through the middle. Owing to the retraction of the wall of the vessel under the level of the surrounding surface of the section, its lumen presents the appearance of a little dimple, to which notice has been drawn by the Brothers Wenzel. Several vessels, in the form of rays, meet at the anterior edge of the lumen of said venous stems, while only one larger vessel, or several feebler twigs enter at its posterior edge. . . . On the ground of artificial injections I can regard these canals only as vessels containing venous blood. The venous blood of the pituitary gland is mostly emptied into the sinus circularis Ridley, along the inner side of which are seen a number of fine roundish little mouths, and on either side there is one larger orifice which serves to discharge the blood into the sinus cavernosus."

From this description it appears that capillary veins which seem identical with Mihalkovics' "lymphatic vessels," enter into venous stems at either side of the gland, from the posterior lobe; for we read "one larger vessel or several feebler twigs enter at the *posterior* edge" of these venous stems, and hence come from the posterior lobe. These venous stems, however, discharge their contents into the anterior branch of the circular sinus.

The spirituous lymph, enriched with animal spirit, is, however, not simply derived into the posterior and anterior branches of the circular sinus; but on the way it is also "mixed with blood, so that it may pursue its way towards the lateral sinuses, and may not be dissipated on the way and escape" (no. 625*i*). On this subject Swedenborg says further, "The spirituous juice of the gland—the fluid of the *first* order . . . is derived into the little sinus—the circular sinus—together with the venous blood which flows into that same sinus; namely, with that blood which is carried away from the muscular part of the gland, which seems to be of a venous character, so far as it enters the little sinuses of the gland. Thus," he further says, "the spirit, which leaves the gland embodied in lymph, is wedded also to the blood" (no. 625*j*).

In order that the spirituous lymph, which collects in the circular sinus, may be still further "wedded" to blood, before it is consigned to the superior petrosal sinuses, according to *Theile*,[1] "the circular

[1] Sömmering (S. Th. von). "Vom Baue des menschlichen Körpers." "Lehre von den Muskeln und Gefässen des menschlichen Körpers," umgearbeitet von F. W. Theile, Leipzig, 1841; p. 274.

sinus receives little veins from the tuber cinereum, the infundibulum and the sphenoid bone." *Haller*[1] also says that "not unfrequently the circular sinus receives considerable veins from the sella equina, and from the osseous, spongy substance of the sphenoid bone."

The discharge of the circular siuus into the superior petrosal sinuses is discussed below in no. 32.

17. The next question concerns the second species of spirituous lymph which, through a stratum of "cylindrical epithelium" communicating with the cavity of the infundibulum, distils into the central cavity of the pituitary gland.

This portion of the pituitary gland has been most accurately described by *Peremeschko.*[2] From his description we gather the following particulars.

The central cavity or canal of the gland is not situated precisely between the anterior and posterior lobes of the gland; but it is mostly contained within the anterior lobe, a narrow stratum of the same, called by Peremeschko the "Markschicht" (medullary zone), enclosing it behind. In some animals (calf and sheep) it is a simple cleft running from right to left. In other animals, and sometimes also in man, it ramifies in such a manner that a branch of it runs through the middle of the posterior lobe. In man there are always two lateral branches, one on the right and one on the left side; but they do not meet in the centre. Further down, below the middle of the gland, the canal becomes circular, and towards the bottom it has the shape of an acute angle. The canal always keeps within the substance of the gland, and never reaches the enclosing membrane.

In human pituitary glands, the canal is always lined with ciliated epithelium. In fresh specimens this epithelium can be discovered without difficulty. The lateral branches of the canal in hardened human specimens are almost always crowded with colloid bullæ, so that the canal is reduced to a very narrow cleft. The central portion of the canal which extends into the posterior lobe, whenever it exists, has an oval shape with a diameter of 2mm. from right to left.

The question as to the beginning of the canal, Peremeschko answers as follows, "Only in the pig I could be convinced by horizontal sections through the narrow portions of the gland—the processus infundibuli—that the central cavity or canal of the gland is a continuation of the cavity of the infundibulum. In other animals, the calf for instance, the lower portion of the infundibulum does not

[1] "Op. citat.," iv., p. 156.

[2] "Op. citat.," p. 333, *et seq.*

seem to have any opening; so that in their case the beginning of the canal is in that portion of the gland where the infundibulum becomes joined with the gland proper, and that the canal itself presents a closed cavity. In human pituitary glands, hardened somewhat in alcohol, I sometimes succeeded in injecting the canal, that is, its central portion and the lateral branches, in such a manner that in these cases also the canal seemed to communicate with the cavity of the infundibulum. The difficulty here is that the infundibulum, even when it lies for a long time in the strongest alcohol, does not become sufficiently hard for suitable sections."

In considering the facts which Dr. Peremeschko here brings to our notice, in connection with the facts observed by Prof. Mihalkovics, namely, that a stratum of epithelium extends from the central side of the anterior lobe into the interior of the infundibulum, it becomes very evident that at one period of fetal existence there is an uninterrupted passage, lined with ciliated epithelium, between the cavity of the infundibulum and the central canal of the gland; which passage becomes closed up in such a manner that a stratum of cylindrical epithelium remains between those two cavities, through which the spirituous lymph, the purer blood, percolates with the greatest ease during the systole of the infundibulum, and the diastole of the gland.

The existence of such an uninterrupted passage between the cavity of the infundibulum and the central cavity of the gland in the case of embryos, is placed beyond doubt by the researches of *W. Müller*.[1] He examined a number of human embryos, and also embryos of sheep and swine.

In describing the processus infundibuli in these embryos he says, "In its place of departure from the infundibulum the cavity of the latter was continued through the middle of the processus infundibuli, 0·5mm. in width. It gradually diminished in size, assuming the form of a cone, and finally ended in a point. The walls of the cavity were lined with cylindrical epithelium. Towards the middle of the processus infundibuli the cavity had already disappeared; but remnants of the same still continued in its thickened, button-like end, in the form of irregularly-bent clefts, which were lined with cylindrical epithelium."

This same transit or passage in the processus infundibuli was discovered and described by *Sapolini*,[2] and in the "thickened, button-like end" of the same he detected besides a sort of sphincter by which

[1] "Op. citat.," p. 390, *et seq.*
[2] "Op. citat.," p. 308.

the continuity of the passage is interrupted. His language is as follows: "Let us begin with cutting the infundibulum from top to bottom, laying bare its canal, which is shaped like a funnel. Let us now continue cutting the processus infundibuli with lancetted needles, but blunt at the end, using for our guidance a magnifying glass; for the canal which succeeds the tapering end of the infundibulum is thread-like. This canal may easily be traced; for, thanks to the ependyma with which it is lined, it is very shining. Let us now continue the incision as far as the groove or the indenture of the pituitary body. When the processus enters the gland, the operation of cutting becomes very difficult; for at that point there is, in the processus, an orbicular constriction, a sort of circular valve, whereby the continuity of the canal is interrupted." This valve, Sapolini suggests at the end of his paper, is opened and shut by one of those independent nervous fibres which enter the pituitary gland from the cavernous or carotid plexus, or as he himself supposes, from the sixth pair of nerves.

By a novel, but successful method of injection, Sapolini discovered in the interior of the pituitary gland two receptacles or cavities; one of which is in the anterior lobe, and the other in the posterior lobe. The one in the anterior lobe—the central cavity, the receptacle of the fluid of the *second* order—he did not succeed in injecting; but the second receptacle in the posterior lobe, where a grosser serum—the fluid of the *third* order—collects, he managed to inject beautifully. In alcoholic preparations, Peremeschko succeeded sometimes in injecting the central cavity, but Sapolini's watery injection did not penetrate thither. This bears out completely Swedenborg's own statement of the matter; for he declared repeatedly that it was impossible for injections of a lower elemental or saline character to penetrate into the interior of the pituitary gland; and that fluids of that description could be received only in receptacles at the side of the gland. The whole of Sapolini's interesting experience is introduced below, in no. 26, in the chapter which treats of the fluid of the *third* order, of that fluid which is excreted from the gland into the posterior receptacle of the sella.

But to return to the fluid of the *second* order, which, through a passage consisting of epithelial cells, penetrates from the infundibulum into the central cavity of the gland.

18. Concerning the discharge of this spirituous fluid from the pituitary gland, Swedenborg makes the following statement: "The fluid of a middle quality—the spirituous lymph or purer blood—the gland dispatches through lympheducts and venous vessels into the

bones of the cranium" (no. 593). In another place he adds the following particulars, "The spirituous lymph is dispatched into the lateral sinuses through foramina of the sphenoid bone, as has been proved through the experiments of Willis. For when the bone of the sella turcica is laid bare, or when its covering of dura mater is removed, chiefly in the calf, foramina are presented to the sight, and when they are injected, the liquid penetrates into the lateral sinuses. Willis suspects that similar foramina exist also in the sella of the human cranium, and Vieussens demonstrated them by autopsy; although he says they are obliterated in dried skulls. . . . The existence of what Willis terms 'lympheducts' is thus placed beyond doubt. That the above-mentioned lymph of exquisite purity is carried away from the gland through foramina in the bottom of the sella, appears from the filaments or small membranous processes, seemingly nervous, which are continued from the body of the gland into the membrane of the parietes. Of these filaments or processes Vieussens always observed two or three, but Littre innumerable. That similar processes emanate also from the posterior lobe of the gland is scarcely doubtful, since it is closely fastened to the bottom or to the mater underneath" (no. 602*e*).

The central cavity of the gland, as shown by Peremeschko, extends on the one hand to the bottom of the gland, and on the other it is continued through its lateral branches along the sides of the posterior lobe; and although it never reaches the enclosing capsule of the gland, nevertheless, as shown by the same observer, bundles of pia mater from without penetrate everywhere into the interior of the gland, where they serve as a framework by which veins and lymphatic vessels—lympheducts—would be led from the central canal or cavity of the gland to its surface; and there by the channels described by Swedenborg, they would be led into the interior of the sphenoid bone, and thence into the lateral sinuses or jugular veins.

Among modern authors *Langer* seems to be the only one who actually noticed the passage of little tubes from the body of the pituitary gland into the venous "rete" by which the dura mater lining the pituitary gland is closely invested. Concerning the venous network, he says that it "adheres closely to the sphenoid bone, whence it derives a *diploic*, venous twig." Concerning the connection of this vascular network with the gland, he says, "Fragments of more delicate little tubes point out the existence of vessels which enter into this net from the pituitary gland" (see above, no. 621*x*).

Other authors have discovered a number of foramina through which veins or lymphatic vessels are led from the surface of the sella into the interior of the bone; and they have likewise discovered vessels which, out of the sphenoid bone, lead directly or indirectly into the jugular veins.

The experience of modern science on this subject is fitly introduced by the experiments instituted more than two hundred years ago by the celebrated *Willis*.[1] He says, "In those animals which are furnished with the rete mirabile, of which many shoots pass into the gland, several foramina are wrought into the bone underneath. . . . Further, if by pulling off the membrane from the fossa of the sella turcica you expose these foramina, and then pour water upon it, that water will quickly permeate the compages of the whole bone, and will trickle out suddenly through other foramina which are open in the sides of the bone, and for the most part are absent in the human cranium. But when they are present, as in the calf, we have to take especial notice that these foramina are filled by certain hollow vessels; and if a blackened liquor is injected by a syringe or canule, it passes through the compages of the bone, and permeates most other vessels which are below the bone, entering finally into the trunk of the jugular vein. . . . But as to the vessels which invest the foramina of the bone, and which are still more numerous under the bone, they seem to be either veins or lympheducts."

This experience has not been disproved by modern science. *Langer*, on the contrary, as we have seen, declares that the venous net which surrounds the pituitary glands on all sides, and adheres closely to the sphenoid bone, "receives thence a *diploic* venous twig;" by which is meant that the contents which this net receives from the pituitary gland are discharged into the diploë, or into the interior of the sphenoid bone. *Henle*[2] also distinctly admits the existence of such foramina in the pituitary fossa, even in the human cranium. Speaking of the bony structure of the sella turcica, he says, "Not unfrequently we find behind the olivary process—tuberculum sellæ—a second more shallow and narrower transverse groove which receives the anterior portion of a circular venous sinus surrounding the pituitary gland. The low portion of bone which separates that groove from the pituitary fossa behind, occasionally, on either side, terminates in a blunt or pointed little projection called the *middle clinoid process.*

[1] Willis (Th.). "Cerebri Anatome," etc. London, 1664; p. 78.

[2] Henle (J.). "Handbuch der Knochenlehre des Menschen," Part I., Section i., of his "Handbuch der systematischen Anatomie," etc. Third edition, Braunschweig, 1871; p. 111.

. . . Between the two middle clinoid processes *there is a fine foramen, or several foramina, through which vessels enter into the interior of the bone.*"

Landzert[1] says, "I regularly find in the anterior portion of the sella turcica, in the fetus, a hole of considerable size, into which the membrane which invests the bottom of the sella lets itself down; near that hole, or a little behind it, I find a few smaller foramina which afford an entrance for nutritive vessels."

Müller[2] also speaks of a vessel which enters the gland from the sphenoid bone underneath; only he declares that vessel to be an artery. He says: "The gland is supplied, at least very frequently, by a small arterial branch entering from below through the sphenoid bone. I judge that it is a branch of the arteria pharyngea ascendens."

19. The fact, on the other hand, that vessels, after first passing through the sphenoid bone, and thence through the anterior process of the occipital bone, discharge their contents into the jugular vein, is abundantly proved by modern experience—although the particular channels were not known to Swedenborg, when he elaborated his theory of the brain.

On this subject he says, "*The carotids supply twigs also to the bone underneath for the conveyance of the spirituous juice.* This is rendered evident by the experience of Willis and Vieussens, as well as by autopsy. For when a blackened humour is injected into the carotids, the substance of the bone is dyed thereby, and the dye collects in drops in its little crypts. Willis also seems to assert that the little arteries enter likewise into the small orifices themselves, which are open in the bottom of the sella turcica. And Vieussens maintains that little branches of the carotid . . . enter the substance of the bone in the neighbourhood of the four petrosal sinuses; further, that the caliber of the upper cerebral trunk of the carotid is considerably smaller than that of the trunk below; for so much of its ramification cannot be expended simply on the ganglion of the fifth pair and the optic nerves, that a sensible diminution would result thence. . . . Wherefore, most of the branches which do not return into the trunk seem to be expended upon the bone; and, indeed, for this reason, that these arterial twigs may constantly hold out and sprinkle blood upon the spirituous lymph. . . . In order that blood may thus be sprinkled

[1] Landzert (Prof. Th.). "Ueber den Canalis cranio-pharyngeus am Schädel der Neugeborenen." In the "St. Petersburger Medicinische Zeitschrift," vol. xiv., 1868.

[2] "Op. citat," p. 411.

upon the spirituous lymph which is expressed from the pituitary gland, it is necessary that nervous fibres should apply to those shoots of the 'rete mirabile' [that is, of the carotids] which enter the substance of the bone, even as these fibres accompany those shoots which enter the gland. For this purpose, indeed, that at the same moment when the carotid is expanded, or when the spirituous lymph is expressed from the gland, the blood shall be sprinkled upon the spirituous lymph which passes through the lympheducts in the bone" (640*e*).

Again he says, "The lympheducts so-called communicate in the interior of the sphenoid bone with blood-vessels, as appears from Vieussens' experiment. In making this experiment the two carotids are tied above and below [the sella turcica], and then a coloured liquid is injected, when the bony substance becomes dyed, and the injected liquid flows out of a section of the bone. This is a decided proof that arterial shoots of the carotids not only penetrate the bony substance, but also communicate with those lympheducts, especially when it is noticed that the injected liquid trickles out in drops. This communication is for the purpose that the spirituous lymph may be mixed with blood, so that it may pursue its way towards the lateral sinuses, and may not be dissipated on the way, and escape" (no. 625*i*).

From this it appears that Swedenborg, on the basis of the scientific experience of his age, was successful enough in tracing the spirituous lymph—the liquid of the *second* order—from the pituitary gland into the interior of the sphenoid bone, and in having it thoroughly mixed there with arterial blood from the carotids—but the experience of his age abandoned him in the determination of the particular vessels where the spirituous lymph mixed with arterial blood is afterwards collected, and whence it is conveyed into the jugular veins.

In no. 599 he simply says, "Apertures may be noticed in the bottom of the sella when laid bare—but these are sometimes obliterated—which are called lympheducts, and when water is injected into them it penetrates into the jugular veins." And again he says, "The superior petrosal sinuses seem also to admit the fluid of the *second* order, which passes through the bones of the skull; namely, that portion of the same which is not poured immediately into the jugular veins" (no. 623).

Modern science points out two series of vessels which empty into the jugular veins, and derive their supply of blood from the interior of the bones of the skull, between the sella turcica and the foramen magnum of the occipital bone. One of these systems of vessels is on the interior surface of the cranium under the dura mater; and the other is situated on the exterior surface of the cranium immediately under the inferior petrosal sinuses.

Concerning the former of these vessels, *Theile* [1] says in his edition of Sömmering's Angiology, "On the basc of the occipital bone, near the dorsum sellæ, there are situated transverse, reticular venous spaces which, with the exception of a few small branches from the pons Varolii and the medulla oblongata, do not receive any blood out of the parts of the brain, but, on the contrary, *out of the substance of the bone.* They are connected on each side with the cavernous sinuses and the inferior petrosal sinuses, and posteriorly with the venous plexuses of the vertebral column." Concerning this system of "reticular venous spaces," which *Virchow* calls "the plexus basilaris," this author gives us the following additional particulars:[2] "If you make an incision into the dura mater which is here stretched out tightly and smoothly, you will find that it is attached closely only to the dorsum sellæ, and in the region of the spheno-occipital suture. Under the dura, throughout the whole intervening space, lies a spongy tissue, which under favourable circumstance is entirely saturated with blood. . . . On removing that mass from the surface of the bone, the latter appears rough, uneven, almost carious, and perforated by large vascular foramina filled with blood. . . . The surface of the bone is here entirely bare, without any periosteum, . . . and *the vessels of the bone* communicate immediately with the superficial plexus."

This plexus of vessels, formerly called the "anterior occipital or transverse sinus," is discussed more fully below, in no. 37.

The other series of vessels, on the lower side of the cranium, which, in honour to its first discoverer, we call, "the Canal of Tabarrani," for reasons which are more fully given below, we consider as specially devoted to the use of conveying the spirituous lymph, the "fluid of the *second* order," from the interior of the bones of the skull into the jugular veins. This double canal, which extends from the cavernous sinuses to the jugular veins, was discovered in 1743 by the Italian anatomist Pietro Tabarrani, and although the attention of the learned had been directed to it by Haller in his "Elementa Physiologiæ," it

[1] Sömmering (S. Th. v.). "Vom Baue des menschlichen Körpers," "Lehre von den Muskeln und Gefässen des menschlichen Körpers," umgearbeitet von F. W. Theile. Leipzig, 1841; p. 276.

[2] "Op. citat.," p. 48.

has since been forgotten again, and was only rediscovered in 1863, by Dr. Englisch of Vienna. The canal of Tabarrani is discussed at greater length in nos. 38-40 of the present Note.

How far Swedenborg's suggestion, that a portion of the "fluid of the *second* order" is received also by the superior petrosal sinuses, is borne out by the investigations of modern science, will be seen below, in no. 32.

20. Additional reasons why the spirituous lymph, the lymphatic blood, should seek osseous channels for its safe passage into the jugular veins, Swedenborg advances in what follows: "The wisdom which nature displays in the conveyance of said lymph appears plainly from this consideration, that it is carried away, not by one, but by several ways, even by avenues which are wrought into bone, and hence are most safe. For wherever nature intends a constant and sure purpose and effect, as in the present case and also in others, it multiplies ways and means. Nature also observes a proportion between the ways or channels, and the liquid which is to be conveyed; wherefore, in the calf, these foramina are exhibited to the sight, and are pervious to injections, as is also the case with the beak of the infundibulum. But in man these foramina are almost invisible, except in fresh bone, and so also are the pores of the beaked infundibulum. There is also a force in this argument that the above-mentioned lymph flashes afterwards through the bone by the sole impetus given to it in the gland, or is carried along of its own accord, as it were; since there is nothing in the bone to press and urge it along, as is the case with veins, sinuses and arteries, which are engirded by membranes. A reason may also be derived from this circumstance, that these passages are in the sphenoid bone, and also in the petrous portion of the temporal bone, which bones are always tremulous by the membranes of the ear; for by the aid of that tremulousness the spirituous lymph of the gland hastens into its terminal vessels, that is, into the jugular veins, with the greatest ease, according to the nature of its elasticity. Wherefore experience testifies that the blood is considerably vivified by the expansion and dilatation of the cerebrum and its cranium, as well as by the hilarity of the mind, the harmony of sounds, and the vibration of the parts mentioned, through laughter and other causes" (no. 602*e*).

5. Function of the Anterior Lobe of the Gland, and the Lower Intercavernous or Inferior Transverse Sinus.

21. The function of the anterior lobe of the pituitary gland, it seems, is threefold. *First*, it contributes its share towards the production of the motion of the gland; *secondly*, it secretes a refined serum from the blood, and, *thirdly*, as has been observed by Prof. Leydig, it reanimates and restores, at least in some animals, exhausted blood-corpuscles.

The first of these uses has been discussed above in nos. 6 and 8; where it was shown that the motion of the anterior lobe of the gland is due to the expansion and contraction of the smaller arteries with which it is richly supplied. These little arteries by the action of nervous twigs springing from the carotid plexus of the great sympathetic nerve are constricted when the brain contracts, and the blood is then expelled from these little arteries, but when the brain expands, the carotids dispatch blood into the little vessels, and expand the same.

The great abundance of vessels in the anterior lobe has been pointed out above; where it was likewise shown that this lobe consists of glandular, epithelial sacs which are entwined by arterial twigs. These twigs, according to W. Müller, "pass over into a net of capillaries of 0,01 to 0,802mm., whereby the glandular substance is entwined with meshes, which on an average are 0,03—0,04mm. in width."

As to the venous outlets of these capillaries, Swedenborg says, "A few venous vessels depart thence into the membrane which holds the place of a periosteum, and afterwards they are carried into the inferior transverse [or lower intercavernous] and superior circular sinuses, and partly also into the substance of the sphenoid bone, in the direction of the lateral sinuses" (no. 602*i*).

Some of the carotid blood, however, after contributing its share towards the production of muscular motion in the gland, Swedenborg maintains is returned again to the carotids. Thus he says, "The third species of an arterial net enters the gland from tho carotid on either side; for this purpose, indeed, that the muscle of the gland may be in a condition of acting, and may never be deprived of blood which enters into it from so many points, into which it may also flow back—although a part of it passes likewise into the little veins."

Swedenborg does not draw any distinction between the venous blood discharged into the superior circular and the inferior transverse sinuses, but he does distinguish between the character of the superior petrosal sinuses, which, he says, convey a highly spirituous and most volatile blood, and between that of the cavernous sinuses, which are the receptacles of a grosser and more sluggish kind of blood.

As the superior circular sinus, as will be shown presently, empties its contents mostly into the superior petrosal sinuses, while the inferior transverse sinus does not communicate directly with these sinuses, but discharges its contents into the cavernous sinuses—it follows that, according to Swedenborg's principle, the venous blood received by the transverse or inferior intercavernous sinus must be of a lower quality than that which is infused into the circular sinus. While the circular sinus, in fact, receives the highly spirituous lymph, the fluid of the *first* order—secreted and elaborated in the infundibulum and posterior lobe—the transverse or inferior intercavernous sinus, on the contrary, is a receptacle of carotid blood, after this has been utilized in the production of the muscular motion of the gland, and which blood, in animals supplied with the rete mirabile, is returned in part to the carotids themselves, but in man is mostly collected in this transverse sinus, and dispatched thence into the cavernous sinuses, as well as into the interior of the sphenoid bone.

Swedenborg, however, as we have seen above, in no 16, does not maintain that the whole of the venous blood of the pituitary gland is derived into the inferior transverse sinus, but some of it, he holds, is also claimed by the superior circular sinus; and, indeed, for the purpose that the spirituous lymph of the gland which is discharged into the circular sinus may be "wedded to blood," so as not to escape on its way into the lateral sinuses.

That the inferior transverse sinus collects the carotid blood after its use in the pituitary gland has been accomplished, is plainly indicated by *W. Müller*, who says, "The veins into which the arterial vessels passed over in the embryo, emptied in a dense plexus situated at the sides, and also at the bottom of the sella;" and again he says, "those veins in the adult . . . are lastly discharged into the cavernous sinuses."

The venous plexus mentioned by W. Müller is evidently identical with the inferior transverse sinus or the sinus intercavernosus inferior (Henle). Concerning that sinus, *Key* and *Retzius*[1] say that "they always found it larger than the superior circular sinus, and always spread over the fossa pituitaria, serving as a means of communication

[1] "Op. citat.," vol. i., p. 97.

for the cavernous sinuses." They also state that "they *never found it missing* in the numerous subjects which they examined for that purpose." It must be observed here that these anatomists approached the pituitary gland *in situ*, by cutting and scraping off the osseous bulwark, the sella turcica, from below.

This probably accounts for the reason why "they never found that sinus missing;" while other authors either failed to notice it at all, or only met with it occasionally. The constant presence of this sinus is also proved by the casts of the cavernous sinuses obtained by corrosion, which Langer made the basis of his investigation. (See above, nos. 621*e* and 621*x*.)

The inferior transverse or lower intercavernous sinus was first described by *Littre*, who says, "The dura mater invests the bottom of the sella turcica, and within its own thickness, along the middle of that cavity, it forms a little fossula, in which there is situated a sinus, five lines long and one line broad; the sides of which are perforated by several holes, through some of which it communicates with another sinus which is situated near the clinoid process" (see above, no. 587). *Haller*[1] also noticed both sinuses mentioned here; he says, "Often there is a transverse sinus either under the gland or sometimes behind it; it conjoins the cavernous sinuses." *Winslow* called the trausverse sinus "the inferior circular sinus."

Among modern authors this sinus is ignored altogether by Quain, Cruveilhier, Ellis and others. *Henle* says, "The canal at the bottom of the sella turcica is identical with Winslow's inferior circular sinus." *Knott*[2] classifies it among the *sinus intercavernosi*, and says, "A sinus circularis inferior is described by Winslow beneath the pituitary body, and formed by branches which take a course nearly parallel to the one usually described. I have found it in six cases only [out of forty-nine]; in twelve cases there was a single intercavernous vein beneath the pituitary body."

22. The second function of the anterior lobe is that which is carried on by the glandular ducts or sacs, of which the parenchyma of this lobe mainly consists, and which sacs, as we have seen, are closely engirded by a web of arterial capillaries. The organization of the anterior lobe, according to *Mihalkovics*,[3] is as follows: "The

[1] Haller. "Elementa Physiologiæ," etc. Lausanne, 1762; Tom. iv., p. 157.

[2] Knott (J. Freeman), Dublin. "The Cerebral Sinuses and their variations," in "Transactions of the International Medical Congress, seventh Session, held in London, August 2nd to 9th, 1881." London, 1881; vol. i., p. 195.

[3] "Op. citat.," p. 88.

anterior lobe of the hypophysis is an oblong body lying in an almost horizontal position, which sends off a narrow production in front towards the chiasma of the optic nerves. . . . That portion of the pituitary gland which is situated in front of its central cavity, as well as the production of the gland towards the infundibulum, consists of blind epithelial ducts, 0,018—0,03mm. in diameter. These blind ducts are enclosed on the outside by a fine membrana propria, and interiorly they consist of small roundish and polygonal epithelial cells (4—5μ). Horizontal sections of these ducts exhibit those cells arranged in the form of rays, although here and there a narrow lumen may be discovered in the centre. Between these blind ducts there is a scanty supply of connective tissue with an abundance of vessels, whereby the ducts are entwined in the manner of wickerwork."

This same tubular arrangement prevails in the production which extends from the anterior lobe towards the infundibulum. Such is the uniform description given by the authors of the anterior lobe of the pituitary gland as it exists in man and in the vertebrata generally.

To this description *Leydig*[1] adds the following important facts in the case of fishes, to which we have already called attention. In a monograph on the mikroskopic anatomy and embryonic development of fishes belonging to the families of the rays and sharks, he says, "Of all the parts of the brain I have been struck most, on account of their peculiar structure, by the infundibulum and the pituitary gland. With respect to the external form of the gland, I have to mention, first of all, that in a very large specimen of the *raja clavata* I found that organ grown fast to the basis of the cranium, where it extended symmetrically to the right and left, in the form of a yellowish red welt, 7‴ in length. Under the mikroscope it was found to consist of connective tissue, which stretched out in the form of strands and fascicles for the purpose of embracing blind sacs or ducts, which were occasionally lengthened out into canals, and also were twisted. The ducts are filled with light, clear cells. Their structure, as is made plain from all this, coincides with that which is noticed in some vascular glands. This structural arrangement, however, prevails already in the infundibulum; for that organ consists of oblong ducts, 0,0540—0,0180‴ in size. These ducts are grouped into lobes, and contain light, clear cells. Very many vessels entwine these blind ducts throughout the whole of the gland, and what appears strange, in the lateral productions of the gland,

[1] Leydig (Prof. Franz). "Beiträge zur mikroskopischen Anatomie und Entwickelungsgeschichte der Rochen und Haie." Leipzig, 1852, p. 12.

which abound in vessels, and chiefly there, are found blood-globules in their various retrograde metamorphoses. You will notice there in cells, 0,00675—0,0135‴ in size, all the intermediate steps from the still yellow blood-globule to the blackish remnants of such globules. The final state of these cells in the pituitary gland must consequently be described as a transition on their part into clear lymphatic globules of 0,00337.‴ At least the intermediate members between the lymphatic globules and other globules of 0,00675,‴ which contain the sharply-marked fragments of blood-corpuscles, are far too numerous not to give rise in the mind of the observer to this supposition."

Prof. Leydig's observation seems to make it very plain, that while the actual composition of the red blood by the marriage of the spirituous lymph of the brain with the chyle of the body, according to Swedenborg, takes place in the viscera of the thorax, the rejuvenation and restoration of exhausted blood-corpuscles, at least in some subjects of the animal kingdom, takes place already in the pituitary gland, and, indeed, in the epithelial sacs of its anterior lobe. The mechanism by which this is done shall now be explained more fully.

In order to do so we require first of all a more minute knowledge of the arrangement of the glandular ducts or sacs of which the anterior lobe consists. *Peremeschko*[1] explains its organization thus, "Connective-tissue bundles of considerable size depart from the enclosing capsule of the gland. These bundles divide the anterior part of the gland into five or six round, irregularly-formed lobes. Thence smaller fascicles depart, 0,0037‴ in size, by which these lobes are divided into lobules, 0,06‴ in size. From these lobules still finer fascicles branch off, 0,0012—0,0025‴ in size, by which the smallest glandular lobules or ducts are separated. Connective tissue thickened into a kind of membrane extends everywhere between these least fascicles; and by that membrane the glandular ducts are enclosed on all sides in such a manner as to present entirely closed cavities." In another place he says, "The capillaries which everywhere make use of the connective-tissue membranes in this part of the organ measure 0,0025‴. Their meshes are irregularly round or oval in shape, and have a diameter of 0,0025—0,015‴. These capillaries do not engird the individual glandular ducts, but groups formed by the same." The contents of these ducts, as we have seen from Mihalkovics, are epithelial cells.

The anterior lobe thus presents the following arrangement. The individual glandular sacs have each a membrana propria furnished

[1] "Op. citat.," pp. 330, 340.

interiorly with epithelial cells; while groups of these sacs or ducts are embraced exteriorly by a net of capillaries.

Through the coatings of these capillaries exhausted blood-cells divided into fragments, as observed by Prof. Leydig in the *raja clavata*, would penetrate into the interior of said glandular sacs.

In addition to these blood-cells, a refined serum, as is usually the case, is also secreted from the coatings of the capillaries. Yet only a highly-refined serum would pass through the membrana propria of the sacs into the epithelial cells within.

Thither also, through lymphatic vessels described by Mihalkovics and the Brothers Wenzel (see above, no. 16), there is conveyed from the posterior lobe a supply of spirituous lymph thoroughly impregnated by animal spirit—the fluid of the *first* order. This animal spirit, duly mixed with an appropriate serum, distils through the epithelial cells into the interior of the glandular sacs, and, as has been observed by Prof. Leydig, rejuvenates and restores there "fragments" of exhausted blood, developing them "into clear, lymphatic globules of 0,003375‴ in size."

This rejuvenated blood consisting of "yellow blood-globules" is then gathered up by the veins of the anterior lobe, and through channels, minutely described by *Luschka*, is conveyed into the superior circular sinus.

According to Luschka, the veins which depart from the interior of the gland, "on either side of the gland, are gathered together into one little stem, the lumen of which usually becomes visible in a horizontal section, when it is accurately made through the middle. . . . Several vessels, in the form of rays, meet at the anterior edge, while only one larger vessel, or several feebler twigs, enter at its posterior edge."

The vessels, which "in the form of rays meet at the anterior edge" of the lumen of the venous stem, would thus convey to the superior circular sinus the blood-cells which have been transformed into "clear, lymphatic globules," floating in a suitable serum; while the vessels, which enter at the posterior edge, as we saw in no. 16, would convey there the balance of the spirituous lymph surcharged with animal spirit which has been prepared in the posterior lobe. Such seems to be the function of the epithelial sacs which are encompassed by a network of arterial capillaries. At least such, as we are justified in concluding on the basis of Prof. Leydig's observations, is the function of these sacs in fishes—but whether these sacs exercise the same function also in man, we are not prepared to decide either in the affirmative or in the negative. There are arguments in favour of either position. In opposition to the theory it may be mentioned that the pituitary gland in man generally receives only the purest arterial blood fresh from the heart, which does not require rejuvenation; although when the blood is generally poor, it is possible that it may receive strength in the pituitary gland, before proceeding on its further journey in the brain. In favour of the theory, however, it may be mentioned, that as the general function of the whole pituitary gland, according to Swedenborg, consists in contributing to the rejuvenation and restoration of the whole venous blood of the body, it would seem in harmony with the general use of the gland, that a portion of the gland should carry on this work of rejuvenation in the gland itself when needed.

Another use of the epithelial sacs, however, which are filled with clear lymph, it seems, consists in contributing to the elasticity of the gland, and hence to its muscular motion; for each of these epithelial sacs would naturally serve in the place of an elastic cushion.

23. An additional use of the anterior lobe, as already mentioned, consists in the secretion of a pure serum from the capillary nets, by which the epithelial sacs are embraced. This serum would only be partially used for the rejuvenation of blood-particles, but the bulk of it would be required for equalizing and adjusting the spirituous lymph secreted from the ventricular liquid, which collects in the central cavity of the gland.

For this cavity, according to Peremeschko, is not situated exactly between the anterior and posterior lobes; but in front, as well as in the rear, it is enclosed by glandular sacs engirded by a capillary network. The division immediately behind the central cavity which Peremeschko calls the "Markschicht"—medullary zone—consists of larger glandular ducts than is the case in the division in front, in the anterior lobe proper. The capillaries also are much more powerful in the "Markschicht," than in the "Korkschicht" of Peremeschko, or in the anterior lobe proper.

As the central cavity or canal is thus enclosed on all sides by glandular ducts encircled by capillary nets, a refined serum, whenever required, would naturally be distilled from these capillaries into the spirituous lymph contained in the central cavity; and this constitutes a third use of the anterior lobe of the gland.

In his later work on the brain, Swedenborg expresses himself very cautiously on the secretion of a refined serum in the gland. He says simply, "Whether the secretion of the little arteries, which are very plentiful in the texture of the gland, is also added to the volume of the lymph, may be inferred, but not asserted with certainty" (no. 596).

In his earlier work, however, he plainly asserts that such is the case, and he devotes an entire section to the discussion of this theme, namely, that "to the spirituous lymph—to the fluid of the *second* order—the pituitary gland adds a quantity of a refined serum from its little arteries" (no. 602*f*).

6. The Third Fluid excreted from the Pituitary Gland.

24. The fluid of the *third* order, which is excreted from the pituitary gland, has been incidentally treated throughout the whole of the present Note. The character of this fluid, which is the residuum of the ventricular liquid after the spirituous lymph—the fluid of the *second* order—has been drained off from it in the infundibulum, according to Swedenborg, is as follows, "It is composed of the lymph of the choroid plexuses, which also seems to be charged with nervous juice—cerebro-spinal liquid" (no. 625*k*). While it partakes thus of a lower character than the spirituous lymph—the fluid of the *second* order—it yet contains important ingredients for the formation of the red blood, and it belongs to the same level of composition as the red blood itself. Through special pores or tubes this fluid is conveyed from the infundibulum into the posterior part of the gland, where it collects on the surface of the gland under a production of the dura mater. And during the expansion of the gland this serum is discharged into the cavernous sinuses through an intercavernous sinus or vein which runs along the lower, posterior surface of the gland.

Swedenborg's own statement of the process by which the above fluid is first secreted in the infundibulum, and afterwards excreted from the pituitary gland, is as follows:

"When the cavity of the infundibulum is constricted, and its beak or process erected, the enclosed moisture is expressed by two ways; namely, the lighter, purer and spirituous portion is pressed into the porous, bibulous and medullary substance of its walls, and thence into the beaked process which is inserted in the pituitary gland, while the heavier, grosser and earthly portion is urged into some lateral ducts and processes in proximity to the pia mater which acts as a lining, and thence it is expressed above, around, and below the pituitary gland" (no. 575).

That such a grosser serosity from the infundibulum is excreted around the pituitary gland, Swedenborg says, in another place, "is completely borne out by experience. For, according to Vieussens, the purer essence of an injection only, not the dye, that is, simply its most subtle particles, make their way down upon the upper and lateral portions of the gland, passing along the infundibulum, not quickly, but gradually. According to Ridley, coloured infusions pass through the infundibulum only very superficially. . . . Littre states that a liquid is always noticed around the gland in which it seems to be bathed. . . . The pituitary gland is so placed in its capsule and engirded with pia mater, and at the same time with dura mater, that not a single drop of the humour, passing down upon its surface, is able to ooze out except through openings established for this purpose, which terminate exclusively in the cavernous sinuses and in the inferior petrosal sinuses" (no. 581*g*).

As to the particular place where this serum is collected, before it is discharged into the cavernous sinuses, Swedenborg says, "The gland discharges this serous juice in the direction of that posterior part of the sella where a quantity of it collects and bathes the gland. This part is between the two sides of the gland which are occupied by the carotids; it is a kind of posterior receptacle, and is a complement of the two cavernous sinuses. It is there where the two posterior clinoid processes, with their ligamentous productions, reach out towards the gland, and, as it were, enclose said posterior receptacle, distinguishing it from the lateral cavernous sinuses. Manget places it beyond doubt that there is here, under the production or duplicature of the dura mater, a communication between the gland or between the cavity of the sella turcica and the cavernous sinuses. He states that 'there is a channel of communication between the posterior surface of the posterior clinoid processes and the production of the dura mater, no less than [in front] between the gland and the sella, which latter communication is of the same kind as the former.' . . . As to the rest, the fact that there is a communication in said place seems to be denied by most authors" (no. 602*h*).

What does modern science say to all this?

25. Modern science has not very much to say either in favour or in opposition to the statements made by Swedenborg. The only observers in fact who, since Swedenborg's time, have followed up the results which Vieussens, Ridley and Littre obtained by injecting the infundibulum and the pituitary gland, are the Brothers *Wenzel* in 1812, and more recently, in 1879, *Sapolini*. The results of these observers, however, prove incontestably that there is a direct line of communication for a grosser fluid between the posterior surface of the gland and

the third ventricle. The account which the Brothers *Wenzel*[1] give of their particular experiment is as follows :—"On the ninth of October, 1800, we cut the infundibulum of a young man near the third ventricle. The brain was then taken out. On examining with a manual mikroscope the dissected surface of the infundibulum, we could not discover there any opening. This time we had resolved to effect an injection through the posterior lobe of the hypophysis in order to see whether anything of the injected liquid would pass thence into the infundibulum and into the anterior lobe. For this purpose we removed out of the posterior wall of the sella with a chisel so much of the bone until a small portion of the surface of the posterior lobe was plainly visible. After perforating the membrane, which lined that lobe, with a pair of scissors, we introduced the small tube of a syringe through the opening into the substance of the lobe, yet not beyond the distance of a line. In order to give to the syringe a horizontal direction, we cut a triangular piece out of the occipital bone. At the first injection the injected liquid rose from the surface of the dissected infundibulum like a little fountain. But whether it came out of one, or out of several openings in the infundibulum we could not tell. We repeated this experiment several times, always with the same result. Finally we took out the hypophysis, and dissected it horizontally through the middle. In the anterior lobe we did not discover anywhere any trace of the injected liquid. Chiefly the middle part of the posterior lobe, where the little tube had been inserted, was blue. At its anterior margin, except where the infundibulum is inserted, nothing whatever of the injection appeared" (p. 229).

Here the practical proof is furnished of the existence of a channel of communication for a fluid of a grosser nature, between the posterior part of the pituitary gland and the infundibulum; since an injection of a grosser nature passed with the greatest ease from the former into the latter organ, without anything of the injection reaching either the anterior part of the posterior lobe, or any part whatever of the anterior lobe.

In their account of this experiment, the Brothers Wenzel do not describe the particular course the injection took in reaching the infundibulum; nor do these observers specify the particular stratum of the posterior lobe through which the injection took place. They simply say that they "introduced the small tube of a syringe into the substance

[1] Wenzel (Josephus et Carolus). "De penitiori structura cerebri hominis et brutorum." Tubingæ, 1812, fol.

of the lobe through the opening, *yet not beyond the distance of a line.*"

Peremeschko[1] is able to tell us through what stratum of the posterior lobe they operated. He says, "The posterior lobe of the hypophysis, as is well known, is surrounded by a capsule common to both lobes. In some animals (calf) the connection between the capsule and the posterior lobe proper is effected through a special system of meshes, the trabeculæ of which, containing numerous pigment-cells, start from the capsule and are lost in the posterior lobe. The meshes are of considerable size, so that when examined by the naked eye they impart to that portion of the capsule a spongy appearance. These meshes are further provided with a scanty finely-granular mass without any morphological elements, which adheres to the trabeculæ. The thickness of that particular stratum, when examined from the front backwards, amounts to 0·4mm., and may be examined best in a section made through the middle of the gland of a calf. The posterior portion of the capsule, where it is conjoined with the above-mentioned system of meshes, presents a stratum of considerable thickness, which, when measured from the front backwards, amounts to almost 2mm. The naked eye is able to distinguish it from the remaining strata by its shining colour. The whole of this stratum consists almost exclusively of connective tissue."

The thickness of the whole capsule in that particular part of the posterior lobe where the Brothers Wenzel operated, that is, suppose the arrangement of the pituitary gland in the calf applies also to man, according to Peremeschko, amounts to 2mm.; while the dimension of the posterior lobe proper, according to the same authority, in the upper portion of the gland amounts to 1·8mm., and in the lower portion of the gland to 2·5mm.

This then would show that the Brothers Wenzel in their experiment did not reach the body proper of the posterior lobe, but injected the inner portion of the capsule, which presents a "spongy appearance," and consists of a "system of meshes," that, from Peremeschko's description, seems eminently fitted for the storing up and the transmission of an injection, and thus of a grosser serum.

26. The result obtained by the Brothers Wenzel, as interpreted by Peremeschko's experience, is borne out in every respect by the minute account furnished by *Sapolini*[2] of the interesting experiments insti-

[1] "Op. citat.," p. 340, *et seq.*
[2] "Op. citat.," p. 308, *et seq.*

tuted by himself. He says, "I prepared a solution of a few drops of very pure, red aniline in two grammes of distilled water. I took a head, from which was removed, in a circle all around, the cranial covering, so as to expose the encephalon. Keeping it in its normal position, I plunged it into a tepid bath, of which the temperature was gradually increased until at last the heat reached 29-30 degrees of Réaumur [97-100 degrees Fahrenheit]. After that operation, which lasted about thirty minutes, I removed the dura and pia maters, and gradually, in proportion as I removed the cerebral lobes by a cut, I raised the base of the encephalon out of the bath; yet without uncovering the ventricles, for fear of allowing the water to penetrate, and being very careful at the same time to keep the water at the same temperature. . . . I now removed from the corpus callosum the portion which corresponds to the roof of the third ventricle, as well as another piece under the fornix, and after withdrawing the velum interpositum, I very gently drew aside the choroid plexuses. Through the window thus obtained, I now introduced my blue liquid. After the introduction of the coloured liquid, I let the preparation rest for twenty-four hours, leaving the head in its normal position. In the morning I began the examination of the head, and opened the third ventricle by removing the cerebral mass, when I found this cavity dyed blue throughout. I now removed the whole of the encephalon, including the septum lucidum, retaining, however, the anterior part of the cerebrum. I thus reached the infundibulum, the whole of which I found dyed blue. In order to facilitate my examination, I had to saw the cranium through horizontally, as far as the dorsum sellæ. The dorsum sellæ itself I also removed with a pair of sharp scissors, and with infinite care I detached the dura and pia maters from the infundibulum and the processus infundibuli. After having finished these preparatory steps, and having placed the head in its normal position, I proceeded to cleave the infundibulum from top to bottom, being guided all the while by the blue dye. I divided as well the processus infundibuli, which displayed the blue colour already on its outside. The division was carried on as far as the superficial groove in the pituitary gland, which I also cleft. I now had no longer any doubt as to the existence of a canal from the third ventricle, as far as the groove in the gland. When I reached that groove, the processus infundibuli, I repeat it here, presented in its interior a circular constriction.

"I now made another preparation exactly like the first; that is, I introduced the blue liquid into the third ventricle. While the head was still in the bath, and after having removed the anterior cerebral lobes, I placed my forefinger on the anterior portion of the pituitary gland; and I was able to observe that by this pressure I caused a kind of undulation on the level of the liquid contained in the third ventricle. I noticed distinctly this undulation, and unless I have been the victim of an optical illusion, I can declare that, after the first pressure which I exerted on the pituitary gland, with the aid of a magnifying-glass, I saw an air-bubble appear on the level of the intra-ventricular liquid. At other times, however, when I tried the same experiment with other heads, I failed to obtain the same result. The processus infundibuli, consequently, is hollow, and it constitutes a canal which not only reaches to the groove of the pituitary gland, but extends even much farther.

"After having done all this, I exposed the large lobe of the pituitary gland, and, in order to make my task easier, I removed also the anterior clinoid processes. I now made an incision into that lobe from the front backwards, and after passing through a reddish stratum about 1mm. in thickness, I felt that I was cutting into a substance which offered less resistance. The first stratum constituted, so to say, an envelope, of which the second substance was the nucleus. This latter substance was granular, and presented not the least trace of a blue colour. . . . But to proceed. With fine needles and small pincers I removed the granular mass which constitutes the internal layer of the large lobe of the pituitary gland; I removed it piecemeal, grain after grain, until at last I reached the centre of the gland. At first, the substance upon which I operated became less consistent, until at last it ceased altogether, and I arrived at a kind of very small semi-circular cavity. . . . I repeated my experiments, and became convinced that in the large lobe of the gland there is a small cleft, a line in width, the concavity of which is turned towards the small lobe. In this cleft I noticed only the slightest bluish tinge, probably the result of imbibition. The processus infundibuli evidently did not dip into this small cavity."

The cleft or cavity which Sapolini discovered here was evidently the central canal described above by Peremeschko, which receives the spirituous lymph, the fluid of the *second* order, from the infundibulum through a passage filled with epithelium. Sapolini continues: "Let us proceed now to the examination of the small posterior lobe of the gland. In following up this examination, I began with laying open the processus infundibuli, by making an incision into it in an antero-posterior direction. . . . When I made such an incision, from the centre towards the circumference, also into the small lobe, I saw that in the whole lobe there was but one substance, quite different from the two substances which constitute the anterior lobe. . . . The dissecting needle cuts that substance with the greatest ease, and sometimes manages to tear it. After passing through a distance of 2mm., the needle met with no further resistance. Upon withdrawing the needle I found it dyed blue. I now made another incision, likewise from the centre towards the circumference, which came out 1mm. behind the processus infundibuli; and upon joining the two incisions, I managed to extract a triangular slice. I then discovered that in the substance of the small lobe there was a cavity which was entirely dyed blue."

This second cavity was the system of meshes, described by Peremeschko, which exists between the substance of the posterior lobe and the capsule of the gland; this capsule is exceedingly thick about the middle of the posterior surface of the gland. In this system of meshes, as we have shown above, there is collected the grosser serum, the fluid of the *third* order, excreted by the gland. Sapolini concludes: "It was my aniline, which, starting from the third ventricle, had passed through the infundibulum, and the processus infundibuli, into that cavity of the gland. By this experiment, therefore, there is established the existence of a perfect communication between the central portion of the posterior lobe and the third ventricle. But what is that orbicular constriction of the processus infundibuli? Is it a valve, a sphincter? For two years I laboured in trying to solve this question; but although I multiplied my experiments, I am still in doubt on the subject."

In examining more closely Sapolini's account of his last experiment, we miss a direct statement whether in this latter experiment, as he did in a former, he had removed the enclosing membrane from the infundibulum and its process. Nor does he state through what particular substance of the infundibulum and of the gland his aniline solution had percolated into the receptacle of the posterior lobe. That his solution, at least in some degree, had passed underneath the pia mater, he states in the account of his first experiment, where he had removed both "the dura and the pia maters" from the infundibulum and its process; for he says, in the description of that experiment, that "the blue colour had appeared already on the outside," and thus in that part of the infundibulum which was immediately underneath the pia mater which had been removed. On the outside of the infundibulum and of its process thus laid bare, the aniline solution seems to have passed into what Sapolini describes as "a cavity in the substance of the small lobe which was entirely dyed blue." At least he does not mention anywhere that the substance itself of the small lobe had also been dyed blue. In his account of the substance of the posterior lobe, which he examined in an antero-posterior direction after it had been injected, he simply says, "After passing through a distance of 2mm., the needle met with no further resistance, and on withdrawing the same, I found it to be dyed blue," because it had dipped into the cavity and receptacle between the nucleus of the posterior lobe and its integument.

The Brothers Wenzel, who approached the gland from behind, and injected it through an aperture made into the capsule, declare positively that the anterior part of the posterior lobe was not affected by their coloured injection. But as their injection passed from the gland easily into the cavity of the infundibulum through its process, it must have done so through some passages between the integument of the gland and the substance proper of its posterior lobe.

The integument of the gland seems to be of varying thickness; for while in the posterior part of the small lobe, where it is fastened to the sella, it is generally uncommonly thick, and in the case of the calf amounts to 2mm.,—around other parts of the same lobe, and also around the whole outer surface of the anterior lobe, it is occasionally quite thin, as appears from Peremeschko's diagrams, and also from the following remarks of the Brothers Wenzel[1]: "In certain places on the surface of the hypophysis, the enclosing membrane is thinner than in other places; whence it is that the substance of the hypophysis is there translucent. That portion of the membrane, however, which lines the smaller lobe of the hypophysis seems to be thinnest of all; wherefore, if you wish to extract the gland unimpaired, you must be extremely careful just there."

Still, however thin the integument of the gland may be, and especially immediately behind the place where the processus infundibuli is inserted in the posterior lobe—passages for the conveyance of a serum of a lower order nevertheless exist there, as is proved by the following observation made by *W. Müller*,[2] in the processus infundibuli and the pituitary gland of newly-born infants. He says, "On the posterior surface of the gland, near the point where it touches the processus infundibuli, there are several hollow spaces, 0,5mm. in length and 0,1mm. in breadth, which are lined with short

[1] "Op. citat.," p. 210.
[2] "Op. citat.," p. 410, *et seq.*

cylindrical epithelium 0,006mm. in length and 0,004mm. in thickness." In speaking of the same parts in adults he says, "Near the posterior surface of the gland, hollow spaces of considerable size are invariably visible, which spaces are observable with the naked eye. The interior of these spaces consists partly of a liquid, and partly of colloid masses."

These same hollow spaces seem also to have been observed by Littre, from whom Swedenborg quotes the statement that "the body of the gland is found bathed in a thin and palish blood" (no. 587).

The liquid observed by Littre, and more recently by W. Müller, is the grosser serum—the fluid of the *third* order—which, according to Swedenborg, is conveyed through the interstices under the pia mater of the processus infundibuli and the posterior surface of the pituitary gland into the posterior receptacle, between the gland and the posterior wall of the sella.

That the integument of the gland which consists of pia mater is continued also into the infundibulum and its process, is proved from the dissection of Sapolini, who succeeded "in detaching the dura [?] and pia maters from the infundibulum and its process." It is also proved by the following experiment of the Brothers Wenzel[1]: "Within that circle—namely, the little circle described by the dura mater around the infundibulum near its insertion in the gland—the process of the infundibulum is enclosed by a certain thin, although dense, reddish membrane, which is a continuation of the external integument of the infundibulum, and thus of the pia mater of the cerebrum. For in a boy one year old we tried to pull one half of the membrane around and above the infundibulum, and we succeeded so well that afterwards the infundibulum was left quite slender."

That the posterior wall of the processus infundibuli differs from the remaining walls, and that its structure affords a passage to a grosser serum, seems proved by the following observation of W. Müller[2]: "Numerous finely-stretched vessels extend along the posterior wall of the processus infundibuli, imparting to it an appearance different from that of the remaining walls."

27. From modern sources we have thus far proved the existence of a regular channel of communication between the upper part of the processus infundibuli and the posterior part of the posterior lobe of the gland. We have further proved the existence of a kind of storeroom for said liquid; namely, "a system of meshes," a kind of spongy substance, intervening between the posterior lobe proper and its

[1] "Op. citat.," p. 210.
[2] "Op. citat.," p. 414.

thickened integument. The question now arises, how is said liquid discharged from the gland?

Both in his first and in his second work on the brain, Swedenborg is emphatic in his declaration that said liquid is excreted in the posterior part of the sella. He describes this place as a kind of "posterior receptacle," and as a "complement of the two cavernous sinuses;" and he declares that the particular place where said serum is excreted is in the lower part of the posterior lobe, where it is widest—and thus below the place where the Brothers Wenzel effected an opening in the bone of the sella, and whence they injected successfully the infundibulum. His statement is as follows: "About its posterior and wide part, the gland is so far distant from the wall of the sella that a probe may be introduced there, and that this interstitial space may be filled with a little volume of liquid; nevertheless, in the middle of the posterior lobe the gland is attached to the lobe, exactly there where the fulcrum is, by which, as well as by its adhesion to the ceiling, the gland is held suspended" (no. 634*r*).

The receptacle in question, therefore, according to Swedenborg, is in the lower posterior part of the gland.

The existence of this receptacle is distinctly admitted by *Bianchi*, who says, "The cavernous sinuses communicate with one another between the anterior face of the posterior clinoid processes of the sella, and the production of the dura mater, and indeed for the purpose that these sinuses may communicate there to one another the humours which they receive from the gland and blood-vessels" (see above, no. 588). *Morgagni* supports Bianchi's statement, and says, "The anterior face of the posterior wall of the sella is closely connected with the gland; the result of which cohesion is, that although between the posterior base of the gland and the lowest part of the sella, and between the part of the wall mentioned above, there is some space left by which the cavernous sinuses communicate with one another; still that communication does not by any means exist there where you ascend a little from the base to the back of the sella" (see above, no. 589). Again he says, "*Ortlob*[1] knew that posterior cavity and gave a drawing of it, and he said that this was a 'communication between the sinuses which are adjacent to the sella turcica, and which is situated near the posterior process of the sella.' He further says that 'this production may not improperly be called the transverse or conciliatory sinus'" (see above, no. 607).

[1] Ortlob (J. Fried.). "Historia partium et œconomiæ hominis secundum naturam." Leipzig, 1697, 4to. Dissertatio 20.

Littre, like Ortlob, described that posterior receptacle as a sinus, and he declared that it communicated with the inferior transverse sinus which is situated under the gland, and which has been described above in no. 21. He says, "Through several holes or foramina, that sinus—the inferior transverse or intercavernous sinus—communicates with another sinus—the posterior receptacle—which is situated near the clinoid process" (see above, no. 587). *Haller* also speaks of two transverse sinuses in the sella equina, of which one is under the gland and the other behind it (see above, no. 21).

Knott[1] the most recent investigator of the cerebral sinuses, after communicating the result of his investigations respecting the inferior transverse sinus, one of the "sinus intercavernosi," says, "A single vein forms the *sinus transversus sellæ equinæ* described by Haller." But what Haller described, in addition to the inferior transverse sinus, is the posterior transverse sinus mentioned by Ortlob and Littre.

Knott, it seems, looks upon Swedenborg's "posterior receptacle" rather in the light of a vein than of a sinus. But whether it be a vein or a sinus, he confirms the existence in the posterior base of a larger vessel which communicates with the cavernous sinuses.

G. The Functions of the Sinuses departing from the Sella Turcica.

28. Swedenborg makes a distinction between the sinuses in the top of the cranium which collect in the torcular Herophili—the confluent of the sinuses in the occipital bone—and are derived thence into the lateral sinuses; and between those in the base of the cranium which concentre in the sella turcica, and are dispatched thence into the lateral sinuses and the internal jugular veins.

The blood in the former sinuses, especially in the longitudinal, he describes as "gross, thick, sluggish and pituitous; because the grey substance, which in great abundance constitutes the circumference of the brain, drains off the spirit and the better life of the blood, and commits it to the fibres" (i., no. 331). While the blood, which is conveyed from the pituitary gland and its vicinity into the lateral sinuses and the jugular veins through the superior and inferior petrosal sinuses, is "a most refined virgin blood, but newly wedded to an abundant supply of spirits, which have been distilled in the large laboratory of the brain" (*ibid.*).

From this it follows that the exhausted and effete blood of the

[1] "Op. citat," p. 195.

brain is attracted towards the two longitudinal, and the straight siuuses; while the blood which is more or less enriched with spirit tends towards those sinuses which depart from the sella turcica. On this account a great proportion of the venous blood of the dura mater also is despatched towards the latter sinuses; for, as is shown in Note vii., no. 53, "the interior lamina of the dura mater is a vehicle for the lymph impregnated with spirit—the cerebro-spinal liquid—which is set free when the nerves are distributed over the muscles and periostea [in the body]." Concerning the manner in which the superfluous nervous juice—the cerebro-spinal liquid—which is dispatched from the brain in the interstices betweeu the fascicles and fibres of the departing nerves, returns from the body, and is collected in the dura mater of the spinal cord, aud pumped thence into the dura mater of the head, see Note vii., no. 48. This nervous juice in the dura mater is absorbed in part by the meningeal veins, and is conveyed thence to some extent into the sinuses which carry the blood from the sella turcica into the lateral sinuses and into the jugular vein. The purely venous blood, on the other hand, which is more or less deprived of its spirit and which finds its way into the veins and sinuses leading into the cavernous sinuses out of parts of the brain and out of exterior portions of the head—this venous blood, according to Swedenborg, is not carried into the lateral siuuses and the jugular foramina through the petrosal sinuses, but leaves the cranium through other channels and foramina. He says on this subject, "If the veins in question—those which, according to Ridley, direct their course towards the sides of the sella turcica—did receive any spirituous essence from the brain, they, like the remaining ducts, would convey it either into the sinuses at the base of the cranium, or into the jugular veins. Wherefore, suppose they carry their blood outside the crauium, through other foramiua, there is ground to conjecture that they imbibe a different blood from the bone; namely, such a blood as the external carotids, for the purpose of nutrition, dispatch thither, as well as into the spacious mucous membrane of the cavities [in the sphenoid bone]" (uo. 625*j*).

Nevertheless, the same venous blood, it would seem, furnishes also some necessary ingredients for fixing the highly spirituous lymph which is distilled from the pituitary gland, or else this venous blood would not be conveyed into the lateral sinuses which receive this lymph in the first place.

29. Another principle which governs the conveyance of blood enriched with spirit from the sella turcica to the lateral sinuses and the internal jugular veins, is this: The blood, which is most highly refined

and charged with animal spirit, enters the lateral sinuses at the greatest distance from the jugular foramina; while the blood which is less rich in spirit is discharged into the jugular veins in these very foramina, or immediately below the cranium; and that which is still more destitute of spirit, that is, ordinary venous blood, enters these vessels at a considerable distanee from the cranium; while the lymph of the body and the fresh chyle, which purvey to the blood the natural or corporeal elements which are required for the formation of the red blood, enter the jugular vein at its junction with the subclavian vein, not far from the heart. Swedenborg's own language on this subject is as follows: "The spirituous lymphs--the fluids of the *first* and *second* order—are emptied into the very troughs of the lateral sinuses, so as to reanimate the whole mass of blood. . . . Presently there is introduced through the inferior petrosal sinuses a liquid which is less spirituous, and which is discharged immediately into the jugular foramina, so that in these bony narrows nothing of the blood previously reanimated in the troughs of the lateral sinuses is able to descend into the body, without receiving a share of the liquid out of the inferior petrosal sinuses. At last the blood, which has been prepared in this manner and made liquid, can beeome embodied, as it were, or furnish itself with a body through the chyle. For unless the chyle were infused into a blood previously vivified, there would result from that mixture a kind of sluggish viscosity. Wherefore, the grosser ingredients succeed in due order, so that the act of eommingling may be successfully accomplished" (no. 625*k*).

A similar principle seems to prevail in the introduetion of blood into the superior petrosal sinuses, through whieh the most spirituous lymph of the brain is conveyed to the lateral sinuses. These same sinuses receive their most spirituous blood in the immediate neighbourhood of the pituitary gland; while a grosser blood is communicated to them on the way, and the grossest blood is introduced into them just before their inosculation in the internal jugular vein.

In the light of these principles we shall now examine in detail those sinuses to which is assigned the function of carrying into the lateral sinuses and the jugular veins the various species of blood which are excreted by the pituitary gland, and which are also received from sundry other sourees by the sinuses in the vieinity of the sella tureiea.

1. The Superior Petrosal Sinuses.

30. Concerning these sinuses Swedenborg says, "The superior petrosal sinuses receive from the circular sinus, and also through veins immediately from the gland, that first and purest essence which the gland expresses, and they convey the same to the receptacles of the lateral sinuses and the jugular veins. These sinuses have their highest heads and lips close to the circular sinus; for near the carotids they curve themselves in the shape of the letter *e*, and thence they incline themselves, and cast themselves towards the above-named [jugular] veins. They are comparatively long and slender, and their tube-like bodies are completely adapted to the swiftness, and the quick flashes of that fluid. Their colour also indicates the extreme liquidity of their blood. . . . These same sinuses also seem to admit in addition the fluid of the *second* order, which passes through the bones of the skull; namely, that portion of the same which is not poured immediately into the jugular veins" (no. 623). Again he says, "The superior petrosal sinus applies itself to the same summit, where the superior circular sinus chiefly shows itself; namely, underneath that angle, which, according to Bianchi, arises from a meeting of the productions of the dura mater. This same petrosal sinus also, by a slender trough, and through an exceedingly small orifice which sometimes is blind, terminates constantly in the enlargement of the lateral sinuses" (no. 602*c*).

31. In a general sense the origin of the superior petrosal sinuses is in the cavernous sinuses, as is also admitted by Swedenborg in no. 315, where he says, "These sinuses derive their blood from the cavernous sinuses, and at the same time by an insertion into them of many veins from the inferior or anterior part of the brain."

In a stricter sense, however, these sinuses are derived from the circular sinus, as is stated by Swedenborg in those passages which we have just quoted in no. 30; or at least they are derived from those parts of the cavernous sinuses which are supplied chiefly, if not altogether, by the circular sinus.

Such also is the opinion expressed by *Haller*[1] who says, "The anterior end of the superior petrosal sinus is constantly in the cavernous sinus, near the interior side of the fifth pair of nerves, and near the anterior side of the posterior clinoid process; *which part may also be ascribed to the circular sinus.*"

Ridley is even more definite in his language; he says, "The superior petrosal sinuses which are longer and narrower, according to Vieussens,

[1] "Op. citat.," p. 152.

arise from the cavernous sinuses, though more truly from the circular sinus, running down from thence upon the internal process of the temporal bone, and terminating in the lateral sinuses" (see Vol. i., no. 317).

Sapolini,[1] however, gives it as the result of his observation that "the circular, cavernous, and anterior occipital sinuses discharge the whole of their contents into the superior petrosal sinuses, which empty their blood into the lateral sinuses." And the *modus operandi* by which this is done he states as follows: "In the circular, and especially in the cavernous sinus there appear an infinite number of little trabeculæ. They are a kind of little valves which spring from the internal wall of the sinus. Their ends are free, and they ought to float in the midst of the blood, without obstructing in the least the current of the sanguineous stream; but for all that they modify essentially its direction. In fact, these kinds of flood-gates, placed in all possible directions, compel the sanguineous wave to turn aside, and to deviate from the straight line." In this way, Sapolini holds, the bulk of the blood coming from the circular and anterior occipital sinuses is directed into the superior petrosal sinuses.

Ordinarily, however, the origin of the superior petrosal sinuses is placed in the text-book simply in the cavernous sinuses.

There are several reasons why the circular sinus should not empty its contents exclusively into the superior petrosal sinuses: *First*, the circular sinus, as shown above in no. 16, is the recipient of the animal spirit secreted in the processus infundibuli and the posterior lobe of the pituitary gland. That spirit, as we have seen above in no. 20, is directly for the purpose of reviving and thus animating the sluggish venous blood of the brain, which collects in the receptacles of the lateral sinuses; whether it reach those receptacles from the torcular Herophili—the confluent of the sinuses in the occipital bone—or whether it be dispatched thither from some of those sinuses or veins which are connected with the cavernous sinuses. If, therefore, for any reason, the venous blood in the latter sinuses should be too sluggish, and thus too much exhausted of spirit to be able to pursue its course, some of the spirituous lymph of the circular sinus, as indicated above in no. 20, would be at once diverted into the cavernous sinuses. Otherwise this sinus dispatches the whole of its supply of lymph directly into the lateral sinuses through the superior petrosal sinuses. *Secondly*, in case the animal spirits are imperfectly fixed or wedded to blood in the circular sinus; or in case the blood attracted into the

[1] "Op. citat.," p. 210.

circular sinus does not possess all the elements for properly fixing the animal spirit of the gland, the necessary ingredients are supplied to the superior petrosal sinuses from the blood in the cavernous sinuses, which is necessarily various, since it is derived from so many different sources.

This then, it would seem, is the reason why the circular sinus is not inosculated exclusively in the superior petrosal sinuses, but empties partly into the latter sinuses, and partly into the cavernous sinuses; and again, why the superior petrosal sinus is not the recipient exclusively of the lymph of the circular sinus, but, if necessary, admits blood also from the cavernous sinuses.

32. As we have thus far seen, according to Swedenborg, there is transmitted into the superior petrosal sinus, through the circular sinus, the spirituous lymph surcharged with animal spirit—the fluid of the *first* order—which, in accordance with Prof. Leydig's observations, as shown above in no. 22, is perhaps increased by antiquated blood which, in the anterior lobe of the pituitary gland, is converted into clear, lymphatic blood. But in no. 603, Swedenborg states further that "the superior petrosal sinuses *seem* also to admit in addition the 'fluid of the *second* order,' which passes through the bones of the skull; namely, that portion of the same which is not poured immediately into the jugular veins."

The only channel through which the superior petrosal sinuses can possibly receive any portion of the fluid of the *second* order, "from the interior of the bones of the skull," is through the "anterior occipital or transverse sinus," which opens into the cavernous sinuses in close proximity to the mouths of the above sinuses. For the superior petrosal sinuses do not themselves receive immediately any accessions from the interior of the bone; but the "anterior occipital or transverse sinus," which is the highest transverse vessel of the "plexus basilaris" of Virchow, does. Besides, according to *Sapolini* (see above, no. 31), the anterior occipital or transverse sinus discharges the whole of its contents into the superior petrosal sinuses. According to *Vicq d'Azyr*, also, "this same sinus communicates with the superior petrosal sinuses" (see above, no. 621*k*); while *Sappey* maintains that this same *anterior occipital or transverse sinus*, "in reuniting the two superior petrosal sinuses, forms with them a large anastomosis extending transversely from the right lateral to the left lateral sinus" (see above, no. 621*l*).

There seems thus to exist a sufficient anatomical basis on which to establish Swedenborg's assertion that a portion of the fluid of the *second* order" is received by the superior petrosal sinuses "from the interior of the bones of the skull."

On the other hand, however, such a communication between the "anterior occipital or transverse sinus," and the superior petrosal sinuses, is totally ignored by Bell, Theile, Quain, Knott and Langer, who declare that the sinus in question communicates only with the inferior petrosal sinuses, while Haller and Cruveilhier, together with Sappey, teach that the "anterior occipital or transverse sinus" serves as a uniting medium not only between the inferior, but also between the superior petrosal sinuses.

If Swedenborg, while writing his work on the brain, had been acquainted with the canal of Tabarrani—a canal on the exterior surface of the cranium which leads from the cavernous sinuses to the internal jugular vein, and which, according to the testimony of Dr. Englisch, during its course receives small tributary branches from the interior of the bones of the cranium—he would probably have claimed for this canal the chief task of conveying the "fluid of the *second* order" from the interior of the sphenoid and occipital bones into the internal jugular vein, and would not have deemed it necessary to impose a part of this task on the superior petrosal sinuses.

Still there cannot be any doubt at all that the superior petrosal sinuses, in company with the inferior petrosal sinuses, do derive blood tinctured with spirituous lymph "from the interior of the bones of the skull;" and indeed through the medium of the "basilar plexus" of Virchow. For both the superior, and the inferior petrosal sinuses, but especially the latter, communicate with this plexus of vessels which derives its supply of blood from the arteries and veins in the "interior of the bones of the skull," between the dorsum sellæ and the foramen magnum of the occipital below. (See the "Plexus basilaris" below, in no. 37.)

33. The next species of venous blood which is introduced into the superior petrosal sinuses is meningeal blood, which, as we have shown in no. 28, is more impregnated with spirit than the venous blood derived from the substance of the brain. It enters into the superior petrosal sinuses through the medium of the *great anastomotic vein*, which has first been minutely described by *Trolard.*[1] This author says, "Towards the middle of the superior petrosal sinus there empties into it a vein to which I apply the name of the *great anasto-*

[1] Trolard (P.). "Recherches sur l'Anatomie du Système veineux du Crâne et de l'Encéphale." (Archives Générales de Médecine, Vol. xv., Paris, 1870, p. 263.)

motic vein (grande veine anastomotique). This vein sometimes takes its rise at the sides of the superior longitudinal sinus; but most frequently it arises from a junction of veins which anastomose in the middle of the convexity of the cerebral hemispheres. After the trunk of this vein has thus been formed, it directs its course downwards from behind forwards. It passes through the fissure of Sylvius, fastens itself to the sharp edge of the small wing of the sphenoid bone; and being imbedded in dura mater, it crosses the spheno-temporal fossa in order to enter the superior petrosal sinus. During its last course, as is very evident, *it is a real sinus*, and its volume is considerable. While traversing the spheno-temporal fossa, it exhibits, on its lower wall, or on its lateral walls, one or two small orifices, whereby it communicates with the *middle meningeal veins*, over which it passes. . . . Precisely at the same moment when it leaves the fissure of Sylvius, in order to attach itself to the wing of the sphenoid bone, it receives a branch which comes from the base of the cerebrum, the volume and length of which are variable. . . . As this vein is voluminous, and establishes an extensive communication between the veins of the base and those of the roof of the cranium, I propose to call it the *great anastomotic vein*."

This same vein had been previously noticed by *Haller*[1] who says, "This sinus—the superior petrosal sinus—also derives some blood from the veins of the dura mater which make their approach over the higher breadth of the petrous bone."

34. After the superior petrosal sinus has received—(1) through the circular sinus, the fluid of the *first* order, that is, the animal spirit with which the spirituous lymph of the gland is surcharged; (2) through the anterior occipital or transverse sinus, some of the fluid of the *second* order, that is, the spirituous lymph of the gland by itself; (3) through the great anastomotic vein a considerable supply of meningeal blood—it finally receives ordinary venous blood, more or less exhausted of spirit, from the outer portions of the head, as well as from the interior portions of the cerebrum and cerebellum.

The first supply of this venous blood, namely, from the exterior parts of the head, which supply is not constant, is furnished to the superior petrosal sinus through the *sinus ophthalmo-petrosus*, described by *Hyrtl.*[2] This author says, "The *sinus ophthalmo-petrosus* begins in the fissura orbitalis superior from the sinus Brescheti—the sinus spheno-parietalis;

[1] "Op. citat.," iv., p. 152.

[2] Hyrtl (Prof.). "Der Sinus ophthalmo-petrosus," in "Wiener medicinische Wochenschrift," Vol. xii., 19, 1862.

and as this latter sinus is frequently wanting [?], it arises from the veins which run along the outer wall of the orbit towards the fissura orbitalis superior. Its posterior extremity may be threefold. *First:* It follows the direction of the Vidian or pterygoid canal, bends upwards quickly in the neighbourhood of the hiatus Fallopii, and *empties into the superior petrosal sinus. Secondly:* It follows more directly the sutura petroso-squamosa, and empties itself either at the junction of the petrosal sinus with the transverse sinus, or it opens altogether into the latter sinus. *Thirdly:* The sinus in question seems to have a blind ending near the anterior surface of the petrous bone; but on opening what appears to be a cœcum, from two to four openings are noticed at the lower wall of the sinus, through which it communicates with the venous plexuses which accompany the Art. meningea media, and also with those of the ganglion Gasserii. In the two former cases the sinus supplies blood from the eye to the superior petrosal sinus; and in the latter case, to the venous plexuses between the sphenoid bone and the apex of the petrous bone, which discharge most of their contents through the foramen ovale. A foramen of various size, which not unfrequently occurs between the foramen ovale and the foramen rotuudum, accommodates an emissary of the above sinus." Prof. Theile,[1] in his review of Hyrtl's article, writes, "The observations of the author seem to show, besides, that the above sinus as to size is influenced by the ophthalmic vein; for in proportion to the decrease in the size of the ophthalmic vein, the sinus enlarges in size. The author also is of opinion that the relation which the above sinus occupies in respect to the superior petrosal sinus explains at the same time the reason why the latter sinus presents so many remarkable differences in size."

Knott[2] seems to have noticed this sinus; for he says, "I have found a vessel answering to this description—namely, a communicating *vas aberrans* between the opthalmic vein in front, and the superior petrosal sinus behind—in three instances. They all occurred on the left side." Knott, however, it seems, made a mistake in identifying said "*vas aberrans*" with the *canaliculus s. aquœductus communicationis* which *Verga*[3] described in 1856. That little canal is situated in the edge of the border between the mastoid and petrous portions of the temporal bone, and carries a very fiue venous twig from the

[1] "Schmidt's Jahrbücher," etc., Jahrgang 1862, Vol. cxvi.; Leipzig, 1862, p. 27.

[2] "Op. citat.," p. 196.

[3] Verga in "Ann. univers. di medicina," 1856, p. 175.

middle cranial fossa to the end of the lateral sinus; but it is not connected either with the ophthalmic vein, or the superior petrosal sinus.

35. The grossest and most effete blood, the superior petrosal sinus receives in the immediate neighbourhood of the lateral sinuses from the medulla oblongata and the cerebellum, as well as from the cerebrum.

The venous supply of these sinuses from the cerebellum *Luschka*[1] describes as follows, "The inferior cerebellar veins reach the lower surface of the cerebellar hemispheres in a number which varies in different individuals. After arriving there they direct their course either towards the anterior lateral margin of the cerebellum, in order to become inosculated in the superior petrosal sinuses, or they approach its posterior margin in order to empty afterwards into the lateral sinus."

Concerning the cerebral veins which terminate in the superior petrosal sinus, the same author says, "Among the inferior cerebral veins, those which are derived from the temporal and occipital lobes of the cerebrum enter into the superior petrosal sinus, as well as into the lateral sinus."

According to *Haller*,[2] the latter veins empty also into the anterior occipital or transverse sinus. He says, "The inferior veins of the cerebrum, at least of the posterior lobes, empty sometimes into the superior petrosal sinuses, as well as into the anterior occipital, or transverse sinus." Of the cerebellar veins he says, "the inferior veins of the cerebellum, however, are constantly inserted into the superior petrosal sinus, *not far from its posterior end*—in conjunction with the veins of the medulla oblongata and the pons Varolii, which arrive between the medulla oblongata and the cerebellum."

36. Swedenborg's theory, that the blood richest in spirit is first introduced into the sinuses of the base of the cranium, then a blood less rich, and so on, until it finally receives a blood which is almost entirely destitute of spirit, is thus completely borne out by the facts in connection with the superior petrosal sinuses.

There is one feature, however, to be borne in mind, namely, that the function of the superior petrosal sinuses consists in carrying a most spirituous blood to the lateral sinuses, and not simply ordinary venous blood. Great care, therefore, is taken in preventing these sinuses from being flooded by an excess of ordinary venous blood.

[1] Luschka (H. von). "Die Anatomie der Menschen," Bd. iii., Abth. 2. Tübingen, 1867; p. 247.

[2] Haller. "Elementa Physiologiæ," iv., p. 152.

For the attainment of this object the various large veins which open into the superior petrosal sinuses, anastomose frequently with other veins, and they are all connected with emissary veins, by which they are able to send abroad, outside of the cranium, any amount of venous blood, by which the superior petrosal sinuses are threatened to be inundated.

The caliber of the circular sinus which conveys the richest and swiftest blood to the superior petrosal sinuses, according to *Krause*,[1] is $1\frac{1}{2}'''$, and that of each of the superior petrosal sinuses $1\frac{2}{8}'''$, which, for the two sinuses, makes $2\frac{1}{8}'''$. If, therefore, the supply received from the circular sinus is equal to $1\frac{1}{2}'''$, or $1\frac{3}{8}'''$, the superior petrosal sinuses can receive from other sources only so much venous blood as equals the difference between $1\frac{3}{8}'''$ and $2\frac{1}{8}'''$; consequently, only so much as can be accommodated in a tube, the dimension of which is $1\frac{1}{8}'''$.

Hence the necessity of those anastomoses and emissary veins with which the veins terminating in the superior petrosal sinuses are richly furnished.

The first of these veins, the "great anastomotic vein," as its name implies, anastomoses largely with other veins in the dura mater, even with such as terminate in the superior longitudinal sinus. While traversing the spheno-temporal fossa, according to Trolard, it communicates with the middle meningeal vein, over which it passes. That vein acts as its emissary vein; for it terminates in the internal maxillary vein, which enters into the formation of the pterygoid plexus, and through this plexus it communicates with the external jugular vein, and also with the internal jugular vein at a considerable distance below the foramen jugulare.

The venous vessel, next in importance, which opens into the superior petrosal sinus, is the *sinus ophthalmo-petrosus* of Hyrtl. This sinus anastomoses with the ophthalmic vein; in fact, the size of this sinus is influenced by the size of the ophthalmic vein. If the latter vein be small, the sinus is large; and if the sinus be small, the ophthalmic vein is large. At other times this sinus is connected with the superior petrosal sinus and with the anterior occipital or transverse sinus as well, so that it is able to discharge its contents into either of these sinuses. And then, again, the above sinus communicates with the pterygoid plexus through veins which pass through the foramen ovale. Hyrtl also notices a special emissary in connection

[1] Krause (Wilh.). "De vasis sanguiferis in cavo cranii." Dissertatio inauguralis. Kiew, 1855; p. 10.

with the sinus ophthalmo-petrosus, concerning which he says, "A foramen of various size, which not unfrequently occurs between the foramen ovale and the foramen rotundum, accommodates an emissary of the above sinus."

The inferior cerebellar vein, which opens into the superior petrosal sinus near its entrance into the lateral sinus, according to Luschka, communicates also with the lateral sinus, so that, when necessary, it may pour its blood immediately into the lateral sinus, without burdening the petrosal sinus at all. The same applies to the inferior cerebral vein, which, according to Haller, communicates besides with the anterior occipital or transverse sinus.

On the basis of facts recorded by Vieussens and Morgagni, Swedenborg states that the posterior end of the above sinuses is sometimes impervious. He says, "Where these sinuses are inosculated in the troughs or receptacles of the lateral sinuses, the foramen through which their contents pass is sometimes impervious, like that of the process of the infundibulum, to which it corresponds in point of dimension, and through which a similar kind of fluid is instilled into the gland" (no. 623). The more spirituous ingredients of the blood in this case would pass through the impervious end of the sinus, even as they pass through the closed end of the infundibulum; while the grosser portion of the blood would be discharged through one of the emissary veins specified above.

2. *The Anterior Occipital or Transverse Sinus, together with the Plexus Basilaris.*

37. The anatomists differ widely in respect to the character and form of the sinus called the "anterior occipital or transverse sinus." Some authors speak only of one transverse vessel between the dorsum sellæ and the magnum foramen of the occipital bone. Others notice there two transverse vessels. Others, again, have discovered there an entire plexus of vessels, which, according to *Virchow*, "consists usually of several larger vessels, of which one or two are longitudinal, and from two to three transversal, between which there is a large number of smaller vessels." Still, all agree that the transverse sinus, or the plexus of vessels of which it consists, derives its blood mostly *from the interior of the bone.*

Some, again, declare that the transverse sinus extends as far as the superior petrosal sinuses, which it connects; while others maintain that it reaches only to the inferior petrosal sinuses, and connects those.

According to *Vicq d'Azyr*,[1] "Behind the posterior clinoid processes there is a furrow which contains the sinus called by some the *posterior clinoid sinus.* Six or eight lines further down is the *basilar* or *anterior occipital sinus.*" He says, further, "The extremities of the posterior clinoid sinus open into the cavernous sinus." And again, "The posterior clinoid sinus communicates on the one hand with the superior petrosal sinuses; on the other with the anterior occipital sinus."

Bell[2] recognises only one transverse sinus. He says, "The *transverse* or *posterior clinoid sinus* runs across from one inferior petrosal sinus to the other, behind the posterior clinoid processes. In truth, the superior and inferior petrosal sinuses, the cavernous, and the transverse, meet nearly at a point."

Cruveilhier[3] says, "The *anterior* or *transverse occipital sinus* is median and single; it extends transversely across the basilar groove from the foramen lacerum posticum of one side to that of the other; it is of an irregular form, much larger in the aged than in adult and young subjects, and connects the superior and inferior petrosal sinuses and the cavernous sinus of one side with the corresponding sinuses of the other side. In old subjects, the basilar surface not unfrequently appears as if corroded opposite this sinus, the cavity of which often presents a cellular and spongy appearance."

Quain[4] says simply, "The *anterior occipital* or *transverse sinus* (sinus basilaris) is placed at the forepart of the basilar process of the occipital bone, so as to establish a transverse communication between the two inferior petrosal sinuses."

The first author who gave a comprehensive view of the whole extent of the anterior occipital or transverse sinus is *Haller*.[5] He says, "The *anterior occipital sinuses* which follow here do not receive any vein from the brain; but they are received in a like manner between the laminæ of the dura mater. In the first place, then, the whole of that anterior process of the occipital bone, which is conjoined with

[1] Vicq d'Azyr. "Traité d'Anatomie et de Physiologie." Tom. i., Paris, 1786, large folio; p. 107.

[2] Bell (Sir Charles). "The Anatomy and Physiology of the Brain and Nerves, the Organs of the Senses, and the Viscera," 4th edit., Vol. ii., 1816; p. 429.

[3] "Op. citat.," ii., p. 778.

[4] Quain's "Elements of Anatomy," 8th edit., London, 1876; Vol. i., p. 484.

[5] "Op. citat.," iv., p. 157.

the sella turcica, is penetrated by venous sinuses which are filled with blood, or [in injections] with wax which takes the place of blood. The transverse sinus [which is one of Haller's anterior occipital sinuses], is almost perpetual, and mostly wide and important, and conjoins the right inferior petrosal sinus with the left, and where it joins these sinuses it communicates with the cavernous sinuses. Often a multiplex sinus, with various branches, passes through the dura mater of the basilar process of the occipital bone, and is inosculated with the cavernous sinuses along the sixth pair of nerves. Again, in the same place it is inosculated with the inferior petrosal sinuses, exteriorly in the neighbourhood of the carotid. Further, that same sinus interiorly of the carotid communicates with the posterior semicircle of the circular sinus. With the superior petrosal sinus it is inosculated in various ways, and finally with the trunk of the jugular vein."

A similar presentation of the interior occipital or transverse sinus is given by *Theile*, in his edition of Sömmering's[1] "Angiology." He says, "On the base of the occipital bone, near the dorsum sellæ, there are situated transverse, reticular venous spaces which, with the exception of a few small branches from the pons Varolii and the medulla oblongata, do not receive any blood out of the parts of the brain, but, on the contrary, *out of the substance of the bone.* They are connected on each side with the cavernous sinuses and the inferior petrosal sinuses, and posteriorly with the venous plexuses of the vertebral column."

Some of these quotations on the subject of the anterior occipital or transverse sinus we had occasion to refer to before, but we repeat them here in full, in order to exhibit at a glance the diversity which prevails in our text-books with respect to this sinus. The most thorough examination of this sinus, undoubtedly, was made by *Virchow*,[1] and the results of his investigation are contained in his paper on the Basilar Plexus, which *in extenso* reads as follows: "Most anatomists describe in this part of the base of the skull—along the clivus, behind the posterior clinoid processes—only an anastomosis between the two inferior petrosal sinuses; but on examining this part more closely, there is discovered, on the sphenoidal surface of the clivus, rather a sinuous wickerwork, which I shall term *plexus basilaris.* Usually it consists of several large vessels, of which one or two are longitudinal, and from two to three transversal; between these there is a large number of smaller vessels. If you make an incision into

[1] "Op. citat.," p. 48.

the dura mater which is here stretched out tightly and smoothly, you will find that it is attached closely only to the dorsum sellæ, and in the region of the spheno-occipital suture. Under the dura, throughout the whole of the intervening space, lies a spongy tissue which, under favourable circumstances, is entirely saturated with blood. In adults there is exhibited here a series of firm trabeculæ which pass from the dura mater to the surface of the bone, and which are distinctly visible by their whitish, sinewy appearance. To these trabeculæ there is usually attached a scanty, soft, fatty tissue, which sometimes is reddish, and at other times yellowish; just as is the case in the cavernous sinus. The rest is made up of anastomosing vascular spaces in wide meshes. On removing this mass from the surface of the bone, the latter appears rough, uneven, almost carious, and perforated by large vascular foramina filled with blood. Frequently, also, there are small, flat fossulæ furnished with larger or smaller osseous projections. The eminence of the dorsum sellæ also, not unfrequently, exhibits similar fossulæ and osseous projections which sometimes assume the form of regular small exostoses. This condition is by no means exceptional, but is to a certain degree the normal condition. If these parts are examined mikroskopically, the trabeculæ appear formed of a dense, filamentous tissue, richly furnished with elastic elements. The soft mass which is attached to them, and which fills the fine fossulæ in the surface of the bone, is altogether circumstanced like the marrow of bones. Sometimes it consists altogether of fatty tissue, which is permeated by vessels, and in some parts by nerves. . . . All the remaining space, not occupied by trabeculæ or marrow, belongs to vessels. When examined very closely, even with the naked eye, there are noticed, on the small osseous projections, bluish-white little scales or linings, usually with some striated fundamental substance, but with very large vesicular cells which are often arranged in larger groups. . . . If we abstract these parts, the surface of the bone is entirely bare, without any periosteum; the spaces, which are filled with marrow, open directly to the surface, as is indicated by the occurrence of marrow or medullary tissue on the same; and *the vessels of the bone communicate directly with the superficial plexus.*"

Luschka and *Henle*, in their text-books of anatomy, adopt the presentation of the anterior occipital sinus by Virchow; likewise *Sappey.*[1] This latter author says, "The anterior occipital sinus, called also the transverse sinus, belongs to the class of anastomotic sinuses. It is formed of two or three irregular ducts, which open into one another,

[1] "Op. citat.," ii., p. 735.

and extend transversely from the confluent of the petrosal and cavernous sinuses of the one side to the similar confluent of the other side. . . . In reuniting the two superior petrosal sinuses, it forms with them a large anastomosis, extending transversely from the right lateral sinus to the left lateral sinus."

Knott[1] says, "The so-called transverse sinus of our text-books ill deserves the name; for it does not form a separate or distinct canal, as in the case of the sinuses previously described. The name of *plexus basilaris* given to it by Virchow is much more applicable, as it is formed of a network of anastomosing veins placed between the layers of the piece of dura mater which covers the clivus. Some of them open into the inferior petrosal sinus of either side, some communicate anteriorly with the receptaculum, or *sinus cavernosus posterior;* while others pass downwards to the margin of the foramen magnum to anastomose with the anterior rachidian veins. I have found a notable variation in their arrangement, except in the varying size of the branches which go in the direction already mentioned."

Langer, who made a cast of the venous vessels connected with the cavernous sinuses, says, "The venous net, the *plexus basilaris* of Virchow, which covers the clivus and conjoins the inferior petrosal sinuses, is perfectly developed in the child. It consists of two layers of intertwined vessels; of a superficial one composed of more delicate vessels, and of a lower one which is composed of thicker tubes. . . . In adults the clivus, which is covered with this net, is often sunk in, and mostly also seems carious and perforated. This is due, as has been observed already by Virchow, to a tissue, the foundation of which is formed by a sinuous texture of veins. This texture is circumstanced exactly like the sinus cavernosus. The veins, which were originally arranged in the distinct form of a net, in the course of time, through enlargements, become sinuous, and by confluence they at last give rise to an extensive common lacuna, which is traversed by fibrous trabeculæ" (see above, no. 621*n*).

From an analysis of the information furnished by the authors concerning the "anterior occipital or transverse sinus," or respectively concerning the "plexus basilaris" of Virchow, it appears—*first*, that it receives its supply of blood almost altogether from the interior of the bones of the skull; which blood, according to Swedenborg, is mainly arterial blood from the carotids, enriched with spirituous lymph, the "fluid of the *second* order," which is dispatched from the pituitary gland.

[1] In "Transactions of International Medical Congress," London, 1881, Vol. i., p. 195, *et seq.*

Secondly, that through its highest, transverse branch, which opens into the cavernous sinuses, this plexus of vessels communicates on the one hand with the superior and inferior petrosal sinuses, and on the other, serves as an anastomosis, and thus as a uniting medium between the two cavernous sinuses. By this means the spirituous lymph, the fluid of the *second* order, as Swedenborg suggests, is partly diverted into the superior petrosal sinuses; yet not only into these, but also into the inferior petrosal sinuses; for with these latter sinuses the "plexus basilaris" communicates not only through its "anterior occipital or transverse" branch, which opens into the cavernous sinuses, but it opens into them also during the whole of their downward course. As to the anastomotic use of the highest, transverse branch of the "plexus basilaris," by which the contents of the two cavernous sinuses are equalized—this is discussed below in no. 44 of the present Note. *Thirdly*, it appears also that the "plexus basilaris" acts as a medium of connection between the sinuses of the sella turcica and the venous vessels of the vertebral canal, enriching the latter with a more spirituous blood.

3. The Canal of Tabarrani.

38. This canal is the recipient of the bulk of the spirituous lymph, the fluid of the *second* order, which is dispatched from the pituitary gland through lympheducts into the interior of the sphenoid bone. After this lymph has first been commingled there with blood, it is determined into the tributaries of the above canal; while the remainder of the blood, which is likewise more or less enriched with lymph, is directed into the "basilar plexus" of Virchow, and conveyed thence into the superior and inferior petrosal sinuses, and also into the veins of the vertebral canal.

Attention has first been called to this canal by Tabarrani in 1743. It starts sometimes immediately from the cavernous sinuses, and at other times from the "funnel" of the carotid in the carotid canal, and thence it runs on the external, lower side of the cranium, either directly into the internal jugular vein, or it terminates in the inferior petrosal sinus near its juncture with the jugular vein. Tabarrani describes it as immediately underneath the groove of the inferior petrosal sinus, between the basilar process of the occipital bone and the petrous portion of the temporal bone, so that by breaking through this groove you reach the canal underneath.

Haller[1] gives the following description of this canal: "To the anterior occipital sinuses I would refer also a new sinus of which Pietro Tabarrani says, that it springs from the funnel of the carotid, and terminates either by a single orifice in the foramen jugulare, or empties there obliquely into the inferior petrosal sinus." He also attributes to this "sinus" a diverticle which enters the vertebral vein, and opens also into the present sinus.

This same canal, it seems, was known to Malacarne and Sir Charles Bell; for this latter author mentions, among the Emissaria of the Cavernous Sinuses, "the interosseous sinus of Malacarne." (See Bell on the Cavernous Sinuses, in no. 621*b* of the present volume.)

Tabarrani[2] himself gives the following additional particulars respecting the sinus or canal discovered by himself: "This new sinus, I believe, has not been hitherto observed by the anatomists on account of the difficult place which it occupies. It is situated on either side between the basilar process and the petrous bone, in the interior of the bone underneath the inferior petrosal sinus; or in order to express myself better, under the groove in which said petrosal sinus pursues its course, exactly there where a certain substance is found which is almost intermediate between cartilage and ligament. There this same sinus pursues its course on the bone of the basilar process; a slight groove which sometimes is seen imprinted there pointing out the way. The beginning of said sinus is usually found between the carotid and the sella turcica; but its end is mostly in the foramen jugulare, near its own diverticle, and in connexion with the inferior petrosal sinus. . . . During its passage it generally sends out a little canal which enters the vertebral vein near its entrance into the foramen of the eleventh pair of nerves."

39. This canal or sinus, which was thus minutely described by Tabarrani, and which was introduced to the knowledge of the learned in general by Haller, in his "Elementa Physiologiæ," became forgotten again since Haller's, or perhaps Bell's time, until it was rediscovered in 1863 by *Englisch.*[3] The description of this author agrees in

[1] "Op. citat.," iv., p. 158.

[2] Tabarrani (Pietro). "Observationes anatomicæ," etc., in Giuliani's "Memorie sopra la Fisica e Istoria naturale di diversi valentuomini," Tom. i., Lucca, 1743, pp. 33-38.

[3] Englisch (Dr. J.). "Ueber eine constante Verbindung des Sinus cavernosus mit dem hinteren Ende des Sinus petrosus inferior ausserhalb des Schädels," in "Sitzungsberichte der mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften," Band xlviii., Abtheil. i., Jahrgang, 1863; Heft. vi., Wien, 1863; p. 27, *et seq.*

all essential particulars with that given by Tabarrani in 1743. He says, "An examination of the contents of the foramen jugulare led us to the following results:—If you open the *vena jugularis interna*, you will notice at its interior wall an opening which is closed up by a kind of valve, the free concave margin of which is turned downwards and outwards. The ends of said valve run down along the wall of the vein perhaps to the distance of an inch. Said opening is either in the *bulbus venæ jugularis sup.*, or at some distance below the same, even $1\frac{1}{2}$ inches from it. This same opening corresponds with the mouth of the vein, into which the posterior end of the inferior petrosal sinus passes over. In addition to this opening, however, there are in the *bulbus ven. jug. sup.* always from two to six additional orifices, through which you obtain access to the intermediate spaces between the *nervus glosso-pharyngeus*, the *nervus vagus*, and the *nervus recurrens Willisii*. These spaces are divided by transverse trabeculæ into smaller compartments, and out of these spaces there constantly descend, between those three nerves, slender veins, in order to conjoin themselves with neighbouring veins. If there is no opening below the foramen jugulare in the vena jugularis, one of the last-mentioned orifices is always larger than the others, and it leads between the above-named nerves into the posterior extremity of the inferior petrosal sinus. If now, in the case where the inferior petrosal sinus passes over into a vein, and terminates further down in the jugular vein, you follow the same upwards, you will notice in its inferior wall an orifice which is contracted through a kind of valve, and which leads into a canal [Tabarrani's canal] through which, upwards in a concave direction, you get into the posterior extremity of the cavernous sinus, or into its continuation in the carotid canal. In respect to the position of said canal, it is situated in the lower margin of the cartilage which conjoins the two sides of the *pars petrosa ossis temporalis* and the *pars basilaris ossis occipitalis* which face one another. Where this canal departs from the inferior petrosal sinus, its wall protrudes in the form of a more or less acute edge; and there also the tube of the canal, which is slightly enlarged, is constantly united with the cellular spaces between the afore-mentioned nerves. . . . The width of the canal amounts in most cases to $\frac{1}{2}$-1 line in diameter, and this width is either constant, or else at one or at both extremities it is narrower than in the middle; so that on the one hand, where it approaches the cavernous sinus, or on the other, where it draws near to the posterior end of the inferior petrosal sinus, it gradually, or suddenly, contracts. The wall of the canal is either smooth or furnished with fold-like eminences, which are more strongly developed in that part of the canal which is nearer to the cavernous sinuses. In many cases trabeculæ even extend from one wall to the other, and these decussate in a more or less acute angle, so that the canal presents an appearance similar to that of the cavernous sinuses. The communication of the canal with the cavernous sinus is effected either through one larger, or several smaller orifices. . . . In addition to the openings of the canal at its beginning and at its end, *there are numerous orifices along the walls*, especially along the inferior wall. Through one of these openings you get into a slender canal which is situated in the firm, cartilaginous, connective-tissue mass which lines the lower surface of the *pars basilaris ossis occipitalis.* It converges in an anterior direction with another corresponding canal of the other side, until they meet in the middle. . . . In addition to this constant branch which departs from the posterior end of the canal, there is often a second or even a third branch, which move in a like direction, and which again may be conjoined by transverse branches so as to produce an entire net. If you examine a dried skull, you will find between the lower edge of the lateral margin of the basilar process, and the lower posterior margin of the petrous part of the temporal bone, a gutter-like groove, in which place also the connective-tissue mass must be wider. In this groove the canal in question is contained. The examination, in all cases, showed the canal to be double; but it was impossible to establish a reciprocity, in respect to size, between the canal and the cavernous sinus."

40. In 1870, *Trolard*,[1] who evidently was unacquainted with the paper of Dr. Englisch which was published in 1863, discovered the "canal of Tabarrani" afresh.

His description of this canal, which he styles the "lower petro-occipital sinus," is as follows: "On examining the exterior of the basis of a skull, you will notice, on the level of the petro-occipital suture, a groove running from the foramen lacerum anterius to the foramen lacerum posterius. The groove, which sometimes is very marked, is occupied by a sinus. This sinus is semi-cylindrical. Its base rests on a thick layer of fibrous tissue. Its direction is from within outwards, and from before backwards. Its anterior extremity is not always circumstanced alike. At one time it communicates immediately with the cavernous sinus, at the meeting of that sinus with the carotid sinus; in this case it crosses the foramen lacerum anterius. At another time it does not go so far as that foramen; through one or two little orifices

[1] "Op. citat.," p. 267.

it communicates with the middle portion of the carotid sinus. As the dissection in this latter case—which case, besides, occurs most frequently—is not very easy, in order to have a direct proof of this communication, it suffices to inject some liquid through one of the orifices of which I have just spoken; you will then notice a liquid bubbling up in the carotid sinus. The posterior extremity of the sinus terminates in the anterior condylar foramen. The sinus itself is not very large, although sometimes it equals in size the inferior petrosal sinus. From its position I propose to call it the petro-occipital sinus. And as the inferior petrosal sinus reclines also on the very same suture, and is far from partaking of a petrous character, since it is situated almost altogether on the occipital bone, I am of opinion that it ought to be called the upper petro-occipital sinus, in which case the new sinus would be the *lower petro-occipital sinus.*"

Trolard, and also Tabarrani, call the vessel we are now discussing a sinus; yet it lacks one of the most important attributes of a sinus; namely, it is not enclosed in a duplicature of the dura mater, but it is simply, as Bell describes it, an "interosseous canal." *Knott* calls it "an external vein which passes backwards along the petro-occipital suture." As it is, however, imbedded in the cartilaginous substance which covers that part of the exterior base of the cranium, it is with greater propriety called a "canal" than a sinus, or even a vein; and we propose to call it the "canal of Tabarrani," after its first discoverer.

Langer[2] gives the following description of this canal: "As one of the emissaria of the cavernous sinus, we have to mention here the sinus petro-occipitalis inferior of Trolard, attention to which had been previously called by Englisch. This is a venous canal, not very large, which, in company with the plexus or sinus caroticus, leaves the cavernous sinus in the foramen lacerum anticum, and which pursues its course in the groove between the petrous part of the temporal bone and the basilar part of the occipital bone. In casts of the venous vessels of the cavernous sinus obtained by corrosion, I noticed a junction of this canal with the plexus nervi hypoglosso, both in the heads of adults and of children; I also noticed little vascular twigs communicating with it, as an evidence that it gathers its supply also from the lower surface of the base of the cranium."

41. If now we carefully consider this canal in the light thrown upon it especially by the researches of Dr. Englisch, we shall find that this canal harmonizes in a remarkable manner Swedenborg's

[1] In "Sitzungsberichte," etc., Wien, 1885, p. 313.

theory of the three liquids which are dispatched from the pituitary gland.

The fluid of the *first* order, according to this theory, is thus discharged through the circular sinus of the gland, into the superior petrosal sinuses, and thence into the lateral sinuses.

The fluid of the *second* order, the spirituous lymph now under discussion, is sent from the gland through lympheducts into the interior of the sphenoid bone, and of the basilar process of the occipital bone; there it is partly gathered up by the "basilar plexus" of Virchow, and discharged thence into the superior and inferior petrosal sinuses—chiefly into the latter; while the remaining lymph enters "the canal of Tabarrani" through "the numerous orifices in its walls," and also through "a net of communicant branches in the firm, cartilaginous, connective-tissue mass which lines the lower surface of the basilar process of the occipital bone." But lest any of this precious spirituous lymph should escape, an abundant supply of arterial and venous blood enters the canal directly either from the cavernous sinus, or from the sinus which encloses the carotid in the carotid canal. Its main supply of blood or lymph, however, our canal, as it seems, derives from the interior of the bone, and not from the cavernous sinus, for on approaching the cavernous sinus, the canal contracts, and besides, according to Dr. Englisch, there is "no reciprocity, in respect to size, between the canal and the cavernous sinuses." From the fact that the canal also frequently contracts in width as it approaches the jugular vein, it follows that it serves likewise in the capacity of a storehouse for the spirituous lymph, upon which the heart may draw *ad libitum* through the jugular vein. This explains also the fact of the existence of "fold-like eminences," in the interior of the canal, and likewise of trabeculæ which decussate from one wall of the canal to another; for by these appliances the spirituous lymph is capable of being retained in the canal, when not immediately wanted by the jugular vein. The same purpose also is served by the valves, by which the opening of the canal into the extremity of the inferior petrosal sinus, as well as into the jugular vein, is controlled.

The facts adduced here respecting the "canal of Tabarrani," and in the preceding subsection respecting the "plexus basilaris" of Virchow, confirm also, in a remarkable manner, Swedenborg's theory respecting the dispatch of blood from the area of the sella turcica towards the lateral sinuses and the interior jugular veins. For, while the blood richest in spirit, namely, that which carries the fluid of the *first* order, is discharged by the superior petrosal sinuses into the very receptacles of the lateral sinuses at some distance above the foramen jugulare—the canal of Tabarrani and the inferior petrosal sinuses, both of which carry the fluid of the *second* order, enter the jugular vein in the neighbourhood of the foramen jugulare. Sometimes, however, the canal of Tabarrani opens into the foramen jugulare itself, while the inferior petrosal sinus empties its contents into the jugular vein at some distance below the foramen jugulare—and, indeed, for this reason, because the inferior petrosal sinus carries, besides, the fluid of the *third* order from the cavernous sinuses. For the same reason, also, that the higher liquid may suitably mix with the lower, at other times, the canal of Tabarrani pours its contents into the inferior petrosal sinus itself, before this vessel reaches the jugular vein.

4. The Cavernous Sinuses.

42. The function of these sinuses Swedenborg describes as follows: "The cavernous sinuses, which are adjacent to three of the sides of the sella turcica, afford a convenient and safe passage to the carotids, to sinuses, veins, and nerves, and they warm all parts with the heat, as it were, of a bath, which is increased to such a point that the processes of dissolving, commingling and transmitting liquids are carried on in a satisfactory manner; and, further, that through the mediation of the cavernous sinuses there may exist a due communication, *first*, of the liquid—the grosser serum—which presses in from the sella turcica; *secondly*, of the carotids with one another, as well as with the pituitary gland; and, *thirdly*, of the lympheducts with blood-vessels, both in the subjacent bone and in the dura mater which lines the sella. It seems also as if the cavernous sinuses did not admit [from the pituitary gland] into their cavity any other fluid except that which collects around the gland; while the larger veins at the bottom of the cavernous sinuses, mentioned by Ridley, seem to receive the nutritive blood of the bone underneath" (no. 625*a*).

Again he says, "If the veins in question—those which, according to Ridley, direct their course towards the sides of the sella turcica—did receive any spirituous essence from the brain, they, like the remaining ducts, would convey it either into the sinuses of the base of the cranium—the superior or inferior petrosal sinuses—or into the jugular vein. Wherefore, suppose they carry their blood outside the cranium through other foramina, there is ground for conjecturing that they imbibe a different blood," etc. (no. 625*j*).

The points which Swedenborg lays down here, and in other places, in respect to the cavernous sinuses, are as follows :—

First, the cavernous sinuses do not admit into their cavity from the pituitary gland any other fluid except that which collects in the posterior part of the sella, and which empties into the cavernous sinuses through the posterior receptacle which is underneath the posterior lobe of the gland.

Secondly, this grosser serum—the fluid of the *third* order—is discharged from the cavernous sinuses through the inferior petrosal sinuses.

Thirdly, the cavernous sinuses are the recipients also of blood more or less destitute of spirit, which they discharge through special emissaria, and not through the sinuses of the base of the cranium, namely, through the superior and inferior petrosal sinuses, and the anterior occipital or transverse sinus.

The first and third of these points we shall discuss in connection with the cavernous sinuses, the second point in connection with the inferior petrosal sinuses.

43. Of the three fluids which are discharged from the pituitary gland, strictly speaking two, namely, the fluids of the *first* and of the *third* order, are emptied into the cavernous sinuses. Still, the bulk of the fluid of the *first* order, which is discharged from the circular sinus, as was shown above, in no. 30, is carried away immediately by the superior petrosal sinuses, and does not mix with the contents of the cavernous sinuses generally; so that the fluid of the *third* order is actually the only liquid which is received in its totality by the cavernous sinuses from the pituitary gland.

Concerning this fluid, which is a serum of a grosser nature, we have shown above, in nos. 24-27, that it collects in a system of meshes which is situated under the integument of the gland, in its posterior part. Thence it is discharged into the posterior receptacle which is placed under the posterior lobe of the gland.

The question here arises, in what manner does the posterior receptacle or sinus empty its contents into the cavernous sinuses? Swedenborg declares that this discharge takes place through a duplicature of the dura mater in the posterior part of the sella, which duplicature is relaxed during the expansile motion of the gland.

Another means of discharge would be the holes or foramina through which, according to Littre, the posterior receptacle or sinus communicates with the anterior vessel—the inferior transverse or intercavernous sinus.

Tabarrani[1] describes plainly the method through which the latter sinus—the inferior transverse, or intercavernous sinus—discharges its contents into the cavernous sinuses. He declares, that the transverse sinus under the pituitary gland communicates with the cavernous sinuses "through two round foramina, between the clinoid processes of the sella turcica."

In case the posterior receptacle discharged its contents into the cavernous sinuses through the inferior transverse or intercavernous sinus, the fluid of the *third* order would reach the cavernous sinuses thoroughly mixed with carotid blood; while in the former case, that is, if it should be discharged immediately through a duplicature of the dura mater, it would arrive in the cavernous sinuses but little altered in its composition.

Both methods, it would seem, are brought into requisition. By an immediate discharge of the fluid of the *third* order from the posterior receptacle, the supply of serum in the cavernous sinuses would be better regulated. But by the discharge of the serum in company with the carotid blood of the gland, through the "inferior transverse or intercavernous sinus," the serum would enter the cavernous sinuses, and thence the jugular veins, in a form in which it can be more easily assimilated by the blood in the jugular veins.

44. For the sake of obtaining a proper mixture of sanguineous elements, the cavernous sinuses, in addition to the grosser serum which pours in from the pituitary gland, receive venous blood from nearly all parts of the head. And that portion of this blood, which is more or less mixed with spirit, they discharge through the inferior petrosal sinuses; while the remaining portion, which is nearly devoid of spirit, they consign to particular emissary ducts. A special use, however, in respect to the cavernous sinus, is performed by the "anterior occipital or transverse sinus," which opens into the posterior extremity of each cavernous sinus. For, in addition to the use which said sinus affords to the superior and inferior sinuses by supplying to them blood from the interior of the bone, enriched with the spirituous lymph, the fluid of the *second* order—that sinus acts at the same time as a communicant or anastomotic vessel between the two cavernous sinuses by which their contents are equalized and balanced.

The small sinuses of the pituitary gland are usually supposed to act in this capacity; yet these sinuses—the superior circular and the inferior transverse [that is, the intercavernous] sinuses—simply discharge their contents in the direction of the cavernous sinuses, and

[1] "Op. citat.," p. 35.

they do not receive any liquid from them in return. For, as stated by *Theile* in his edition of Sömmering's Angiology, "the flux of blood in the cavernous sinuses is in an antero-posterior direction." The blood thus moves from the anterior to the posterior extremity of the cavernous sinuses, where are situated the mouths of the inferior and superior petrosal sinuses, and also of the anterior occipital or transverse sinus; and, therefore, the restoration of the balance between the two cavernous sinuses must be effected through a sinus which opens into the posterior extremity of these sinuses, namely, through the anterior occipital sinus.

45. We shall now examine in regular order the venous blood which the cavernous sinuses receive in addition to the fluid of the *third* order which presses in from the posterior receptacle of the sella; and, also, in addition to the carotid blood of the gland which is discharged into the cavernous sinuses through the "inferior transverse or intercavernous sinus."

This venous blood is of a threefold description. It enters (1) from the interior of the brain, (2) from the dura mater, and (3) from the external parts of the head. In accordance with the flux of the blood in the cavernous sinuses, and of the venous blood generally, in the anterior part of the base of the skull, which is in an antero-posterior direction, these three species of blood enter the cavernous sinuses through their *anterior* extremities, and especially through the two large veins already noticed by Ridley.

These two veins are the *spheno-parietal sinus*, and the *ophthalmic vein*. Through the former of these channels there enters mostly the blood from the brain and from the dura mater, and through the latter the external blood of the head.

Concerning the former of these sinuses *Luschka*[1] says, "The *sinus spheno-parietalis* or *sinus alæ parvæ*, which has been described by Breschet, was hitherto regarded as an independent sinus, but it may be defined as a branch of the cavernous sinus." *Henle*[2] says respecting it, "The *sinus spheno-parietalis* of Breschet is 2mm. wide. Under the cover of the lateral point of the great wing of the sphenoid bone, it takes its origin from a meningeal vein; and in a shallow groove of the lower plane of that wing it moves in a median direction. It enters the anterior point of the cavernous sinus." *Knott* describes the origin of the sinus in a similar manner."

[1] Luschka (H. v.). "Die Anatomie des Menschen," Vol. iii., Abth. 2, Tübingen, 1867; p. 152.

[2] "Op. citat.," iii. 1, p. 333.

According to *Henle*,[1] the spheno-parietal sinus derives a supply from the following additional sources: *First*, he says, "The lateral point of the *sinus spheno-parietalis* communicates by a considerable anastomosis with the venous stems which accompany the middle or great meningeal artery." *Secondly*, "The *vena diploica temporalis anterior* empties into a vena temporalis profunda, and also into the spheno-parietal sinus." *Thirdly*, he says, "A vein of changing caliber, the *vena ophthalmo-meningea* HYRTL,[2] passes from the region of the Sylvian fissure to the spheno-parietal sinus; or it crosses this sinus and goes to the venous stems of the orbits. In the latter case it is sometimes provided with valves which allow the motion of the blood in one direction only; namely, from the orbit towards the cavity of the cranium."

Luschka[3] describes the venous supply of this sinus in a similar manner.

Thus far the venous supply of the spheno-parietal sinus has been shown to be derived chiefly from the dura mater, and from the interior of the cranium, but this sinus receives also tributaries from the interior of the brain.

Henle[4] says further, "The *vena cerebri media*, the attendant on the artery of the same name, is formed in the Sylvian fissure out of twigs from the anterior and posterior lobes of the brain. It anastomoses with basal twigs of the *vena cerebri anterior*, and ends either in the cavernous or the spheno-parietal sinus."

The fact of cerebral veins entering the cavernous sinuses had been previously noted by others. So *Haller*[5] says, "Venous blood is brought into the cavernous sinuses by four or five anterior, inferior veins of the lobes of the cerebrum, which descend from the fossa of Sylvius." *Bell*[6] and *Theile*[7] repeat the same statement.

Cruveilhier[8] says, "The cavernous sinuses receive in front the *inferior* and *anterior cerebral* veins, which commence upon the lower surface of

[1] "Op. citat.," pp. 338, 339.

[2] In "Oesterreichische Zeitschrift für praktische Heilkunde," 1859, no. 46.

[3] "Op. citat.," p. 333. [4] "Op. citat.," p. 338.

[5] "Op. citat," iv., p. 154.

[6] Bell (Sir Charles). "The Anatomy and Physiology of the Brain and Nerves, the Organs of the Senses," etc., 4th edit., Vol. ii., 1816; p. 429.

[7] Sömmering (S. Th. v.). "Vom Baue des menschlichen Körpers," "Lehre von den Muskeln u. Gefässen des menschlichen Körpers," umgearbeitet von F. W. Theile. Leipzig, 1841; p. 272.

[8] Cruveilhier (J.). "Descriptive Anatomy," in Tweedie's "Library of Medicine." London, 1842; Vol. ii., p. 777.

the anterior lobe of the cerebrum. The largest of these veins on each side reaches the sphenoidal fissure, turns backwards over the lateral and middle fossa of the base of the cranium, and enters the *middle meningeal vein*. Several anatomists state that they have seen the middle meningeal vein open into the cavernous fossa."

From the statements which we have thus far quoted, it is made very plain that the cavernous sinuses receive a supply of venous blood not only from the dura mater, but also from the anterior and posterior lobes of the cerebrum. But there is one circumstance involved in these statements to which we have now to call attention. Henle states that the blood derived from the brain through the Sylvian fissure is received either by the spheno-parietal sinus, or by the cavernous sinus directly; while the other authors declare that it is received immediately by the cavernous sinuses. And again, while Bell and Theile, at the same time, admit the existence of the spheno-parietal sinus, Cruveilhier ignores the existence of this sinus altogether. In this particular he is joined by several other modern authors. Thus we look in vain for this sinus in the text-books of Todd,[1] Quain,[2] Ellis,[3] and Sappey.[4] *Knott*[5] notices this omission in these words: "I have observed great variability in the size of this venous canal; but in no case did I meet with an instance of its complete absence; a small vein at least was found in those cases in which the normal sinus was not fairly represented. I am surprised that a description is so often omitted from our text-books."

The discovery of the spheno-parietal sinus is usually attributed to *Breschet*,[6] but it was long before described by *Sir Charles Bell*,[7] in these words: "The *superior sphenoidal sinuses* are seated in a fold of the dura mater, on the internal margin of the wings of Ingrassias—*alæ minores*—and before the great wings of the sphenoid bone; they receive the blood in part from the orbit and from the dura mater. They open into the cavernous sinus, or perhaps into the ophthalmic sinus," etc.

1 Todd (R. B.). "The Descriptive Anatomy and Physiology of the Brain," etc. London, 1845.

2 Quain's "Elements of Anatomy," 8th edit. London, 1876.

3 Ellis (G. v.). "Demonstrations of Anatomy," 7th edit. London, 1874.

4 Sappey (Ph. C.). "Traité d'Anatomie Descriptive," 3me édit. Paris, 1876.

5 "Op. citat.," p. 195.

6 Breschet (G.). "Recherches anatomiques sur le systéme veineux," Livr. ii., pl. 3. Paris, 1829-30.

7 "Op. citat," p. 427.

According to *Trolard*,[1] the spheno-parietal sinus is nothing else than one of two veins by which the principal branch of the middle meningeal artery is attended. He says, "One of these veins is usually more developed than the other, and it is ordinarily that which is in advance of the artery. . . . That vein, I believe, Breschet described under the name of the spheno-parietal sinus."

46. The authors are pretty nearly unanimous as to the second source of venous blood of the cavernous sinuses; namely, the *ophthalmic vein.* According to Sir Charles Bell, the ophthalmic veins open only "sometimes" into the cavernous sinus; but some of the more recent anatomists go even so far as to declare that the ophthalmic vein is the only constant source of supply of the cavernous sinuses. So *Sappey*[2] says, "During the short distance which the cavernous sinuses run, from the sphenoidal fissure to the apex of the petrous bone, these sinuses receive the *ophthalmic vein*, and sometimes a meningeal vein coming from the spheno-temporal fossa."

Luschka[3] expresses the relation of the ophthalmic vein to the cavernous sinus, in these words: "The anterior smaller end of the sinus cavernosus which was formerly called the *ophthalmic sinus*, represents the enlarged end of the *ophthalmic vein* which empties into the cavernous sinus, interiorly of the Nerv. oculo motorius, under the anterior clinoid process."

Henle[4] distinguishes the ophthalmic vein into the *vena ophthalmica superior*—supraorbital branch—and the *vena ophthalmica inferior*—infraorbital branch, and of the former he says, "The vena ophthalmica superior enters the cranial cavity through the fissura orbitalis superior, near the origin of the Musculus rectus oculi superior, and after becoming enlarged, it terminates in the *cavernous*[5] sinus." Of the latter he says, "The vena ophthalmica inferior passes likewise through the fissura orbitalis superior into the cavernous sinus, or into the enlargement of the vena ophthalmica superior. Or, as generally seems to be the rule, it leaves the orbit through the fissura orbitalis inferior, turns downwards to the plexus pterygoideus, and is conjoined with the vena ophthalmica superior only through an anastomosis." Of the *vena centralis retinæ* which is connected with the ciliary veins, he says, that "instead of terminating in the ophthalmic vein it frequently opens directly into the cavernous sinus."

Langer, who made casts by corrosion of the cavernous sinuses, in

[1] "Op. citat.," p. 259. [2] "Op. citat.," ii., p. 733.
[3] "Op. citat.," iii., Abth. 2, p. 151. [4] "Op. citat.," iii., Abth. 1, p. 342.
[5] Henle says here *sinus transversus*, evidently by mistake for *sinus cavernosus*.

respect to the original formation of the cavernous sinuses, showed that in children they constitute venous plexuses or nets, which in time become sinuous, and at last by confluence present those lacunæ, in which form the sinuses are usually presented in the text-books. The cavernous sinus, according to him, originally consists of two nets, a superficial and a deeper one. Concerning the origin of this deeper net from the ophthalmic vein, he says, "Underneath the superficial, more delicate net, there is another, which consists of larger vessels, and is attached immediately to the bone. The ophthalmic veins, and generally also the spheno-parietal sinus, upon their arrival, enter into this latter net, and the departing larger veins, whether they bear the character of anastomoses, emissaria, or sinuses, proceed from it. This lower, grosser net constitutes the sinus cavernosus proper, which, therefore, in harmony with its original form, may be defined as a 'plexus cavernosus.' By a removal of the upper, more delicate net, or also by an examination of that lower side of a cast of the sinus which is turned towards the bone, it becomes evident that the little trunks of the ophthalmic veins, whether they be single or double, immediately after their passage through the inner part of the sphenoidal fissure become ramified, and in this divided form enter the plexus cavernosus. The roots of the departing veins usually proceed from this plexus in such a way that they are recognised as the immediate successions of the branches or twigs of the ophthalmic veins, which may be traced directly not only into the plexus which encompasses the pituitary gland, but also into the emissary vessel of the foramen ovale, as well as into the inferior petrosal sinus. . . .

"In respect to the ophthalmic veins, it must be mentioned here, that after all their formatory branches have been united into one trunk, that trunk indeed is of considerable size, yet without becoming enlarged into a sinus. . . . Still, not all veins coming from the eye unite in one stem; not unfrequently there are two, or even three stems, all of which become ramified, and enter into the formation of the cavernous net. A noteworthy object here is a net or rete which, I believe, has not been described before. It is formed of two of the root-branches of the ophthalmic vein, and is situated along the orbital extent of the ala magna of the sphenoid bone. I met with it in two successful casts of the cavernous sinuses of recently-born infants, and in a very well injected head of a child two years old. It consists of robust little tubes which depart from the roots of the ophthalmic vein, and which are woven into close meshes. It extends in an anterior direction, where the tubes gradually become more slender, and the meshes looser. Posteriorly, it extends as far as the sphenoidal fissures, and is connected there with the veins of the fissura pterygo-palatina, which are likewise woven into a plexus. By this means the whole complex of the veins of the orbit and the cavernous sinus is connected with the nasal veins" (*loc. cit.*, pp. 311, 312).

It will be observed here that, according to Langer's experience, the ophthalmic veins, and hence the veins which chiefly enter into the formation of the cavernous sinus, were distinctly traced by him into the emissary vein of the foramen ovale, and into the inferior petrosal sinus—and hence into those vessels which, according to Swedenborg, carry off the grosser venous blood of the cavernous sinus. He also traced a continuation of the ophthalmic vein into the circular sinus (concerning which see above, no. 621*s*), but not into the superior petrosal sinus, which, according to Swedenborg, is charged with the conveyance of the spirituous lymph of the *first* degree, and partly also with that of the *second* degree from the pituitary gland into the jugular vein. But from this it follows that the secretion of the pituitary gland which is intended for the superior petrosal sinus, although it is discharged into the posterior end of the cavernous sinus, is in a manner outside of the cavernous sinus proper; that, therefore, this secretion does not mix generally with the contents of the above sinus which are derived from the ophthalmic vein and the spheno-parietal sinus, but hastens at once towards the superior petrosal sinus—even as it is declared by Swedenborg himself.

47. In addition to the three sources thus far mentioned, by which the cavernous sinuses receive their supply of venous blood; namely, 1, the ophthalmic vein; 2, the spheno-parietal sinus; and 3, the vena cerebri media which opens either directly into the cavernous sinus, or enters first into the spheno-parietal sinus—a few other sources of venous blood are mentioned by some authors.

So *Henle*[1] says, that "the cavernous sinuses receive a series of venous stems from the tentorium;" while *Knott*[2] calls our attention to the *inferior sphenoidal sinus* in these words: "Another inconstant vein, which lies in the dura mater on the inner surface of the great wing of the sphenoid bone, has been described by Sir Charles Bell, and some other anatomists, as the inferior sphenoidal sinus. I have found this vessel twenty-three times in forty-four subjects; fourteen occurring on the right side, and nine on the left."

Sir Charles Bell[3] speaks of this sinus in the following terms: "The

[1] "Op. citat.," p. 338. [2] "Op. citat.," p. 195

[3] "Op. citat.," p. 427.

inferior sphenoidal sinus is very irregular and inconstant. It is in the dura mater covering the great wing of the sphenoid bone: the blood is emptied into the cavernous sinus, or escapes by emissaria into the trunk of the temporal vein."

48. If now we take a survey of all the facts which have thus far been established in respect to the cavernous sinuses, it appears: that into the posterior extremities of these sinuses there are discharged from the pituitary gland the liquids most highly charged with spirituous lymph; namely, 1, the fluid of the *first* order, through the circular sinus; 2, an arterial blood enriched with the fluid of the *second* order, through the anterior occipital or transverse sinus; and, 3, the fluid of the *third* order, which is a grosser serum, through the posterior receptacle of the sella. Further, that a liquid of a middle kind, namely, an arterial blood not much deprived of spirit, is discharged from the pituitary gland, at a middle distance between the anterior and posterior clinoid processes, through the inferior transverse or intercavernous sinus. And lastly, that at the anterior extremities of the cavernous sinuses there pours into them, 1, meningeal blood, through the spheno-parietal and the inferior sphenoidal sinuses; 2, venous blood from the interior of the brain, through the middle cerebral vein; and 3, venous blood from the exterior parts of the head, namely, the orbits, through the ophthalmic vein.

It appears also that the more spirituous blood is discharged into the upper part of the cavernous sinuses, while the more sluggish, venous blood enters more at the bottom.

This arrangement is evidently for the purpose that the various kinds of blood, namely, those which are highly enriched with spirit, and those which are comparatively exhausted and effete shall not be mixed promiscuously in the cavernous sinuses. This arrangement, in the light of Langer's experience, would apply to the cavernous sinuses in the heads of adults, after the original venous plexuses of childhood, by confluence, have assumed the form of extended lacunæ. In infancy, however, a portion of the cavernous plexus, and thus some of its meshes, would serve for the conveyance of the contents of the circular sinus to the superior petrosal sinus, while another portion of the plexus would carry the contents of the ophthalmic veins and of the spheno-parietal sinus to the inferior petrosal sinus, and to the other emissaria of the cavernous sinus.

In order to prevent such a commingling of essences, the cavernous sinuses, in adult heads also, do not present a smooth surface in their interior, but are intersected and interlarded by membranous ligaments and trabeculæ.

Sömmering's[1] description of the interior of the cavernous sinuses [in adult subjects] is as follows: "The entire cavity of the cavernous sinus acquires a cellular appearance from the fact of numerous fibrous and filamentous cords being stretched out in it." *Sir Charles Bell*[2] says, "The cavernous sinus is irregular, having fibrous cords traversing it, which gives it a kind of cellular appearance. It is like the diseased parts into which blood has been driven, till the cellular texture has been distended and partly destroyed."

Luschka[3] explains the interior arrangement of the cavernous sinuses in this wise, "This venous space is crossed by a delicate system of trabeculæ, by which the sinus is broken up into compartments. The component parts of this trabecular system—in which are enclosed partly arterial vessels and partly nervous fibres of the sympathetic nerve—consists of cellular fibrils and elastic fibrils."

If now we bear in mind this internal arrangement of the cavernous sinuses, we are able to see how the spirituous lymph of the circular sinus may be absorbed at once by the superior petrosal sinuses, before becoming mixed with the general contents of the cavernous sinuses. Also, how the blood enriched with spirituous lymph which collects in the anterior occipital or transverse sinus out of the interior of the sphenoid bone, and which is discharged thence into the posterior extremities of the cavernous sinuses, may likewise be absorbed by the superior and inferior petrosal sinuses without spreading through the general contents of the cavernous sinuses. Besides, it must be remembered that the flux of the blood in the cavernous sinuses is in an antero-posterior direction, so that not only the trabecular arrangement of these sinuses in the adult head, but also the very stream of blood in the same, is opposed to a general diffusion of the contents of the anterior occipital sinus through the cavernous sinuses. The same applies to the grosser serum—the fluid of the *third* order—which is discharged into the cavernous sinus out of the posterior receptacle of the sella. This serum, also, compared with the exhausted and effete venous blood which is poured into the cavernous sinus from the middle cerebral vein, is comparatively rich in spirit; for, according to Swedenborg, it contains a considerable amount of nervous juice—cerebro-spinal liquid; this serum therefore follows the general course of all those fluids which are discharged from the

[1] "Op. citat," p. 272. [2] "Op. citat.," p. 429.
[3] "Op. citat.," p. 151.

pituitary gland, and rushes at once into the inferior petrosal sinuses, in order to be conveyed through these channels by the shortest possible way into the jugular vein.

The only liquid of a better nature which becomes thoroughly mixed with the venous blood which enters through the anterior extremity of the cavernous sinus, is the arterial blood from the pituitary gland, which pours into the cavernous sinus through the inferior transverse or intercavernous sinus. This blood enters the cavernous sinuses about the middle, and on account of the interior cellular arrangement of these sinuses, in the adult, it cannot rush at once into either of the petrosal sinuses; but undergoes first a thorough mixture with venous blood, and then follows in the direction of the carotid artery, which is stretched out at the bottom of each of the cavernous sinuses, and along that artery it pursues its way into the interior of the carotid canal, where it forms a venous sinus around the arterial vessel, and through that venous sinus it is conveyed outside of the cranium.

This same blood also constitutes one of the supplies of the canal of Tabarrani; for, according to Englisch and Trolard, this canal communicates with the cavernous sinus, either directly, between the carotid artery and the side of the sphenoid bone, or else indirectly through the carotid sinus.

In the infantile head, however, the arterial blood of the pituitary gland would be conveyed from the inferior transverse or intercavernous sinus of the pituitary gland into special meshes of the cavernous plexus, and after mixing there thoroughly with venous blood, it would be conveyed into the carotid plexus or sinus which encompasses the carotid in the carotid canal.

49. This brings us to the consideration of the emissary vessels through which, according to Swedenborg—see above, no. 41—the more sluggish venous blood is carried away from the cavernous sinuses. The most important of these emissary vessels is the CAROTID SINUS which has just been mentioned, and which was first described by *Santorini*[1] in 1724, in the following words: "While the carotids are in their osseous cave, ready to emerge towards the sides of the pituitary gland, they do not adhere closely either to the osseous wall, or to the surrounding meninx, but repose so loosely on the dura mater which is stretched out around them, that a by no means inconsiderable space intervenes between them and the dura mater. And this is the case not only near their outlet, but also at such a considerable

[1] Santorini (J. D.). "Observationes Anatomicæ." Venice, 1724, p. 73.

distance into the interior of the bone, that there results thence a kind of funnel. The dura mater again is not only situated at some distance from the artery, but also from the osseous cave by which it is enclosed, so that if it were possible for the dura mater to contract and to curl up, this might be effected here most easily, and most conveniently. By the sublime design of our All-Wise Creator, it was thus provided that the carotid arteries should not adhere to the surface of the bone, not only for this reason, that by this means they should never be prevented from displaying the activity necessary for propelling the blood, but also that the same power and force might be applied in a certain measure both to the inflowing and the outflowing blood. Now, since the blood which is in the cavernous sinuses must necessarily descend into what may be called the funnel formed by the osseous cave of the carotid, it cannot help being urged forward and propelled, whenever the sides of the artery are dilated; and thus it must needs be that the blood actuated by this motion should exert a similar urging and propelling motion upon the remaining blood which is in the neighbourhood of these places, and that by this motion should provide for itself an outlet out of the cavernous sinus either through the neighbouring sinuses, or through the remaining emissaries."

Tabarrani[1] speaks of this sinus in the following words: "Nature has provided around the carotid, in its osseous canal, a funnel-like arrangement, which, to my knowledge, has been hitherto described only by Santorini." He speaks of this "funnel-like arrangement around the carotid," in the neighbourhood of the cavernous sinuses, as furnishing the initial point of an emissary canal whereby said sinuses communicate with the pterygoid plexus. This emissary canal will be referred to again below.

Haller[2] also mentions at least a partial venous sinus around the carotid; for he says, "The blood of the cavernous sinuses follows the carotid through its entire first curve."

The knowledge of the carotid sinus, which had become lost in the course of time, was revived again in our own days by *Rektorzik*.[3] He says, "If you examine the posterior extremity of the cavernous sinus—the point of the apex of the petrous bone—which, in all anatomical treatises, is described alike, you will not meet there with a

[1] Tabarrani (P.). "Observationes anatomicæ," § xix., p. 38.

[2] "Op. citat.," iv., p. 156.

[3] Rektorzik (Dr. E.). "Ueber das Vorkommen eines Sinus venosus im Canalis caroticus des Menschen." "In Sitzungsberichte, etc., der mathematisch—naturwissenschaftlichen Classe," Bd. xxxii. Wien, 1858.

membrane whereby the sinus is completely blocked up, but you will notice there openings out of which venous blood trickles. This blood comes forth out of those spaces or lacunæ whereby the cerebral carotid is surrounded in the carotid canal. In order to obtain a good view of this system of lacunæ in the carotid canal, you require to remove the upper wall of this canal, which corresponds with the anterior inner surface of the apex of the petrous bone. If, for this purpose, you select a cranium, the sinuses of which abound with blood, that blood will then be found oozing forth in considerable quantity." After describing the conditions of the dura mater in and about the carotid canal, Rektorzik continues, "On the basis of the facts which are here detailed respecting the dura mater and its relation to the osseous carotid canal and the cerebral carotid, I am justified in assuming, in the carotid canal, the existence of an irregular cavity, which, through trabeculæ, is divided into small compartments; and, because this cavity is enclosed by dura mater and carries venous blood, it deserves the name of a sinus of that membrane. The internal carotid, therefore, is not attached everywhere firmly to the walls of the carotid canal, as has been hitherto assumed, but it is separated from its walls by venous blood, even as is the case with the carotid in the cavernous sinus. In respect to the size of that sinus, it is naturally larger or smaller, like that of the cavernous sinus, according as the cerebral carotid is either expanded or contracted. During the diastole of this vessel, consequently, the sinus will decrease in size, and during its systole it will increase. The width of the sinus also varies, according as it is examined nearer to the entrance of the carotid canal, or nearer its outlet into the cavernous sinus. It increases in size the nearer it approaches to this latter sinus; and in harmony therewith I find that the carotid canal, at its entrance into the temporal bone, is narrower, and that it enlarges gradually, until at last it terminates in a wide and long fissure. Whence does that sinus derive its blood? The answer is near at hand; namely, it derives some of its blood from the cavernous sinus, with which it is directly conjoined. In addition to this copious source, it has another source besides, although it is considerably smaller. This latter source is due to the existence of several osseous veins in the petrous bone, which terminate in the carotid sinus, the orifices of which become visible in the internal surface of the sinus, when it is slit open. The blood which from these sources is conveyed into the venous sinus, is carried off by proportionally small veins, which, commencing at a variable distance from the entrance of the carotid canal, are situated under the adventitia of the carotid, and which, in the form of a wide-meshed net, engird the artery. These little veins gradually unite into one or several stems, which empty their contents directly into the external jugular vein."

The carotid canal, on the lines of Rektorzik's description, is discussed in the text-books of Luschka and Henle. *Trolard*,[1] who made an independent examination of this sinus, gives the following description of it: "The carotid is well bathed in venous blood before plunging into the cavernous sinus, and this venous blood is furnished to it by that sinus. It is carried off by the lower petro-occipital sinus—the canal of Tabarrani,—and by one or two little veins which come from the vein of the foramen ovale, or from the meningeal veins. These little veins open into the carotid canal by the anterior wall of this canal, which is most frequently wanting, and which in this case is replaced by a fibrous membrane. The venous blood circulates around the carotid in little areolæ; wherefore a real sinus is there, which may be called the *carotid sinus*."

By making a resinous injection of the cavernous sinus, and afterwards corroding its membraneous parts, *Langer* obtained a clear view of the carotid sinus. His statement is as follows: "The fact of the carotid being accompanied by a small vein through its osseous canal in the temporal bone, was known already to Burdach ("Gehirn," ii., p. 181), but Rektorzik has first proved that the artery is encircled by a venous plexus. This *plexus venosus caroticus* originates likewise from the cavernous sinus; in the foramen lacerum it forms a kind of funnel, and then encloses the carotid in a tube-like form. By means of a small venous stem it is connected with the jugular vein. . . . This plexus is thus, in a certain sense, a continuation of the cavernous sinus" (*loc. cit.*, p. 314).

According to Rektorzik, the carotid sinus empties its contents, through little veins, into the external jugular vein. Trolard, however, without gainsaying Rektorzik's statement, describes the "lower petro-occipital sinus"—the canal of Tabarrani—as an emissary vein of the carotid sinus; and herein is supported by Dr. Englisch, who declares that said canal originates either in the posterior extremity of the cavernous sinus, or in the carotid sinus. Trolard also mentions "one or two little veins which come from the foramen ovale, or from the meningeal veins," as outlets of the carotid sinus.

The vein of the foramen ovale, which we shall discuss presently, leads from the lower part of the cavernous sinus into the pterygoid plexus. Wherefore Trolard maintains here that the carotid sinus,

[1] "Op. citat," p. 264.

"through one or two little veins which come from the vein of the foramen ovale," discharges a portion of its contents into the pterygoid plexus.

This same statement was made by *Tabarrani*[1] as far back as 1743, in the following words: "It seems to me that in addition to this new sinus—the canal of Tabarrani, which he derives exclusively from the cavernous sinuses—there is still another little canal which leads out of these sinuses close by. This little canal does not begin in the cavity of the cavernous sinuses, but has its beginning a little further down, exteriorly out of the funnel-like arrangement around the carotid; which arrangement nature contrived around the carotid within its osseous canal, and which, to my knowledge, has hitherto been described only by Santorini. The little canal mentioned above, on passing through the cranium, terminates in that vascular plexus, or in that cavernous substance which is spread over the external pterygoid muscle, and which Santorini described as a diverticle of his emissaria. This vascular plexus I have repeatedly found to consist of shoots of the external jugular vein."

Bell[2] also speaks of "the funnel of the carotid through which descends a vein—the vena sodalis carotidis—which terminates in the pterygoid plexus of veins."

As the pterygoid plexus discharges its contents either through the facial vein into the internal jugular vein, as this latter vessel approaches the upper part of the neck, or through the internal maxillary into the external jugular vein, it appears that a great portion of the blood received by the carotid sinus from the cavernous sinuses is poured either into the external jugular vein, or into the internal jugular vein far below the foramen jugulare; although some of it, according to Englisch and Trolard, is also received by the canal of Tabarrani.

50. The venous plexus or venous sinus which intervenes between the carotid and its osseous wall, besides answering the purpose of an emissary vessel of the cavernous sinus, serves also an important use in helping to emancipate the carotid blood from the ruling motion of the heart, and subjecting the same to the movement of the brain, which is in harmony with the respiratory motion of the lungs.

Several provisions, according to Swedenborg, are made in man for the purpose of checking the flow of the cerebral blood in obedience to the systaltic and diastaltic motion of the heart: (1) the carotid artery, before entering the cranial cavity, makes four bends or flexures;

[1] "Op. citat.," § xix., p. 38. [2] "Op. citat.," p. 429.

two in the interior of the bone, in the carotid eanal, and two in the cavernous sinus—by these bends the flow of the blood is cheeked and retarded; (2) "As soon as the carotid artery approaches the eranium," according to Swedenborg (no. 387), "it is strippcd of its museular eoating or of that of the heart—and the heart is unable to act upon any part which lies beyond the continuity of its own muscle;" and (3) "it is furnished with a meningeal coating, that is, with one derived from the membranes of the brain;" and (4) "afterwards it is embraced by a filamentous covering from small branches of the grcat sympathetic ncrve." (5) "Besides, in the cavernous sinuses this artery itself bccomes swollen into a sinus and increascs in bulk, quite contrary to what is customary in othcr arteries, which decrease in bulk as they pursue their course." In most of the animals, however, this samo purpose is attained by a breaking-up of the earotid trunk in the cavernous sinus into a large number of small vessels, which are woven into a kind of net, called "rete mirabile" (nos. 626-640*e*), and which are afterwards re-united in one trunk.

Of the five methods resorted to in man for the purpose of emancipating the cerebral blood from the motion of the heart, the one detailed under no. 1 is based on a well-known anatomical fact, according to which the carotid artery bcfore ascending into the brain makes four well-defined curves or bcnds.

The second and third methods, according to which the carotid artery on approaehing the cranium "is stripped of its muscular eoating, and is furnished instead with a mcningeal eoating derived from the membranes of the brain"—require to be modified somewhat, so far as the facts are concerned on which they are based, in order to make them agree with the experience of modern seicnce. Modern scienco admits that the coatings of the internal carotid, on entering the cranium, undergo a rcmarkable change, not indeed by losing their muscular eoat altogether, but by bccoming thin-coated. Thus *Sömmering*[1] says, "The artcries of the brain are constructed of subtle membranes, so that they are thought to be without a muscular coating." And *Burdach*,[2] "After gaining an entrance into the eranium, the arterics give up their fibrous sheath, which passes over into the fila-

[1] Sömmering (S. Th.). "Academicæ annotationcs de ccrebri administrationibus anatomieis, vasorumque ejus habitu." In "Denkschriften der königliehen Akademie der Wissenschaften zu München, für das Jahr. 1808." Munich, 1809; p. 64.

[2] Burdach (C. F.). "Vom Baue und Lcben des Gehirnes." Leipzig, 1822; Vol. ii., p. 21.

mentous coating of the brain; and, in correspondence with the sphere to which they henceforth belong, they acquire a peculiar character, for, . . . together with their annular, muscular fibres, they lose every vestige of a proper or independent irritability by becoming thin-coated." And in *Quain*[1] we read, "Some arteries want sheaths, as those, for example, which are situated within the cavity of the cranium;" and again, "Some arteries have much thinner coats than the rest, in proportion to their calibre. This is strikingly the case with those contained within the cavity of the cranium and in the vertebral canal; the difference depends on the external and middle coats, which in the vessels referred to are thinner than elsewhere."

As to the carotid on "approaching the cranium being furnished with a coat of dura mater," this, according to Swedenborg, takes place in the carotid canal, which is lined with dura mater. On this subject we read in Cruveilhier,[2] "A very thin, fibrous lamina, a prolongation of the dura mater separates the vessel from the bony walls of the carotid canal." But as to the continuation of this lamina around the carotid after its entrance into the cavernous sinus, he says, "It is said that the artery is not bathed in the blood contained in the sinus, but is protected from it by a very thin layer of membrane, continuous with the internal coat of the veins. However careful I may have been, I have never succeeded in separating this membrane." Other anatomists, however, are very positive as to the existence of such a membrane; so *Langer* says that he "agrees with Sappey as to the existence of such an adscititious coating of the carotid during its stay in the cavernous sinuses" (*loc. cit.*).

On the subject of the attachment of the carotid in the carotid canal to the dural lining of the same, Sömmering says, "It is most worthy of our attention, that the four trunks of the arteries of the brain—namely, the two carotid and the two vertebral arteries—approach the brain through bony canals, so that in these places they are found altogether incapable of going through their process of contraction and dilatation, which is called systole and diastole. For the contraction is prevented through the close cohesion of the artery with the periosteum; its dilatation, however, by the rigid substance of the bone, void of elasticity. By this means it is provided that the stream of blood shall reach the encephalon not by starts, but altogether equably" (*loc. cit.*).

[1] Quain. "Elements of Anatomy." Eighth Edition. London, 1876; Vol. ii., pp. 166, 170.

[2] Cruveilhier (J.). "Descriptive Anatomy." London, 1842; ii., p. 698.

Sömmering's view of the attachment of the carotid to the periosteum of the carotid canal, is disproved through the discovery of the venous plexus or sinus caroticus by which the carotid is encompassed in its bony cavity, and which we are now considering. But the same result which, according to his theory, is obtained by the attachment of the carotid to the periosteum of the carotid canal—namely, that "the stream of blood reaches the encephalon, not by starts, but altogether equably"—is produced by the passage of this vessel through a plexus of venous vessels, in which the blood is propelled in the intervals of the respiratory motion of the brain. That this animatory or respiratory motion prevails in the venous sinuses of the brain, was proved experimentally by Key and Retzius (see above, Vol i., p. 301, *et seq.*).

The facts of the case, therefore, are, that as the carotid approaches the cranial cavity, the motion imparted to the blood by the heart becomes slackened and neutralised, not only through the curves in the carotid canal, against which the arterial current impinges, but also through this circumstance that the blood in the venous sinus or plexus which embraces the artery in the carotid canal, runs in an opposite direction to the current in the carotid artery, and, indeed, in the intervals of the respiratory motion of the brain. This counter-impetus of the venous blood in the carotid canal exerts a similar effect on the movement of the blood in the carotid artery, which the backing of the oars has on the motion of a boat in the water—it stops it. Here also it must be borne in mind, that the middle coating of the artery, according to Burdach, is beginning to lose its muscular rings, and thereby "its proper and independent irritability," so that the vessel is no longer able to offer a firm resistance to the active pressure of the venous sinus without.

This, then, seems to be one of the important uses of the carotid sinus, or rather plexus, and this same use, namely, that of slackening the speed of the blood in the carotid artery, is continued during the stay of that artery in the cavernous sinus. For, as Swedenborg observes, "in the cavernous sinus the carotid artery becomes swollen into a sinus, and increases in bulk, quite contrary to what is customary in other arteries, which decrease in bulk as they pursue their course," —but such a widening in the caliber of the artery would naturally slacken the speed of its current. This statement, which Swedenborg makes on the strength of Wepfer's declaration (see above, Vol. i., p. 330), is corroborated by Portal, who speaks of "a frequent enlargement of the arteries" on their entrance into the brain (see footnote above on p. 201).

The motion of the blood in the carotid arteries, however, is not only slackened and retarded at the entrance of these vessels into the cranial cavity, but the intervals of this motion are also gradually made to keep pace with those of the motion of the brain and of the nervous system in general. This is brought about by the arteries in the cavernous sinus being invested with a dense net of nervous fibres from the great sympathetic nerve. By these fibres the cardiac motion of the carotids is thoroughly coërced and subdued, and by these fibres also the animatory motion of the brain is imparted to these vessels.

A similar effect, according to Swedenborg, is exerted by the fibres of the sympathetic nerve on the arterial shoots into which the carotids are resolved in those animals which have a "rete mirabile." On this subject he says, "As soon as the carotids in these animals enter the cranial cavity under the posterior clinoid processes, they are almost entirely broken up into small branches, with the exception of a small canal which continues its way, and with which the other small branches again become united before it ascends into the brain. Fibres of the great sympathetic nerve embrace the carotids, and from their trunks are transferred altogether to their arterial shoots; and these shoots they follow, so that if the nerve is unable to coërce the carotid trunk as a whole, it is able to subdue its individual parts and branches. And the nerve does not allow these branches to rejoin the small trunk which is left, until the intervals of their motion are reduced into harmony with the motion of the nerve itself" (no. 640*f*).

Concerning the fibres which compose the cavernous plexus of the great sympathetic nerve, we read in *Sappey*,[1] "The cavernous plexus is made up of soft, reddish threads, which spread over the internal carotid during its passage through the cavernous sinus. Interwoven with, and anastomosing among, one another, they envelop the arterial trunk on all sides. Nevertheless, it is chiefly on its external side that the greatest number of these nervous threads are found. These fibres decussate in various ways with small thread-like arteries which are equally numerous, and which depart out of the same trunk. Hence the name 'arterioso-nervous plexus' with which Walther designates collectively these diverse filaments." These nervous plexuses seem to attend even the larger branches of the cerebral carotid. So *Henle*[2] says, "From the plexus cavernosus proceed

[1] Sappey (Ph. C.). "Traité d'Anatomie Descriptive." Troisième Edition. Paris, 1876; iii., p. 528.

[2] Henle (J.). "Handbuch der systematischen Anatomie des Menschen," Vol. iii. "Nervenlehre," Braunschweig, 1871; p. 568.

extremely fine *rami vasculares*, which accompany and engird the branches of the internal carotid, viz. the anterior and middle cerebral arteries, according to Bourgery and Arnold."

After the cardiac motion has been thoroughly subdued, and the artery appears in the cranial cavity, Cruveilhier states that "at the point where the artery emerges from the dura mater, above the anterior clinoid process, it is received in a sheath formed of the arachnoid" (*loc. cit.*, ii., p. 698).

But to return to the emissaria of the cavernous sinuses.

51. Another important emissarium of the cavernous sinus is the "vein of the foramen ovale," concerning which *Trolard*[1] says, "From the lower part of the cavernous sinus there departs a sufficiently voluminous vein which places itself about the inferior maxillary branch of the trifacial nerve. With this nerve it passes into the foramen ovale, and terminates in the pterygoid plexus. It may be called 'the vein of the foramen ovale.' It communicates sometimes with the meningeal veins."

Henle[2] says concerning this emissarium, "The cavernous sinus despatches through the foramen ovale a few veins, which, after joining some branches of the meningeal veins, encompass the third branch of the trifacial nerve in the form of a plexus, and terminate in the venous plexus of the inferior temporal fossa—the pterygoid plexus—according to *Nuhn*.[3]"

Henle[2] says further, "More rarely the second branch of the trifacial nerve is accompanied by venous twigs from the cavernous sinus." *Knott*[4] says, "An additional tributary of the cavernous sinus, in the form of an emissary vein, passing through the canalis rotundus—the foramen rotundum—of the sphenoid bone, in company with the superior maxillary nerve, has been described by Nuhn.—This I have seen twice, in both cases on the right side."

According to *Langer*, "the emissarium of the foramen ovale consists of two or three larger tubes, which partly proceed directly from the ramification of the ophthalmic vein, and partly are formed of twigs of the cavernous net. The veins of this emissarium, as is well known, on the outside of the cranium pass over into the plexus pterygoideus, which, through several little stems, in an outside direction, joins the vena facialis posterior. The plexus pterygoideus encompasses the

[1] "Op. citat.," p. 263.

[2] "Op. citat.," iii., Abth. 1, p. 341.

[3] Nuhn (Anton). "Untersuchungen und Beobachtungen aus dem Gebiete der Anatomie," etc. Heidelberg, 1849; Heft 1, p. 6.

[4] "Op. citat.," p. 195.

nervus infra-maxillaris on all sides, and, as I was able to see in preparations obtained by corrosion, it terminates in a fine, closely-meshed net which is situated along the medial side of the nerve, and, therefore, covers the ganglion oticum. These emissary veins and their plexus are approached best by following Nuhn's advice, and making an injection of the inferior petrosal sinus" (*loc. cit.*, p. 312).

52. In addition to the emissary vessels which have thus far been specified, *Henle*[1] mentions some veins which leave the cavernous sinus through the foramen lacerum. He says, "Through the mass of connective tissue which fills the foramen lacerum there is a passage for veins, which on the one hand are connected with the cavernous sinuses, and on the other with veins of the exterior surface of the base of the skull."

Vicq d'Azyr[2] also speaks of a number of little veins which lead from the cavernous sinuses into the posterior cavities of the nose. He says, "The cavernous and orbital sinuses [*i.e.* the cavernous sinus and the ophthalmic vein] communicate by a large number of little veins with the posterior cavities of the nose; so that critical hemorrhages through the nose which take place in acute fevers where the head is affected, are easily explained by their means."

53. If now we pass in review the considerable number of emissary veins by which the cavernous sinuses communicate with the exterior veins of the head, in order to discharge into them the exhausted venous blood which is denied admittance into the petrosal sinuses—we see that Swedenborg is completely borne out in his declaration, where he says that those vessels which receive a spirituous essence from the brain, namely, the superior and inferior petrosal sinuses and the canal of Tabarrani, convey that essence into the lateral sinuses and also into the beginning of the internal jugular vein in the foramen jugulare; while the exhausted venous blood is conveyed outside the cranium through special emissary ducts or veins. These veins finally empty either into the external jugular vein, or into the internal jugular vein, outside the cranium, and considerably below those points where the petrosal sinus and the canal of Tabarrani discharge their precious contents into these veins.

Besides, it must be borne in mind, that those veins or sinuses which carry venous blood into the cavernous sinuses, namely, the

[1] "Op. citat.," iii., Abth. 1, p. 341.

[2] Vicq d'Azyr. "Recherches sur la structure du cerveau, du cervelet," etc., in "Mémoires de l'Académie des Sciences, Mémoires de Mathématique et de Physique, Année, 1781." Paris, 1784; p. 504.

ophthalmic vein, the spheno-parietal sinus, the middle cerebral vein, and the inferior sphenoidal sinus, before reaching the cavernous sinuses, anastomose largely with external veins of the head; so that, whenever there is too copious an afflux of venous blood towards the cavernous sinuses, the threatened inundation is mostly averted even before that blood reaches the cavernous sinuses.

The ophthalmic vein, through its infra-orbital branches, thus communicates immediately with the pterygoid plexus, and thereby with the external jugular vein and the lower internal jugular vein.

The spheno-parietal sinus anastomoses with the middle meningeal vein, and through this vein is connected with the internal maxillary vein; and again through one of its tributaries, the vena diploica temporalis anterior, it is connected with the deep temporal vein. Through both these veins, however, it communicates with the pterygoid plexus, and thereby with the external jugular vein, and also with the internal jugular vein at a considerable distance below the foramen jugulare.

The middle cerebral vein enters partly into the cavernous sinus, and partly into the middle meningeal vein, and through this vein communicates with the external veins of the head.

The inferior sphenoidal sinus, according to Bell, "is either emptied into the cavernous sinus, or else escapes by emissaria into the trunk of the temporal vein," and thereby communicates with the external jugular vein, and with the facial vein near its termination.

Ample provision is thus made against a flooding of the cavernous sinuses by exhausted venous blood; only so much of this blood, in fact, being admitted as is of actual use for the fixation of the spirituous lymph of the brain; or so much as the cavernous sinuses are able to revive by the infusion of some of the spirituous lymph which is poured from the pituitary gland into the posterior extremity of these sinuses preparatory to its being carried away by the superior petrosal sinuses.

But in case the cavernous sinuses should actually be congested by venous blood, these sinuses, as has been pointed out by Vicq d'Azyr, are relieved of that pressure by a hemorrhage through the nose.

5. *The Inferior Petrosal Sinuses.*

54. The function of these sinuses Swedenborg explains in the following manner:—"The larger, interior, and shorter sinuses at the base—the inferior petrosal sinuses—seem to swallow up all that serous fluid in which the gland is bathed on all sides, and which is derived

into the cavernous sinuses, and discharged thence. This serum they convey into the common trough of the sinuses—the foramen jugulare. For these sinuses lie a little more to the back than the superior petrosal sinuses, and they bend themselves into the shape of the letter *ſ* towards the production of the posterior clinoids; and at the same time with their stretched-out veins and lips they sip in mediately and immediately the moisture which showers down, and in this wise they drain the caverns. This we learn from injections, and it is confirmed by the situation, extent, and number of the little mouths, so that they must needs be canals intended for the conveyance of a more sluggish and grosser fluid. Besides, they also derive blood from the spongy substance of the cranium, which is immediately under them, and which is irrigated from branches of the internal carotid. They also receive any other blood which cannot be discharged in any other direction" (no. 624).

The fact that the inferior petrosal sinuses convey not merely blood, but also a serum "mixed with nervous juice," and with a portion of the spirituous lymph of the pituitary gland, cannot be proved by ocular demonstration, but, as we have shown, is the unavoidable result of a rational induction based on the facts of science.

Said serum is mixed in the cavernous sinuses with carotid blood from the pituitary gland, which is discharged into these sinuses through the "inferior transverse or intercavernous sinus." It is also more or less mixed with the venous blood which is poured into the anterior extremity of these sinuses through the ophthalmic vein and the spheno-parietal sinus.

The inferior petrosal sinus, like the superior petrosal sinus, is the recipient also, only in a larger degree, of blood from the interior of the cranium enriched with spirituous lymph from the pituitary gland, which it receives in the posterior extremity of the cavernous sinus from the "basilar plexus" through its highest, transverse branch, the "anterior occipital or transverse sinus," and also throughout the rest of its course. This is also admitted by Swedenborg where he says, that during its course towards the internal jugular vein, the inferior petrosal sinus "derives also blood from the spongy substance of the cranium, which is immediately underneath them, and which is irrigated from branches of the internal carotid." The vessels through which it derives this supply of blood, are those of the *plexus basilaris* of Virchow, mentioned above, with which, according to the testimony of Henle, Knott, and Theile (see above, no. 37), the inferior petrosal sinuses are "laterally connected."

Swedenborg says further, "These sinuses receive also some other blood which cannot be discharged in any other direction." Concerning the veins which carry such blood into the inferior petrosal sinus, *Haller*[1] says, "Into this same sinus are discharged some veins of the dura mater from the region of the vertebræ, and from the place where they are joined with the occiput. Some veins also come from the beginning of the spinal marrow and from the medulla oblongata." *Sappey's*[2] more precise statement concerning these veins is, "The inferior petrosal sinuses receive a vein which starts from that portion of the dura mater which lines the inferior cerebellar fossæ of the occipital bone."

Cruveilhier[3] speaks of another vein which joins the inferior petrosal sinus near its anterior extremity; he says, "Excepting one vein which comes from the base of the cranium through the foramen laccrum anticum, the inferior petrosal sinus receives no vein of importance." This same vein is described by *Sappey*[2] as "an ascending vein of a very slender caliber which traverses the foramen lacerum anticum."

According to *Henle*,[4] however, "Veins from the lower surface of the cerebellar hemispheres, the pons Varolii and medulla oblongata empty into the *inferior petrosal*, the occipital, and the lower part of the lateral sinuses." He further says, "The venæ auditivæ internæ empty into the lower end of the inferior petrosal, or into that of the lateral sinus."

55. As in the case of the superior petrosal and of the cavernous sinuses, nature has made a provision against an inundation of blood also in the case of the inferior petrosal sinuses, by the introduction of anastomoses and an emissary vein.

Trolard[5] accordingly informs us that "the lower wall of the inferior petrosal sinus sometimes presents openings through which it communicates with the lower petroso-occipital sinus—the canal of Tabarrani—underneath."

An emissary vessel of the above sinus is described by the same author in the following terms: "This vein"—the vein which constitutes the posterior end of the inferior petrosal sinus, see below—"offers towards its middle portion an opening whereby it communicates with the *anterior condylar confluent*." This confluent enters the anterior condylar foramen which is within the foramen jugulare, and

[1] "Op. citat.," iv., p. 153.
[2] "Op. citat.," ii., p. 734.
[3] "Op. citat.," ii., p. 777.
[4] "Op. citat.," iii. 1, pp. 338, 342.
[5] "Op. citat.," pp. 264, 268.

at its other end which opens into the foramen magnum occipitale, it communicates with the venous plexus with which this foramen is encircled, and which is continued into the vertebral plexuses and thence into the vertebral sinuses. According to Trolard, this confluent receives a vein not only from the inferior petrosal sinus, but also from the lower petroso-occipital sinus, that is, from the canal of Tabarrani.

According to *Henle*[1] and *Luschka*,[2] the emissary vessel in question does not lead away from the inferior petrosal sinus into the vertebral plexus; but it follows an opposite course, and carries blood from the plexus vertebralis, and hence from the occipital sinus which is connected therewith, into the inferior petrosal sinus.

There are strong grounds in favour of either of these views; for while the nervus hypoglossus enters the anterior condylar canal at its opening in the foramen magnum, and leaves it through the jugular foramen, a twig of the arteria pharyngea ascendens enters the condylar or hypoglossal canal at its exterior opening, and pursues an opposite course. The cranial veins, it is true, usually carry blood away from the cranium; and yet the ophthalmic vein and others enter the cranium from without, and help to swell the contents of the intra-cranial sinuses.

Trolard, therefore, seems just as much justified in regarding the inferior petrosal sinus as the starting-point of the emissarium in question; as Luschka and Henle in considering the plexus venosus of the foramen magnum and the occipital sinus as its original source.

If we consider, however, that not only the inferior petrosal sinus, but also especially the canal of Tabarrani, carry a blood which is charged with spirituous lymph, there seems to be an important reason why both these canals should communicate through the venous plexus of the foramen magnum with the vertebral plexuses, and thus with the anterior longitudinal spinal veins.

For these latter veins also carry a blood which like that of the lateral sinuses is more or less exhausted, and requires restoration and re-animation by the spirituous lymph of the pituitary gland, which is carried by the canal of Tabarrani, and in a lesser degree by the inferior petrosal sinuses. Besides, the "plexus basilaris," which carries a blood, likewise endowed with spirit, as shown above in no.

[1] "Op. citat.," iii. 1, p. 341.

[2] "Op. citat.," (Die Anatomie des Menschen), Vol. i., Abth. 1, pp. 26, 99, 357. Also in "*Joh. Müller's* Archiv für Anatomie," etc., for 1856, p. 79.

37, is also connected with the venous plexuses of the vertebral canal.

56. In respect to the posterior extremity of the inferior petrosal sinuses, Swedenborg says, "These sinuses run out between the sphenoid and temporal bones. They become larger on the way, and being but slightly bent, they seek those petrous reservoirs—the foramina jugularia or foramina lacera postica—into which the lateral sinuses discharge themselves, with a view of entering the jugular veins."

This represents the state of science on this subject, in Swedenborg's time, and also until quite recently that of modern science. Thus *Todd*[1] makes the following statement concerning the posterior terminus of the inferior petrosal sinuses: "These sinuses open into the inferior portion of the lateral sinus, just before it unites with the jugular vein."

Cruveilhier[2] says, "The posterior extremity of the sinus opens into the anterior end of the corresponding lateral sinus, opposite the commencement of the internal jugular vein."

Quain[3] also says, "The inferior petrosal sinus opens into the lateral sinus near its termination;" but he is careful to add afterwards, "or into the jugular vein."

The fact is, this sinus does not enter the lateral sinus at all, nor even the foramen jugulare proper; but it enters a separate compartment of the foramen lacerum posticum, where it lays aside the character of a sinus, and assumes that of a vein. And this terminal vein of the inferior petrosal sinus enters the jugular vein at a variable distance from the terminus of the lateral sinus, often even exteriorly of the cranium.

This condition is described by *Luschka*[4] thus, "Shortly after the internal jugular vein has made its appearance at the external surface of the cranium, there enters into its anterior circumference the posterior end of the inferior petrosal sinus. This sinus, which pursues its course in a groove between the petrous bone and the body of the occipital bone, at the anterior extremity of the foramen lacerum posticum, through which it descends, usually passes over into a vein with its own independent coatings and walls. This vein in adult persons averages in width 2 mm., and in length 6 mm.

[1] Todd (R. B.). "Descriptive and Physiological Anatomy of the Brain," etc. London, 1845; p. 20.

[2] "Op. citat.," ii., p. 777. [3] "Op. citat." Eighth Edition. i., p. 483.

[4] "Op. citat.," i. 1, p. 356.

Closely behind the plaee where this vein penetrates the foramen laeerum, three nerves, the glossopharyngeus, the vagus, and the aeeessorius Willisii, all surrounded by speeial produetions of the dura mater, pass through the anterior smaller division of the foramen lacerum; and during their passage they are separated from the internal jugular vein by the proeessus jugularis spurius, or by a fibrous partition whieh replaces said processus."

He says further, "Into this vein, aecording to the observations of J. Englisch, there lapses a canal—the canal of Tabarrani—$1\frac{1}{2}$ mm. in width, whieh is contained in the cartilage between the petrous bone and the pars basilaris of the oeeipital bone," ete.

Very often, accordiug to *Theile*,[1] an osseous bridge even occurs between the inferior petrosal sinus and the three nerves specified above, during their passage through the foramen laeerum. He says, "In twelve eases out of forty-six, I found in the petrous aud occipital bones, more seldom in the substance of the occipital bone alone, a foramen whieh is separated from the foramen laeerum by a narrow bridge, which, however, is sometimes three lines in width. Both bones contribute to the formation of this bridge, but the share of the oceipital bone is greater. The *sulcus pro sinu petroso inferiori* always leads into that hole, and through that hole the sinus petrosus inferior leaves the cavity of the skull. The twelve cases which I observed justify me in the declaration that besides the inferior petrosal sinus no other part enters said foramen. This foramen occurs more frequently on one side, than on both sides simultaneously. Immediately after the sinus leaves the cranium, it enters the internal jugular vein. Once I saw it euter the vena thyrioidea superior."

The following represents the result at which *Knott*[2] arrived in trying to aseertain the level at which the inferior petrosal sinus enters the jugular vein. He says, "With the purpose of ascertaining the exact level of the terminatiou of said sinus, I made a careful examinatiou of the bases of eleven skulls [tweuty-two sinuses], after the disseetion of all the other sinuses had beeu completed. In eight out of the twenty-two sinuses so inspected, the termiuation was as nearly as possible at the level of the lower margiu of the jugular foramen. In nine instances it was a little above, and iu the

[1] Theile (Prof., Dr.). "Das *foramen pro sinu petroso inferiori* an der Schädelbasis." In "Zeitschrift für rationelle Medicin." Neue Folge, Band vi. Heidelberg und Leipzig, 1855.

[2] "Op. citat.," p. 195, *et seq.*

remaining five a little below that point. In two cases it terminated about $\frac{3}{8}$ of an inch below the base of the skull."

The fact of the inferior petrosal sinus terminating posteriorly in a vein, which is only now beginning to be recognised in our text-books, was known to *Vicq d'Azyr*[1] as far back as 1786. He says, "It has been thought that the inferior petrosal sinus opened into the foramen jugulare, together with the lateral sinus. My observations have taught me that it is separated from that foramen by an osseous apex covered with a cartilaginous lining [the processus jugularis spurius], and by the eighth pair of nerves to which the foramen lacerum posticum lends passage. This sinus discharges its contents through the intermediation of a vein which is found at the base of the cranium, before the internal jugular vein. . . . The structure, as here given, is not in accordance with the description as usually given, and it is what I have observed in the subjects where I made my researches."

Bell,[2] among the earlier authors, is the only one who noticed the facts observed by Vicq d'Azyr. He says, "The inferior petrosal sinus is continued to the termination of the lateral sinus, or rather into the beginning of the jugular vein, by a channel, separated by a bony lamina from the termination of the lateral sinus; or it is continued into a vein in the base of the cranium, which afterwards joins the jugular vein."

Vicq d'Azyr also says, "When the jugular vein is injected with a view of filling the sinuses, the fluid does not pass into the inferior petrosal sinuses, except after having flowed first through the cavernous sinuses" (*Ibid.*). This is no doubt owing to the valve by which, according to Englisch, the opening of this sinus is closed in the internal jugular vein (see above, no. 39). This author also furnishes additional particulars of the mode in which the inferior petrosal sinus terminates in the interior of the jugular vein.

In conclusion, it has been supposed that the inferior petrosal sinus serves in the capacity of a grand anastomosis between the anterior and posterior sinuses in the basis of the cranium. This position is expressed by *Cruveilhier*[3] thus, "The inferior petrosal sinuses establish a free anastomosis between the anterior and posterior sinuses found at the base of the cranium." This anastomosis does not exist, as has been truly stated by *Trolard*[4] in the following

[1] Vicq d'Azyr. "Traité d'Anatomie et de Physiologie," Tom. i. Paris, 1786; p. 103.
[2] "Op. citat.," Vol. ii., p. 430.
[3] "Op. citat.," ii., p. 777.
[4] "Op. citat.," p. 264.

passage, where he sums up the results of his own observations, which agree in every particular with those results which we have quoted above from other authors, "The inferior petrosal sinus does not terminate in the lateral sinus. After reaching the internal extremity of the foramen lacerum posticum, it traverses this foramen, placing itself in front of the nervous trunks, and it goes to meet the jugular vein below the foramen jugulare. It opens into it through an oblique orifice. During this passage it is no longer a sinus, but a vein. This vein, about its middle, offers an opening whereby it communicates with the 'anterior condylar confluent.' In the foramen lacerum posticum, proceeding from within outwards, there are: 1, the vein which unites the inferior petrosal sinus with the jugular vein; 2, three nervous trunks; 3, the internal jugular vein. I have often seen the foramen lacerum posticum divided very neatly into three orifices, by the interposition of two complete osseous bridges; the most internal of these orifices was destined for the petrous sinus, the middle for the nervous branches, and the external for the jugular sinus. The grand anastomosis admitted at the present day between the anterior and posterior sinuses, through the intermediation of the inferior petrosal sinus, consequently does not exist."

H. Concluding Remarks, with a Bibliography.

57. We have now followed up the whole of Swedenborg's theory concerning the "Chymical Laboratory of the Brain," from the corpus callosum to the sinuses of the sella turcica, by which the various lymphs prepared by the brain for the use of the body, are consigned to the internal jugular vein; and we have tested the whole of this theory from beginning to end, by subjecting it to a most rigorous examination in the combined light of all the facts of modern science bearing upon the subject—and at the end of our examination we can truthfully assert that this theory has passed triumphantly through all the crucial tests to which it has been submitted.

We shall now close our Note with a statement of Swedenborg as to the ulterior fate of the spirituous lymph of the brain after its entrance into the jugular vein, first giving a description of the kind of blood which it meets with in that vein. "Only the softer, lighter, and more liquid blood is conveyed and propelled towards the cerebrum and cerebellum through the carotid and vertebral arteries. The purer, spirituous essence of this blood is re-absorbed by the cortical substance, and, together with the newly-elaborated spirit, is committed to the fibres; so that only the grosser, harder, the more inert and merely corporeal part of the blood remains, which is rejected into the longitudinal, lateral, and straight sinuses. This blood, after being deprived of its better life, becomes sluggish and dark, and is urged into the widened ends or receptacles of the sinuses, and towards the jugular veins. Unless it were animated there by a new spirit, and thus revived, it would be unable to flow, and would clog up the orifices; its bulk then would be increased, and after accomplishing a few rounds of its circulation, the blood would transgress its limits, and flood the whole brain, which is the court and council-chamber of the body. It would thereby deprive the brain altogether of its sensory and motory functions; thus of its providence and omniscience, and of its power in its little world, and hence would put an end to the kingdom. In order to escape this danger, the brain establishes its laboratory, which it furnishes with a vast array of organs, and thither it sends its spirit through fibres, both that which it has recently elaborated, and also the old spirit which it has received back from the body, in order that this spirit may restore and vivify the dying blood—the supply of spirit being always proportionate to the exigency of the case. In this wise the blood, which but a short while previously was lifeless, is re-animated, and after being made liquid again, it returns into the body, where it describes and perpetuates its circles. On this account the petrosal sinuses originate at the very sella of the pituitary gland, and they burst out thence as from a prison; and on this account they empty their contents in due order into the receptacles or troughs of the lateral sinuses and into the jugular veins themselves.

"After the blood on its return journey has been imbued with spirit, it is received by the new chyle, or in its stead by a most refined lymph, which are conveyed into the subclavian vein by the thoracic duct. Into this chyle or lymph the blood is at once introduced, and presently it is carried into the general whirlpool, that is, into the right ventricle of the heart. Afterwards it is dispersed through the pulmonary tubes and vesicles, and imbibes the purest nitrous substances and the saline elements conveyed thither by the atmospheres; whence it becomes of a more lively and ruddy colour, and returns into the other chamber of the heart, from which it is expressed into arterial, and thence into venous vessels. In the capillary vessels the blood which has been generated in this manner, is freed by excretion from all that is antiquated and obsolete, and also from all useless and urinous serosities, which are cast out. Such is the use for the sake of which the apparatus of the chymical organs in the brain has been established" (no. 648).

58. The following literature has been consulted in the preparation of the foregoing Notes:

a. The Infundibulum and the Pituitary Gland.[1]

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[1] The authorities marked with an asterisk (*) have also been quoted by Swedenborg.

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NOTE VII.

THE CEREBRO-SPINAL LIQUID.

a. Its Existence and Origin.

1. This liquid, the discovery of which is usually considered as of comparatively modern date, was well known to Swedenborg; and his description of it agrees with all that science, since his time, has established respecting it.

In speaking of the existence and the nature of this liquid, he uses the following language :—

"The arachnoid membrane may be separated from the subjacent pia mater by injection and a blow of air, and in dropsical brains it actually appears separated; whence it follows that a humour flows between it and the pia mater, by which they are kept apart, and prevented from coalescing" (II., no. 500).

"A subtle liquid is expressed from the little arteries of the cerebrum which pass through the cortical substance, or else from the pia mater which under pressure always yields some moisture. This fluid is kept under the arachnoid membrane and cannot rise upwards, but has to flow down between the cortical tori, and the divisions of the tori; the arachnoid membrane also contributing its aid thereto" (II., no. 529).

"This liquid is obtained from the delicate arterial filaments which, by the constant animation, that is, the respiratory motion of the cortex of the brain, are pulled and again relaxed, and thus milked" (no. 715*k*).

"Between the arachnoid membrane and the pia mater there are formed duct-like cells, through which the juice which is expressed from the pia mater and the little arteries, is directed to those places, whence it may be derived between the fibres, as well as between the fascicles of the fibres, and into the very medullary substance of the brain; so that all parts, being anointed with a suitable moisture, may accomplish their functions; while the superfluous juice is carried away through the duets of the araehnoid membrane. Thenee it appears that this membrane performs in the brain the same use which the lymphatics perform in the body" (no. 715*p*).

The eerebro-spinal liquid, aceording to Swedenborg, is derived not so mueh from the eerebrum, as from the cerebellum; for the *cerebral* moisture triekles into the lateral ventrieles, and, as has been proved from modern sourees in Vol. I., Editorial Note iii. (pp. 713-728), in the living human organism does not pass into the fourth, that is, the *cerebellar* ventricle—wherefore the cerebro-spinal liquid must be looked upon as chiefly a cerebellar, and not so mueh a eerebral seeretion. On this subject we read:

"The above applies also to the cerebellum and to both medullæ, where there is any grey substance. In the cerebellum this liquid is seereted between its numerous folds which are perpetually rubbed and acted upon during the moments of the animation of the brain; wherefore there must needs be expressed thenee a juiee whieh can pass only into its white or medullary substanee, and thenee into its medullary trunk, and eonsequently into its proeesses or nerves. A like fluid is derived in a similar manner from the spinal eord between its fibres, and thence into the very roots of the nerves which are presently invested with pia mater" (no. 715*m*).

Coneerning the eerebellar seeretion which is eolleeted in the fourth ventricle, we read further:

"The fourth ventricle, on aecount of the possibility of aetual motion which it seeures for the eircumjaeent members of the encephalon, supplies also a noble and most highly-gifted juiee impregnated with spirit. . . . This ehoicest serum and defeeated lymph, whieh is expressed from the tender shoots and villi of the vertebral artery between the laminæ and inmost folds of the cerebellum, and which enters thenee into the fibrillous interstices of its medulla, cannot eseape or be discharged by any other way than by that of the medullary stems into the subjacent ventriele, that is, into that eavity which is intercepted and elosed up by the peduneles; for there is no other egress. Such also is the ease with that moisture which does not penetrate the arboreseent growth of the eerebellum, but passes through the folds of the pia mater, and through the duplieatures of the same, and whieh pursues its course until it finds an exit. This humour also cannot shower down anywhere else than under the membrane whereby the peduncles are lined, and through the vermiform proeess where this same membrane is attaehed to the valve of Vieussens. Inasmueh as this ventriele eannot absorb the whole of that noble moisture which is collected in the whole medullary substance of the cerebellum, and in its laminated surface, it is pumped out by its alternate motion. The *modus operandi* by which this result is accomplished, appears also clearly from the way in which the peduncles, namely, their medullary portion is inrooted, and by which the enclosing membrane or outer covering is inserted in the edges of this cistern" (no. 712).

"The lymph, which by the medullary stems is conveyed into this cistern, out of every cleft of the cerebellum, and out of the medullary branches of its arborescent organism, must needs be most refined and of a spirituous nature, and it cannot be a pituitous humour or feculent liquid such as is found between the meninges, and sometimes in the anfractuous folds of the cerebrum. For the cerebellum goes through its alternate motions with constancy and tranquillity, in deep silence and with an ever serene complexion. The cerebrum, on the other hand, very often displays in its motion inconstancy, impetuosity, and again inactivity, wherefore a grosser species of lymph is excreted there. The cerebellum also sends off the feculent portion of the serum into its larger-sized veins, and presently into the straight sinus.

"This most refined lymph of the cerebellum is soon joined by a lymph endowed with fresh spirit from the choroid plexus which lines both sides of the fourth ventricle, both portions of which intercommunicate by anastomoses. This plexus also serves to show that a similar kind of lymph is distilled into this cistern as into the lateral ventricles of the cerebrum, since its texture is similar, and it is interspersed with similar glands" (no. 713).

On the ground of the cerebellum being the principal source of the cerebro-spinal liquid, Swedenborg styles the cerebellum one of the chief glands in the human organism. He says, "On this account also the cerebellum seems to represent a gland, and indeed the chiefest among the conglobate or lymphatic glands; for through emissary ducts or peduncles it excretes a juice into a cavity, that is, into the fourth ventricle, and thereby provides for the subjacent roots of the nerves" (no. 713).

As to the place where the cerebro-spinal liquid is discharged from the fourth ventricle into the subarachnoid space, and where it mainly accumulates, Swedenborg says: "The lymph of the fourth ventricle and of the choroid plexus is discharged into the duplicature between the pia mater and the arachnoid membrane; and thence, through the continuous and customary ducts and follicles of the arachnoid membrane, it is derived especially into the posterior part of the medulla oblongata, where that membrane floats about quite densely and loosely" (no. 714).

"The forum or market-place where the lymph, which is contained under the arachnoid membrane, flows together, is in the lowest and hindmost region of the medulla oblongata around the calamus scriptorius. Thither it flows from both brains, and thither it is conveyed from the whole circumference of the medulla oblongata; and thence, through the foramen magnum of the occiput, it descends towards the posterior surface of the spinal cord" (no. 715*q*).

2. The ultimate destination of the cerebro-spinal liquid in the peripheral nervous system will be discussed below in the light of modern science; likewise the special channels through which this liquid is discharged from the fourth ventricle into the subarachnoid space. Meanwhile Swedenborg's doctrine of the existence and origin of the cerebro-spinal fluid, will be found fully confirmed by the following historical account which Key and Retzius give of the various facts elicited by modern science respecting this liquid: "Although Haller came very near discovering the cerebro-spinal fluid, and although some important observations bearing upon the subject had been made before him by Pacchioni, and by others also it had been noticed as a pathological formation—still it cannot be gainsayed that to *Cotugno* is due the honour of having discovered this fluid as a constant formation occurring in the living subject under entirely normal conditions."

Swedenborg's MSS. from which the circumstantial account of this liquid, as given above, has been quoted, date from the years 1735 to 1743; while the first edition of Cotugno's treatise, "*De Ischiade Nervosa commentarius*," which contains the first published account of the cerebro-spinal liquid (see above, no. 704*f*) was issued in 1764. Our authors continue:

"Cotugno first demonstrated that the above liquid fills up the large interstice between the dura and the spinal cord from the occiput to the os sacrum, and also all the interstices between the brain and the dura; he found also that such interstices exist always in the base of the brain, and not unfrequently, and under peculiar conditions, with aged and cachectic persons also between the remaining surface of the brain and the dura. . . . The utter forgetfulness into which this discovery of Cotugno lapsed, proves in a singular degree how difficult it is for a well-demonstrated, extremely-important truth to make its way in the world of science. Twenty-two years later, Sömmering knew no more about the cerebro-spinal liquid than what is contained in his expression that between the arachnoidea and the pia mater there is often discovered a phlegmy water. By Bichat's doctrine, according to which the arachnoidea is a closed serous sack, analogous to the remaining serous membranes of the body, the attention of the learned was diverted from the subarachnoid spaces and their contents, and directed mainly to the so-called arachnoidal sack into which they endeavoured to place the normal as well as the morbid secretion of the arachnoidea. . . .

"The cerebro-spinal fluid, as a normal formation which constantly occurs in life, had to be discovered anew, and this was done by *Magendie*.[1] He moreover demonstrated that this fluid on the surface of the brain and the spinal cord is contained under the arachnoidea in the subarachnoid spaces; and he showed by experiments that it is under a positive pressure, and in a constant state of motion in connection with respiration. The subarachnoid spaces themselves he explored more minutely than any one before him, and most observers after him. The additional points which he established are chiefly these: That the above fluid fills the cellular vascular tissue between the pia mater and the arachnoidea not only in the sulci, but also around the surface of the cerebrum above the convolutions. That at the base of the brain it extends over its whole surface, but scarcely enters beyond the convolutions. That all cranial nerves as far as their egress through the dura mater, are bathed by it. In certain places of the surface of the brain, according to him, the liquid is collected in larger quantities, which places he called 'confluents.' He assumed four of these places; the first or *posterior* confluent, 'the most important'—Swedenborg's *forum*—is situated below and behind the cerebellum. The second or *inferior* lies before the pons Varolii and between the cerebral peduncles; the basilar artery is in it. The third or *superior* is situated behind, above, and on each side of the pineal gland; and the fourth or *anterior* is before the chiasma of the optic nerves. Among these confluents, according to Magendie, may also be classed the small liquid masses which encompass the ganglion of the fifth pair of nerves, on the right and left, which would be the *lateral* confluents" (I., pp. 76, 77).

These subarachnoid spaces are described much more minutely, and their number has been considerably increased, by Key and Retzius,

[1] Magendie (François). "Mémoire sur un liquide qui se trouve dans le crâne et le canal vertebral de l'homme et des animaux mammifères." In "Journal de Physiologie expérimentale," Vol. v., pp. 25-37. Paris, 1825.—EDITOR.

who injected heads with a blue mass and then froze them. Their description is contained in "Studien," etc., Vol. I., pp. 93-100, and "the largest and most important of these spaces"—Swedenborg's *forum*—they denominate the "cisterna magna cerebello-medullaris."

As to the source or origin of this fluid, Magendie deems it probable that it is "an exudation or transpiration of the blood-vessels of the pia mater." He also says that "after it is discharged or drawn off, it is speedily replaced." Luschka, on the other hand, declares in the preface of his work on the Choroid Plexuses (*Die Adergeflechte des menschlichen Gehirns*, 1885) that "some time ago (in the 'Archiv für physiologische Heilkunde,' Jahrgang xii.) he had endeavoured to show that the cerebro-spinal liquid must not be regarded as an exudation in the proper sense of that word, but that the choroid plexuses of the brain are related to this liquid in the capacity of genuine secretory organs." This idea seems also to be entertained by Key and Retzius, for in Vol. I., p. 107 (*l. c.*), they speak of the secretion of the cerebro-spinal liquid in connection with the choroid plexuses.

Swedenborg, as we have seen, maintains that this liquid is secreted not only by the blood-vessels of the pia mater and by the pia mater itself, but also by the choroid plexuses.

b. Relation of the Cerebral and Cerebellar Liquids.

3. In our Note iii. (Vol. I., pp. 713-718) we have shown fully, that in the living body the valve of Vieussens presents an effective barrier against the promiscuous mixing up of the cerebral and cerebellar liquids; that is, of the liquids which are collected respectively in the cerebral or lateral ventricles, and in the cerebellar or fourth ventricle. In confirming this fundamental position of Swedenborg's theory respecting the liquids of the brain, we based ourselves on facts drawn from anatomy, pathology, and chemistry. The fact drawn from chemistry seems to be conclusive in itself, for it is an acknowledged fact in the text-books of Organical Chemistry, that there is a radical difference in the chemical composition of the ventricular, that is, the cerebral fluid, and the cerebro-spinal, that is, the cerebellar liquid (see Vol. I., pp. 726, 727). This difference in the chemical composition of the two liquids arises from a difference in their function; for while the cerebrum, according to Swedenborg, through the ventricular liquid, "cares for the mass of the blood,"

the cerebellum, through its liquid, "provides for the subjacent roots of the nerves." Yet in spite of this radical difference between the two kinds of liquids, which, according to Swedenborg, amounts to this, that the cerebral liquid is of a grosser kind than that which is collected in the fourth ventricle (see no. 713), these liquids nevertheless seem to communicate under certain conditions—not in this sense, however, that the cerebral liquid is instilled into the cerebellar (for the grosser should not be mixed with the finer), but that the cerebellar, that is, the cerebro-spinal liquid, under certain contingencies, is added to the cerebral or ventricular liquid. This seems to be the reason why the valve of Vieussens does not interrupt entirely the line of communication between the fourth ventricle and the Sylvian aqueduct, that is, why it serves the purposes of a valve, and does not present itself anatomically as a membrane completely closing up said passage.

The contingencies, however, under which the valve grants a passage to the cerebellar liquid, seem to be these: Under ordinary circumstances, that is, so long as the contents of the third and fourth ventricles are evenly balanced, the communication between the two is intercepted by the valve of Vieussens; but, when for any reason whatsoever the moisture in the lateral, that is, respectively in the third ventricle, is abnormally scanty, then the valve of Vieussens, under instructions received from the cerebellum, which superintends all the involuntary or vegetative processes in the human body, opens its flood-gates, and admits so much of the cerebellar wave, that is, of the cerebro-spinal liquid, as is required for the restoration of the equilibrium in the cerebral ventricles.

The fourth ventricle in this case supplies to the lateral ventricles a serosity analogous to that of which Swedenborg states in his "Memorabilia," that "it trickles down into the larger ventricles of the cerebrum from the interstices between the fibres, and from other sources" (see Note vi., no. 3). It is possible also that the contents of the fourth ventricle are brought into requisition, when this kind of serosity is of too gross a nature, as it would naturally be when the cerebrum labours under certain affections or diseases, and when it thus threatens to clog up the avenues, that is, the various foramina in the system of the lateral ventricles.

4. In his earlier work on the brain, written between 1735 and 1740, Swedenborg holds that the liquid which courses through the lymphatic spaces of the peripheral nerves—the nervous juice or cerebro-spinal liquid—furnishes the medium through which the

animal spirit which is contained in the interior of the medullary and nervous fibres, is combined in the lateral ventricles with the secretion of the choroid plexuses. Thus he says, "In the lateral ventricles the spirituous juice or animal spirit is to be mixed with nervous juice—the cerebro-spinal liquid—and this again is to be commingled with the secretion of the choroid plexuses" (no. 715*i*).

In his later work, which he wrote between 1740 and 1743, and which furnishes the substance of our present work, Swedenborg ignored the presence of the cerebro-spinal liquid in the choroid plexuses of the lateral ventricles; probably because the science of his day did not furnish him with sufficient data by which to prove the introduction of this liquid into these plexuses. He simply says, "Thin, very soft and moist fimbriæ and roots extend from the body of the fornix, and are affixed to the highest coasts of the choroid plexuses. These fimbriæ pour out the pure [animal] spirit which through numerous fibres of the corpus callosum is conveyed to its centre of rest, the body of the fornix. . . . The blood is conveyed to meet this spirit; and by coursing through the web of the choroid plexus, it is consociated and mixed with the arriving spirit in every point, and in this wise celebrates as it were a marriage union with its spouse" (I., no. 511).

In his "Memorabilia," under the date of 1748, Swedenborg revives again his former theory, and in speaking of the serosities which trickle into the lateral ventricles from the interstices between the fibres, and from other sources, he says, "A part of this serosity is absorbed by the choroid plexus, even as a part is again thence distilled" (no. 831).

The avenue through which the cerebro-spinal liquid, the nervous juice, reaches the choroid plexuses is through the velum interpositum, which communicates on the one hand with the subarachnoid space; and on the other, according to Key and Retzius, "enters into a most intimate conjunction with the 'lower leaf' of the choroid plexuses in the lateral ventricles" (see Vol. I., p. 602, *et seq.*).

That there is such a communication between the choroid plexuses of the lateral ventricles and the subarachnoid space, is proved by the experiments instituted by M. Sée [1] and Quincke. The former says, "By experiments, we learn abundantly that the liquids of the

[1] Sée (le docteur Marc). "Sur la communication des cavités ventriculaires de l'encéphale." In "Revue mensuelle de Médecine et Chirurgie," Vol. III. for 1879; pp. 302-306. Paris.

subarachnoid spaces are able to penetrate into the cerebral ventricles by filtering through the pia mater across the middle portion of the large fissure of Bichat. . . . . In those cases where the experiment has been perfectly successful, the coloured liquid is found in the cerebral ventricles and in the aqueduct of Sylvius, and an accumulation of the coloured mass is noticed in the velum interpositum and in the choroid plexuses. But the most instructive cases are those where for some reason or other the injection has remained incomplete, because then you are able to trace in some measure the course of the liquid, and the road which it has followed. It thus has repeatedly happened to me, to find the velum interpositum dyed blue throughout its entire thickness, and the middle and lateral ventricles filled with the injected liquid, without the least particle of the dye having penetrated into the fourth ventricle."

Quincke,[1] who injected an emulsion of vermilion into the subarachnoid space of the brains, of living dogs, states as the result of his experiment: "The lateral ventricle seems also to communicate with the subarachnoid space in the neighbourhood of the Vena magna Galeni, where the subarachnoid tissue is more loose (the 'confluent supérieur' of Magendie)—which place must not be confounded with the 'foramen of Bichat,' through which a communication used to take place with the subdural space proper; for this foramen is an artificial product. . . . . How the vermilion in three cases, after subarachnoidal injections, found its way into the epithelia of the choroid plexuses, I am unable to state with certainty. It accumulated there so copiously, that to the naked eye the plexus appeared totally dyed red; in the connective tissue stroma of the plexus the vermilion was found only here and there, in stray lymphatic corpuscles."

That the cerebellar or cerebro-spinal liquid, under certain conditions, mixes with the cerebellar or ventricular liquid which contains the elements of the white lymphatic blood, follows from this general position of Swedenborg's theory of the cerebro-spinal liquid; namely, that the various lymphs and serosities which pass under this name are all contained in the first place in the red blood, and that they are derived thence through a resolution of the blood into its constituent elements, in the substance of the brain. As the cerebral and cerebellar liquids are thus derived from the same original source,

[1] Quincke (Dr. H.). "Zur Physiologie der Cerebrospinalflüssigkeit." In the "Archiv für Anatomie, Physiologie, und wissenschaftliche Medicin," for 1872. Berlin.

they are able, under certain conditions, to be of assistance to each other, and thus to be commingled.

5. Concerning the discharge of an infected serosity from the lateral ventricle, Swedenborg says, that "it is emitted through some apertures and passages which are not yet discovered; for wherever there is a liquid, there also are ducts or asylums for the evacuations" (see Vol. I., Note iii., p. 759). Such an "asylum" or place of evacuation *Mierziewsky*[1] discovered by his injections in the descending cornu of the lateral ventricle where, according to his statement, "the fissure through which the communication between the lateral ventricle and the subarachnoid space is effected, extends from the corpora quadrigemina to the gyrus uncinatus" (see above, Vol. I., p. 758).

This same "asylum" is also pointed out by M. Sée,[2] who states that a communication between the lateral ventricle and the subarachnoid space is effected through the "descending cornu" of the ventricle. He says, moreover, that the area of this communication "is not as large as that of the velum interpositum." Nevertheless, he adds, "the injection of the velum interpositum sometimes was less complete, while at the same time the impregnation of the pia mater with a solution of Prussian blue could easily be traced across the descending cornu of the lateral ventricles."

The final excretion of this vitiated serosity takes place into the venous sinuses of the dura mater, through the mediation of the Pacchionian corpuscles; concerning which see below, no. 35.

c. THE FOURTH VENTRICLE AND ITS COMMUNICATION WITH THE SUBARACHNOID SPACE.

6. Concerning the channels by which the cerebellar, that is, the cerebro-spinal liquid is discharged from the fourth ventricle, Swedenborg says:

"In respect to the excretory duct of the lymph contained in the fourth ventricle, this ventricle indeed has no outwardly visible duct of this kind, as is the case with the cavities of other glands. But from the fact that the connection between this ventricle and the double lamina of the pia mater is interrupted by clefts, it appears that this lymph is expressed and excreted between the duplicature, that is, between the pia mater and the arachnoid membrane. For

[1] Mierziewski (Dr. J.). "Die Ventrikel des Gehirns." In the "Centralblatt für die medicinischen Wissenschaften," September 28, 1872. Berlin.

[2] "Op. citat.," p. 302, *et seq.*

the interior lamina of the pia mater—*i.e.* the pia proper—invests the ventricle itself, while the exterior lamina—the arachnoidea—passes around over it; and the duplicature appears remarkably thick-set and voluminous around the terminus of the calamus scriptorius, so that, according to Ridley's observation, in dropsical subjects it is found turgid with serum.

"It follows hence, that the lymph of this cistern and of the choroid plexus is discharged into the duplicature between the pia mater and the arachnoid membrane, and that thence through the continuous and customary ducts and follicles of the arachnoid membrane it is derived especially into the posterior part of the medulla oblongata, where that membrane floats about quite thickly and loosely" (no. 714).

Swedenborg speaks here plainly of a cleft at the terminus of the calamus scriptorius, through which the contents of the fourth ventricle are discharged into the subarachnoid space. The existence of this cleft or foramen is now beginning to be admitted in our text books, and by Luschka was called the foramen Magendii.

An opening from the fourth ventricle into the subarachnoid space was already known to Haller; for in Vol. iv. of his "Elementa Physiologiæ," etc. (Lausanne, 1757-1776), he says, "Where the choroid plexus passes out of the ventricle, water easily makes a way for itself into the space which surrounds the spinal cord" (p. 77). This opening, however, was denied again by A. Monro, who said in his "Observations on the Structure and Functions of the Nervous System," in 1783, "The bottom of the fourth ventricle has no such communications with the cavity of the spinal marrow, as Dr. Haller supposed, being completely shut by the choroid plexus and pia mater" (chap. iv., section 1).

Magendie, whose labours in connection with the cerebro-spinal liquid began in 1825, demonstrated beyond any reasonable doubt the normal existence at the extremity of the calamus scriptorius of that opening which was first pointed out by Swedenborg in 1743. His description of this foramen, as given by Key and Retzius, is as follows: "Magendie discovered a real, constant, and normal aperture, through which the cerebro-spinal fluid perpetually passes, in order to enter and leave the fourth ventricle. This aperture is situated at the lower extremity of the fourth ventricle, which by the older anatomists was called the calamus scriptorius. In order to convince yourself of the existence of this opening, all you have to do is to raise a little the edges of the inferior vermiform process of the cerebellum, and draw them apart. Without tearing any of the tissues whereby the vessels of this portion of the cerebellum are attached to the pia mater, you will then see an actual inlet terminating in the fourth ventricle," etc. (see above, no. 704*j*).

In another place the Swedish authors give an account of the subsequent history of this foramen after its existence had been established by Magendie. They say, "If Magendie's doctrine of the cerebro-spinal fluid and of the place it occupies, only very slowly and gradually came to be acknowleged by the learned, his description of the foramen under discussion met with still greater opposition at their hands. *Ecker*[1] and *Cruveilhier*,[2] it is true, declared themselves entirely in favour of its normal existence, and *Luschka*[3] gave a minute description of this foramen accompanied by a plate, which agrees on the main with that furnished by Magendie, in whose honour he termed the aperture 'foramen Magendii;' *Stilling*[4] also sided completely with these authors. Yet their united voices could not prevail on the learned to acknowledge openly the existence of this foramen; although here and there you would meet in text-books with a confirmatory statement of its actual existence. *Krause*[5] declares that the fourth ventricle is closed behind by the pia mater, and *Reichert*[6] asserts most positively that this aperture is entirely artificial, and that its origin is due to a tearing of the tissue in removing the brain out of the cranium. When *Kölliker*[7] also asserted that this foramen is not a natural aperture, he no doubt contributed much to the spread of the opposite doctrine. More recently *Henle*[8] described

[1] Ecker (A.). "Ueber die Cerebrospinalflüssigkeit." In "Archiv für physiologische Heilkunde," Zweiter Jahrgang, 1843.

[2] Cruveilhier (J.). "Traité d'Anatomie descriptive." English translation. London, 1842.

[3] Lusehka (v. H.). "Die Adergeflechte des menschlichen Gehirns," Berlin, 1858. Also in a later article, "Ueber dio Communication der vierten Hirnhöhle mit dem Subarachnoidalraume;" in "Zeitschrift für rationelle Medicin," dritte Reihe, Band iii., 1859.

[4] Stilling (B.). "Untersuchungen über den Bau des kleinen Gehirns des Menschen." Cassel, 1870. In the explanation of the plates. (Plates 5, 6, and 8.)

[5] Krause (C.). "Handbuch der menschlichen Anatomie." Second edition, Vol. i. Hanover, 1843.

[6] Reichert (C. B.). "Der Bau des menschlichen Gehirns." Zweite Abtheilung. Leipzig, 1861.

[7] Kölliker (Alb.). "Handbuch der Gewebelehre des Menschen." Fifth edition. Leipzig, 1867.

[8] Henle (J.). "Handbuch der systematischen Anatomie des Menchen." Band iii. Braunschweig, 1871.

this foramen briefly, and delineated it in full harmony with Magendie, Luschka, and Stilling; but as his sketch is not supported by injections, the same objections may be raised to his presentation. *We*—Key and Retzius [1]—demonstrated by injections made from the subarachnoid spaces, as well as from the ventricles, that the foramen Magendii is indeed not an artificial product caused by a laceration and bursting of the tissue, as asserted by Reichert; and this we proved by means of congealing injections which furnished complete casts of the foramen and the surrounding spaces" (i., p. 113).

Since the publication of the results which were obtained by Key and Retzius by their injections (concerning which see above, no. 704*l*), a description of the foramen of Magendie has gradually found its way into the leading text-books. Thus we read in the eighth edition of Quain's "Elements of Anatomy," published in 1876, "At the lower end of the [fourth] ventricle, there is, as was ascertained by Magendie, a narrow orifice in the membrane by which the cavity communicates with the subarachnoid space" (ii., p. 513). And in the ninth edition of 1882 we read, "The subarachnoid space communicates with the ventricles of the brain by means of the foramen of Magendie, the opening into the lower part of the ventricle, through the pia-matral expansion (tela choroidea inferior) which closes it" (ii., p. 376).

7. Other authors again, while admitting the genuineness of the foramen of Magendie, seem disinclined to allow it that importance which is claimed for it by Magendie, and Key and Retzius. Thus M. Sée, in communicating the results at which he arrived in experimenting upon this foramen, says,[2] "If, after placing the brain on its convex surface, you tear the arachnoid membrane which passes from the cerebellum to the bulb of the medulla oblongata; and if you then raise slightly the latter, you will at first discover under the arachnoid membrane a considerable quantity of connective and vascular trabeculæ extending in an irregular manner towards both organs. Afterwards, more deeply, you will observe a small lamina, irregular in form and cellular in appearance, which extends from the edges of the rhomboidal sinus—calamus scriptorius—as far as the amygdalæ of the cerebellum. This lamina where it is inserted into the cerebellum, possesses at first considerable resisting power, but gradually as it approaches the

[1] Axel Key and Gustav Retzius. "On the Communication of the Ventricles of the Brain with the Subarachnoid Spaces." In "Nordiskt Medicinskt Arkiv," Vol. vi., no. 5, 1874.

[2] Sée (le Dr. Marc). "Sur la communication des cavités ventriculaires de l'encéphale." In "Revue mensuelle," etc. Paris, 1879.

point or beak of the calamus scriptorius, where ordinarily an aperture —the *foramen of Magendie*—is observed, it becomes more and more attenuated. This foramen is of very variable dimensions, and seems to be only one of the lacunæ left between the connective fasciculi of the lamina. There is nothing regular about the edges of this orifice, and when it is examined under a magnifying glass, you will frequently notice that these edges are continuous with small trabeculæ or blood-vessels, which are the cause of the variation in form noticed in this foramen by the authors. Very often it also happens that the lamina is lacerated to a greater or less extent from its insertion in the internal edge of the corpora restiformia, and indeed in spite of all the precautions which you may take in raising the bulb of the medulla oblongata. This necessarily enlarges the foramen of Magendie ever so much, or else creates an accessory opening in its neighbourhood. At the level of its lower end, the foramen of Magendie affords a passage to the middle portion of the choroid plexus of the fourth ventricle.

"What is the signification of this lamina which thus closes imperfectly the cerebellar ventricle behind and below? An examination of its structure removes all doubts. When examined under the microscope, it exhibits two distinct strata. The one which is external or superficial is formed of fascicles of connective tissue which run in various directions; this stratum is continuous with the pia mater of the medulla oblongata and cerebellum, and presents the lowest portion of this membrane which is crowded or heaped up in a certain manner, where the two organs are mutually brought into juxtaposition. The other, the internal or deep layer, consists of a simple stratum of scaly or tesselated epithelium (*pavement epithelium*), the cells of which, arranged in regular mosaic order, contain voluminous nuclei. This deep layer represents the ventricular ependyma, and is continuous with the epithelial lining of the central canal of the spinal cord, and also with that on the floor of the fourth ventricle.

"The constitution of this ventricle is thus identical with that of the other ventricles and of the central canal of the cord, of which it is an enlargement. The difference only is, that its posterior wall, during its ascent, where the cerebellum is formed, is considerably thicker, while below it is almost totally deprived of nervous substance; so that the pia mater there is applied immediately to the ependyma. Besides, the meshes of the pia mater, in man, in the neighbourhood of the point or beak of the calamus scriptorius, are very much larger, and in the majority of cases they form an opening through which the fourth ventricle communicates with the subarachnoid space.

"Still it must not be supposed that this communication is as large and as easy as it appears when the bulb of the medulla oblongata is raised up. When the parts are in their natural position, and when the medulla oblongata occupies the gutter left for it by the amygdalæ, it is probable that the foramen Magendii is almost entirely stopped up, and allows the passage of a liquid only under the influence of a certain pressure. At least such has been the result of my experiments on dead bodies. In my injections, even in those that have succeeded best, I have almost constantly seen the coloured liquid infiltrating the pia mater of the medulla oblongata as far as the calamus scriptorius, and thence spreading itself over the pia mater of the cerebellum at the foramen Magendii; so that the bottom of the fourth ventricle remained perfectly white" (pp. 300-304).

In summing up the results of his experiments concerning the foramen of Magendie, M. Sée says, "The foramen of Magendie does not possess that importance which is attributed to it, and its obliteration, which is normal in certain classes of animals, does not cause any trouble in the mechanism of the circulation of the cerebro-spinal liquid" (p. 304).

The objections of M. Sée may be partly answered on these grounds, that the passage of an injection through the foramen Magendii would probably be easier in a living and warm body, than in one which is dead and cold. Besides, a liquid rushing directly against the foramen from within through the calamus scriptorius would presumably experience less difficulty in finding the opening than a diffuse, general injection made into the subarachnoid space; especially if, according to Quincke's experiments, the foramen in question does not admit in the living body, and thus in a natural state, any liquid into the fourth ventricle. His language is: "This negative result shows that it is impossible for a current of this liquid to take place *into* the ventricles; just as little as there is an alternate influx and efflux of this liquid, caused as a collateral result by the flux of the cerebro-spinal fluid under the influence of respiration. If we must still admit an opening in the posterior part of the fourth ventricle, there remains now only the possibility of the flow of a liquid *out of* the fourth ventricle; which possibility is supported by the opinion of those anatomists according to whom the choroid plexuses are organs of secretion" (*Op. cit.*, p. 172).

8. In addition to the foramen Magendii at the extremity of the

calamus scriptorius, Luschka discovered two lateral openings leading from the fourth ventricle into the subarachnoid spaces. His description is as follows:[1] "On either side the outer angles of the fourth ventricle assume the form of a gutter leading outside, whereby the lateral portion of the choroid plexus passes outside of the fourth ventricle, while the arachnoidea stretches freely over the place in question. The fourth ventricle, therefore, by its exterior angles, has an open communication with the subarachnoid space. The hiatus, however, where the pia mater passes over into the ependyma, through the lateral portion of the choroid plexus of the fourth ventricle, is so much contracted that only a narrow slit remains, which, nevertheless, is sufficiently ample to grant an entrance here, under the arachnoidea, to a liquid which is injected from below with a tubulus, the tela choroidea inferior still being fully preserved. This anatomical fact is of considerable importance, because in some animals, for instance the horse, the lower extremity of the fourth ventricle is completely closed up, in which case the exterior angles of this cavity are the only means whereby a communication may be effected between the fourth ventricle and the subarachnoid space."

The existence of these lateral foramina of Luschka has been fully confirmed by Key and Retzius (see above, no. 704*l*); it is also acknowledged in the Ninth Edition of Quain's "Elements of Anatomy" (1882) in these words: "Two other openings through the tela choroidea inferior exist, one on each side behind the upper roots of the glosso-pharyngeal nerve, in the pouch-like extension of this membrane beneath the flocculus" (ii., p. 376).

M. Sée,[2] while admitting the existence of these lateral foramina and giving an exact description of the same, impugns the fact of their being the chief outlets of the fourth ventricle, and indeed on the same grounds on which he opposes the idea of the foramen of Magendie being regarded in this light. His description is as follows: "At the level of the lateral angles of the fourth ventricle, the conjunctivo-epithelial lamina—the tela choroidea inferior—is prolonged outside as far as the pedicle of the flocculus, where its conjunctivo-vascular portion is continued into the pia mater of the cerebellum. There, just as at the lower angle of the ventricle, appears a very neat lacuna, in the form of a cleft, which allows a passage to the lateral portion of the choroid plexus of the fourth ventricle. Immediately after its passage outside of the ventricle,

[1] Luschka (v. H.). "Adergeflechte," etc. Berlin, 1855.
[2] "Op. citat.," p. 302.

this plexus becomes enlarged, and finally terminates in the form of a swollen club-like extension, which plunges into the subarachnoid space and covers the roots of the glosso-pharyngeal and pneumogastric nerves. In addition to the foramen of Magendie, the fourth ventricle thus presents two lateral orifices—the foramina of Luschka—which in a like manner are traversed by a prolongation of the choroid plexuses, establishing by the same means communications between the ventricular cavity and the subarachnoid space. The same considerations apply to these lateral apertures, which above [in no. 7] were made in connection with the lower orifice, that is, the foramen of Magendie."

d. The Central Canal of the Spinal Cord.

9. Swedenborg, as we have shown in the last section, was well acquainted with the aperture at the lower extremity of the fourth ventricle, which is known as the foramen of Magendie. His theory, however, is not satisfied with one class of foramina only, through which the cerebro-spinal liquid is conveyed simply into the subarachnoid space. These foramina answer for the cerebellar fluid after it is mixed with the grosser serum secreted from the choroid plexus, which mixture constitutes the cerebro-spinal liquid proper or the subarachnoid fluid. A more refined kind of liquid, however, circulates in the spaces by which the individual fibres in the medulla of the cord and in the departing nerve-roots are surrounded. This more refined kind of liquid distils into the fourth ventricle out of the peduncles or processes of the cerebellum; and in order to convey it into the interior of the spinal cord, another foramen is required which leads from the fourth ventricle immediately into the medulla of the cord. On this account Swedenborg, after describing the aperture in the lower part of the calamus scriptorius through which there is a discharge into the subarachnoid space, says: "Whether there be still other channels for the discharge of the lymph [from the fourth ventricle]; namely, whether such a channel open immediately from the calamus scriptorius into the medullary portion of the spinal cord, to my knowledge has not yet been discovered. For this purpose the fourth ventricle is contracted into the narrow form of a goose-quill" (no. 714).

10. A cavity of this description, which runs through the interior of the spinal cord, according to Swedenborg, is not only required for

ministering properly to the uses of the cerebro-spinal liquid; but also for enabling the spinal cord to go through its general systaltic and diastaltic motion in connection with the cerebrum and cerebellum; so that a hollow axis in the interior of the spinal cord, which is continued to the cerebellum and cerebrum, is a requirement also of Swedenborg's theory of the movement of the brain. On this subject he says, "If any one examines the form of the cerebrum more thoroughly, and if he contemplates its members, anfractuosities, protuberances, cavities, and parts under one gaze, he easily recognises that all things in it, in general and in particular, are formed in agreement with the inmost laws of nature, so as to be in a perpetual state of motion. For there are in it axes, centres, poles, or again, larger and smaller gyres, which furnish it with power, and which have this effect, that the cerebrum undergoes its alternate motion as it were spontaneously and naturally, without any effort at expansion and constriction.

"There are two *axes*—the longitudinal and the transverse. The *longitudinal axis* runs through the middle of the cerebrum and the medulla oblongata; from the septum lucidum, under the body of the fornix, through the third ventricle and the aqueduct to the fourth ventricle and the calamus scriptorius, and sometimes further into certain cavities of the spinal marrow on the back; there, besides, it is inflected and continued through the anterior fissure of the same spinal cord down to the cauda equina. This axis is hollow, and is interrupted by certain obstructions or septa; as, for instance, at either end of the third ventricle, then again by the valve of Vieussens, and afterwards in several other places. It may also be traced on the external face of the cerebrum; for instance, through the deep fissure between the umbones or the protuberances in front of the brain, and also by the interstice between the hemispheres under the longitudinal sinus. The *transverse axis*, however, runs from the middle of the occipital bone through the straight sinus into the third ventricle; and afterwards through the infundibulum into the pituitary gland, near the sella turcica of the sphenoid bone. This axis also is hollow and interpolated in a like manner. Both axes are for the purpose of conveying the fluids of the cerebrum; the transverse axis, however, for conveying the spirituous essences, as well as the blood" (I., nos. 104*d*, 104*e*).

In Part II. of the present work, Swedenborg says in respect to the longitudinal axis of the brain, "I speak here of the axis of the whole encephalon: There is a certain perpetual duct or canal beginning at the fissure between the frontal [illegible] of the [illegible], progressing under the base of the brain, through the third ventricle, the aqueduct of Sylvius and the [illegible], and continued into the spinal marrow, where it projects itself from the center unto the surface, after passing through the great [illegible] of the brain. The individual [illegible] of the grey substance of the cerebellum [illegible], and if they are not [illegible], they are at least [illegible] in respect to the form and [illegible] of their motion. [illegible] that such a [illegible], such a [illegible] and motion as that of the brain, cannot take place without having respect to [illegible] and pores. [illegible] we ask [illegible] where the brain, while the [illegible] and parts are [illegible]—where had I [illegible] all [illegible] by their explanation?" (III., no. [illegible]).

Immediately afterwards our author says: "It is a geometrical truth that where there are pores and [illegible], there also is spiral fluxion; and that where there is a spiral fluxion, there also are pores and [illegible], and larger and smaller pores, altogether as in the large [illegible] sphere" (III., no. [illegible]).

11. Inasmuch as the motion of the brain—which is inherent in the brain, and not derived from the motion of the heart nor from that of the lungs, although it is synchronous with the latter—is a fundamental principle of Swedenborg's theory of the brain, which, as we have shown in Note [illegible], is fully confirmed by all the facts of modern science; and inasmuch as a motion like that of the brain, which is spiral, requires pores and [illegible]; it follows that the existence of a hollow axis from the highest part of the [illegible] near the [illegible] to the [illegible] is a [illegible] postulate of Swedenborg's theory of the brain. Such a hollow axis governing the motion of the [illegible], [illegible] in accordance with the [illegible] of [illegible] [illegible] to the [illegible], [illegible] to the [illegible] of the [illegible]. [illegible] of the [illegible], and [illegible] of the existence of such a hollow axis even in the spinal cord, he was forced to believe, on the evidence of the facts of science known to him in [illegible], [illegible] the [illegible] "projects itself from the center upon the surface," and is confirmed by the anterior [illegible] of the spinal cord.

How essential, however, for the proper accomplishment of the [illegible] and [illegible] motion of the spinal cord, Swedenborg considered the presence of a cavity in its interior, appears from the following passage: "In order that the spinal cord may put on [illegible] conveniently special or individual changes in its state of motion, or that it may apply itself to the individual motions of the cerebrum, cavities or hollows are sometimes formed in the spinal cord of the neck; sometimes also in some lower parts of the cord. Wherever a cavity is, there also exists a better disposition for all the acts which the cerebrum intends to produce in the body. Those persons, consequently, with whom there are such cavities in the spinal cord, may be considered as more apt for the production of such acts as are voluntary and natural at the same time" (no. 814).

The existence of such spaces Swedenborg learned from Morgagni, and he maintained that the cerebellar fluid of the fourth ventricle is discharged into them. On this subject he says in his earlier work on the Brain, "The moisture of the cerebellum is afterwards received by another cavity in the medulla of the neck, and at last by several additional cavities in the medulla of the spine. But," he continues, "whether these cavities are continuous I do not know, and I even hesitate in believing it" (no. 715*j*).

In his later work on the Brain, however, the one now published, Swedenborg does not hesitate to express his belief that there is such a hollow axis in the spinal cord; for "although," he says, "to my knowledge it has not yet been discovered whether a channel for the discharge of the lymph of the fourth ventricle opens immediately from the calamus scriptorius into the medullary portion of the spinal cord. Still," he adds, "for this purpose the fourth ventricle is contracted into the narrow form of a goose-quill" (no. 714). He thus is evidently confident that this central canal in the spinal cord will some day be discovered.

12. *Morgagni's*[1] statement, quoted by Swedenborg in Part I., no. 803 (in Vol. III. of the present work), is as follows: "Other human bodies again there are, where in addition to the anterior and posterior fissures of the spinal cord, there is noticed without any difficulty a small hollow or canal which runs down longitudinally in the middle of the substance of the upper part of the spinal marrow. Of this nature was especially the body of a Venetian fisherman, where, after dividing the spinal cord from the medulla oblongata by a transverse section, I noticed, in company with Santorini, a cavity which almost admitted the tip of the small finger, and which was continued downwards to the distance of five finger-breadths, and perhaps further, if any one had then had time to take out the spinal

[1] Morgagni (J. B.). "Adversaria Anatomica" vi. Animadversio xiv. Leyden, 1740.

cord from the vertebral column to a greater distance. This hollow or canal occupied the middle of the cord, except that it was nearer to the dorsal surface; the fissures, however, as I could plainly see, did not reach to this canal. Besides, the surface of this canal and the neighbouring parts consisted of grey matter, nor was there anything connected with it which I did not deem in full harmony with nature, except that this canal was very large" (pp. 17, 18). Nevertheless, Morgagni, at the same time, made a statement to this effect, that "the so-called calamus scriptorius is continued in the dorsal surface of the cord into its posterior fissure."

The existence of this central canal in the spinal cord was again asserted by Portal, and afterwards by Gall and Spurzheim, and more recently by Stilling and Wallach;[1] yet as late as 1847, in the second edition of his work on the "Human Brain," *Solly* says, "I am glad to think that, notwithstanding the opinions of Drs. Stilling and Wallach, regarding the existence of a canal in the spinal cord, and this in the grey substance, my denial of its existence is supported by the observations of Dr. Todd, who says, 'I have never, after numberless experiments, been able to see it'" (p. 199, *et seq.*).

By the recent investigations, however, of R. Wagner,[2] Owsjannikow,[3] Schröder v. d. Kolk,[4] v. Lenhossek,[5] Lockhart Clarke,[6] Stilling,[7] Bidder,[8] the existence of a central canal in the spinal cord is established beyond a doubt. *Henle*,[9] from whom we quote the above authorities, says on the subject, "By the improved methods of investigation of modern times, and especially by the microscopical

[1] Stilling and Wallach. "Untersuchung über die Textur des Rückenmarks." Leipzig, 1842.

[2] Wagner (R.). "Neurologische Untersuchungen." Göttingen, 1854.

[3] Owsjannikow (P.). "Disquisitio microscopica de medullæ spinalis textura." Dorpat, 1854.

[4] Schröder v. d. Kolk. "Anatomisch-physiologisch onderzoek over het fijnere zamenstel en de werking van het ruggemerg." Amsterdam, 1854.

[5] Lenhossek (Jos. v.). "Neue Untersuchungen über den Bau des centralen Nervensystems." Wien, 1855.

[6] Clarke (Lockhart). "Further Researches on the Grey Substance of the Spinal Cord." In "Philosophical Transactions," etc., for 1859. Vol. 149. London, 1860.

[7] Stilling (B.). "Neuere Untersuchungen über den Bau des Rückenmarks." Cassel, 1857.

[8] Bidder and Kupffer. "Untersuchungen über die Textur des Rückenmarks." Leipzig, 1857.

[9] Henle (J.). "Handbuch der systematischen Anatomie des Menschen," Part III. Braunschweig, 1871; p. 43.

examination of thin, horizontal sections, it has been placed beyond doubt that the central canal, which was formerly considered as a formation peculiar to the fetus, and which in adults was allowed to exist only in the cervical portion of the spinal cord, is of regular occurrence in all vertebrata of all ages, and in every part of the spinal cord. A difference of opinion, however, still prevails on the question whether there are not more or less frequent exceptions to this rule. The following observers admit the absolute constancy of the central canal: Bidder (p. 41), Owsjannikow (p. 33), R. Wagner (p. 166), Schröder van der Kolk (p. 51), and Stilling (p. 14); and they are of the opinion that the non-discovery of this canal is due to a fault in the method of preparation or of hardening. According to Foville,[1] this canal is constant in children, and easily demonstrable in their case, but not so easily in adults. Kölliker, on the contrary, firmly maintains that not unfrequently the central canal becomes obliterated, chiefly in the cervical portion; in which case it is replaced by a cord of cells which partly contain several nuclei. Among twenty-five spinal cords, Frommann[2] found only three where the central canal was open, in all the rest there was instead an agglomeration of nucleolar cells which carried blood-vessels. Clarke (p. 455) also often noticed the canal filled up with grains or nuclei, which he supposed to be remnants of epithelium; yet in the midst of this irregular agglomeration of grains, he saw the horizontal section of a simple, sometimes also of a double lumen, lined with epithelium" (p. 43).

Schwalbe[3] says on the same subject, "The central canal is frequently found obliterated in many places with adults, especially in the cervical portion of the cord (Kölliker). According to Goll its obliteration in the cervical part is constant. . . . The obliteration is most probably caused by a cellular material arising from epithelium; not unfrequently blood-vessels are noticed within the range of the former central canal. I myself noticed an obliteration of the canal by a solid epithelial plug, whose central cells still exhibited a radiated arrangement" (p. 344).

[1] Foville. "Traité complet de l'anatomie, de la physiologie et de la pathologie du système nerveux cérébro-spinal," I partie. Paris, 1844; p. 268.

[2] Frommann (C.). "Untersuchungen über die normale und pathologische Anatomie des Rückenmarks." Jena, 1864; p. 62.

[3] Schwalbe (G.). "Lehrbuch der Neurologie;" Abtheilung 2, Band II. in Hoffmann's "Lehrbuch der Anatomie des Menschen." Second edition. Erlangen, 1881; p. 343.

The description of the central canal as given by *Gerlach*[1] is as follows: "The central canal is not of a uniform diameter throughout the cord, for it presents in transverse sections an ovaloid outline in the cervical region, a rounded one in the dorsal region, while in the lumbar region it has a more or less cordiform shape. It begins at the lower end of the fourth ventricle, and extends in man, as determined by Stilling, down into the *conus medullaris*, where it approaches nearer and nearer to the posterior longitudinal fissure, and finally unites with it. This canal is filled in young adults and children with the cerebro-spinal fluid; but in adults it is compressed, and, especially in the cervical region, obliterated; or, more properly speaking, choked up with the product of epithelial cell-proliferation, which begins to show itself soon after puberty; at least I found an evidence of it in the cord of a girl eighteen years of age. The innermost layer of the central canal is a tissue composed of cylindrical epithelial cells which in children exhibit vibratile cilia, which are lost in later years" (p. 640).

In *Quain*[1] we read, "Extending through the whole length of the spinal cord, in the substance of the grey commissure, there is a minute central canal, which, in prepared transverse sections of the cord, is barely visible as a speck with the naked eye. Superiorly, it is continued into and opens out at the calamus scriptorius of the fourth ventricle; and inferiorly, at the extremity of the conus medullaris, it becomes enlarged, shaped like the letter T, and extends backwards to the surface of the cord, being covered in only by pia mater and connective tissue. . . . It is more distinctly seen in fishes, reptiles, and birds, than in mammals" (II., p. 496).

13. In this varied description of the central canal by the different authors, it must not be forgotten, that we have to do here with the spinal cord, and thus with the central canal, in a state of collapse. From the fact, therefore, that in some, perhaps in many cases, this canal, when in such a collapsed state, seems to be obliterated, or at least choked up by epithelial formations, it does not follow that in a living subject, and thus when the spinal cord is undergoing its expansile motion, this canal does not grant a passage to a highly refined lymph. Clarke, at least, even when he found the canal filled up with grains, in the midst of their agglomeration observed the horizontal section of a simple, and sometimes also of a double lumen,

[1] Gerlach (J.). "The Spinal Cord," in Stricker's "Manual of Histology." New York, 1872.

[2] Quain. "Elements of Anatomy." EIGHTH EDITION. London, 1876.

lined with epithelium; thus showing that even in those cases where the canal seems entirely choked up with epithelium, there is still an uninterrupted passage left between the epithelium. Besides, the epithelial cells themselves, when filling up entirely the lumen of the canal, would only strain the liquid pumped into the canal from the fourth ventricle, but would not obstruct the passage of this liquid through the central canal.

The authors, however, differ further as to the place of discharge of the lymph contained in the spinal canal. Thus Gerlach, on the authority of Stilling, declares that "in the conus medullaris this canal approaches nearer and nearer to the posterior longitudinal fissure, and finally unites with it." While Quain admits that "at the extremity of the conus medullaris it extends backwards to the surface of the cord, being covered in only by pia mater and connective tissue." Schwalbe, however, on the authority of W. Krause, maintains that the central canal is continued from the conus medullaris into the filum terminale, where at last it terminates blindly. Schwalbe's[1] entire description of the central canal is as follows: "The central canal which is enclosed in the grey commissure varies in shape and size in the different regions of the spinal cord. It is least in width in the dorsal region; its diameter there amounts to 0,045 to 0,1 mm., and in horizontal sections its shape is generally circular. This circular shape becomes oval beyond the cervical enlargement, and beyond the lumbar enlargement the canal is altered into a sagittal cleft. This same sagittal shape the canal also assumes as it approaches the medulla oblongata from the cervical enlargement. In the greater part of the cord the canal lies nearer to its anterior or ventral, than to its posterior or dorsal surface; its distance from the latter is almost twice as large as from the former. In the lumbar enlargement its situation is about equidistant from either surface; and in proportion as the dorso-ventral cleft, by which it is represented in the conus medullaris, increases in size, it gradually draws very near to the posterior longitudinal fissure of the cord, and thus to the surface of the cord. On this account it was formerly believed (*e.g.* by Stilling) that the central canal right here has an opening into the posterior longitudinal fissure. It has been demonstrated, however, by W. Krause,[2] that the central canal at this place,

[1] "Op. cit.," p. 340, *et seq.*

[2] Krause (W.). "Ueber den Ventriculus terminalis des Rückenmarks." In "Archiv für mikroskopische Anatomie," vol. xi., p. 216; and in "Centralblatt für medicinische Wissenschaften." Berlin, 1876.

as well as everywhere else, is completely closed up, only it becomes considerably enlarged at the lower extremity of the conus medullaris. This terminal enlargement of the central canal W. Krause calls 'ventriculus terminalis.' It usually exhibits a triangular shape in horizontal sections with the base in front and the point directed towards the posterior longitudinal fissure. Its length amounts to 8-10 mm., its width to 0,5 to 2 mm. (generally only to 0,6 to 1 mm.), and its depth to 0,4 to 1,1 mm. Since the posterior border of this small ventricle consists only of a thin layer of substance, which is easily torn in subjects not perfectly fresh, the statement made by earlier observers respecting an opening of the central canal at the lower end of the conus medullaris becomes intelligible. At the transition of the conus medullaris into the filum terminale, the ventriculus terminalis, after a considerable reduction in its caliber, continues its course in the form of an attenuated canal, which may be traced in the filum for about half its length, where it finally terminates blindly."

On the question in what way this description of the central canal agrees with Swedenborg's theory of the cerebro-spinal liquid, we reply: According to Swedenborg's doctrine there is a minute correspondence between the membranes and coatings of the human body, and the liquids which they carry. The finer, therefore, a membrane, the more refined the liquid which it contains. Now, since the membranulæ derived from the pia mater, by which the interstitial spaces between the individual nervous fibres are bounded, are most attenuated, it follows that the liquid coursing through these membranulæ must be equally refined. A liquid of this description is secreted from the minute capillaries in the neighbourhood of the cortical glandulæ or nerve-cells of the spinal cord; and the same kind of liquid also is furnished to the spinal cord from the fourth ventricle through the central canal. In the fourth ventricle itself, this refined lymph is mixed with serosities of a lower order. These serosities are unable to penetrate through the epithelial lining of the central canal, while the refined lymph itself is freely received in the epithelial cells, and is transmitted thence, as required, into the interstices between those fibres which are intended for the anterior and posterior nervous roots. In childhood and youth, so long as the cavity in the central canal remains open, the ventricular liquid would freely pass and repass through the entire central canal, and during its passage would part with its refined lymph to the epithelial cells, by which it is lined. But by and by, as the spinal canal begins to be choked up by epithelial accumulations, especially in its cervical portion, only the refined lymph would be able to pass through the epithelial stratum, while the grosser serositics, which are denied admission, would at once be returned to the fourth ventricle, in order to be discharged thence into the subarachnoid space through the foramina of Magendie and Luschka. The refined lymph, however, after entering the epithelial stratum, would gradually make its way through the central canal, until finally it would reach the ventriculus terminalis of Krause, where any surplus of lymph would transpire into the subarachnoid space through the pia matral covering of the cord.

e. The General Purpose and final Destiny of the Cerebro-Spinal Liquid.

14. Before discussing the general purpose and the final destiny of the cerebro-spinal liquid in the light of Swedenborg's theory, and in that of modern science, we deem it necessary to remind our readers of the fact that although Swedenborg divined the existence of the central canal of the spinal cord, and although this canal constitutes a necessary link in his theory of the brain—still its existence was not a scientific fact at his time, and, consequently, in deference to his own principle of investigation, he did not consider himself at liberty to make use of this undiscovered canal in his inductions respecting the course and destiny of the cerebro-spinal liquid. Although, therefore, the existence of the central canal, which has now become a scientific fact, enables us to declare in full harmony with Swedenborg's theory of the brain, that the refined lymph, described above in no. 13, is secreted from the cerebro-spinal liquid, before it is discharged from the fourth ventricle—still, Swedenborg himself, on the basis of the facts of science, as they were known to him, felt himself bound to declare that the cerebro-spinal liquid is discharged from the fourth ventricle in that general condition in which it is, before the refined lymph specified above is secreted from it through the mediation of the central canal of the spinal cord.

With this preliminary caution our readers will be enabled to appreciate thoroughly the following extracts from Swedenborg's theory of the brain, concerning the final destiny of the cerebro-spinal liquid.

The general purpose of the cerebro-spinal liquid, according to our author, is to lubricate and moisten the spaces which exist between the fibres and fasciculi in the interiors of the nerves. His statement concerning these spaces is as follows:

"The genuine fibre itself is pervious; between the fibres there are small interstices; other interstices of the same kind, but larger, exist between the fasciculi of the fibres, and also between the general coatings of the nerve itself, or between those by which the fascicles are bound together. Upon the well-ordered and distinct arrangement of these spaces and their communications, and upon their permeability, depends altogether the health and integrity of the bodily system, the faculty of the fibre of obeying the brain, and the freedom required by it for action in the body, that is, in the appended muscle, gland, joint, member, and viscus" (IV., no. 70).

"There are spaces between the fibres, and there are still larger ones between the fascicles of the fibres. For the fibres are small tubes which are not fastened to the neighbouring fibres, and the fascicles are round cylinders, distinct from the neighbouring ones. Inasmuch as every fibre, yea, every fascicle of fibres, flows forth from its own origins in the two brains, and descends thence into the body for the purpose of doing there its own work, every fibre and every fascicle requires to be detached from its own associate and neighbouring fibres and fascicles, and should not touch them, except in their highest, topmost points of contact. Otherwise the individual forces and acts would coalesce confusedly into one general indistinct act. . . . Such is the condition of the fibres, fascicles, and nerves in the flower of man's age, but it is altogether different in the winter-time of old age. As many spaces, therefore, as are open throughout the nerves, just so many avenues are there prepared for liquids. . . . Nevertheless not the same kind of humour circulates through the spaces between the fascicles, as passes through the small spaces between the fibres, or again as runs through the very tubules of the fibres" (Part II., nos. 350-352).

A general statement concerning the lymph which courses through the spaces in the interiors of the nerves, Swedenborg makes in the following passage:

"The lymph which is contained under the arachnoid membrane circulates between the medullary fibres of the brain and the nervous fibres of the body. Without such a perennial source, and without a lymph flowing between them, the fibres would easily coalesce; whereby the individual or single forces of the nerves and muscles would run together into such as are merely general; as is usually the case in persons where the motory fibres no longer yield obedience to the mind. Wherefore this lymph is like an ointment which oils, smoothes, and lubricates the hinges. This same lymph is derived between the laminæ of the fascicles of the nerve. Every fascicle of fibres within the cranium and the vertebral theca is called the root of a nerve, and is covered with a double or triple coating; the inmost of which has respect to the fibres, but the outermost to its associate fibres in the nerve. These laminæ are kept apart and prevented from coalescing by a juice of a most subtle quality. This juice is none other than that which runs between the fibres, or which is also reserved for this use under the arachnoid membrane. The arachnoid membrane not only covers the cerebrum and cerebellum, but it accompanies also the roots of the nerves in the cranium, as well as in the spinal cord, as far as their outlets; thus sprinkling its noble juice between the laminæ of the nervous roots, as it does between the fibres. It appears as if the arachnoid membrane had chiefly the care of the nerves of the body under its charge" (no. 715*r*).

This same lymph or cerebro-spinal liquid, which is derived from the fourth ventricle, is supplied by the arachnoid membrane to the medulla oblongata in its widest sense, as well as to the spinal cord. It thus provides for the cranial nerves which start from the medulla oblongata, as well as for those which proceed from the spinal cord. A general statement to this effect Swedenborg makes in the following passage: "The fourth ventricle supplies also a noble and most highly-gifted juice impregnated with spirit to the roots of the nerves, and hands it for distribution to the medulla oblongata, and especially to the spinal cord" (no. 712).

The wants of the medulla oblongata having been supplied, the rest of the cerebro-spinal liquid, that is, of the future nervous juice, is dispatched to the spinal cord. This follows from the following statement of Swedenborg: "When the ventricle expresses this liquid out of its drawn-up edges, an open course is left for it down the spinal cord. For in the foramen magnum of the occipital bone the spinal cord does not adhere to the dura mater, nor is it united with it in the back and at the sides, but only in front. Now since the whole of the liquid which is expressed from the cerebellum is harmless and spirituous, it is for this very reason fit to enter the roots of the nerves which require such a humour. Without such a moisture, or without some interstitial juice, these busy nerves would be dried up and deprived of the faculty of attending to their duties. For all intermediate spaces, wherever they are, whether in membranes or in nerves, require to be filled with a suitable, appropriate juice, so as not to become sinewy. And as to the spinal cord itself, it cannot supply such a copious juice as would answer to the activity of the nerves, and to the continuous waste of the same; wherefore it seems constantly to be under the necessity of borrowing this juice from the cerebellum. On this account also the arachnoid membrane of the spinal cord, that is, its general lymphatic duct, is denser, and floats around it more loosely; and it determines the juice which is confined under it towards either roots, the anterior as well as the posterior" (no. 715*h*).

15. If now the question is asked how far modern experience bears out Swedenborg's theory of a liquid which circulates through the interstices in the interior of the nerves, which liquid is identical with the subarachnoid, that is, the cerebro-spinal liquid—we are first of all able to declare that *Cotugno* in 1764, in his treatise entitled, *De ischiade nervosa commentarius*, proved experimentally the continuity of the subarachnoid space with the interstitial spaces in the spinal nerves, beyond the spinal ganglia; he also maintained that the cerebro-spinal liquid circulates through these spaces, and he explained the origin of the disease, known as "sciatica," by a deterioration of this interstitial liquid. The experiments by which he proved this continuity, as is shown above in no. 704*r*, consisted in his driving air and mercury through the open sheath of a spinal nerve this side the spinal ganglion, into the cellular sheaths of this same nerve on the further side of the ganglion.

This experiment, by which Cotugno proved unquestionably the continuity of the subarachnoid space around the spinal cord with the interstitial spaces in the sheaths of the peripheral spinal nerves, appears somehow to have escaped the attention of Key and Retzius, who otherwise have done full justice to this distinguished observer. They declare ("Studien," etc., II., p. 100) that "the history of the exploration of the lymph-paths in the peripheral nerves begins really with *Bogros*,[1] who by injections of mercury obtained the idea that the nerves are pierced by a comparatively narrow canal open to injections, and bounded by the various neural membranes. These injections, according to him, do not penetrate the nerve-roots; while in the direction of the peripheral terminations of the nerves, they are continued into ramifications invisible to the naked eye, as for instance into the muscles, skin, and mucous membrane." They add,

[1] Bogros in "Répertoire général d'anatomie et physiologie." Vol. iv. Paris, 1827.

that "Breschet and Raspail controverted the results obtained by Bogros' injections, which were soon completely forgotten."

The Swedish authors continue, "*Cruveilhier*[1] was the only one who repeated the experiments of Bogros with dyed liquids. He injected the nerves by puncture, whereby the fascicles composing the nervous trunk were filled more or less copiously as far as their remotest ramifications; thus, for instance, in the twigs of the nervus lingualis the injection reached the papillæ of the tongue. . . . The injection succeeds better from the central organ towards the circumference, than in an opposite direction. For a long time after Cruveilhier no further experiments were made towards discovering the lymph paths of the nerves, and the only additional data respecting such paths which we meet with in literature, are contained in *Roudanovsky's* paper on the structure of the spinal nerves,[2] where he speaks of hollows (*réservoirs*) in the reticulum between the nerve-tubes, whereby the nutrition of the nervous elements is effected."

As to their own labours in this direction, Key and Retzius say, "We[3] instituted next a long series of injections into the peripheral nerves, partly from the serous spaces of the central organs, and partly by direct puncture of the nerves. From the former spaces we succeeded in injecting various nerves far into their peripheral ramifications. In both kinds of injections, the injected liquid passed between the concentric, perineural laminæ around the nerve-fascicles, as well as between their endoneural continuations into the interior of the nerves, where it made its way between the individual nerve-fibres, bathing them thoroughly. On the other hand, also, it spread here and there beyond into the epineural laminæ. The great sympathetic nerve also was filled through the rami communicantes. *Kurkovsky*[4] became convinced by injections that there is a cavity around the nerve fascicles, but not around the individual nerve-tubules. *Ranvier*[5] gave a description of the results he obtained by

[1] Cruveilhier (J.). "Traité d'Anatomie descriptive." Vol. iv. Seconde édition. Paris, 1845.

[2] "Comptes rendus hebdomadaires des Séances de l'Académie des Sciences." Vol. iv. Paris, 1864 for December.

[3] In "Nordiskt Medicinskt Archiv." Vol. iv.; Nos. 21 and 25. Stockholm, 1872.

[4] In "Journal für normale und pathologische Histologie." Edited by Rudnew, Bogdanawitsch, Zabelin, and Zawarykin. 1870.

[5] In "Archives de Physiologie normale et pathologique." Vol. iv., for March and July, 1872.

injecting the peripheral nerves. With a moderate pressure he saw the injected liquid remaining in the nerve-fascicles, and penetrating at the same time between the nerve-fibres; but he did not see any preformed canal. On increasing the pressure, the liquid passed through the laminated sheath into the perifascicular tissue."

An abstract of the final results obtained by Key and Retzius, as published in their "Studien," etc., in 1875 and 1876, is contained above in nos. 704*u* to 704*z*, to which we direct the attention of our readers.

16. Modern science thus fully bears out the position asserted by Swedenborg in 1740; namely, that there is a continuity between the lymphatic spaces of the brain and spinal cord on the one hand, and those of the cranial and spinal nerves on the other. The next point to be confirmed is this, that in the living subject there is a constant current of the cerebro-spinal liquid from the subarachnoid space of the brain and spinal cord towards the lymphatic spaces of the cranial and spinal nerves.

This point is fully proved by Quincke's[1] experiments, to which the attention of our readers has been directed before. With the view of discovering the direction whither the current of the cerebro-spinal liquid tends in the living body, this observer injected an emulsion of vermilion and sugar-water into the subarachnoid space of the brain and spinal cord of living dogs. After allowing the vermilion to be carried about in the living animal during a space of time ranging between one and twelve weeks, an examination of their bodies, by dissection, exhibited the following results: "The vermilion was discovered along all the cranial and spinal nerves, as long as their roots passed through the cerebro-spinal cavity. The greatest accumulation of vermilion in all cases was where the nerves leave the dura-matral sack; thus in the cranium in those places where the nerves enter into the cranial foramina. The distribution of vermilion varied in the different nerves, without any apparent reason. In a number of cases the vermilion penetrated beyond the cerebro-spinal cavity. Thus, for instance, in about one-half of the experiments, it made its appearance along the intercostal nerves as far as the point where the rami communicantes depart for the great sympathetic nerve, and in some cases a few millimetres further. On folding back the lungs, the translucency of the pleura, without any further preparation, presented to view a neat picture of this particular diffusion of the vermilion. In the lumbar nerves, in a

[1] "Op. cit.," pp. 155-164.

number of cases, the vermilion could be traced as far as the lumbar plexus between the origins of the psoas muscle, and on the other hand as far as the plexus ischiadicus where it enters the pelvis. Among the cranial nerves the olfactory nerve did not carry any vermilion beyond the cribriform plate, while the optic nerve, on the other hand, constantly conveyed it in its sheath. . . . The accumulation of the colouring matter was always most copious immediately before the entrance of the optic nerve into the globe of the eye, so that it gradually decreased in quantity, in proportion as it approached the foramen opticum" (pp. 155-158).

In another place, in summing up his results, Quincke says, "A portion of the cerebro-spinal liquid leaves the cerebro-spinal cavity in conjunction with the nerves. Only by this assumption, it seems to me, are we able to explain the accumulation of colouring matter at the places of exit of the nerves. . . . Along the peripheral nerves there appear thus to be tracks which ordinarily carry only a liquid, but which at times permit also the passage of solid particles" (p. 164).

17. The experimental researches instituted by Cotugno in the last century, and by Bogros, Cruveilhier, and especially by Key and Retzius, and Quincke in the present century, thus confirm in a remarkable degree the theory laid down by Swedenborg concerning the continuance of the subarachnoid spaces into the interior of the peripheral, cranial, and spinal nerves, and concerning the circulation of the cerebro-spinal liquid in these nerves, in the form and under the name of the "nervous juice."

The question here naturally arises, why modern science generally up to the most recent times, has most persistently ignored this true state of things? The reason is an erroneous notion started by *Bichat* respecting the structure of the arachnoid membrane, and its relation to the dura mater. According to this notion, which was adopted by most text-books of Anatomy to within the last ten years, the arachnoidea, following the analogy of the serous membranes of the body, consists of two layers, a visceral and a parietal. The latter or visceral layer, according to this idea, is free, but in the neighbourhood of the departing cranial and spinal nerves it doubles up, and is reflected upon the inner surface of the dura mater; thus giving rise to the parietal layer of the membrane. The two layers of the arachnoidea were thus supposed to constitute a serous sack which is not connected in any way with the departing nerves.

Until the recent most thorough-going researches of Key and

Retzius, the arachnoidea consequently was not supposed to furnish any sheaths to the peripheral nerves, and hence the subarachnoid liquid, in the estimation of the learned, could not be directed into the interior of the nerves; wherefore this liquid lost the greater part of its importance in their eyes, and it was possible for a writer in the "Lancet" to declare in 1860, that "only recently, when conversing with a distinguished physiologist, the latter told him he considered 'the cerebro-spinal liquid played but a very subordinate part in the animal economy'" (see above, no. 704*s*).

Bichat's theory respecting the arachnoidea was still upheld in the eighth edition of Quain's "Elements of Anatomy," published in 1876. We read there concerning it, "The nerve-roots in their course run beneath the arachnoid membrane, and do not perforate it on issuing from the cranio-vertebral cavity; for the loose or visceral layer of the arachnoid is prolonged on the nerve, and loosely surrounds it as far as the aperture of egress in the dura mater, where, quitting the nerve, *it is reflected* upon the inner surface of the latter membrane, and becomes continuous with the parietal or adherent layer of the arachnoid" (II., p. 144).

In the ninth edition of this same work, published in 1882, Bichat's theory is given up, and the results of Key and Retzius are properly taken into account; we thus read there instead, "The nerves as they pass from the brain and spinal cord receive their perineural covering from the pia mater, and in addition, two looser sheaths, an outer from the dura mater, and an inner from the arachnoid. Upon the optic nerve these sheaths remain distinct and separate, so that the space which each encloses may be injected, the outer from the subdural, the inner from the subarachnoid space. On the other nerves the arachnoidal sheath soon ceases, and the single sheath eventually blends with both the epineurium and perineurium of the nerves. Accordingly it is found that an injection driven into either the subdural or the subarachnoid space passes readily along the nerves even as far as the limbs. There thus exists a continuity between the ventricles of the brain, the subarachnoid space, the perivascular canals of the cerebral substance, and the lymphatic spaces within the nerve-sheaths" (II., p. 377).

Schwalbe[1] also in his recent treatise on "Neurology" (1881) regards Bichat's theory of the arachnoidal sack as completely exploded. He says, "Formerly the subdural space was called the arachnoidal space, because the idea prevailed that an inner leaf of

[1] "Op. citat.," p. 785.

the dura covered with endothelium belonged to the arachnoid membrane; that this membrane consequently represented a serous sack—the arachnoidal sack—the outer, parietal layer of which was blended with the dura mater, while the inner layer represented the visceral leaf or layer of the arachnoidea."

. *The Laws of Motion of the Cerebro-Spinal Liquid.*

18. So far as the elementary character of the cerebro-spinal liquid is concerned, it possesses, according to Swedenborg, more of a passive than of an active force, and, therefore, different from the blood and the animal spirit, it has not within itself the elements of motion. He says, "In the spirituous lymph—the cerebro-spinal liquid—there are also aqueous, oily, and subtle urinous elements, and perchance there is likewise contained in it some spirituous element which vivifies the rest. Wherefore this liquid cannot be of a perpetual mobility; it cannot be expansible, compressible, elastic, etc., except through that portion of it which arises from the spirituous element admixed to it. This liquid, therefore, is comparatively inert, and possesses more of a passive, than of an active force" (no. 715*n*).

From this it follows, that motion has to be imparted to this liquid by those parts of the nervous system through which it passes, and which are themselves in a state of motion; namely, by the nervous fibres, and those nervous centres which are bathed in the subarachnoid liquid. Thus the most refined species of the cerebro-spinal liquid, which is excreted from the capillaries in the immediate neighbourhood of the grey substance, as soon as by the animatory or respiratory action of the grey glandules it is pumped into the interstices between the medullary fibres of the cerebrum and cerebellum, is propelled onward by the living force, that is, the contractile and expansile motion, imparted to the nerve-fibres by the animal spirit—the nervous fluid—which passes through them; and it is thus urged onwards, until it reaches the very termini of the nerves in the motory and sensory organs, and the viscera of the body. The grosser species of this liquid, on the other hand, which is received in the interstices between the various nerve-roots or nerve-fasciculi, is propelled by the expansile force inherent in the nerve-roots or fasciculi. So long, however, as this liquid is contained in the subarachnoid spaces, it is pushed onward by the expansile force of the encephalic centres, taken at large; namely, the spinal cord, medulla oblongata, cerebrum, and cerebellum.

So far as the motion of this liquid in the interstices between the nervous fibres in the body is concerned, Swedenborg attributes it plainly to the active motion of the peripheral nervous fibres, although he says that these fibres are greatly assisted herein by the respiratory motion of the lungs. He says, "The purest humour between the fibres is urged towards its outlets by the expansion and constriction of the fibres. For this humour is not liquid, that is, flowing *per se*; wherefore it is propelled by the most active force of the fibres. Imagine to yourself round, polished tubes closely packed together, and between each of them an interstice: whenever, therefore, the tube is expanded, it follows that the interfluent humour by the force of this expansion is pushed forwards. The same is the case with the grosser serum between the nerve-fasciculi, which is of a still more sluggish and inert nature, because impregnated by larger, and more unequal particles. . . . This then is the efficient cause, by which the humour—the cerebro-spinal liquid—is propelled and circulated through the nerves; to which is added the auxiliary and promoting force of the respiration of the lungs, which contributes in a wonderful manner to the transfusion of this juice through the nerves" (II., no. 364).

19. From this passage it follows that the interstices between the fibres and fascicles of the nerves are contracted—that thus the cerebro-spinal liquid is ejected from these interstices, whenever the nervous fibres themselves are expanded or swollen; and, on the other hand, it follows that when the nervous fibres are contracted, the interstitial spaces between them are opened and prepared for the reception of the advancing wave of the cerebro-spinal liquid.

As the fibres of the brain, however, are contracted and thus have their systole, whenever the grey substance of the brain is expanded and has its diastole (see I., no. 467), it follows that during the expansile motion of the brain and spinal marrow the cerebro-spinal liquid is driven out of its various reservoirs within the cranial cavity into the nerve-roots, and thus into the interstices between the nervous fibres.

As the medullary fibres of the brain are thus contracted and relaxed during the expansion of the grey substance, and as all the interstices between the fibres are then opened, it follows that such also must be the case with the medullary fibres which enter into the composition of the velum medullare inferior or tela choroidea inferior; wherefore the foramina of the fourth ventricle, which are situated in this membrane, are likewise opened, and prepared for the discharge of the cerebellar liquid, when the grey matter of the cerebellum and of the medulla oblongata is expanded. Again, as the central canal of the spinal cord is encompassed in front and behind by the medullary fibres which compose the anterior and posterior commissures of the spinal cord, and as these fibres are contracted during the diastole of the grey substance of the cord; and again, as the substantia gelatinosa centralis in which the central canal is immediately situated, according to Schwalbe (p. 343) is void of nerve-cells or grey glandules—it follows that the central canal also during the diastole of the brain and spinal cord is distended, and together with the interstices between the medullary fibres of the cord, is ready to receive the cerebellar liquid from the fourth ventricle.

Now from all this it follows that during the diastole or expansile motion of the brain and spinal marrow, the cerebro-spinal liquid is expressed from the fourth ventricle both into the central canal of the spinal cord, and also into the subarachnoid space by which it is surrounded. And further, that from the central canal, at the same time, the more refined portion of this liquid is driven into the interstices between the individual medullary fibres which enter into the composition of the anterior and posterior spinal roots; while from the subarachnoid space which encompasses the spinal cord on the outside, especially on its dorsal side, the grosser cerebro-spinal liquid is propelled into the interstices between the various nerve-roots or fascicles which make up the departing spinal nerves.

By the energy of the spinal cord, however, which during its diastole fills up nearly the whole of the vertebral canal, the excess of that subarachnoid liquid which is not absorbed by the departing spinal nerve-roots, escapes out of the vertebral canal into the larger subarachnoid cisterns in the neighbourhood of the medulla oblongata and cerebellum, and thus rises from the vertebral into the cranial cavity.

From the fact, however, which has been abundantly proved in our Note on the "Respiratory Motion of the Brain" (Vol. I., p. 673, *et seq.*), namely, that while the brain swells and has its diastole, the lungs expire, and *vice versa*, it follows in conclusion that the cerebro-spinal liquid rises into the cranium during the expiration of the lungs, and descends into the spinal cord during their inspiration.

If now we examine once more the condition of the fourth ventricle while the cerebro-spinal liquid is being expelled from its cavity, we find that this takes place while the grey substance of the medulla oblongata is being expanded, and thus while the floor of the fourth ventricle is being raised up. And, on the other hand, it happens while the peduncles of the cerebellum are being contracted, and hence lessened in width, and at the same time lengthened and thus spread apart. For, according to one of the general rules laid down by Swedenborg concerning the motion of the brain, "each fibre, vein, and sinus, at such time as they subside and are constricted, are lengthened out and corrotated in respect to their width, and *vice versa*" (Vol. I., no. 467). Now, if the cerebellar peduncles which form the greater part of the roof and sides of the fourth ventricle are extended, and thus spread apart during the expansion or diastole of the cerebellum and medulla oblongata, it follows that the medullary edges of the ventricle are unfolded at the same time, and hence that the area of this cavity is enlarged, and thus that the fourth ventricle has its diastole during the same period. From this, however, it follows again that the fourth ventricle has its diastole, that is, is enlarged in width, while the lateral ventricles have their systole; and further, that the fourth ventricle discharges its contents during its diastole, while the lateral ventricles discharge them during their systole.

20. All these points are stated clearly in the following passages from our author:

"*The fourth ventricle is opened and constricted in a peculiar way.* For this motion seems to be a kind of unfolding of the edges of the ventricle, and an elevation of its floor to such a degree, that if it contains any liquid at all, especially in the calamus scriptorius, it ejects the same superiorly in a place where it is not covered up by a ceiling." And again, "It thus seems that when the bottom, and at the same time the extremity of the pons Varolii is raised up, the calamus scriptorius unfolds its edges, and partly also the rest of the fourth ventricle, that is, the upper part of its cavity; whence it is that this latter part propels its liquid, if it contains any, into the calamus scriptorius, rather during the state when it is unfolded" (no. 715*c*).

"From the thrusting forth and drawing back of the peduncles of the cerebellum there results, as from their efficient cause, the dilatation and constriction of the fourth ventricle. It appears thence that this ventricle is widened and spread apart in its middle when the superincumbent peduncles stretch themselves and pour themselves out on all sides; but that the reverse happens when they draw themselves back. The diastole of this cavity thus happens, when the cerebellum stretches out its fibres; that is, when the cerebellum expands itself: but, under a reverse condition, the fourth ventricle has its systole. The very way in which this cavity runs, or in which it is notched, shows that its edges are unfolded and its floor cast up by the opposite medulla, *i.e.* the pons Varolii during that time [that is, during the diastole of the ventricle]. But when the ventricle is thus constricted [or flattened out by the elevation of its floor] the enclosed lymph is driven out from its middle towards its extremities on either side; namely, against the valve of Vieussens which is above, as well as into the calamus scriptorius which is below; and thus it is expressed into the above-named duplicature [in the tela choroidea inferior]" (no. 715).

"From what has been said above, it follows that the dilatation of this ventricle and the elevation of its floor coincides . . . with the spreading apart of the processes of the cerebellum, so that through the mediation of the cerebellum while the ventricle is being widened, it is also shortened. It further coincides with the contraction and elevation of the spinal cord, . . . even as it coincides with the expression of the liquid out of the choroid plexus" (no. 715*i*).

"Every part of the spinal cord goes through its systaltic and diastaltic motion. From the determination of the fibres follows the mode in which each part of the cord accomplishes its expansions; namely, it expands in width and at the same time in length, so as to fill up the vertebral cavity with its whole body. For the cervical fibres, many of which are longitudinal and the rest transverse, extend in length, while they expand in width. The same is the case in the dorsum—there the spinal cord also is elevated [that is, is extended or stretched upwards], while it is being widened; for the longitudinal fibres extend or stretch it, but the spiral ones extend as well as widen it. Those which are still further down, or those of the cauda equina, simply extend or elevate the upper cord, but do not widen it. Between the caudex of these fibres, however, and the walls of the vertebral cavity a small space seems to be left, where there is a place for the reception of some liquid which is then being expressed [out of the ventriculus terminalis of the central canal]. This coincides with the periods of expansion and constriction of both brains. For when the brain is expanded, its medullary fibre, according to rules, is extended; consequently also the fibres which pass along the spinal cord; and consequently the fibre of the medulla, its cortex being then expanded" (no. 810).

"As often as the two brains animate [that is, contract or expire], and with them the spinal cord, they flow into their nerves, and the nerves into the muscles; consequently, also into the intercostal muscles; and when these contract themselves, the ribs are raised and the thorax is expanded; and this coincides with the moments when the lungs *inspire*. The outlying little ganglia are constricted at the same time, and by a sort of contraction exert a force on the same nerves" (no. 818).

21. The laws of motion which are claimed here for the spinal cord, the medulla oblongata, and the cerebellum, and which result in the movement of the cerebro-spinal liquid, have been abundantly confirmed by the facts of modern science in Note I. (Vol. I., pp. 645-700), to which we refer our readers. Still the reality of this motion is far from being universally recognised by the men of science at the present day, and many perhaps, at the first blush, would chime in with Dr. Quincke, who says, "I emphasize my statement here, that I speak only of the movement of the liquid, but not of a movement of the brain or spinal cord; for such a movement, at least in the case of the brain, is refuted by the insertion of glass windows into the cranium by Donders, Leyden, etc." (*Op. cit.*, p. 162)—although the fallacious reasonings based on these "glass windows" of Donders and others, have been exploded over and over again by the experiments of François-Franck, Mosso, and others (see Vol. I., p. 646, *et seq.*).

Still the general results of Swedenborg's theory of the motion of the cerebro-spinal liquid are all confirmed by the researches of modern science. Thus the fact that the cerebro-spinal liquid escapes from the subarachnoid spaces through the sheaths of the departing cranial and spinal nerves, has now become an admitted fact of science, and is taught in the most recent text-books of anatomy. From this fact it also follows that the chief current of the cerebro-spinal liquid is in the direction of those places where the nerve-roots burst out from the central organs; thus, in the direction of the medulla oblongata, pons Varolii, and corpora quadrigemina, and in the vertebral canal towards those points where the spinal nerve-roots pierce the dura mater.

This is abundantly proved by Quincke's experiments, who says, "In ten out of twelve cases where vermilion was injected into the subarachnoid spaces of the vertebral canal, the colouring matter penetrated into the cranial cavity, where it chiefly accumulated at the base of the brain, especially where the arachnoidea and pia mater are separated by the more extended meshes of the subarachnoid tissue. . . . When injected into the cranium the vermilion remains mostly at the base of the brain, and at the sides of its convexity.

It appears besides at the outlets of the cranial nerves, and in the majority of cases descends into the vertebral cavity, where it penetrates as far as the cauda equina, the vermilion being deposited in the pia mater and around the nerve-roots" (*Op. cit.*, pp. 160, 161).

Again he says, "It is easily conceivable that the tracks in which the current of the cerebro-spinal liquid moves are chiefly situated in the ampler parts of the subarachnoid spaces; thus in the cranium chiefly within the range of the so-called subarachnoidal sinuses—'confluents' Magendii (see above, no. 2);—further, that thence there is only a weak current towards the convexity of the hemispheres. Even in those cases where the injected matter was introduced at the crown of one of the hemispheres, it spread chiefly around the corpora quadrigemina and along the base of the cranium. Only small quantities of the colouring matter were carried to the convexity of the opposite hemisphere" (*Ibid.*, p. 163).

From the fact, however, that in the living subject colouring matter, when injected into the vertebral canal, is carried by the cerebro-spinal liquid into the cranium, and when injected into the cranium is conveyed by this liquid into the vertebral canal—it follows that there is an ascending as well as a descending current of this liquid, as required by Swedenborg's theory.

The particular experience of Quincke on this subject is as follows: "During life there is a current of the subarachnoid liquid in a postero-anterior, as well as in an antero-posterior direction. For the colouring matter which is admixed to this liquid is conveyed from the spinal cord into the brain, and from the brain into the spinal cord" (p. 167).

Again he says, "The pressure exerted upon the liquid varies at different times and in different places of the cerebro-spinal cavity, so that there is a movement to and fro. The respiratory movements operate as a pump upon the liquid under consideration, even as they exert a similar effect on the lymphatic stream in the pleura, and upon the venous blood" (p. 166).

22. As to the particular periods when the cerebro-spinal liquid rises and when it falls in the cerebro-spinal cavity, we have the direct experiments of Ecker[1] and others to show that during expiration the liquid rises, and during inspiration it falls. In the account of his *tenth* experiment he says, "After trepanning the dog, I could see plainly that at each *expiration*, 1. the brain rose; 2. that a liquid

[1] Ecker (A.). "Physiologische Untersuchungen über die Bewegungen des Gehirns und Rückenmarks, insbesondere den Einfluss der Cerebrospinalflüssigkeit auf dieselben." Stuttgart, 1843.

was discharged out of an opening in the dura mater; 3. that a liquid which collected under the arachnoid membrane, first issued out of an opening in that membrane, and afterwards poured out of the aperture which had been made in the dura mater. At each *inspiration* the brain subsided, and no more liquid was discharged" (p. 76). In a footnote he adds, "In this experiment it could be seen very plainly how easily the motion communicated to the cerebro-spinal liquid in one point, is communicated to the same liquid at a distant point. When the obturator ligament was touched only very slightly—before much liquid had escaped—there was at once a discharge of liquid out of the aperture in the cerebral membrane."

In the account of his *eleventh* experiment he states, that "the cerebro-spinal liquid gushed forth and filled the aperture at each expiration; during the inspiration it was sucked in as it were, and disappeared" (p. 87). And in his *eighteenth* experiment he observed, that "the obturator ligament moved plainly synchronously with respiration; it rose during expiration, and subsided during inspiration. The cerebro-spinal liquid escaped in a forcible current during expiration. . . . The medulla oblongata and spinal cord rose at each expiration, and subsided during inspiration" (p. 109, *et seq.*).

That the cerebro-spinal liquid during expiration is under the influence of a greater pressure, and hence rises in the cranial cavity, Salathé proved by the graphic method. In his drawing, which is reproduced in Note I. (Vol. I., p. 663), it can be seen clearly how the cerebro-spinal liquid rises during the expiration of the lungs, and how it sinks or subsides during their inspiration.

Key and Retzius measured the pressure of this liquid in the vertebral cavity by the manometer. They say, "After the animals had been brought under the influence of ether, their vertebral canal was opened, the dura mater was exposed, and a small incision made. . . . A fine glass canula, which was connected with a manometer, was then introduced into the subarachnoid space through an aperture in the arachnoidea. . . . We communicate as an example the following series of numbers obtained from a successful experiment:—

During Inspiration.	During Expiration.
+12	+18
+12	+16
+14	+20
+16	+20"

("Studien," etc., Vol. I., p. 189.)

The values here indicated are those of millimeters of mercury. Key and Retzius proved by their experiments that the pressure of the cerebro-spinal liquid, on the whole, is somewhat higher than that of the blood in the longitudinal sinus, although the difference does not amount to much; and further that the pressure is diminished during inspiration, and increased during expiration.

23. The upward current of the cerebro-spinal liquid, during the expiration of the lungs, according to Swedenborg's theory, is brought about thus: During the expiration of the lungs the cortical substance of the brain and spinal cord expands and swells, and the medullary or fibrillous substance contracts. During the contraction of the fibres, however, the interstices between them are open, wherefore during the expiration of the lungs these same interstices are receptive of the cerebro-spinal liquid. While the grey substance of the cord, however, undergoes its expansile or diastaltic motion, its medullary substance, as shown above, extends longitudinally and expands in width, so that gradually it fills up the whole of the vertebral canal; and in proportion as it does so, the surplus of the cerebro-spinal liquid which is not absorbed by the departing nerve-roots, is urged out of the vertebral cavity into the "confluents" or cisterns of the subarachnoid spaces in the cranium. Hence the rise of the cerebro-spinal liquid during the expiration of the lungs.

The pressure in this liquid is thus caused by the expansile force which dwells in the cortical or grey substance of the spinal cord. And this pressure is required in order that this liquid may be urged into all the interstices of the departing spinal nerves. This energy of the cerebro-spinal liquid, however, is displayed only during the diastole of the cortical substance; for during its systole the nervous fluid—the animal spirit—which is prepared in the grey glandules or nerve-cells is pumped into the medullary and nervous fibres; wherefore these fibres have then their diastole, and during their diastole or expansion the interstices between them are closed against any further admission of the cerebro-spinal liquid. The energy in the current of this liquid is therefore displayed at the time when it rises into the cranial cavity, as has been fully confirmed by Quincke's experiments; for he says, "The ascending current from the vertebral cavity into the cranium, upon the whole, seems more powerful than the descending current; since the vermilion was carried much more copiously and constantly in the former than in the latter direction" (p. 163).

24. In an altogether different way the so-called respiratory movement of the cerebro-spinal liquid is brought about according to

Magendie and Ecker, and their explanation is still quoted with approbation at the present day. Ecker in his explanation bases himself on the generally known fact that the veins, especially those within the radius of the thorax, swell during the expiration of the lungs, and subside during their inspiration. He says on this subject, "It is well known, and has been noticed by older observers (as Haller, Lamure, Walsdorff), that the veins, at least their larger trunks, swell during expiration; that they then teem with blood and turn blue; while during inspiration they subside and become flat." And again he says, "When a vein is cut, the blood flows out of the central end much more copiously during expiration than during inspiration" (*Op. citat.*, p. 61).

The same fact he applies to the veins in the interior of the vertebral cavity, and he maintains that these veins, that is, the anterior longitudinal spinal veins, which he styles the vertebral or spinal sinuses, during the expiration of the lungs are so much expanded, that they displace the cerebro-spinal liquid out of the vertebral cavity, causing it to rise into the interior of the cranium. Quincke, in assenting to this hypothesis of Ecker, says, "Ecker has clearly shown in what way the respiratory motion of the cerebro-spinal liquid is brought about. The venous plexuses of the spine—the anterior longitudinal spinal vein—which are yielding, during inspiration subside more, and during expiration expand more than the sinuses of the cranium with their unyielding walls. By this circumstance, during expiration, the cerebro-spinal liquid is expelled from the vertebral cavity towards the cranium, while the opposite takes place during inspiration" (*Op. citat.*, p. 163).

The fault in this reasoning is *first*: Suppose the anterior longitudinal spinal veins really swell during expiration, which they do not—as will presently be shown—the swelling of these veins would scarcely be productive of sufficient displacement in the vertebral cavity as to cause such a forcible ejectment thence of the cerebro-spinal liquid, as is described by Ecker in the account of his experiments. But, *secondly*, as has been proved by Key and Retzius by direct experiment: the sinuses and blood-vessels within the encephalic, and thus within the spinal cavity which are governed by precisely the same conditions, are affected by the expiration and inspiration of the lungs differently from what are the veins and arteries in the thorax and in the rest of the body. For during the expiration of the lungs the pressure in the cerebral and consequently in the spinal vessels, as was proved experimentally by Key and Retzius, *increases*, and hence these vessels are then contracted; for the pressure of the blood in the blood-vessels increases during their period of contraction, and it decreases during the period of their impletion. Wherefore, the interior longitudinal spinal veins or vertebral sinuses do not swell during the expiration of the lungs, as is maintained by Magendie and Ecker, and after them by Quincke, but are even emptied and depleted; and, therefore, the whole of that theory which they based on the supposed swelling of these sinuses during the expiration of the lungs, falls to the ground.

Compare the account of Key and Retzius of the experiments instituted by them with the view of ascertaining the pressure of the blood in the superior longitudinal sinus during the expiration and inspiration of the lungs in "Studien," etc. (Vol. I., p. 188), as quoted in our Vol. I., p. 301, *et seq.*

Ecker, indeed, was willing to ascertain by ocular inspection the fact that the vertebral sinuses *swell* during expiration; but his experiment failed. In the account of his eighteenth experiment he says, "The obturator ligament in a dog was somewhat folded back on either side, in order, if possible, to make a direct observation of the swelling of the vertebral sinuses. On the interior surface of the dura mater, the bluish sinus was indeed noticed extending along the posterior roots, and at each expiration they *seemed* to swell. I now tried to loosen carefully the ligament from the upper edge of the atlas with the view of increasing the field of vision, but an unavoidable lesion of one of the sinuses prevented all further observation" (*Op. cit.*, p. 110).

25. Paulet[1] also speaks of a continual rise and fall of the cerebro-spinal liquid, synchronous with the movements of respiration, which was observed by Magendie. He says, "Direct examination shows in a complete manner that the cerebro-spinal liquid is subject to a constant change of place, to an incessant ascent and descent from the cranium into the spinal cavity, and *vice versa.* Magendie was the first to direct attention to this double movement, and he observed that it is synchronous with the movements of respiration: During inspiration the liquid flows into the spinal cavity, during expiration it ascends into the cranium. After exposing in a living he-goat the interior of the cerebral ventricles, this physiologist saw how at each expiration the liquid contained in these ventricles rose, and how it subsided at each inspiration, as though it were alternately supplied and absorbed by the spinal cord" (p. 59).

[1] Paulet. "Céphalo-rachidien liquide." In "Dictionnaire encyclopédique des sciences médicales," Vol. xiv. Paris, 1873.

We do not propose to impugn the correctness of the fact which Paulet quotes here from Magendie—so far as a rise and fall of a liquid in the lateral ventricles is concerned; but we object altogether to his identifying this liquid with the cerebro-spinal liquid, and to the road by which Magendie[1] holds that the cerebro-spinal liquid makes its way into the lateral ventricles. His language on this subject is as follows: "Aqueous or other injections made from the spine into the subarachnoid space have never failed to arrive in the lateral ventricles. The route which they follow *is known to every one;* and, if I detail it here, it is only for the purpose of not omitting anything important. The liquid first enters the ventricle of the cerebellum, which it fills completely, distending its walls; it raises the valve of Vieussens; afterwards it penetrates into the canal which leads from the fourth into the third ventricle, and which by Sylvius has so appropriately been called the aqueduct" (pp. 28, 29).

Marc Sée already objected to this positive language of Magendie; for says he, "From the fact that the liquid injected through the spinal cavity made its way into the lateral ventricles, it does not follow necessarily that it pursued the way indicated by Magendie, and surely that gentleman himself has not seen the liquid making its way successively through the different parts pointed out by him" (*Op. cit.*, p. 295).

As for our part, we do not object to Magendie's statement, so far as he describes the course which an injection makes in a dead, collapsed brain. On the same ground also we fully agree to the correctness of the experiments of Key and Retzius, who, under similar conditions, injected the lateral ventricles even with congealing substances, through the same course pointed out by Magendie. But we maintain, in accordance with Swedenborg's theory of the brain, that in the living subject the cerebro-spinal liquid does not pass into the lateral ventricles by the way described above by Magendie and Paulet; and herein we are fully borne out by Quincke, who experimented on the circulation of the cerebro-spinal liquid in living animals.

In the first place, although this author assents to Ecker's explanation of the rise and fall of the cerebro-spinal liquid in the subarachnoid space, he takes issues with him, on the ground of the results of his experiments on the living animal, as to the existence of a current of this liquid from the subarachnoid space into the fourth ventricle.

[1] Magendie (François). "Recherches sur le liquide céphalo-rachidien." Paris, 1842.

He says, "The only point where I feel compelled to oppose Ecker is this, that through the rise and fall of the cerebro-spinal liquid an alternate impletion and depletion of the lateral ventricle is effected; for if this were a fact, vermilion would have been constantly present in these cavities" (*Op. cit.*, p. 163).

And, in conclusion, in summing up the results of his experiments, he says: "1. If in none of my experiments the colouring matter entered into the central canal of the spinal cord, into the perivascular spaces of the brain, or in those of the spinal cord, the reason probably is, that in a normal condition these spaces, indeed, discharge their contents into the subarachnoid space, without, however, receiving any liquid from the subarachnoid space in return. 2. The ventricles also, in a general diffusion of the colouring matter throughout the brain, scarcely ever contained any free vermilion. In a few cases only it had found its way into the interior of the ventricles imbedded in stray particles of pus, or in flakes formed of similar particles by which they had probably been conveyed thither. This negative result shows that it is impossible for a current of this liquid to take place *into* the ventricles; just as little as there is an alternate influx and efflux of this liquid, caused as a collateral result by the current of the cerebro-spinal liquid under the influence of respiration. If we must still admit an opening in the posterior part of the fourth ventricle, there remains now only the possibility of the . . . flow of a liquid *out of* the fourth ventricle; which possibility is supported by the opinion of those anatomists according to whom the choroid plexuses are organs of secretion" (*Ibid.*, p. 172).

g. The various Species and Degrees of the Cerebro-Spinal Liquid.

26. According to Swedenborg, there are distinctions and degrees in the liquid which circulates through the interstices of a nerve; and hence in the liquid which passes under the general name of the cerebro-spinal liquid. A more refined kind of liquid thus circulates through the least spaces around the individual fibres of which a nerve consists, and a grosser kind through the spaces of those attenuated membranes by which the nerve-roots or fascicles are encompassed, and also through the spaces of that general integument by which an entire nerve is invested. A general statement of Swedenborg's doctrine of the nerve and its interstices is as follows:

"The *simplest fibres*—the fibrils which compose the axis-cylinder—are invisible to the eye; they excite the subtle medulla of each cortical particle. The *less simple fibres*—the medullated and non-medullated fibres—are those which are produced from the whole cortical or grey substance, and constitute the medullary fibre of the brain, and the nervous fibre of the body. Of these fibres is composed the *nerve-fascicle* or bundle, which in the body is called a small nerve, but in the brain a 'nerve-root.' When such fascicles or roots are united into one trunk, and covered with a double, and perhaps a triple coating, they give birth to a *nerve*.

"The genuine fibre itself is *pervious*; between the fibres there are small interstices; other interstices of the same kind, but larger, exist between the fascicles of the fibres, and also between the general coatings of the nerve itself, or those by which the fascicles are bound together.

"Wherever in the body there is anything pervious, there also is a liquid which passes through it. Through the genuine fibre there flashes the so-called *animal spirit*. Through the interstices between the fibres passes a noble, highly-refined liquid, which we shall denominate the '*spirituous lymph*.' Through the interstices between the fascicles, however, there percolates a pure oleaginous serosity or defecated humour—*cerebro-spinal liquid*—whose office it is to lubricate properly these hinges. The same kind of humour also circulates between the coatings of the nerve.

"To these juices corresponds exactly the *medullary texture* of the brain; and to this its cortical fabric. The texture of the medullary substance is a kind of perpetual network consisting of an infinite number of plexuses, or of plexuses betwixt plexuses; and this kind of compagination continues as far as the corpora striata and optic thalami, where the fascicular structure begins. From this extremely loose kind of texture results this, that the 'animal spirits' pass in all freedom through its fibres, the 'spirituous lymph' through the interstices between the fibres, and the oily serosity—the 'cerebro-spinal liquid'—through the larger spaces between the fascicles. Moreover, among these plexuses there are gaping cavities or hollows which are permeated by serosities too gross for circulating through the structure of the nerves.

"To this arrangement of the medullary texture again there corresponds the *cortical fabric* of the brain. For there are individual *cortical particles*—nerve-cells; there are clusters or *glomes* formed of these particles; and again there are larger congeries or *tori* composed of these glomes; and each of these divisions is surrounded by its pores, clefts, interstices, spaces, and anfractuosities. Every individual cortical particle, as a gland by eminence, pours its *animal spirit* immediately into its medullary fibre, and into the nervous fibre continued therefrom. From the small interstices around these individual particles a noble, highly-refined liquid—the *spirituous lymph*—flows into the interstices between the fibres. From the small cells of the arachnoid membrane, and from the clefts around the clusters and glomes of these particles, there distils a pure oily serosity—the *cerebro-spinal liquid*—between the fascicles and also between the coatings of the nerve, which are thereby properly lubricated.

"The coarser, more *pituitous humour*, however, which is secreted and collected from the arteries between the meninges or in the anfractuous fissures of the brain, is not derived into the constituent parts of the nerves; but through a porous lamina—the cribriform plate—is naturally determined into the cavities of the ethmoid bone. Thus for every genus and species of moisture or humour, born, excreted, and circulating in the brain certain determinations and proper pathways are formed and designated by nature.

"The red blood-corpuscle contains or has stored up in its bosom each of these species of fluids; and when in the threshold before the cortex of the brain, it is resolved into its constituent parts, it contributes a share of its humour to each pore and interstice.

"A nerve thus constituted which is interpolated by as many cavities, as perhaps a pumice-stone, the tufa, and the stalk of a bulrush, and which is permeated by as many indigenous juices as are proper to it—is inserted into the muscles, glands, and membranes of the body, and deposits there the burthens which it bears" (IV., no. 70).

"Besides the above-named noble lymph which oozes out of the cellules of the arachnoid membrane, and penetrates between the interstices of the fibres, there is another humour—*the subdural juice*—which descends out of the cranial cavity around the spinal cord; namely, that which is wont to collect between the [outer lamina of the] pia mater—the arachnoid membrane—and the dura mater of the brain. To this, namely, to that which collects around the cerebellum, no other egress remains open, except the posterior part of the foramen magnum, and thence between the outer coatings of the nerves of that region. All the remaining ways are closed to it; for there are no veins anywhere by which it may be absorbed" (I., no. 773).

From the above compendious statement concerning the nerves and their connection with the central organs, we see that Swedenborg distinguishes three degrees or species in the cerebro-spinal liquid taken in its most general form. The liquid of the *first* order—the spirituous lymph—courses in the interstices around the individual nerve-fibres; that of the *second* order—the subarachnoid fluid or cerebro-spinal liquid proper—around the nerve-roots or fascicles which are composed of the individual nerve-fibres; and the liquid of the *third* order—the subdural fluid—through the spaces in the general coating of the nerve; through these latter spaces, according to Swedenborg, there circulates also the liquid of the *second* order.

These various liquids we shall now take up separately, and discuss each in the light of modern experience.

1. *The Spirituous Lymph—the Cerebro-Spinal Liquid of the First Order.*

27. Concerning the liquid of the *first* order, namely, that which circulates in the interstices around the individual nerve-fibres, Swedenborg says further:

"Each of the glandules of the cortical substance is separated from the neighbouring ones, and encircled by a small space. . . . From this space a most refined humour, rich in principles and elements subtly sulphureous and ethereal, flows down between the fibres: for no other outlet is open to it; wherefore every glandule seems constantly anointed by such a moisture" (II., no. 355).

Again we read, "A subtle liquid distilled from the least arteries of the brain . . . penetrates between the fibres in the fascicles or in the so-called nerve-roots. This liquid . . . flows outside the cortical spherules, wherefore it must betake itself between the fibres, which, in alternate periods, are pulled and again relaxed, or which, in alternate periods, open their interstices for the reception of such a liquid. . . . And besides, the fibres require to be bathed by such a liquid, lest they should coalesce: for it is a matter of demonstration that the veriest simple fibres are held together among one another by the most delicate membranes . . . which of a necessity must contain a moisture through the mediation of which the fibres are kept in a condition in which they are able to act, and in which they do not become torpid, as is the case when there is no fluid, by which they are kept apart" (I., no. 715*l*).

But as to the method by which this liquid makes its way through the medullary or white substance of the brain, we read, "The fibres and least vessels of the medullary substance of the brain mutually connect and distinctly intertwine themselves into reticular plexuses: for there are lesser plexuses within the larger, and each is enveloped by delicate membranes. . . . Thence there results a loose and spongy compages, pervious to lymphs, bibulous, soft, capable of expansion, free to act and fit to construct nerves. It hence appears, how distinctly the medulla of the brain leads the humours received from the brain down into the framework of the nerves: for each fibre which flows there most freely transmits its own spirit—the animal spirit; each lesser plexus formed of loosely flowing fibres pours its purest humour—the 'spirituous lymph' now under discussion—between the fibres of the nerves; and every larger plexus its oleaginous serum—the cerebro-spinal liquid proper—between the fascicles of the fibres. And lest the liquids shall transgress beyond their appointed pathways, each individual plexus is enveloped and fortified by a certain delicate coating. When such plexiform fascicles emerge out of the medullary caudex, they are invested with pia mater, and presently with dura mater. Thus great care is taken, and provision is made, lest the enclosed humours should escape in a wrong direction, and so that, on the contrary, by distinct ways they shall be determined into the corresponding pores of the nerve" (II., no. 354).

28. The question arises here first, What has modern science to say to those purest lymph-spaces by which the individual cortical glandules are surrounded, and which are afterwards continued around the individual nerve-fibres, first during their passage through the medullary substance of the brain and spinal cord, and afterwards as they make up the various cranial and spinal nerves?

We may state here in brief that delicate lymph-spaces have been distinctly observed around the cortical glandules or nerve-cells of the brain by Obersteiner and Bevan Lewis, and that they have been demonstrated around the individual nerve-fibres in the peripheral nerves by Key and Retzius.

Schwalbe says, "Obersteiner[1] succeeded by puncture in filling those spaces by which the larger nerve-cells in the cortex are enclosed. He called them 'pericellular spaces.' Bevan Lewis did the same" (*Op. cit.*, p. 725).

[1] Obersteiner (H.). "Ueber einige Lymphräume im Gehirne." In "Sitzungsberichte der Wiener Akademie," Vol. lxi. (Abth. 1). Wien, 1870.

Bevan Lewis[1] says: "*Existence of Pericellular Lymph-sacs in the Brain.*—My attention was first attracted to the significance of these spaces by . . . the appearance of pericellular spaces in healthy brains occasionally where the cells appeared perfectly normal, and certainly not atrophic. . . . In all cases I never failed to recognise, on careful examination, a small capillary either passing immediately across the nerve-cell, or running with a gentle curve along the confines of the pericellular space. . . . In many instances a distinct connexion between perivascular and pericellular spaces could be clearly observed (p. 330). . . . With regard to the mode of connexion it must be remembered that the pericellular sacs are laterally disposed along the sides of the smaller capillaries, and in no case occupy a terminal position; hence the nerve-cell is bathed in a constantly renewed current of lymph on all sides" (p. 331).

Bevan Lewis thus confirms clearly the following positions of Swedenborg; namely, that, "a subtle liquid is distilled from the least arteries of the brain," which liquid "flows outside the cortical glandules."

Swedenborg says further that this liquid "flows down between the fibres: for no other egress is open to it;" and again he says that "this liquid betakes itself between the fibres which in alternate periods are pulled and again relaxed, or which in alternate periods open their interstices for the reception of such a liquid." Inasmuch as modern science, at least as represented by the most recent text-books of anatomy and physiology, does not believe in any motion of the brain, so also it does not believe in any drawing and relaxing of the fibres of the medullary substance of the brain in alternate periods, whereby the interstices between these fibres are opened for the reception of a liquid. According to Swedenborg, however, this liquid "must flow down between the fibres, because no other outlet is open to it." The only other escape for the liquid is by returning the same way by which it came; which, however, can scarcely be entertained, because it would be like the arterial blood returning to the heart, not through veins, but through the arteries themselves. Schwalbe acknowledges plainly that "a discharge from the above 'pericellular' sacs into lymphatic clefts or lymphatic vessels cannot be demonstrated;" and again he says, "the only real lymphatic vessels are here the 'perivascular' spaces around

[1] Bevan Lewis. "The Relationship of the Nerve-Cells of the Cortex to the Lymphatic System of the Brain." In "Proceedings of the Royal Society," Vol. xxvi. 1877.

the arterial vessels which communicate with the subarachnoid spaces" (*Op. cit.*, p. 725, *et seq.*); which are the identical spaces by which, according to Bevan Lewis, the "pericellular sacs" are supplied with their moisture. The only satisfactory escape out of the dilemma, which evidently exists here, is by acknowledging with Swedenborg that the moisture in the "pericellular sacs" is expressed in alternate periods into the interstices around the medullary fibres, which are continuous with the same spaces in the peripheral cranial and spinal nerves.

29. It is interesting to watch the effect of the alternate rise and subsidence of the cortical substance, according to Swedenborg's theory of the motion of the brain, upon the liquid which we are now discussing. This liquid, the purest species of the cerebro-spinal fluid, is secreted from the little arteries and capillaries which are carried about in the smallest clefts and sulci of the grey substance, and it is expressed into the perivascular sheaths, consisting of pia mater, with which these vessels are furnished upon their entrance from the subarachnoid space into the substance of the brain, and by which they are attended as far as their termination in the "pericellular spaces" around the nerve-cells. At either end of these "perivascular" sheaths there are thus lymphatic spaces which receive the lymph or serum secreted from the arterial twigs and capillaries; namely, the "pericellular sacs" at one end, and the subarachnoid space at the other. Whenever the arteries swell, the perivascular sheaths are contracted and eject their contents into their respective lymphatic spaces; and when the arteries contract, they express from the blood which they convey a serosity or lymph into the perivascular sheaths which are then rapidly filled; that is, so far as the swelling cortical substance around them permits them to do so. By the expansion or swelling of the cortical substance, however, the outlets of the "perivascular" sheaths at either end are presently closed up, so that the serosity or lymph excreted into these spaces remains confined in them; and indeed so long until the cortical substance again subsides, whereby the openings at either end of the perivascular sheaths are again dilated, so that they are able to discharge their contents into their respective lymphatic spaces. While the "pericellular sacs" are now being filled, the nerve-cells which are contained in these sacs are undergoing their systaltic motion, and discharge the animal spirit which they have been elaborating into the medullary fibres. These fibres thereby become swollen and shortened, and the intermediate spaces between them are constricted,

and unable to receive any further additions of lymph. But when the nerve-cells are undergoing their diastole, then the medullary fibres contract, and the intermediate spaces around them are opened, so that the pericellular sacs are able to discharge their lymph into these spaces. This lymph, however, is denied admission into the perivascular sheaths of the vessels whence it was discharged in the first place, because these sheaths are then being supplied with a serosity or lymph out of the arteries and capillaries themselves, and besides their mouth is gradually being closed up by the swelling grey substance around them. This same lymph, however, experiences no difficulty whatever in gaining admission into the interstices around the departing medullary fibres; for these interstices are thirsty for the lymph of the pericellular sacs, because they receive no moisture and no nutriment whatever from the medullary fibres which they enclose. Hence the reason why Swedenborg says, that for the moisture which fills the spaces around the cortical glands, there is "no other outlet, except into the interstitial spaces around the fibres."

30. The perivascular sheaths with which the arterial twigs are furnished on leaving the sulci of the convolutions and on entering the substance of the brain, it seems, were first described by Kölliker in 1850, and afterwards by Robin in 1859. For a while they were disregarded, but were newly described by Arndt and Golgi in 1870; but their continuity with the subarachnoid space was only fully established by Key and Retzius. These authors describe the course of the blood-vessels in the brain in the following manner: "The blood-vessels, before ramifying and losing themselves in the cortex, for some distance run along the exterior surface of the pia mater. These vessels are fastened most intimately to the pia mater by fine little membranes. . . . The pia mater always follows the surface of the brain very accurately into all its anfractuosities and depressions. . . . Vascular shoots, which at first still preserve their natural position, deflect at last from the vessels in the pia mater, and at right angles penetrate into the cortex. On entering the cortex they run along a funnel-shaped indentation of pia mater, which by and by fits more closely around the coating of the vessel, and which in the form of a sheath accompanies each vessel. . . . This perivascular sheath, in larger vessels, is slightly different from what it is in capillaries; thus in the former vessels it is more or less removed from the parietes of the vessel. . . . In the sheath itself there is scarcely any trace of structure; it appears almost as clear as glass and homogeneous. . . . In the smaller transitional blood-vessels the

middle, muscular coat disappears altogether, the perivascular sheath remaining as a clear homogeneous sheath, more or less distant from the interior coat. Often, however, in the capillaries this sheath becomes plainly visible as it retreats from the interior coat. Everywhere, in fact, its presence is indicated by small, beautiful, and singular nuclei. . . . The spaces which are contained within the perivascular sheaths are serous canals which are in open communication with all the subarachnoid spaces. A communication between these spaces and the epicerebral space of His, the existence of which, however, is doubtful, does not exist" ("Studien," etc., I., pp. 142-156).

Two stages are plainly marked here in the course of the blood-vessels through the brain. During the first stage the vessels pursue their course through the fissures and sulci of the brain while they are attached to the pia mater, and where they ramify into smaller branches. The second stage begins when arterial twigs separate from their parent stems in the pia mater at right angles, and dip into the grey substance. The serosity distilled from the vessels during their first stage seems to be discharged into the subarachnoid space, while that which is distilled from them after they have separated from the parent stem at a right angle seems to be destined for the interior of the brain; for it is received in the perivascular sheaths and is urged along the course which is pursued by the blood-vessels themselves.

Yet during this second stage in the course of the blood-vessels, a new change, or a break, occurs as well. For by and by the muscular coat of the vessels disappears, and the vessel becomes a capillary where nothing except the tunica intima, lined with the perivascular sheath, remains. At first also the perivascular sheath hangs loosely about the vessel, but after it has become a capillary, the sheath embraces most closely the tunica intima, the only coating of the vessel which remains. A different, nobler, and more refined kind of liquid seems to be distilled from the vessel after it has become a capillary; and this last and most refined kind of liquid, according to Swedenborg's theory, is destined for the "pericellular sac," in order that thence it may be derived between the individual medullary fibres which originate from the cortical substance of the brain—while, on the other hand, the liquid secreted from the vessel before the loss of its muscular coating, seems to be of a grosser kind, and intended for the irrigation of those membranes by which the groups of fibres of which the future nerve-roots are made up, are enclosed. Any surplus of this liquid which would remain stored up in the perivascular sheaths, during the systole of the cortical substance, is expressed into the sulci and fissures of this substance, and is finally discharged into the subarachnoid space.

31. But let us pursue still further the fluid of the *first* order which collects in the "pericellular sacs," and is derived thence between the individual medullary fibres in the brain.

So far as that fluid is concerned, which collects in the pericellular sacs of the grey substance of the *cerebrum*, its further history is twofold: for the fibres between which it courses have a twofold destiny. One portion is carried through the ceiling of the lateral ventricles and through the "centrum ovale" generally into the corpus callosum, and thence through the fornix and the fimbriæ of the fornix into the choroid plexuses of the lateral ventricles; while the other portion is directed through the corona radiata into the corpora striata and optic thalami.

As the fibres of the corpus callosum terminate in this organ, and in the fornix which is a process of the corpus callosum, so also the refined serum—the spirituous lymph—which lubricates the sides of the individual medullary fibres conveyed thither, terminates its course here. In the choroid plexuses, whither this lymph is taken through the fimbriæ of the fornix, a grosser serum is added to it which is secreted from the choroid plexuses themselves, and both these lymphs are utilized in fixing the spirit of the fibres—the animal spirit—for the purposes of the red blood, in the manner and mode described in our Notes III. and VI., which treat of the "Chymical Laboratory of the Brain."

Those fibres of the cerebrum, on the other hand, which through the corona radiata are directed into the corpora striata and optic thalami, are there gathered into groups for the use of the future peripheral nerves of the body; and there our present liquid—the highest and most refined portion of the cerebro-spinal fluid—fills a most important part; for it lubricates these fibres, and enables them in freedom to enter upon their uses in the body.

The corpora striata and optic thalami, however, and also the "tegmentum" and "pes" of the crura cerebri—the continuations of the above central ganglia—add to the cerebral fibres indigenous fibres of their own, which likewise require to be lubricated and moistened. And in the region of the corpora quadrigemina, as well as in the pons Varolii, and throughout the whole course of the medulla oblongata and the spinal cord, a large quantity of cerebellar fibres are intermixed with those which come from the cerebrum. Besides, the fibres of this threefold progeny of the cerebrum, cerebellum, and central ganglia, in the medulla oblongata and spinal cord are joined by those which originate in these common appendages of the cerebrum and cerebellum—so that a large amount of the above most refined species of the cerebro-spinal liquid is in constant demand.

For this reason an extra supply of this lymph is supplied by the cerebellum which abounds in grey substance more than any other member of the encephalon; and which for the same reason also enjoys an abundant apparatus for the distillation of the "spirituous lymph" which we are now discussing. This lymph is distilled from the cerebellum through its processes and peduncles which constitute the ceiling and sides of the fourth ventricle, into this ventricle; and wherever a supply of this lymph is required, be it for the cranial nerves which have their nuclei of departure in the immediate neighbourhood of this cavity, or be it for the spinal nerves, the needed wants are here supplied. The cranial nerves the cerebellum supplies immediately from its own stores through the mediation of its processes or peduncles, but for the spinal nerves it makes provision through the mediation of the fourth ventricle and the central canal of the spinal cord, in the manner described above in Section *d*.

32. The further course of the present fluid through the anterior and posterior roots of the spinal nerves is described and delineated by Key and Retzius.

These authors, in the first place, have proved by direct injections that the individual nerve-fibres in the spinal nerves are enclosed by "fibrillous sheaths" which intercommunicate, and may be injected by a delicate liquid. Their description of these sheaths is as follows: "Outside the sheath of the Schwann, which belongs more especially to the nerve-fibre itself, there are obtained by teasing more or less numerous, delicate fibrils of connective tissue. . . . In successful preparations they are seen arranged around the nerve-fibre in regular order, forming a membrane which appears more or less distinctly marked with streaks due to fibrils. These fibrils, therefore, belong to an outer sheath which encompasses each single nerve-fibre in the shape of an ample tube or pipe. . . . An injection passing from the 'perineurium'—the membranous covering of the fascicles—into the interior of the nerve, sometimes enters on the way into the interstices between the fibrillous sheaths of the individual nerve-fibres; yet without remaining confined there, it penetrates even into the interior of these fibrillous sheaths, thus irrigating immediately the sheath of Schwann" ("Studien," etc., II., p. 102; see above, no. 704*w*).

These fibrillous sheaths, together with the membranes which enclose the groups of nerve-fibres in the interior of the fascicles, these authors denominate 'endoneurium," as appears from the following quotations:

"All that connective tissue which extends inward from the 'perineurium,' and which is thus contained in the interior of the nerve-fascicles, we denominate 'endoneurium' (*Op. cit.*, II., p. 68).

"The fibrillous sheaths, as well as the membranes which enclose the groups of nerve-fibres within the fascicles, we term 'endoneurium'" (*Ibid.*, p. 102).

The further course of this fluid, after the nervous fibres have reached their places of destination in the muscles and in the organs of sense, will be treated of below.

2. *The Subarachnoid Juice or Cerebro-Spinal Liquid proper: the Fluid of the Second Order.*

33. This *second* species of the cerebro-spinal liquid in general—the cerebro-spinal liquid proper—that is, that liquid which is generally understood under this name by the learned, has been treated throughout the whole of this present Note, especially in Sections *a* and *b*, entitled respectively: "The Existence and Origin of the Cerebro-Spinal Liquid," and "The Relation of the Cerebral and Cerebellar Liquids," and also in Sectious *e* and *f*, which treat of "The General Purpose and the Final Destiny of the Cerebro-Spinal Liquid" and of "its Laws of Motion."

Our object in the present subdivision is to trace this liquid more definitely from its beginnings in the interior of the brain, through the various stages of its course, until at last it bathes the fascicles of the peripheral nerves; and at the same time to exhibit clearly the relations in which it stands to the cerebral fluid in the lateral ventricles; and thus to summarize the results at which we have thus far arrived, and to draw thence some necessary conclusions.

The homestead of the present species of the cerebro-spinal liquid in general, according to Swedenborg, is in the sulci and anfractuosities which encompass the glomes and tori, that is, the various congeries of the cortical substance. There it is distilled out of the arterial shoots which by the pia mater are directed into the interior of the substance of the brain.

The course of these shoots we traced in no. 30 in the previous subdivision, where we showed that two, or rather three, stages may be marked in their course. During the first two stages the vessel is an ordinary arterial vessel furnished with two coats, the muscular and the tunica intima; during the third stage it is a capillary which has lost its muscular coating. The serum which is distilled from the arterial vessel during its first two stages, that is, before it becomes a capillary, is our present species of the cerebro-spinal liquid in general; and the goals where it is discharged are twofold—a central and a peripheral one. The central one is under the membranulæ which enclose the plexuses of the second order in the medullary substance (concerning which see above, no. 27); the peripheral one is the subarachnoid space. For it must be remembered here that, according to Key and Retzius, the subarachnoid tissue accompanies the pia mater wherever it dips into the sulci and anfractuosities of the cortical substance, while the arachnoidea itself remains on the surface. The fluid discharged into the medullary substance with the view of irrigating there the plexuses of the second order, whence arise the future nerve-roots or fasciculi, is of a purer nature than that which is received in the subarachnoid space; and again that which is distilled into the subarachnoid space from the *cerebellum* is purer and more homogeneous than that which is received in this space from the *cerebrum*. The general position, that the fluid under consideration irrigates, on the one hand, the membranulæ enclosing the plexuses of the second order, and by and by those which encircle the nerve-roots and fasciculi, and that, on the other hand, it is received in the cells of the arachnoidea, is stated by Swedenborg in the following passages:

"As each of the glandules of the cortical substance is separated from the neighbouring ones, and enclosed by a small space; so each lesser congeries or cortical glome is encompassed by clefts and sulculi, and each larger congeries or cortical torus by deep and anfractuous fissures. . . . From the clefts and commissures by which the larger congeries of cortical glandules are distinguished, a genuine serum impregnated with urino-saline and fatty particles is derived between the fasciculi of the nervous fibres. The arachnoid membrane is spread over the pia mater for this purpose, that it may be instrumental in pouring a lymph of a better quality on the nerves" (II., no. 355).

"From the small cells of the arachnoid membrane, and from the clefts around the clusters and glomes of the cortical particles there distils a pure and oily serosity, between the fasciculi of the medullary and nervous fibres, and also between the coatings of the nerves, which are thereby properly lubricated" (IV., no. 170).

34. Our next object will be to trace the further course of the fluid of the *second* order, both that of its purer kind which circulates through the plexuses of the medullary substance, and that of its comparatively grosser kind which is received by the subarachnoidal tissue. And here again we shall have to distinguish between the fluid derived from the cerebrum, and that which is secreted in the cerebellum.

Beginning with that species which owes its origin to the cerebrum, we first notice that a portion of it is directed towards the corpus callosum, and the other towards the corpora striata and the optic thalami.

The whole of the fluid which follows in the latter direction, that is, in that of the central ganglia, is freed on the way from its grosser ingredients. The more refined fluid is reserved for circulation between the fascicles of the departing nerves; while the serum of a grosser quality is excreted into the larger spaces of the medullary substance, and thence through the corpora striata is directed into the corresponding spaces of the olfactory bulbs; whence it is finally discharged into the nares through the cribriform plate.

That fluid which is carried by the fibres in the direction of the corpus callosum is for the most part excreted into the lateral ventricles. For Swedenborg states in his "Memorabilia," that "the large ventricles of the cerebrum are places where serosities trickle down from the interstices between the fibres, and from other sources. These ventricles are a kind of urinary bladder of the cerebrum" (no. 830). This statement he made in 1748.

In an earlier draught of his work on the "Brain," Swedenborg states, that "the nervous juice which courses between the fibres which are carried to the corpus callosum is sent to the optic thalami" (see above, I., no. 430*e*). This juice is the more refined part of this liquid, after the grosser serosities have been strained off from it; and, as we have shown (Vol. I., p. 741), it is probably carried into the thalami optici through the anterior roots of the fornix which are planted in the interior of the thalami, and also through its posterior roots which are fastened to the surface of the thalami optici during their descent into the lower cornua of the lateral ventricles.

35. As to that portion of our present liquid which is received in the subarachnoid space, we must first call attention to the anatomical fact, that through the intervention of the tentorium the cranial cavity is divided into two compartments, a superior and an inferior, or a cerebral and a cerebellar. The opening through which these compartments communicate is called by some authors the "foramen occipitale superius," and is formed by the free edge of the tentorium

—the incisura tentorii. According to Luschka,[1] this foramen is filled up by "the crura cerebri, the corpora quadrigemina with the pineal gland, the anterior end of the superior vermiform process of the cerebellum, the basilar artery, and the vena magna Galeni." And he adds, "Whenever the available space of the inferior compartment is reduced by illness, not only the contents of this latter compartment suffer in a general way from pressure, but also the parts specified above are liable to be wedged into the foramen occipitale superius, and to be strangulated as it were by the sharp edge of the tentorium" (p. 139).

From this it follows that by a mere expansion of these parts also, which is caused by the diastole of the cerebrum, this foramen would be closed up, and would thus prevent the passage of the subarachnoid liquid from the lower into the higher compartment, although these compartments would no doubt freely communicate during the systole of the brain, and also in collapsed brains after death.

During the diastole of the brain, therefore, in conformity with what has been established above (in Section *f*, nos. 18-25), the cerebro-spinal liquid rises from the spinal cavity into the lower cranial compartment, filling there all the subarachnoid spaces or confluents; and it is directed thence into the subarachnoid spaces of the departing cranial and spinal nerves. But this same liquid would not be able to pass through the foramen occipitale superius; because during the diastole of the brain this foramen is completely closed up by the swelling of the parts specified above. Whence it follows that there exists an anatomical division between the subarachnoid fluids in the higher and lower compartments of the cranial cavity, during the diastole of the brain which is synchronous with the expiration of the lungs.

This division is so much the more necessary, because, suppose the descending cornu of the lateral ventricles should be distended, as is the case sometimes, by an "infected serum, as in the case of hydrocephali," etc. (see above, Vol. I., p. 759, and also our present Note, no. 5)—this serum would be discharged into the subarachnoid space of the upper compartment during the diastole of the brain, and thus during the time when the "foramen occipitale superius," in the "incisura tentorii," is completely closed up, so that not a drop of it can escape into the lower compartment, and thus vitiate the cerebro-spinal liquid which is about to depart into the interstices of the

[1] Luschka (H. v.). "Die Anatomie des Menschen," Vol. III., Section ii. Tübingen, 1867.

cranial nerves. Besides, during the diastole of the cerebrum the sulci and anfractuosities of its convolutions are closed up,[1] so that no vitiated serum in the subarachnoid space of the upper compartment can penetrate into them, but is at once urged towards the outlets of this space. These outlets, as is proved by Key and Retzius and Quincke, are the Pacchionian corpuscles along the sinuses of the dura mater. These corpuscles, as will presently be shown, receive the subarachnoid fluid of the upper cranial compartment, whether healthy or diseased, during the diastole of the brain; and during its systole they discharge it into the sinuses, and thus into the venous system of the brain.

Luschka[2] proved that these Pacchionian corpuscles are only an enlarged condition of normal villi of the arachnoidea, and that no other structure is involved in their formation.

The ordinary structure of the corpuscles, as seen under the microscope, according to Key and Retzius, is as follows: "A narrow stem departs from the arachnoidea; it penetrates into the dura mater between its fascicles of connective tissue, and there it enlarges into a club-like or pyriform shape; or else makes its way into a vein, or into a venous sinus, or again into one of those large, peculiar, venous lacunæ which we discovered along the sides of the longitudinal sinus, which lacunæ more or less intercommunicate with one another" ("Nordiskt Medicinskt Arkiv," Vol. iv. of 1870; p. 38). The lacunæ containing these granulations were discovered about the same time by Trolard[3] (see above, Vol. I., p. 295).

The further description of the corpuscles, as given in Quain's Anatomy, is as follows: "Each villus is covered by an epitheliated membrane, continuous with the arachnoid. Outside this is another fine membranous sheath proceeding from the dura mater, and the interval between the two is continuous with the subdural space. Within the villus is a spongy trabecular tissue, continuous with the subarachnoid tissue, and of similar tissue" (8th edit., p. 576).

[1] Quincke's experience applies here, who says, "In none of my experiments did the colouring matter enter . . . the perivascular spaces of the brain and spine; the reason of which seems to be, that in a normal condition these spaces, indeed, discharge their contents into the subarachnoid space, without, however, receiving any liquid from the subarachnoid space in return" (*Op. cit.*, p. 172).

[2] In "Archiv für Anatomie, Physiologie und wissenschaftliche Medicin," for 1852; and in "Adergeflechte," etc. Berlin, 1855.

[3] Trolard (Dr. P.). "Recherches sur l'Anatomie du Système veineux du Crâne et de l'encéphale." In "Archives Générales de Médecine," Vol. xv. Paris, 1870.

The following are the results obtained by an injection of these corpuscles as described by Key and Retzius: "On making a subarachnoidal injection under very light pressure, the liquid penetrates through the subarachnoid spaces of the brain, and through the meshes of the subarachnoid trabecular system which is usually found in the neighbourhood of the arachnoidal villi; it passes through the trabecular meshes in the stems of the villi, into the villi themselves; and, indeed, without passing into the subdural space of the cerebrum. After arriving in the villi, it spreads through the meshes of their tissue with the same facility with which a sponge is filled [with water]. The meshes between the trabeculæ are thereby rendered tense, the villi are erected, and they appear tinged with the colour of the injected fluid. The liquid, however, does not remain long confined within the limits of the trabecular system of the villi. On the contrary, it soon passes through the layer which constitutes their surface, and enters into the subdural space of the villus. This also it fills, and renders tense, as well as the dural sheath by which it is encompassed. Yet it does not remain even there, but flows through the dural sheath into the venous sinus or the lacuna without, in order in this manner to mix with the blood. . . . On the question of the function of the arachnoid villi, we answer, their function is certainly to effect a junction between the serous spaces, that is, between the cerebro-spinal liquid of the brain, and the system of the blood" ("Studien," etc., I., pp. 183, 185).

From this then it follows that the Pacchionian corpuscles are the channels through which the subarachnoid liquid of the cerebral, or superior cranial compartment, whether in a healthy or morbid condition, is introduced into the venous system of the brain. According to Key and Retzius, the liquid which these villi imbibe is also discharged into the veins of the dura mater. In this wise then, that is, through the mediation of the Pacchionian corpuscles or arachnoidal villi, the membranes of the encephalon are relieved of any ultra-pressure of the cerebro-spinal liquid. For if there is any extra pressure of this liquid at all in the inferior cranial compartment, it will naturally escape into the higher compartment; and when once there, through the expansion of the brain, it is urged into the arachnoidal villi, distending the same; but during the subsidence or systole of the brain, the contents of these villi are emptied into the sinuses.

That these corpuscles are the goal whither the stream of the cerebro-spinal liquid tends in the higher cranial cavity, is proved also by Quincke's experiments on living animals. He says, "An additional place of discharge for the subdural and subarachnoid fluids, according to Key and Retzius, is in the Pacchionian granulations. . . . In my own experiments also these formations were distinguished by being strongly tinged with vermilion; whether the injection was made from the vertebral column, or the cranium. These places were along the longitudinal and lateral sinuses; and also along the cavernous sinuses I sometimes noticed these formations" (*Op. cit.*, p. 164).

During the systole of the cortical substance or grey matter of the brain, the subarachnoid spaces of the whole encephalon, including those of the spinal cord, enlarge, and receive the serosity which has collected in the sulci and perivascular spaces of the cerebrum, medulla oblongata, and spinal cord. During this period also the foramen occipitale superius in the "incisura tentorii" is opened, so that the serum which has been excreted in the larger sulci and anfractuosities of the cerebrum from the shoots of the carotid arteries, may mix with the general contents of the subarachnoid spaces. This also is the period generally when the cerebro-spinal liquid retreats from the cranial into the vertebral cavity—which the authors inform us takes place during the inspiration of the lungs, and thus during the systole of the brain.

36. The cerebellum, according to Swedenborg, follows a different plan from the cerebrum in the discharge of the serum or lymph excreted in its gyres and sulci; for all these gyres converge in the poles of this organ, namely, in its horizontal fissure (see above, no. 675). Thither presses not only the animal spirit which is elaborated in its grey substance, but also the refined serum or lymph which is extracted in its folds from the shoots of the vertebral artery; and while the animal spirit is urged into the medullary stem of the cerebellum, which divides on either side into three processes or peduncles, the refined serum which collects in the horizontal fissure, is carried towards the inferior vermiform process in the middle; and thence through the endothelial membrane with which it is lined, and which is continuous with the valve of Vieussens—the velum medullare anterius—this serum or lymph trickles into the fourth ventricle, between the first processes of the cerebellum.

This Swedenborg states in the following words: "Such also is the case with that moisture which does not penetrate the arborescent growth of the cerebellum, but passes through the folds under the pia mater, and through the duplicatures of the same, and which pursues its course until it finds an exit. This humour also cannot shower down anywhere else than under the membrane whereby the peduncles are lined, and through the vermiform process where this same membrane is attached to the valve of Vieussens" (I., no. 712).

The above cerebellar secretion in the fourth ventricle receives accessions from two sources; *first*, from the most refined serum or lymph—the cerebro-spinal liquid of the *first* order—which from the pericellular spaces encircling the cortical glandules, the nerve-cells, of the cerebellum is urged into the interstices between the individual medullary fibres which make up the three peduncles of the cerebellum (see above, no. 31). Any surplus of this refined lymph, according to Swedenborg, is likewise discharged into the fourth ventricle, during the systole of the cerebellum. Thus he says, "The medullary processes of the cerebellum become inserted, and as it were ingrafted, in the medulla oblongata, exactly near the edges of its ventricle; but the spreading apart of these processes takes place almost above the middle of the ventricle. Should, therefore, the medullary substance of the cerebellum, at any time, be supplied with more liquid than is required for the use of its fibres, it would seem to exude the same into the ventricle, likewise in this very place" (I., no. 715*g*).

Its *second* accession, and indeed one of a grosser order, the cerebellar fluid receives from the choroid plexus in the fourth ventricle. On this subject Swedenborg says, "To the above liquid the fourth ventricle adds its own dew which is distilled out of the choroid plexus; for this reason indeed that this liquid may pass into the interstitial spaces around the roots or fasciculi of the spinal nerves. . . . The secretion of the choroid plexus seems to be required for the composition of this liquid, almost in the same manner in which in the lateral ventricles the animal spirit requires to be mixed with the nervous juice—the cerebro-spinal liquid; and this again with the secretion of the choroid plexus. . . . This appears sufficiently from the transverse production of this plexus near the extremity of the calamus scriptorius, where there is the beginning of the downward flow of the liquid; and also from the glandular character of the plexus itself, and its close application to the bottom of the ventricle. This plexus also is not subject to those changes to which the choroid plexuses of the lateral ventricles are exposed, so that it constantly pours forth a homogeneous moisture" (I., no. 715*i*).

From this history of the composition of the cerebro-spinal liquid in the fourth ventricle, it appears that the liquid which collects there bears a different character from that which is excreted into the subarachnoid space from the fissures and sulculi of the cerebrum, and the perivascular spaces of the medulla oblongata and spinal cord; and it follows thence also that the real essence of the cerebro-spinal liquid is derived from the cerebellum, so that this liquid is in a supereminent degree a cerebellar, and not a cerebral liquid.

After this liquid has received all its various ingredients, its contents—as shown above in sections *c* and *d*—are discharged on the one hand into the central canal of the spinal cord, and on the other through the foramina of Magendie and Luschka they pass into the subarachnoid space. The cerebro-spinal liquid of the *first* degree, according to the needs of the spinal cord, is excreted from the fourth ventricle, through the epithelial lining of the central canal, while the rest of the moisture of that ventricle—the cerebro-spinal liquid of the *second* degree—is derived thence into the subarachnoid space, where it mixes with the rest of its sera or lymphs.

The fourth ventricle discharges its contents during the diastole of the brain, and thus while the cerebro-spinal liquid rises from the vertebral into the cranial cavity, that is, into the lower compartment of the same. It is thus sent first into the confluents or cisterns of the subarachnoid space which are situated around the dorsal and ventral sides of the medulla oblongata; and which on the one hand extend over the central portion of the posterior surface of the cerebellum, and on the other are continued over the ventral portion of the pons Varolii as far as the infundibulum and the crura cerebri, and which on the opposite side likewise bathe the corpora quadrigemina and the pineal gland.

These confluents include thus the whole area where the cranial nerves emerge from the cranial cavity; and from these confluents the cerebellar liquid is at once carried into the subarachnoid spaces of the departing cranial nerves.

During the systole of the brain the cerebellar liquid descends into the vertebral cavity, where it becomes thoroughly mixed with the cerebro-spinal liquid which is there, and during the diastole of the cord it is urged into the subarachnoid spaces of the anterior and posterior nerve-roots of the cord.

37. W. Krause[1] speaks of primary and secondary fasciculi which make up the whole of a cranial or spinal nerve.

The primary fasciculi are formed before the nerve-roots enter the

[1] Krause (W.). "Beiträge zur Neurologie der oberen Extremität." Leipzig und Heidelberg, 1865. Also, Kraues (W.) and Telgmann (J.). "The Nerven-Varietäten beim Menschen." Leipzig, 1868.

subarachnoid space. They are nerve-groups encompassed with pia mater; and this same pia mater also encloses the whole of the nerve-roots as they leave the central organs. Between the membranulæ of the pia mater there courses the cerebro-spinal liquid of the *first* order, which also bathes the individual nerve-fibres.

On entering the subarachnoidal space, the nerve-roots, according to Key and Retzius, are enveloped by the membranous and trabecular tissue peculiar to this space. Portions of this tissue let themselves down between the primary fasciculi of the roots, establishing thereby trabecular and membranous connections between them.—These are the beginnings of Krause's secondary fasciculi.

As the nerve-roots approach the outer wall of the subarachnoid space, the arachnoidea and dura mater each furnish a sheath to the departing nerves. The sheath which consists of subarachnoid tissue is likewise continued; and it begins to connect itself now with the arachnoidea by means of a trabecular network. By this connection of the two there is formed the subarachnoid space of the nerve-roots. This space encloses the secondary fasciculi of the nerve-roots, and in this space is received the cerebro-spinal liquid of the *second* order.

Sheaths and membranulæ of a threefold origin thus accompany the nerves, as they leave the central nervous organs. Membranulæ from the pia mater enclose the individual fibres and the primary fasciculi. Laminæ from the arachnoidal sheath, together with membranulæ and trabeculæ of the subarachnoid tissue, encircle the secondary fasciculi; while the dural sheath encompasses the whole nerve. Liquids also of a threefold kind, namely, the cerebro-spinal liquid of the first, second, and third orders, irrigate the membranulæ and sheaths of the departing nerves. Such is the complexion of the nerves, as they leave the cranium and vertebral theca.

The original distinctions between the sheaths and membranulæ of a threefold origin, however, begin to be lost as the nerves enter upon an independent course in the body—they are preserved only in the optic nerve.

The results at which Key and Retzius arrived in their experiments upon the peripheral nerves, and which are stated above at large in nos. 704*u* to 704*z*, may be summed up thus:

1. The dura mater, the arachnoidea, and the subarachnoid tissue are continued from the central nervous organs into the very end-bulb of each single nerve-fibre.

2. The dura mater is transformed into the *epineurium* of the

departing nerves; and the arachnoidea together with the subarachnoid tissue into their *perineurium* and *endoneurium.*

3. The interstices between the laminæ of the perineurium and endoneurium are continuations of the subarachnoid space.

4. As the perineurium thus blends with the endoneurium, so also it blends, on the other hand, with the epineurium. While, therefore, laminæ from the epineurium will descend into the perineural spaces, laminæ from the perineurium ascend also into the epineural circumference of the nerves. The cerebro-spinal liquid follows the example set by the membranulæ and sheaths; and in proportion as the boundaries which originally existed between the dural and arachnoidal sheaths on the one hand, and between the latter and the pia-matral productions on the other, are in a measure abolished, the liquids which circulate in their interstitial spaces become also in a certain measure amalgamated; yet so that the grosser serosities would still be in the circumference of the nerves, and the more refined lymph in their interiors.

The cerebro-spinal liquid of the *second* order would thus at first circulate through the subarachnoid spaces, and hence through the perineurium of the peripheral nerves, but in time would blend and mix with the cerebro-spinal liquids both of the *first* and of the *third* order.

3. *The Subdural Juice: the Fluid of the Third Order.*

38. Concerning this liquid Swedenborg says, "Besides the above-named noble lymph which oozes out of the arachnoid membrane . . . there is another humour—*the subdural juice*—which descends from the cranial cavity into that cavity which surrounds the spinal cord. . . . Still, the pituitous liquid of the cerebrum, which collects between the membranes [the dura mater and the arachnoidea], cannot be carried into the spinal cord; for the tentorium is in the way, and prevents it; but only that particular liquid which lodges on the surface of the cerebellum, and of the medulla oblongata of that region. That this latter liquid or juice is of a better character than that secreted around the cerebrum, follows from the same cause which was given above. That this liquid, however, penetrates between the membranes or fascicles of the nerves, may be concluded and confirmed from the viscous and mucilaginous humour, by which the dura mater appears anointed, especially around its bottom part; and further

from innumerable phenomena of diseases, when the nerves are infested by humours percolating through them. In addition, it is proved by autopsy, for such a humour has been observed between the coatings and fascicles of the nerves" (I., no. 773).

The next thing which concerns us is to confirm the existence of this subdural juice by reference to the experience of modern science.

Schwalbe says, "The subdural space contains only a very small quantity of a liquid, whereby the surfaces of the membranes which are turned toward each other, are kept smooth and slippery" (*Op. cit.*, p. 784).

Key and Retzius observe, "Generally during life there seems to be a greater proportion of this liquid in the subdural space than is discovered there after death. Through a series of vivisections in dogs, which amounted to several hundred, *Hitzig* convinced himself abundantly of the existence of a small portion of liquid in the sack of the dura; in the case of dogs also he found that twenty-four hours after death not a single drop of the liquid could be found there over the convexity of the brain. . . . As to ourselves, although we cannot base ourselves on so many vivisections as Hitzig, still after a sufficient number of experiments made upon dogs and rabbits . . . we are able to state that if, without injuring the arachnoidea, a little opening be made in the dura mater, a small quantity of fluid may be seen oozing out of the opening, and, as Hitzig states, you may constantly see it pouring out from the sides. Still, in comparison with the subarachnoid juice, the quantity is small, not large. It evidently forms only a very thin, capillary stratum between the dura and the arachnoidea" ("Studien," etc., I., p. 73).

39. After thus proving the existence of this liquid, our next point will be to determine whence it comes, and where it goes. But here it will be necessary to call attention again to the anatomical fact, discussed above in no. 35, namely, that the cranial cavity through the intervention of the tentorium is distinguished into an upper and a lower compartment; and that during the diastole of the brain the foramen occipitale superius in the "incisura tentorii," which connects the two compartments, is closed up, so that the cerebral subarachnoid liquid cannot mix with that secreted by the cerebellum.

A similar distinction, according to Swedenborg, exists in the subdural space of the cranium; and this distinction in space implies also a distinction in the subdural liquid. Swedenborg says on this subject, "To that liquid which is wont to collect between [the outer lamina of the] pia mater—the arachnoidea—and the dura mater; to that, namely, which collects around the cerebellum, no other egress remains open, except either between the coatings of the cranial nerves, or through the posterior part of the foramen magnum into the spinal cord, and thence between the coatings of the nerves of that region. All the remaining ways are closed to it: for there are no veins anywhere, by which it may be absorbed." And then he continues and says, "But the pituitous juice of the cerebrum which collects between those membranes, cannot be carried into the spinal cord (for the tentorium is in the way and prevents it), but only that particular liquid which lodges on the surface of the cerebellum, and of the medulla oblongata of that region" (I., no. 773).

The subdural liquid of the *cerebrum* is thus prevented from descending into the lower cranial compartment, and thence into the vertebral cavity; but by the expansile motion of the brain is urged towards the peculiar outlets of the subdural space, which, according to Swedenborg, open into the interior nares through the cribriform plate. He says, "In order that the brain may have the faculty of performing its functions, it must be constantly purged and relieved of that liquid which is perpetually expressed from its members and arterial vessels (no. 825). . . . There are a number of foramina by which the lamina cribrosa of the ethmoid bone is pierced in many places. Not only fibres, but also the pia mater, and at the same time the dura mater, pass through these foramina; the pia mater investing the fibres, and the dura mater lining the orifices. The pia mater thus constantly passes out under the dura mater, and thereby opens a passage; and unless this passage is always bathed by some lubricating moisture, these two membranes will speedily coalesce. Wherefore we are compelled to assume that the above liquid passes into the cavities of the nose through the above openings. And again it appears that this liquid does not flow out of its own accord, but is pumped, and thus forced out. For while the cerebrum is being expanded, every one of its cavities and every one of its fibres is lengthened out, and at the same time, so far as their width is concerned, contracted. From this retraction of the coatings of the fibres, there results not only an alternate swelling [and contraction], but also a species of pumping, so that when the passages between the pia and dura mater are open, there must needs be discharged through them the above liquid; and its discharge must take place at the same time, when the cerebrum rises and urges the liquid in that direction. . . . In defunct brains, however, and in such as are collapsed, these communicatory passages must necessarily be strictly closed, so that they are not pervious even to the most rectified spirit, and still less to one which is coloured. . . . This explanation is also favoured and attested by the glandular and papillary texture of the mucous membrane, and especially by its duplicature, and the wonderful insertion of the pia and dura maters into this extensive region. Here the excrementitious humour of the cerebrum is mixed with the glandular and arterial humour expressed out of the mucous membrane, and thus seems to produce that phlegmy substance which is called the mucus of the nose" (I., no. 827). But the channel through which this liquid is conveyed into the subdural space, according to Swedenborg, are the olfactory bulbs, in which he holds "the medullary substance of the cerebrum is concentrated," and towards which also "the determination of its motion converges" (see I., no. 829).

The truth of this position, namely, that a liquid distils out of the subdural space of the cerebrum into the mucous membrane of the nose, has been proved experimentally by Schwalbe, and Key and Retzius. Subdural injections which these latter observers made in rabbits just killed, penetrated through the foramina of the cribriform plate into the mucous membrane of the nares, and "through special channels in the epithelium of that membrane reached its surface" (*Op. cit.*, I., p. 220).

Waldeyer,[1] under whose superintendence Dr. F. Fischer[2] repeated and tested the whole of the experiments made by Key and Retzius, says, "In conclusion, I have to observe, that we succeeded in filling completely the lymphatic vessels of the *human* mucous membrane of the nares, through injections made from the large lymphatic spaces of the membranes of the brain. Key and Retzius were unable to do this; thus far they had been successful only in experiments made upon animals" (p. 366).

40. Swedenborg adds, "Whether such excretory passages and emissary ducts exist anywhere else, experience thus far has failed to answer in the affirmative; and yet it is an undoubted fact that this humour is actually discharged" (I., no. 826). Swedenborg speaks here of outlets out of the upper cranial compartment; for the

[1] Waldeyer und Fischer (Fr.). "Beiträge zur Kenntniss der Lymphbahnen des Central-Nervensystems." In "Archiv für Mikroskopische Anatomie," Vol. xvii. Bonn, 1880.

[2] Fischer (Fr.). "Untersuchungen über die Lymphbahnen des Central-Nervensystems." Strassburger Dissertation. Bonn, 1879.

subdural liquid of the lower compartment, he maintains, is regularly discharged into the subdural spaces of the peripheral nerves.

Such additional outlets out of the subdural space of the upper cranial compartment have been discovered since Swedenborg's time, both into the sinuses of the dura mater, and into the lymphatic system of the body. Thus Key and Retzius say, "By injections it is found, that a liquid which is under the influence of some pressure in the subdural space, through the mediation of Pacchionian granulations, especially in man, passes with great ease into veins . . . or, again, through lymphatic vessels it passes into the lymphatic system of the body" (*Op. cit.*, I., p. 75).

Schwalbe says, "Communications of the subdural space with deep lymphatic vessels and lymphatic glands of the neck, may be demonstrated by the injection of coloured masses into the subdural space. This communication was first discovered in rabbits by Schwalbe, who injected the subdural space of the brain, and his discovery was confirmed by Key and Retzius so far as rabbits and dogs are concerned. In the human subject, on the other hand, the injected mass was found to penetrate much more easily into veins by the way of the Pacchionian corpuscles" (*Op. cit.*, p. 785).

41. Waldeyer points out still another outlet out of the subdural space. He says, "There is, however, still another communication between the subdural space and the blood-vessels of the dura mater, than through the arachnoid villi—the Pacchionian corpuscles—and the sinuses; and herein I shall have to correct and supplement the data of the Swedish authors. For, after injecting the subdural space, we found that the injected mass adhered closely to the inner surface of the dura mater; especially in the neighbourhood of the longitudinal sinus. These portions of the dura mater, indeed, as is well known, exhibit constantly that appearance which Key and Retzius describe as 'cribriform.' On making vertical sections through such places, you are able to see how the injected mass from place to place has entered the substance of the dura mater through some small, narrow paths. In the dura mater itself the injected mass appears at one time in small, stellated lacunæ, at another in larger, fissure-like spaces, and in the veins generally. This regular occurrence can scarcely be explained otherwise than that the injection penetrates through the interior, endothelial lining of the dura mater into its system of lymphatic spaces or canals, which in its turn communicates with the venous apparatus of this membrane" (*Op. cit.*, p. 365, *et seq.*).

Concerning these openings from the interior of the dura mater into the subdural space, we have to observe here that we do not consider it at all as an established fact that these openings are for the purpose of introducing the subdural juice into the veins of the dura mater, as Waldeyer seems to think. On the contrary, they may just as well be outlets for the lymphatic juice contained in the dura mater; wherefore we maintain that the openings and passages discovered by Waldeyer and Fischer are the real sources of the subdural juice, and thus of the cerebro-spinal liquid of the *third* order—both in the upper and lower cranial compartments. In the upper craniai compartment, in the neighbourhood of the cribriform plate of the ethmoid bone, there is, besides the gross, pituitous humour which, according to Swedenborg, is excreted from the cerebrum through the olfactory bulbs. For these bulbs, as Schwalbe correctly observes (*Op. cit.*, p. 814), bear no analogy whatever to the rest of the cranial or spinal nerves. They are prolongations of the cerebral substance, and the individual olfactory fibres or groups of fibres—*fila olfactoria*—pass through the ventral portion of these bulbs, without being first collected into fasciculi or nerve-roots; but, through the interstices of the medullary substance in these bulbs, there is carried along the excrementitious, pituitous humour which is to be discharged from the subdural space into the cavities of the nares; and one of the objects of the abundance of grey substance in the olfactory lobes seems to be, that there shall be an abundance of motive power for the ultimate expulsion of the sluggish pituitous secretion.

42. The question here arises whether the subdural juice, and thus the cerebro-spinal liquid of the *third* order, does not receive any additions from the subarachnoid juice, and thus from the cerebro-spinal liquid of the *second* order?

Where the dura mater, in the form of a dural sheath, accompanies the departing cranial and spinal nerves, there Swedenborg believes that the two liquids, the subdural and the subarachnoidal, commingle. For, speaking of the place of departure of the nerves, he says, "Whether the arachnoid membrane pours out also something of the store of its noble lymph—this question we may decide in the affirmative, since it seems probable from the connection of the parts: for right here it seems duplicated" (I., no. 773). Up to this point, according to him, the liquids are kept separate.

Herein Swedenborg is fully borne out by modern science. Thus, Waldeyer says, "In all successful injections it was clearly shown that *the subdural space does not communicate directly with the sub-*

arachnoid space. But both injected masses, the one tinged yellow from the subdural space, the other of a blue colour which was injected from the subarachnoid space, passed into the Pacchionian granulations, and thence into the sinuses, into which these granulations projected. The whole process was found to be exactly as described by Key and Retzius" (*Op. cit.*, p. 365). Schwalbe also substantiates Key and Retzius' statement, that "there is no communication between the subdural and the subarachnoidal spaces" (*l. c.*, p. 785).

Quincke, on the other hand, makes this statement, "Inasmuch as the colouring matter after being injected into the subdural space of the cranium, made its way into the subarachnoid spaces of the brain and spinal cord, there must exist in the arachnoidea openings of communication between the two spaces" (*Op. cit.*, p. 164).

Key and Retzius, in reviewing this statement of Quincke, say, "Quincke introduced a pointed canula through the dura into the subdural space [they themselves used one the point of which was blunted], where he could scarcely avoid injuring the arachnoidea; but it was next to impossible afterwards to find the point of lesion. . . . Neither does he state how many experiments led him to his belief. . . . When Quincke's paper on the cerebro-spinal liquid appeared, we instituted anew a series of injections of an emulsion of vermilion from the subdural space of the brain. The animals—dogs and rabbits—were killed after two or three days. The injection had remained purely subdural. The results agreed totally with those which we had previously obtained by an injection of living and dead animals, and also in dead human subjects. The injected mass was still in the subdural space; the greater part of it had remained spread over the cerebrum itself; not the least particle had penetrated into the subarachnoid spaces" ("Studien," etc., I., p. 67).

43. As to the subdural liquid in the lower cranial compartment, which descends through the subdural space of the spinal cord—this liquid, according to Swedenborg, is finally introduced into the subdural spaces of the peripheral nerves. For he says, "That this liquid, however, penetrates between the membranes or fascicles of the nerves, may be concluded and confirmed by the viscous and mucilaginous humour, by which the dura mater appears anointed, especially around its bottom part. . . . In addition, it is proved by autopsy, for such a humour has been observed between the coatings and fasciculi of the nerves" (I., no. 773).

Swedenborg, however, is evidently in error where, on the strength of the anatomical observations of his time, he declares that the coating of the peripheral nerves consists only of the outer lamina of the dura mater. His statement is as follows: "The coating of the nerves consists of the outermost lamina of the dura mater only, and not of its inmost, which is perforated in two places by the anterior and posterior roots of the spinal cord : wherefore a small space is left between the two laminæ of the dura mater, from which no exit is possible, except between the coatings and fascicles of the nerves" (I., no. 773). He is, however, quite right in the continuation of his statement, where he maintains that some of the subarachnoid liquid is introduced into the subdural space of the departing nerves. This takes place in proportion as the dural and arachnoidal sheaths begin to be conjoined in the departing nerves, and in proportion as the dural sheath of the nerves is changed into *epineurium*. This process is minutely described by Key and Retzius. A summary of their results is contained above, in the text of our work, in nos. 704*u* to 704*z*. From this summary we introduce here all that refers to the gradual transformation of the dural sheath into the epineurium of the peripheral nerves :

On approaching the outer wall of the subarachnoidal space, so far as the spinal nerves are concerned, their anterior and posterior roots draw nearer together, so as to leave that space in company; the arachnoidea and dura mater each furnishing a sheath to the departing spinal nerves.

On the outside of the arachnoid sheath, between the latter and the dural sheath, there is formed the subdural space of the nerve-roots, which is connected immediately with the subdural space of the spinal cord. This subdural space is richly interspersed by trabeculæ, whereby the arachnoidal and dural sheaths are connected.

In this manner the nerve-roots are attended by an arachnoidal and a dural sheath, until the nerves reach the spinal ganglia.

Before approaching the ganglion, however, the nerve-roots are at first broken up more and more into [secondary] fasciculi; and here the dural sheath plays an important part. In the first place, a dural partition is always erected between the anterior and posterior roots after they are united into one nerve. The dural sheath itself is fortified in addition, on the outside, by a layer of connective tissue derived from the outermost integument of the spinal cord, which is attached interiorly to the bony surface of the vertebral column. In the nerve-roots this exterior tissue works itself more and more into the substance of the dural sheath, so that at last the boundary line between the two becomes effaced.

A similar process takes place interiorly between the dural and arachnoidal sheaths; for trabeculæ in an increasing ratio pass from the dura into the arachnoidea. Besides, through the mediation of small membranes which are generated between them, these two sheaths become attached to each other over larger or smaller tracts, so that at last they can be separated only through artificial means.

The dura mater, besides, goes on forming additional partitions between the individual fascicles; and between the dural partitions and these fascicles themselves there is always some arachnoidal tissue. The further, therefore, the nerve-roots retreat from the cord, the more are they subdivided into distinct nerve-fascicles, each of which is encompassed by an arachnoido-dural sheath.

On examining the spinal ganglion the existing arrangements are continued there. The dural sheath is thus found to be continued over the whole surface of the ganglion, after it has first entered into an intimate conjunction with the adipose tissue from the vertebral theca by which the nerve-roots had been attended. Under the dural sheath of the ganglion the arachnoid tissue, consisting of many cellular membranes in close juxtaposition to one another, is continued. The dura and arachnoidea are joined together in many places, and many trabeculæ pass from the former into the latter, so that the boundary line between the two is effaced.

A similar resolution into their constituent membranulæ, and at the same time an effacement of the boundary line, takes place in the interior of the ganglion between the pia-matral and arachnoidal sheaths, and there results thence by degrees what Key and Retzius denominate the *endoneurium* and *perineurium of the ganglion.*

From the perineurium of the ganglion, however, new membranes are rising towards the outer covering of the ganglion; and as they draw nearer to the outer surface of the ganglion, oblique clefts open here and there between them. Thence there arises, according to Key and Retzius, the *epineurium of the ganglion,* which becomes amalgamated completely with the original dural sheath of the nerve-roots, and finally becomes attached to the outermost adipose tissue of the ganglion.

The perineurium and endoneurium, therefore, are not new creations wrought in the ganglion, but they are simply homogeneous laminated transformations of the dural and arachnoidal sheaths which through the nerve-roots have been continued from the spinal cord.

44. In this transformed form the dural, arachnoidal, and pia-matral sheaths of the nerve-roots are continued into the peripheral,

spinal, and cranial nerves. And in proportion as these sheaths become thus transformed, and as the boundary lines between them become effaced, the liquids which circulate under these sheaths are also gradually amalgamated, and thus the subarachnoidal juice, as Swedenborg observes, commingles freely with the subdural juice—although the grosser ingredients of the "nervous juice" which arises from an amalgamation of the original, three species of cerebro-spinal liquid, would still press into the larger interstices of the nerve in its epineurium, while only the most refined portion of this liquid would penetrate into the least interstitial spaces whereby the individual nervous fibres are encompassed.

All this is further proved by the injections instituted by Key and Retzius. A few of these results we here subjoin:

"When an injection is made from the subdural space of the brain or spinal cord, the liquid passes with great ease between the dural and arachnoidal sheaths as far as the ganglion. Afterwards both liquids enter the ganglion" (see above, I., no. 704*x*).

"On injecting simultaneously both the subdural and subarachnoid spaces, the respective liquids pursue for a time each a separate path. In the neighbourhood of the ganglion, however, where the dural and arachnoidal sheaths begin to be more and more connected, the paths of the liquids also encounter one another here and there, so that the liquids will commingle. In the interior of the ganglion they encounter one another still more. *Generally perhaps the subdural liquid remains within the dural sheath.* . . . From the laminæ of the arachnoidal sheath the injected liquid penetrates here and there easily into the subdural space, and into the laminæ of the dura mater, and thence farther into the spaces of the adipose tissue, wherewith the nerve-root is engirded. Nevertheless, this is no reason why at other times *the two different injections should not remain confined each to its own territory*" (*Ibid.*).

h. The Universal Circulation of the Cerebro-Spinal Liquid.

45. We have thus far traced the course of the cerebro spinal liquid from its origin in the larger and smaller fissures and sulculi of the brain, where it is secreted from the arterial twigs and capillaries—through the interstices between the individual and collective nerve-fibres, as far as their peripheral terminations in the body.

The stage at which we have now arrived in our discussion is perhaps expressed best by the following words of our author: "A nerve of the above description which is interpolated by as many cavities as perhaps a pumice-stone, the tufa, and the stalk of a bulrush, and which is permeated by as many indigenous juices as are proper to it, is inserted into the muscles, glands, and membranes of the body, and deposits there the burthens which it bears" (IV., no. 70).

We shall not enter here into the very complex question of the modes of termination of the nervous fibres, and the mode by which nervous fibres are able to produce actions in and by the body, but we shall limit ourselves to the simple inquiry of what becomes of the cerebro-spinal liquid which is set free at the terminations of the nerves in the muscles. For unless it be removed and despatched as soon as it arrives there, the peripheral organs of the body would soon be flooded by this liquid which is constantly being formed anew in the brain by the resolution of blood-corpuscles, and conveyed in the interstices of the nerves to their termini in the body.

Swedenborg answers this question in a general way, thus: "The liquids which are secreted from the arterial twigs of the brain, between the convolutions and subdivisions of the cortical tori, enter into the roots of the nerves, and after passing through the nerves, they return to the brain, yet to its outermost circumferences" (II., no. 528).

Again he says, "This nervous juice—the cerebro-spinal liquid—according to the extent of the nerves, seems to spread over the coatings of the muscles, and to be conveyed thence into the periostea, and by continuity therewith into the integuments of the spinal cord; whence it rises into the dura mater and the pericranium, that is, into the outermost circumferences of the brain, in order that there it may either be utilized in the nutrition of the hair and bones, or be exterminated" (*Ibid.*).

46. The individual steps in this general circulation of the cerebro-spinal liquid, in the language of our author, are as follows:

"As soon as a nerve enters its muscle or gland, that is, some viscus of the body, it becomes at once divided into branches, these are divided into twigs, and afterwards into shoots, and thus into the original fasciculi of the nerve, and presently into its individual fibres, so that it may attend to its functions. When, therefore, the nerve unfolds itself, it also seems to offer to the enclosed juice an opportunity of flowing forth. That the muscular coats are irrigated by a certain nervous juice, which is also continued into their tendons and beyond, appears from a description of the muscles" (II., no. 533).

"The last coat of the muscles is continued to fixed boundaries or solid substances; for the muscle, which is a soft substance, is unable to found or base its forces upon things soft, but upon solids capable of offering resistance: hence the outermost lamina, which constitutes the periosteum, is a continuation of that vascular membrane which surrounds the muscular flesh. . . . The second or interior lamina of the periosteum, however—for it is composed of two membranes—consists simply of tendinous filaments drawn out from the muscular flesh; it immediately encircles the bones, inserting and implanting its roots in fixed spots therein; thus enabling the bones to yield to the muscular force, and to nature's decrees. . . . This interior lamina serves as a cushion for the blood-vessels and nerves, so that in the freest manner they may pass or flow into the osseous and medullary substance of the bones" (II., no. 545).

"These two laminæ of the periosteum are perfectly distinct from each other; and indeed the innermost lamina is also separate or distinct from the surface of the bone; for it does not adhere to it, except where tendinous or ligamentous filaments, and blood-vessels and nervous fibres, are inserted into the bone. And as the laminæ are distinct, and the texture of the periosteum is lax or loose, it follows that some species of liquid percolates and circulates through it: that liquid, namely, which is expressed from the muscles, especially from those which are in the seat of motion, and which is collected between the motive fibres, and also in the cellular tissue of the muscles; which liquid is at the same time oily and watery, and gently touches and lubricates the bones" (II., no. 546).

"The motion of these laminæ arises from that of the surrounding muscles, which as they are variously called into play, exert a varying action upon these laminæ, and indeed a reciprocal action of the internal and external periosteum, causing a traction and retraction—a drawing to and fro—whereby the liquid is driven from part to part" (*Ibid.*).

"The fluid, however, which circulates through the muscular membranes and their cellular tissues, and in the end through the periostea, is discharged in divers places; namely into the adipose cells, producing fat, and into all the interstices of the body. Besides, it may be discharged through the more open pores of the skin, in which case it passes off in sweat; and again it may take its course towards the peritonæum and the pleura, whose channels of discharge have already been pointed out [in "Regnum Animale, I., no. 325; II., nos. 426, 427]; for when the pores of the skin are closed, and perspiration prevented, it then either circulates through the periosteum, or is driven towards the peritonæum and pleura, and *vice versa*" (II., no. 547).

47. Again, "According to the general rule, every liquid tends from the circumferences towards the centres, or from the greatest motion to the least; consequently, from every particular bone which is a circumference towards the vertebral column which is the central axis of the bones" (II., no. 546).

"As all the bones of the whole body refer themselves to the vertebral column as to their fulcrum, or as to the common axis of the centres of gravity of their motions, in which they finally merge, so also is the case with the periostea. For in this axis terminate the shoulder-blades, the ribs with the sternum, the collar-bones, the bones of the arm; and further down the ossa innominata, the ossa pubis, and the rest; in this axis consequently the action of the whole body expires. This same stream of motion follows the volume of the liquids which occupy the fibres of the periostea" (II., no. 535).

"The ligamentous covering which invests the vertebral canal, connects its articulations and junctures from within; it governs and moderates the varieties of its motion, and acts as a uniting medium, as it were, between the things of the body and those of the spinal cord. It also transmits a juice and a portion of its aliment to the periostea of the cranium; which juice, in company with the arteries, produces the hair of the head, feeds it, and causes it to grow. This coating is continued from all the membranes, vaginæ, and capsular ligaments of the bones, such as the ribs, shoulder-blade, collar-bone, sternum, the ossa innominata or ischii, the ilium and os pubis; in short, from every one of their periostea. Thence a continuous pathway is established into this integument.

"For cavities, like windows, are between the posterior articulations and the spinous processes; similar ones are also anteriorly in the os sacrum; and these cavities are covered with this ligamentous coating or covering. To this coating there is attached very closely on the outside, at the edges, the vagina or covering which invests the vertebral column; and further the ligamentum sacro-sciaticum, and several others of the os sacrum. The liquid which is drawn from these sources is poured around the whole of the ligamentous covering in the interior, and is pumped up towards the higher regions; and near the foramen magnum, where this covering is thickest, it is transferred to the dura mater, and at the same time to the pericranium; for these coatings are there very closely united.

"This is confirmed by a great number of phenomena; namely, by the oleaginous lymph and viscidity which constantly oozes out from this coating, at least where it is turned towards the dura mater. A similar oily humour is also abundantly met with under the epidermis, or near the roots of the hair. It is further confirmed by the determination of liquids towards their centres; consequently, by the determination of the humours of the periostea towards the vertebral column which is the first and last terminus or centre of all the solid parts of the body. Again, by its own very soft fibres, and their oblique and straight continuations towards the edges of the foramen magnum. And, further, by a kind of pumping which is continued from the bottom upwards. For the vertebral column, by the elevation of the ribs, is inclined forwards and bent back again in alternate periods; and the very windows or fenestræ at the back are constricted and relaxed at the same moments, and thus imbibe and propel the humour mentioned above. The muscles and ligaments also, with which that part in the back is closely lined, lend their aid.

"There is thus carried on a certain perpetual circulation; for the brain sends out its vital spirit into the body through the fibres; but the body sends back a more ignoble juice which is relegated into the outermost circumferences of the brain" (I., no. 772).

48. "As the spinal cord approaches the foramen magnum, its dura mater, which is there thicker and more ruddy with carneous fibres, becomes attached more strongly to the ligamentous covering of the vertebral cavity. This latter covering also is fortified there by additional coatings. Many delicate filaments also are bathed there in an abundant stream, so that this place seems to be, as it were, a meeting-place of the juice which is poured into it, and propelled thence into the higher regions. Pressing closely to the osseous walls, this juice cannot pass anywhere else than through the foramen magnum into the dura mater, and at the same time into the pericranium; for these membranes are continuations of the two integuments of the spinal cord mentioned above. Perpetual filaments also pass and repass between the ligamentous covering and the dura mater. The action of the atlas or of the first vertebra on which the head revolves, contributes likewise to this result; for the action of this vertebra is more powerful than that of the remaining vertebræ; and that of the cervical vertebræ surpasses that of the

dorsal. For the production of this result also, all the vertebræ are fitted into each other, and fortified by muscles.

"In the dura mater itself, there are strata recipient of a juice, and it is also furnished with fibres which are neither nervous nor tendinous, and yet are pervious to moisture, and which therefore must needs be irrigated by a juice similar to that which has just been described. Such a juice also the dura mater communicates immediately through filaments produced from its outer lamina which pass through the sutures, to the osseous substance of the cranium, and likewise to the pericranium, which originally was closely and intimately connected with the dura mater" (II., no. 536).

"That the nervous juice is propelled further by the cerebellum and cerebrum, appears from the fibres of the dura mater which are as it were muscular, . . . and from several other adscititious forces whereby the dura mater is moved when the cerebrum is in a state of motion. In this manner, then, that juice is propelled. The road which it takes seems to be from the foramen magnum towards the middle of the sphenoid bone, and laterally upwards into the dura mater itself, where it is loosely adjoined to the cranium. In the upper part of the dura mater it seems to be carried along the canal [the longitudinal sinus], where there is also a duplicature of the membrane [the falx cerebri], which when it is acted upon on both sides propels the juice forwards, and thence towards the whole circumference. The greater portion of the nervous juice, however, insinuates itself first into the tentorium, and thence upwards in the direction of the cerebrum, and likewise into the falx cerebri, and thus upwards in exactly the same direction as that taken by the fibres. Thus every part of the dura mater obtains its supply. All this appears manifestly from the direction of the fibres of the dura mater" (I., no. 286*d*).

"The interior lamina of the dura mater is a peculiar membrane which is a vehicle for the lymph impregnated with spirit that is set free when the nerves are distributed over the muscles and periostea. . . . The interior lamina consists of ducts or tubes which convey the nervous juice; this appears from the formation of these ducts; for they are ample and large. They also transmit a copious supply to the periosteum; and if no passage is granted to it there, it transmits this juice between the meninges [*i.e.* into the subdural space]" (I., no. 286*c*).

"It appears that the dura mater adheres to the cranium through a certain spongy substance, through which other shoots than those of blood-vessels pass. Further, that cords and ligaments pass in a wonderful manner from one lamina of the dura mater into the other; by this process of crossing the two laminæ are not only made to cohere, and the blood-vessels compressed, but the ducts or tubes containing the nervous juice are also pressed together at the same time; and each time when they are thus compressed, they emit their juice. From the inflection of the strata it appears, that the determination of the fibres has this effect, that the liquids contained in the dura mater are determined in that direction where this membrane is attached closely to the cranium; namely, under the sagittal, lambdoidal, and coronal sutures, or towards the cavities between the meninges [*i.e.* the subdural space], which is proved by experience; or finally, towards the roots of the nerves; in order that the circle, that is the circulation, may be continued. This, however, takes place chiefly with that lymph which has only once been collected between the meninges [*i.e.* in the subdural space]" (Swedenborg's Photo-lithographed MSS., Vol. vi., p. 293, nos. 83 and 84).

"Into those peculiar little tumours—the Pacchionian corpuscles—ducts are opened from the arachnoid membrane and the pia mater, through which there is instilled a liquid or refined lymph. For there is a connection of causes, and from remote parts there is constantly derived thither a certain lymph, whence some suppose these corpuscles to be lymphatic vessels. The above theory is confirmed by experience; for throughout the whole brain no lymphatic vessels proper have been discovered" (I., no. 286*e*).

49. As the elements of Swedenborg's theory of the universal circulation of the cerebro-spinal liquid are contained in various parts of his scientific MSS., we considered it useful to combine these stray parts into a united whole in the preceding paragraphs—hence the lengthy presentation. The above theory appears strange and startling at first, but when the individual steps of which it consists are critically examined, this strangeness disappears. Most of these steps are based on general anatomical facts. As for instance, that the cerebro-spinal liquid on arriving in a muscle spreads first throughout the whole of the muscle; that then it collects under its areolar or aponeurotic sheath, and by the continuity of that sheath with the periosteum is transmitted in that direction. All that is required here to be proved is the continuity of the muscular sheath with the periosteum; which, however, is a general anatomical fact. The fact once admitted that the cerebro-spinal liquid, in its capacity of nervous juice, accompanies the nervous fibres to their terminations in the muscles, places must be provided for, through which this liquid

may be led away from the muscles. But the continuity of the outer sheath of the muscle with the periosteum shows that the liquid is discharged in this direction.

On this subject we read in Cruveilhier,[1] "The *aponeuroses* are fibrous membranes, arranged in the form of inextensible textures, which constitute sheaths for the muscles, and at the same time afford them broad surfaces for attachment. . . . The *periosteum* must also be annexed to the aponeurotic system; it is a true aponeurosis, covering every part of the bones, and constituting a fibrous sheath for them. We may consider the periosteum as the central point of the aponeurotic system, proceeding from which, we find tendons expanding either upon the surface, or in the substance of muscles, and constituting the aponeuroses of insertion; or else those fibrous cones or pyramids, from the interior of which the fleshy fibres take their origin. From the periosteum, or rather from the ridges or clefts by which the surfaces of bones are marked, both the parietal and general investing aponeuroses arise" (p. 388).

The fact, however, that a liquid is conveyed under the aponeuroses, and thus under the sheaths of the muscles, and that from the muscles it is conveyed into the sinews and tendons by which the muscles are appended to the bones, and through which the aponeurotic coating of the muscles is continued into the periosteum of the bones—has been proved experimentally by Key and Retzius.[2] They say, "When a sinew or tendon is injected by puncture, the moisture runs along the individual sinewy strands. Upon examining such injected sinews, it appears, especially in horizontal sections, that each individual strand is surrounded by an injected ring, which, when examined under a high magnifying power, is found to be under the interior of the sheath by which the sinew is enclosed, and by which the individual sinewy strings are separated from one another. . . . The sheaths of the sinews are even continued into the muscles to which they belong, between the fasciculi or bundles of which they send out thin membranous formations; and by these the individual muscular fasciculi are enclosed. The injection which is made into a sinew or tendon thus spreads even under the little membranes by which the individual fasciculi of the muscle are enclosed" (p. 15). The above results Key and Retzius obtained by injecting a rat-tail; yet similar results they obtained by injecting human tendons, and also those of higher

[1] "Op. citat.," Vol. i.

[2] Key and Retzius. "Om senornas byggnad och saftbanor." In "Nordiskt Medicinskt Arkiv," Vol. vii., no. 21. Stockholm, 1875; pp. 1-21.

mammalia, such as the dog (see p. 18). At last, as borne out by their observations, the injection enters into regular lymphatic vessels by which the blood-vessels are attended in the interior of the tendons and sinews. In these lymphatic vessels, according to these authors, the lymphatic spaces in the sinews and tendons finally terminate.

Still it does not follow thence that there is no connection on the other hand between the lymph-tracks of the sinews and those of the periosteum. But the discovery of these tracks will have to be left to future observers—although the continuity of the aponeuroses of the tendons with those of the periosteum, as appears from the quotation from Cruveilhier, is an acknowledged anatomical fact.

50. The next step in Swedenborg's theory is expressed in these words, "As all the bones of the whole body refer themselves to the vertebral column as to their fulcrum, or as to the common axis of the centres of gravity of their motions, in which they finally merge, so also is the case with the periostea."

The general anatomical fact on which this further step in Swedenborg's theory is based is undeniable; for the vertebral column is actually the general axis of all the bones of the human skeleton, to which they refer themselves as to their fulcrum. But experience further proves that the periosteum of the vertebral canal, *i.e.* the ligamentous covering of the spinal cord, contains lymphatic spaces, and that its communications branch out in many directions of the body. Thus Quincke says, "If the vermilion [on making injections into the vertebral canal] is not deposited exclusively in the subarachnoid space, but if some portions, or the whole of it, gets into the cellular tissue between the dura mater and the periosteum of the vertebral canal—in this case, especially from the dorsal surface of the vertebræ, it spreads out to a greater or smaller distance, sometimes as far as the cervical part of the vertebral column. By the lymphatic current it is sometimes carried a good deal farther. It thus makes its appearance in the lumbar lymphatic glands which are situated near the aorta; further, in the subclavian and mediastinal lymphatic glands; also, in the inner surface of the intercostal muscles, so that it shines through the pleura. While in a subarachnoid injection the vermilion is confined closely to the course of the intercostal nerves, the paths of an injection when made into the cellular tissue of the vertebral canal, are marked out much less definitely. It penetrates into the intercostal spaces under the pleura much more diffusely and a good deal farther; sometimes also it seems to follow the course of the vena azygos" (*Op. cit.*, p. 160).

But as to Swedenborg's statement that between the dura mater of the spinal cord and the ligamentous covering in the interior vertebral canal, there is a lymphatic space, in which a liquid may be propelled as far as the foramen magnum, this is placed beyond doubt by Waldeyer and Fischer's experiments. The former says, "Some of the experiments which we instituted seem to prove that the *epidural* space of the spinal cord also, namely, the space between the dura spinalis and the parietal surface of the vertebral canal, may be classed as a lymphatic canal. The injections, which consisted of $\frac{1}{4}$ per cent. of a solution of silver, were accomplished by means of a canula shaped in the form of a screw; that is, they were made by a canula of steel in the form of a hollow screw which was simply bored through a vertebra near a processus spinosus. The lumen of the canula during the act of boring was closed by a peg. After the perforation was accomplished, the peg was withdrawn and the india-rubber tube of the vessel containing the injection raised up. During the injection we always noticed an uncommonly easy advance of the liquid into the serous cavities of the body, that is, into the pleura and peritoneum; likewise along the peripheral spinal nerve-trunks" (*Op. cit.*, p. 366).

51. From the lymphatic spaces in the ligamentous covering the lymph which we are now discussing, according to Swedenborg, is transmitted to the dura mater of the cranium, and in part also to the pericranium. On this subject, as we have seen above, he says, "As the spinal cord approaches the foramen magnum, its dura mater, which is there thicker . . . becomes attached more strongly to the ligamentous covering of the vertebral cavity. This latter covering also is fortified there by additional coatings. Many delicate filaments also are bathed there in an abundant stream, so that this place seems to be, as it were, a meeting-place of the juice which is poured into it, and propelled thence into the higher regions."

The existence of these anatomical conditions is abundantly confirmed by anatomical researches. So, in addition to what was quoted above from Waldeyer and Fischer concerning the lymphatic spaces in the ligamentous covering of the vertebral canal, Richet[1] says, "Throughout the whole extent of this canal, which is really considerable, it consists of walls which are partly osseous and partly membranous, and which are consequently susceptible of a certain degree of extensibility. Besides, between the dura mater which is very loose, and the osseous wall, there exist a great number of venous

[1] Richet (A.). "Traité pratique d'Anatomie Médico-Chirurgicale." Seconde édition. Paris, 1860; p. 284, *et seq.*

plexuses, and a kind of semi-fluid fat, which, like the blood, if required, is able to flow outside of the vertebral canal."

Concerning these venous plexuses we read in Henle,[1] that "the anterior plexuses are more powerful and denser than the posterior; so dense, in fact, that the veins of the injected plexuses are separated by mere cleft-like interstices" (p. 357). These interstices, according to Richet, are filled with a kind of "semi-fluid fat," which Swedenborg defines as an "oily" or "oleaginous lymph."

The topmost venous plexus of the vertebral column where it approaches the foramen occipitale, as is shown in Breschet's[2] plate, is wider and more expanded than any other plexus of the vertebral canal, and hence also the intermediate spaces which contain the "oily lymph" in question are also wider there, thus furnishing that kind of meeting-place for this lymph, as is described above by Swedenborg.

52. Our author continues on the subject of the further progress of the "oily lymph:" "Pressing closely to the osseous walls, this juice cannot pass anywhere else than through the foramen magnum into the dura mater, and at the same time into the pericranium; for these membranes are continuations of the two integuments of the spinal cord mentioned above. Perpetual filaments also pass and repass between the ligamentous covering and the dura mater." Again he says, "The road which this juice takes, seems to be from the foramen magnum towards the middle of the sphenoid bone, and laterally upwards into the dura mater itself. . . . The largest portion of the nervous juice—the oily lymph—however, insinuates itself first into the tentorium, and thence upwards."

This is proved by the course of the above-mentioned plexuses after they reach the cranial cavity, as this is described by Henle. He says, "The topmost venous ring of the vertebral canal is situated between the occipital bone and the atlas, and is continued in an *anterior* direction into the plexus basilaris; while the *posterior* branch of this same venous ring gives rise to the occipital sinus" (*Op. cit.*, p. 358).

Concerning the "basilar plexus," however, which extends from the occipital bone to the sella turcic of the sphenoid bone, he says, "A more or less copious venous net is formed in that part of the dura mater which covers the carnial declivity, out of canals which

[1] Henle (J.). "Handbuch," etc. Vol. III., sect. i., "Gefässlehre." Braunschweig, 1868.

[2] Breschet (M. G.). "Recherches anatomiques sur le système veineux." Paris, 1829. Livr. 1, planche 5.

originate in the cavernous and intercavernous sinuses; which net is laterally connected with the inferior petrosal sinuses, and in a downward direction empties into the venous plexus of the anterior wall of the foramen magnum. This venous net is the *basilar plexus* of Virchow"[1] (*Ibid.*, p. 335).

In the direction of the "basilar plexus" on the one hand, and of the "occipital sinus" on the other, the "oily lymph" would thus pursue its course after it has reached the foramen occipitale; yet under altered conditions. For the ligamentous covering of the vertebral canal, as it approaches the foramen occipitale, loses its independent character, and partly passes over into the dura mater, and partly is continued into the pericranium.

53. In proportion, however, as the dura mater of the cranium assumes those functions which in the vertebral canal are exercised by the ligamentous covering—in the same proportion lymphatic ducts have to be provided for in the dura mater for the reception of the "oily lymph." On this subject Swedenborg says, "The interior lamina of the dura mater is a peculiar membrane which is a vehicle for that lymph impregnated with spirit which is set free when the nerves are distributed over the muscles and periostea. . . . This interior lamina consists of ducts or tubes which convey the nervous juice. This appears from the formation of these ducts; for they are ample and large."

The existence of such a system of lymphatic tubes in the dura mater, has been abundantly proved by Key and Retzius. From their researches, which are given at full length in our Vol. I., p. 233, *et seq.*, we quote as follows: "On making injections by puncture there are often filled in the tissue of the dura peculiarly formed systems of little tubes. . . . If the injection is very strong, the little tubes are so much crowded that the dural tissue can be scarcely perceived. . . . Each tube is usually quite straight, and, as may be seen in vertical cuts, its shape is generally cylindrical, and it terminates in sharp points. . . . The question now arises whether these spaces are naturally preformed, *i.e.* whether they are natural canals. It is indeed more than probable, nay, it is necessary, that there should be real systems of lymph-canals in the dura mater. Besides the blood-vessels, the above are the only canals which can be demonstrated by methods of injection; therefore it is also highly probable that these tubular systems represent the lymph-canals" ("Studien," etc., Vol. I., pp. 165, 166).

[1] Virchow. "Untersuchungen über die Entwickelung des Schädelgrundes." Berlin, 1857. See above, Note vi., no. 37.

54. The mechanism by which the "nervous juice" or "oily lymph" is circulated through the dura mater, according to Swedenborg, differs essentially from that by which that same lymph is caused to ascend the vertebral canal towards the foramen occipitale. On this subject he says, "That the nervous juice [after reaching the dura mater in the cranial cavity] is propelled farther by the cerebellum and cerebrum, appears from the fibres of the dura mater, which are, as it were, muscular [*i.e.* elastic ; compare on this subject Vol. I., pp. 706-709, where the motion of the dura mater is examined]. It appears further from several other adscititious forces whereby the dura mater is moved, when the cerebrum is in a state of motion." But in what manner the motion of the dura mater, which is excited by that of the cerebrum and cerebellum, acts upon the lymphatic ducts of this membrane, and propels the juice contained therein, Swedenborg explains thus, "Cords and ligaments pass in a wonderful manner from one lamina of the dura mater into the other. By this process of crossing, the two laminæ are not only made to cohere, and the blood-vessels compressed, but the ducts or tubes containing the nervous juice are also pressed together at the same time ; and each time when they are thus compressed, they emit their juice."

Such a crossing of fibres from one lamina of the dura mater into the other, is an anatomical fact. On this subject Key and Retzius say, "As may be seen with the naked eye, and as has been generally acknowledged, the fibrous fascicles in the dura mater of the brain are chiefly arranged into two principal layers. . . . The two principal layers, however, are most intimately conjoined by an interchange of fascicles, so that any separation of the two must be termed an artificial one" (*Op. cit.*, Vol. I., p. 157). Compare Vol. I., p. 702.

The method by which the "nervous juice," the "oily lymph," is propelled in the ligamentous covering of the vertebral canal, is quite different from that which is stated here. There the movement of this juice, according to Swedenborg, is caused mainly by the force of capillary attraction, assisted by the motion of the dura mater and the respiratory motion of the thorax. In illustration of this subject, Swedenborg says, "There is nothing of more frequent occurrence in the vegetable, animal, and also in the mineral kingdoms, than that juices constantly percolate through the fibres of membranes. For whether a juice be of an aqueous or oily nature, it ascends with the greatest ease, and almost spontaneously, from the bottom to the top ; so that in certain vegetable textures, in stalks, twigs, grasses, and trees, the juice or the sap ascends from the root to the highest top; especially, if on the one side there be a hard body to which the percolating membrane is attached. . . . Besides innumerable other instances and phenomena taught by chemistry and physics, by which is proved that liquid menstrua, oil, spirit, or waters, by their own efforts as it were pass through membranes chiefly of the animal kingdom, made for the transmission of liquids; and that they do not rest until they emerge and come into contact with the air" (II., no. 537).

The assistance, however, which the "oily lymph" in its ascent towards the foramen occipitale derives from the motion of the dura mater and the respiratory movements of the thorax, according to Swedenborg, is as follows: "The vaginal coating of the vertebral canal is acted upon immediately by the spinal cord itself by means of the fibres of the nerves and the vascular shoots which it transmits through the same. The dura mater of the cord also, which is closely attached to the ligamentous covering in front . . . . is likewise tightened and relaxed in alternate periods. The very vertebræ also bend and unbend, fold and unfold this coating at the same alternate periods, although in an insensible manner: for when the ribs are raised, the upper part of each vertebra is drawn one way, and its lower part another way; whence there redounds an effect upon the vaginal coating of the vertebral canal" (II., no. 536). "Thence," as we read in another place, "there results a series of pumping which is continued from the bottom upwards. For the vertebral column by the elevation of the ribs is inclined forwards and bent back again, and the very windows or fenestræ in the back [where the oily lymph collects] are constricted and relaxed at the same moments, and thus imbibe and propel the humour mentioned above. The muscles and ligaments also wherewith that part is closely lined on the back, lend their aid" (I., no. 772).

On comparing the two mechanisms for the propulsion of the lymph in question, we find that in the ligamentous covering of the vertebral canal it is chiefly urged on by the force of capillary attraction, while in the cranial dura mater its circulation depends upon the motion of this membrane, which in its turn depends upon that of the cerebrum and cerebellum. In the cranial dura mater the lymphatic ducts are thus alternately opened and shut by the relaxation and stretching of the fibrous fascicles which pass from one of its laminæ into the other, and the juice in question is thus emitted from these ducts in alternate intervals which are dependent in the first place upon the motion of the brain. While thus, in a dead subject, an injection made into the ligamentous covering of the vertebral canal would, without any difficulty, ascend as far as the foramen occipitale by sheer force of capillary attraction, its further progress would be stayed there by the collapsed state of the lymphatic ducts in the cranial dura mater, as has also been proved by experience. Thus Waldeyer says in respect to the injection instituted by Dr. Fischer and himself: "During an injection of the ligamentous covering we always noticed an uncommonly easy advance of the liquid into the serous cavities of the body. . . . But, on the contrary, the mass never penetrated into the cranial cavity, which fact can be very easily explained by the anatomical relations of the spinal and cranial dura mater" (*Op. cit.*, p. 366).

55. As regards the ultimate destiny of the "nervous juice" which circulates through the lymphatic ducts of the cranial dura mater, Swedenborg says, "The nervous juice [originally] secreted from the cerebrum, as well as from the cerebellum, the medulla oblongata, and the spinal cord, and which is transmitted thence in the interstices between the fibres of the fascicles or roots of the nerves, and which is enriched by only a small portion of a spirituous ingredient—[in the end] seems to be expended chiefly on the nutrition of the bones, and at the same time on the production of the hair, lest that spirituous ingredient, which is latent within, should perish without having been productive of any use" (II., no. 539).

From this it would follow that there exists an uninterrupted communication between the lymphatic ducts in the interior of the dura mater, and the pericranium which gives birth to the hair; and, on the other hand, that these ducts are in close connection with the interior surface of the cranium to which the exterior lamina of the dura mater serves in the capacity of periosteum. On this subject Swedenborg says, "A juice of the above description, the dura mater, by means of filaments produced from its outer lamina, which pass through the sutures, furnishes immediately to the osseous substance of the cranium, and likewise to the pericranium, which originally was closely and intimately connected with the dura mater" (II., no. 536). Again he says, "From the inflexion of the strata of the dura mater it appears that the determination of the fibres has this effect, that the liquids contained in the dura mater are determined in that direction where this membrane is closely attached to the cranium; namely, under the sagittal, lambdoidal, and coronal sutures" (see above, in no. 48).

In these statements Swedenborg is fully borne out by the researches of modern science. Thus in respect to the attachment of the dura mater to the cranium we read in Schwalbe, "Fine filaments of connective tissue and small vessels which are produced from the dura matter and enter the osseous substance of the cranium, are always torn when the dura mater is removed from the cranium. On this account the exterior surface of this membrane, after it has been separated from the cranium, always appears rough. . . . Where the dura does not adhere to the cranium, as for instance everywhere, between the fine filaments of connection, on the exterior surface of the dura mater, there is exhibited an endothelium, as may easily be proved by the method of silvering followed by Wiensky and Michel. This endothelium belongs to the fine capillary fissural spaces (*epidural spaces*) which exist here between the dura and the osseous substance of the cranium, and which correspond to the subperiosteal *lymphatic spaces* of other bones" (*Op. cit.*, p. 799).

There exist thus lymphatic spaces lined with endothelium between the dura mater and the substance of the cranium, and the lymph contained in these spaces, which is derived from the lymphatic ducts of the dura mater, must needs be expended on the nutrition of the bone, or else be conveyed towards the sutures which are in immediate connection with the pericranium—the external periosteum of the cranium.

On this subject we read in Luschka,[1] "The periosteum which adheres to the external table of the cranium—*the pericranium*—is a thin, but proportionably firm, fibrous membrane, the tissue of which, without any interruption, passes over into the so-called cartilago suturarum, so that in the neighbourhood of the sutures it adheres more closely to the cranium than elsewhere" (p. 53). And again he says, "In the sutures no matter what their nature may be, there is ever inserted between the edges of the bones a thin layer of a thin, whitish substance, very much like cartilage—*cartilago suturarum*—which is continuous with the external and internal periosteum, but which does not possess the least trace of a cartilaginous texture. This intervening substance consists of closely-woven cellular fascicles intermixed with fine elastic fibres and a number of oblong nuclei" (p. 98).

This texture seems to be perfectly calculated by capillary attraction, and thus by imbibition, to transmit a serous liquid from the

[1] Luschka (H. v.). "Die Anatomie des Menschen," etc., Vol. III., Sect. ii.; "Der Kopf." Tübingen, 1867.

interior periosteum of the cranium—the outer lamina of the dura mater—to the pericranium, where, in addition to the nutriment derived immediately from the blood-vessels, it would contribute to the nutrition of the hair.

56. Swedenborg says in conclusion, "The liquid contained in the dura mater is determined in that direction where this membrane is closely attached to the cranium; namely, under the sagittal, lambdoidal, and coronal sutures—or, as is proved by experience, it is determined towards the cavities between the meninges [*i.e.* into the subdural space]; or, finally, it is directed towards the roots of the nerves, in order that the circle, that is, the circulation of this liquid, may be continued. This, however, takes place chiefly with that lymph which has only once been collected in the subdural space" (see above, no. 48).

The fact that there is such a communication between the lymphatic ducts or tubes of the dura mater and the subdural space, has been abundantly proved by Waldeyer and Fischer. By an experiment bearing upon the present subject, which is detailed in full in no. 41 of the present note, they showed that an injection made into the subdural space penetrates into the interior of the dura mater, especially in the neighbourhood of the longitudinal sinus. They maintain that "this injection penetrates through the interior, endothelial lining of the dura mater into its system of lymphatic spaces, which in its turn communicates with the venous apparatus of this membrane."

We, on the contrary, maintain that the openings and passages discovered by these observers are not inlets, but outlets; and that through them there is discharged in part that lymphatic juice which is received by the lymphatic ducts or tubes of the dura mater at the foramen magnum from the ligamentous covering of the spinal cord.

According to Swedenborg, the lymphatic juice which is received there by the dura mater is determined by the inflection of its fibres into the direction of the sagittal, lambdoidal, and coronal sutures. In the neighbourhood of the longitudinal sinus, however, and "especially in that portion which appears triangular in cross-sections, and which on either side forms the lateral walls of the longitudinal sinus, as well as farther towards the sides, and also above the sinus in the roof," Key and Retzius discovered "a peculiar kind of hollows or lacunæ." Concerning these "lacunæ" they say, that "on making a vertical section of the dura in the neighbourhood of the longitudinal sinus, and on magnifying the tissue, it is usually found more or less cribriform, that is, perforated by a system of hollows, the individual spaces of which are usually of the same shape and size, and are filled with a clear liquid." They further add, that "these spaces occur not only in the neighbourhood of the longitudinal sinus, but also around the lateral sinuses where there may be a great number of them; as well as near the superior petrosal sinuses" ("Studien," etc., Vol. I., pp. 166, 167). See above, Vol. I., p. 229, *et seq.*

The places where these "lacunæ," according to Key and Retzius, exist, agree in a great measure with those whither, as Swedenborg states, the lymphatic juice of the dura mater is determined. And it is this system of lacunæ or hollows which, according to Waldeyer and Fischer's experiments, communicates on the one hand with the venous system of the dura mater, and on the other with the subdural space.

These "lacunæ," in the light of Swedenborg's theory, are reservoirs or receptacles where the lymphatic ducts of the dura mater finally deposit their "nervous juice" or "oily lymph."

Not only the system of terminal lacunæ "communicates with the venous system of the dura mater," but the lymphatic ducts themselves which terminate there also communicate therewith. On this subject Key and Retzius declare that "under a very mild pressure a large system of these tubuli is filled by an injection of the blood-vessels of the dura" (see above, Vol. I., p. 234). As these blood-vessels in their turn communicate with the longitudinal sinus, this arrangement, as suggested in a footnote in Vol. I., p. 252, is no doubt for the purpose of reviving or rendering more liquid the sluggish venous blood of the longitudinal, and of the other sinuses, when it threatens to clog up their avenues.

The remaining portion, however, of the lymphatic juice stored up in these "lacunæ," according to Swedenborg, "is determined towards the cavities between the meninges," namely, into the subdural space.

The discharge of this liquid into the subdural space takes place while the longitudinal as well as the other sinuses are swelling, and thus exert a pressure on the neighbouring "lacunæ," which happens when the brain has its systole, and when the subdural, as well as the subarachnoidal spaces are being dilated. The superior occipital foramen also, in the "incisura tentorii," is then open, and the subdural, as well as the subarachnoidal liquids, that is, the cerebro-spinal fluid in general, is then descending into the vertebral cavity, in order that during the diastole of the spinal cord, and of the encephalon in general, both liquids, the subdural as well as the subarachnoidal, may be urged into the dural and arachnoidal sheaths of the cranial and spinal nerves. Or, in the language of our author, these liquids are then "directed towards the roots of the nerves in order that the circle, that is, the circulation of the cerebro-spinal liquid, may be completed." This, however, according to Swedenborg, "takes place chiefly with that lymph which has only once been collected in the subdural space." For after it has described once a complete round in the circulation of this fluid, from the brain into the muscles of the body, and thence back into the circumference of the brain, that same lymph has exhausted all its spirituous essence—wherefore, upon its return into the body, it is discharged as worthless through one of the many excretory passages of the body.

i. Literature of the Cerebro-Spinal Liquid in General.

1. The Cerebro-Spinal Liquid.

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