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THE

HUMAN BRAIN,

ITS

CONFIGURATION, STRUCTURE,

DEVELOPMENT, AND PHYSIOLOGY;

ILLUSTRATED BY

REFERENCES TO THE NERVOUS SYSTEM IN THE LOWER ORDERS OF ANIMALS.

BY

SAMUEL SOLLY,

LECTURER ON ANATOMY AND PHYSIOLOGY IN ST. THOMAS'S HOSPITAL,

&c., &c.

WITH TWELVE PLATES.

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BENJAMIN TRAVERS, Esq., F.R.S.,

IN REMEMBRANCE OF MANY KINDNESSES,

AND AS A TRIBUTE OF RESPECT

FOR HIS DISTINGUISHED TALENTS,

THIS WORK

IS INSCRIBED BY HIS OBLIGED PUPIL

AND SINCERE FRIEND,

SAMUEL SOLLY.

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Page 10, line 3, *for* fig. 2. *read* figs. 1* and 2*.

INTRODUCTION.

The anatomy and physiology of the Human Brain are subjects not generally pursued with the interest and attention which their importance deserves, by the majority of medical students, that is, of those who are engaged in acquiring a knowledge of the human organism, and are endeavouring to trace the relations existing between its structures and functional manifestations with a view to the successful treatment of its diseases.

According to the plan generally pursued in treating the anatomy of the brain in systematic works of the present day, all the information conveyed amounts to little more than a vain catalogue of names applied to parts, without reference to their structure, their functions, or even their analogies in the nervous system of the lower orders of animals. Such a barren prospect as a list of names, holds out but little to attract the most zealous among students, while the dryness of unconnected detail, and the obstacles to clear conceptions engendered by the absence of everything like arrangement, almost certainly deter him from attempting to learn more than is required to prepare him for examination for the diploma. It is unfortunate indeed that candidates for this honourable certificate are still very generally required to describe the appearances presented by the brain dissected, or rather destroyed, by the old method of slicing; a method most unphilosophical in its conception, and totally inadequate to impart any real information in regard to the structure of the organ. And I do not hesitate to affirm that this circumstance has contributed essentially to retard the diffusion of sound knowledge in regard to the anatomy and physiology of the most important system in the body.

Vieussens, as earlyas 1684, demonstrated the fibrous structure of the medullary portion of the brain. And Reil in 1807-8 published his researches on the structure of the cerebellum, which were in the course of various succeeding years followed by some very elaborate and interesting inquiries into the structure of the cerebrum. Since this time Gall and Spurzheim have followed in the same path, while Vicq. d'Azyr, the Wenzels, Soemmerring, Tiedemann, Serres, and a host of others have added immensely by their labours to our stock of information on the true structure of the enkephalon.

Cuvier, in the report which he made to the Académie Royale des Sciences de Paris upon M. Serres' work, *De l'Anatomie Comparée du Cerveau*, remarked very forcibly on the inconvenience of dissecting the brain from above downwards in the manner generally pursued, and he showed that in consequence of comparative anatomists adopting this mode of dissection, their researches into the constitution of the nervous system of the lower orders were productive of very imperfect results, in as much as the chain of resemblance between the lower and the higher orders of animals was soon lost sight of; whilst M. Serres, by commencing with the dissection of the spinal cord, and tracing it upwards, was enabled to throw great light on this interesting branch of physiology, and to prove that there is a regular gradation in these parts, that the chain is perfect, and that such differences as do occur simply consist in the abstraction of parts, and the loss of those powers which have been proved to be dependent on them.

Familiar with these expressions of condemnation of the old method of dissecting the brain, and from such high authority, I have endeavoured, without presuming to arrogate to myself the credit of discovering any new system, to lay down a plan for the study of the anatomy of the cerebro-spinal axis, founded upon the rational basis of investigating its structure in man by the light of comparative anatomy.

General principles have never been discovered by the observations of isolated facts; a tissue of such facts was therefore of little or no practical value to the student in medicine; and in studying the brain by the old method he was merely loading his memory with a number of names unconnected with all besides included in his studies, and without the most remote bearing upon the object of these studies, the practice of medicine and surgery.

There can be no question but that the only philosophical method of simplifying and giving a character of general interest to the anatomy of the human brain, is by commencing with the structure and functions of a nervous system in the lowest and simplest forms of animal existence, and from this rising by degrees to the highest, carefully observing each addition of parts, and the relationship borne by these to an addition of function. By pursuing this course we shall be rewarded by finding that the enkephalon, this apparently most complicated organ in the human being, is but a gradual development from an extremely simple fundamental type on one uniform and harmonious plan, and that the seeming complexity of the cerebro-spinal axis in man really arises from the great concentration, as opposed to the extreme diffusion of its component parts in the lower order of animals; for in no particular are the higher orders more strikingly distinguished from the lower than in the concentration of function within circumscribed spaces. In following out the plan I have adopted in the following work, I shall strive to avoid, on the one hand, falling into the error of attempting too minute a detail of all the various discoveries which have been made, and giving an account of all the various opinions which have been broached, and on the other, of basing my descriptions, or confining my views to the circle of my own individual researches and speculations. My constant object will be to clear the path of all unnecessary incumbrances; and carefully arranging whatever is known upon the anatomy and physiology of the human brain, to keep in view the principle which Herschel has so concisely stated, that "Science is the knowledge of many, orderly and methodically arranged and digested, so as to be attainable by one."

THE HUMAN BRAIN.

PART I.

COMPARATIVE ANATOMY.

THE naturalist who devotes his time to observing the habits and instincts of animals, their external form and general appearance, pursues a branch of science which has unfolded a multitude of facts highly interesting and amusing to him who delights in the works of nature. But the physiologist follows in his pursuit of knowledge a more arduous and elevated path; for, not satisfied with observing the manners, actions and outward appearance of animals, he carries forward his researches to their internal organism, with the view of ascertaining the relation which structure bears to function.

Researches of this kind afford us the most important and valuable proofs which we possess of the office of a nervous system in the execution of those acts which are exhibited to us by living beings; for by such investigations the physiologist, discovering that the development of their internal organs corresponds with an increased capacity of enjoyment, the existence of which is demonstrated by their habits and instincts, obtains the only evidence which a science of observation like physiology is capable of affording that they stand in the relation of cause and effect.

On this principle, I consider that the study of the anatomy and physiology of the human brain could not be introduced to the student in a more philosophical manner, or with a prospect of greater advantage to himself, than by taking an extended but general view of the nervous system of the lower orders of animals. I shall not enter with much detail into the immense variety of forms which the study of the nervous system of the whole animal kingdom presents to us, because I merely wish to use comparative anatomy as an ally in my attempt to simplify the study of the human brain, without regarding it, as it really might be, as an object of extreme interest independent of the service which it thus is capable of rendering to the student in medicine.

The celebrated Haller, who thoroughly felt the value of comparative anatomy in the study of human physiology, and the importance of taking this course when reasoning on the functions of a nervous system, after observing that a brain and medulla spinalis are met with in animals with a head and with eyes, says, "Neque credo aut oculos absque cerebro, aut absque oculis cerebrum in ullo animale reperiri. Sunt ergo sua cerebra vermibus, mytulis," &c.[1]

All physiologists of the present day agree in considering the nervous system as the medium by which animals are connected with the external world. But when, in our dissection of some of the inferior orders of animals in whom there is an evident susceptibility to receive impressions from external nature, and to re-act upon those impressions, we are unable to demonstrate the existence of a nervous system, we feel rather at a loss to reconcile this apparent discrepancy, and come to the conclusion that the sentient matter which we call neurine is dispersed in such minute quantities throughout their tissues as to escape observation.

Dr. Macartney adverts to this opinion, when after proving the very minute quantity of real nervous matter which exists even in the human brain, he remarks, "We can hardly take upon ourselves to say that the simplest animals, and even plants, may not have some modification of sentient matter incorporated in their structure, instead of being collected as in the higher orders

[1] *Elementa Physiologica*, vol. iv. p .2.

of animals into palpable membranous cords or filaments[1]."

The polypiferous tribes of animals afford us the best specimens of living beings exhibiting a certain extent of consciousness, but without any distinct nervous system: the polype, which simply consists of a digestive cavity, is supplied with exquisitely sensible tentacula, which feel with precision, seize upon all the food within their reach, and convey it into the stomach. But that such instances are viewed as exceptions to the rule of the manifestations of consciousness being in direct relation to the degree of development of a nervous system, is proved by the fact, that physiologists have considered the intimate connexion existing between the nervous system and the grade or condition which the animal occupies in the scale of created beings as the best principle of classification. Proceeding on this plan, the animal kingdom is divided into four subdivisions, which are termed the

Cyclo-neurose of *Grant*,	or	Radiated of *Cuvier*.	
Diplo-neurose	———	Articulated	———
Cyclo-gangliated	———	Molluscous	———
Spini-cerebrata	———	Vertebrated	———

To which may be added a group of still lower organization, answering to the *Acrita* of MacLeay,

[1] Observations on the Structure and Functions of the Nervous System; read before the British Association at Cambridge in 1833,—Med. Gazette, vol. xiv. p. 842.

in which the neurine, if existing at all, being incorporated with the other tissues, cannot be demonstrated as forming a separate system.

It will generally be found that the Cyclo-neurose is the most simple; the Diplo-neurose the next, and so on. But this is not uniformly the case; for the nervous system, to which, as being the most simple, it will be desirable first to direct our attention, is taken from the division of the Diplo-neurose: but it is not improbable that the simplicity in this instance arises solely from its being imperfectly developed or in a rudimentary state, and may perhaps therefore be considered as affording an imperfect type of a nervous system.

As my present object in alluding to the nervous organization of the lower orders is not, as I have said, to carry my readers minutely into the subject, but solely to make the study of the human brain more simple and interesting, I shall confine myself to the description of the most prominent features in each division.

Before we commence the study of the anatomical arrangement of the individual parts composing the nervous system of the lower orders, and trace their relations to the cerebro-spinal system of man, we ought to investigate the physical characters of the material of which they consist. In so doing, we shall be struck with the simple plan upon which these organs, as every other in the construction of a living being, are formed; for instance, the bones are composed of a membranous network, in the meshes of which earthy matter is deposited to give them that firmness which is required for their office in the animal economy; muscles consist of a membranous network, in the interstices of which matter is placed endowed with the power of contraction on the application of its appropriate stimulus; and the nervous system, consisting of a membranous network in the interstices of which is deposited a peculiar substance denominated neurine, forms no exception to this beautiful simplicity. There are two kinds of neurine, differing both in consistence and colour, one being of a pearly white and fibrous texture, the other ash-coloured or grey, soft and pulpy: this difference of colour is most evident in man and the higher orders; the difference of texture depends in all probability more upon the arrangement of the supporting membrane than upon any peculiar difference between their elementary particles of neurine.

This variety of colour is not confined to the human brain, or even others of the higher orders; for Cuvier states that the ganglia in the *Helix stagnalis* and *H. cornea* are bright red; in the Aplysia blackish red and granular; and the ganglia of the freshwater Muscle are well known to be of a bright yellow, while the connecting nerves are uniformly white.

Professor Ehrenberg[1] has shown that neurine actually consists of very minute fibres; and he informs us that these fibres can only be discovered by the aid of a magnifying power of 300 diameters, and that he was sometimes obliged to have recourse to a much greater magnifying power, as 800 diameters, in order to bring them into view. He examined thin slices of the recent brain, and states that the fibrous structure was in general most obvious at the margins of the slices. These fibres in the cineritious portion are interspersed with globules and plates; the greater number of these fibres instead of having a regular cylindrical form are knotted like a string of beads, the swelled portions being situated at some distance from one another, and united by narrower parts which are continuous with them, and are formed apparently of the same material.

Besides these fibres, which Ehrenberg calls *articulated*, he observed towards the base of the brain and crura cerebri, other somewhat larger fibres, of a regular cylindrical form, interspersed upon the knotted ones. The cylindrical fibres are about $\frac{1}{120}$th of a line in diameter.

The cortical substance seems, according to Ehrenberg's observations, to differ from the medullary or white chiefly in the want of the straight cylindrical fibres, and the articulated fibres being

[1] Edinburgh New Philosophical Journal, July 1834.

contained in a denser network of blood-vessels, and being covered by a layer of free granules larger than the dilated parts of the knotted fibres.

The cylindrical fibres are tubular, containing a granular medullary matter; the articulated ones do not appear to be so.

The optic, olfactory and auditory nerves are composed of the articulated fibres, while those of motion are clearly cylindrical, but seem to be continuous with the articulated fibres of the brain and cord: the structure of the nerves of ordinary sensation is not so clearly ascertained.

Comparative Analysis of White and Grey Cerebral Matter.

M. John[1] is the only chemist who, in his analysis of the brain, has hitherto separately examined the grey and white matter. He has stated that the white matter contains more fat than the grey, and that its albumen is more firm. The following comparative analysis was made of the brain of one of the insane patients who died at Salpêtrière.

Entire brain (density=1048.)	
Water	77·0
Albumen	9·6
White fatty matter	7·2
Red fatty matter	3·1
Osmazome, lactic acid, and salts	2·0
Earthy phosphates	1·1

[1] *Journal de Chimie Médicale*, August, 1835.

	White substance.	Grey substance.
Water	73·0	85·0
Albumen	9·9	7·5
White fatty matter	13·9	1·0
Red fatty matter	0·9	3·7
Osmazome, &c.	1·0	1·4
Earthy phosphates	1·3	1·2

The most simple form in which we find the nervous matter arranged when so completely separated from the rest of the body as to constitute a distinct nervous system, is in the Ascaris, a species of intestinal worm: we can scarcely conceive an animal having its relations to the external world more limited than this: it has not even to seek its food beyond the narrow spot to which its existence is confined, and can therefore have little necessity for a nervous system, and we find it accordingly but imperfectly developed.

Jules Cloquet has given us the best account of the nervous system in these animals: it is from a work published by him on this subject in 1824, that the following account and drawing are derived.

Two white cords, rather thicker in the middle of the body than at the extremities, composed of a series of small lines united at angles, or, as it were, broken and slightly swollen at each angle, sending to the right and left filaments so thin that they escape the eye, except when seen through a magnifying lens, constitute their nervous system. These cords are situated within the plane of muscular fibres, and descend, the one on the abdominal, the other on the dorsal surface of the alimentary canal: see Plate I. fig. 2. The abdominal nerve forms a circle around the vulva of the female, as will be seen by reference to the diagram; the slight enlargements Cloquet regards as ganglionic.

Laennec, Otto, Lamarck and Cuvier all agree with Cloquet in considering the lines above described as the nervous system. Nevertheless it appears to me extremely probable that these cords do not represent a perfect type of a nervous system, even in its most simple form, but that in this individual it has been arrested in its development at a period corresponding to one of the regular stages through which the nervous system passes in the higher orders, in whom we know that the nerves are developed first, and the centres or ganglia afterwards; and in this animal, where the ganglia scarcely exist, is it not possible that the organization is incomplete; that the animal, in fact, is not perfect; that the conducting portion of the nervous apparatus has been formed, but not the point from which the power emanates requiring to be conducted?

The above simple arrangement perfectly corresponds with the first appearance of the cerebro-spinal axis during the development of the vertebrated class of animals, and affords a beautiful illustration of the law, that the higher classes of animals during their development go through some of those forms which are permanently retained by the lower orders; and although this interesting subject will be dwelt on at length in the section on the development of the human brain, I must not entirely pass it over in this place.

As the ovum of the bird affords the greatest facility in the study of its progressive development, the appearances, as observed in this class of animated beings, will be described; observing at the same time, that we have every reason to believe similar phenomena take place in the development of the whole series of vertebrated animals.

The following description of these changes are derived from a very useful and instructive paper published by Dr. Allen Thomson.

"If the egg of the common fowl be examined seven or eight hours after incubation, a dark line may, with the aid of a magnifying lens, be discovered on the upper part of the cicatricula, or germ spot, towards the centre of that portion of the disk, or germ spot, which from its greater transparency is called the transparent area.

"This line or primitive trace, is swollen at one extremity, and is placed in the direction of the transverse axis of the egg; its rounded extremity is situated towards the left when the small end of the egg is turned from us, and indicates the place where the head of the fœtus is afterwards formed.

"This large extremity occupies very nearly the centre of the transparent area, while the linear part of the primitive trace, corresponding to the body and tail of the fœtus, approaches the margin of that area on the right side.

"As incubation proceeds, the whole cicatricula expanding, increases in size. The transparent area becomes larger, more pellucid and defined. We are indebted to Pander for the important discovery, that towards the 12th or 14th hour the germinal membrane becomes divided into layers of granules—the serous and mucous layers of the cicatricula; and that the rudimentary trace of the embryo, which has at this time become evident, is placed in the substance of the uppermost or serous layer: the part of this layer which surrounds this primitive trace soon becomes thicker, and, on examining this part with care, towards the 18th hour we observe that a long furrow has been formed in it, in the bottom of which the primitive trace is situated. About the 20th hour this furrow is converted into a canal, open at the two ends, by the junction of its margins. The canal soon becomes closed at the cephalic or swollen extremity of the primitive trace, at which part it is of a pyriform shape, being wider here than at any other part. (Plate I. fig. 2. 24th hour.) Some time after the canal begins to close a semifluid matter is deposited in it, which, on its acquiring greater consistence, becomes the rudiment of the spinal cord, which at this period consists, therefore, of merely a double white line of semifluid neurine[1];" perfectly similar in appearance to the nervous cord in the Ascaris.

Let us next direct our attention to the nervous system of one of the Asterias; it is beautifully simple, and not the less instructive, for in these specimens of the *Radiata* we meet with one of the earliest instances of unequivocal voluntary locomotive power; and when in accordance with these manifestations of consciousness and the power of commanding the execution of certain offices in different portions of its frame, we detect nervous cords emanating from nervous nodules, we are induced to regard them as the instruments employed in the production of these phenomena.

Tiedemann was the first to prove decidedly the existence of a nervous system in the star-fish. His account was published in 1816[2], accompanied with a beautiful drawing of it, representing a ring surrounding the œsophagus giving off a filament to each ray, besides ten smaller ones, which he believes to descend to the stomach: at the same time he observes, that he could not discover anything like ganglia; but in an excellent

[1] Edinburgh Philosophical Journal, p. 299, October, 1830.

[2] *Anatomie der Röhren-Holothurie des Pomeranzfarbigen Seesterns und Steinseeigels.*

preparation of the twelve-rayed star-fish in the museum of King's College, twelve little nodules of neurine or ganglia, one opposite each ray, may be distinctly seen, from which fig. 3. Plate I. is taken.

This nervous system, simple as it is, forms an accurate type of the most complicated in the highest species of animated beings, containing, if I mistake not, exactly the same number of elements; and the distinct portions to which we must now attach different names, should peculiarly engage the student's attention when thus presented to his observation under this the most simple form: if this be not done, when called upon to trace the same arrangement in the human being, he will be in danger, from the greater number of similar parts closely connected together appearing to do away with this fundamental simplicity, of being lost in the labyrinth of perplexing obscurity, which seldom fails to disgust those who attempt to learn the structure of the brain in the ordinary method.

The three portions may be designated, ganglia, commissures and nerves.

The small swellings or nodules of neurine, are the *ganglia*.

The cords which pass between the different ganglia, and thus connect them together, are the *commissures*, or apparatuses of union.

The cords, which are connected to the ganglia by one extremity and the textures of the different organs by the other, are the *nerves*.

The term ganglion is not the best that might be devised for the designation of this portion of the nervous system, as merely signifying a knot: it only characterizes its external appearance, without in the slightest degree noticing its function as distinguished from the nerves and commissures.

But as it seldom answers to attempt a decided change in the nomenclature of a science like anatomy, which has existed for so many years, it will perhaps be better to employ the same term in the comprehensive meaning which comparative anatomy justifies us in adopting.

Human anatomists have been too much in the habit of considering a peculiar rounded form essential to the constitution of a true ganglion, not usually, therefore, applying the term ganglion to a collection of cineritious matter, unless moulded into a knotted form and supported by a dense membrane: thus the medical student has been led to imagine that the neurine which is contained within the human skull is altogether different from the ganglia of the lower orders, merely because it differs from them so much in its outward appearance.

But the fact really is, that if the term ganglion be correct as applied to the nodules of neurine or centres of power in the lowest animals, it is equally correct to apply it to those of the highest; and it therefore follows that the human brain is but a series of large ganglia, though their close connexion and the great size of the commissures give to it a degree of complication which we can only unravel by seizing the thread at this simple though perfect type of a nervous system, and never dropping it till it has conducted us through all the various additions made to its fundamental simplicity up to the perfect but complex organization in the human being.

That a peculiar form is not indispensable to the constitution of a ganglion, even according to the confined sense in which that term is used in the descriptive anatomy of the human body, is proved by the fact, that a simple layer of cineritious neurine of a semilunar form lying between the dura mater and skull in the temporo-sphenoidal fossa, through which the posterior root of the fifth pair of nerves passes, is described as being perfectly analogous to the rounded firm knots which are attached to the posterior roots of all the spinal nerves: and the analogy is perfect; but it ought to teach us this lesson, that a particular form is not essential to the constitution of a ganglion. I think, therefore, that we are justified in extending the term ganglion; and I am quite sure that it would enable us very considerably to simplify the anatomy of the human brain, if we were to apply it thus to any collection of cineritious neurine into a circumscribed mass, whatever form or arrangement it may assume; for instance, the cineritious neurine which forms the convoluted surface of the hemispheres of the human brain I should denominate the hemispherical ganglia; for the convoluted appearance arises solely from the circumstance that it was necessary a contrivance should be adopted to pack a very extensive surface into a small space, on the same principle, (and I trust that the homeliness of my simile will be excused for its simplicity,) that when we put a handkerchief into our pocket we fold it up instead of attempting to carry it about us spread out to its whole extent. Now there would be just as much reason to deprive the semilunar ganglion of its generic title, and give it a name merely in accordance with its appearance, as there is in separating the hemispheres of the human brain from their analogous ganglia in the lower orders, and designating them by a term which gives a mystery to their character they do not deserve.

When the physiologist is engaged in the difficult task of discovering the office of any particular apparatus in the organism of an animal, there are few proofs which are so clear and satisfactory as those derived from some decided peculiarity of structure: as a simple instance we may cite the tubular form of arteries and veins, convincing us that they are intended to carry fluids, and the valves in the interior, proving to us that those fluids could only flow in one direction. Now in our investigations into the functions of a ganglion as distinguished from the other portions of the nervous system, it is true that we shall not be able to derive from the study of its structure proofs of its function so clear and decided as those just cited in reference to the circulating system: but I firmly believe that by availing ourselves of this legitimate source of information, as the first link in a chain of inductive reasoning, we shall be enabled to state with some degree of certainty the broad line of distinction between the office of the ganglia and that of the nerves and commissures in the animal economy. It must be remembered that the essential material of a nervous system, that in fact by which it is distinguished from every other, and upon which the peculiar attributes and powers of this system depend, is not uniformly alike; it is not homogeneous; it is not everywhere the same; its physical properties are different in different situations; in one its colour is grey and its texture is soft and pulpy, in another it is white and distinctly fibrous: these two are not found indiscriminately mingled, but the grey or pulpy is always met with in a ganglion, and the fibrous alone enters into the composition of a nerve, while the commissures are occasionally compounded of the two. From this circumstance, and many others which follow, I come to the conclusion that the peculiar power of the nervous system resides in the cineritious portion, and that the office of the medullary is simply that of a conductor. This conducting power is of a threefold kind:

1st, As a conductor of the stimulus which arouses the cineritious neurine into action (*the nerves of sensation*);

2ndly, As a conductor of the will, which originates in the cineritious or pulpy neurine (*nerves of motion or volition*);

3rdly, As an agent for the purpose of combining the various impressions conveyed to the cineritious neurine in the ganglion, which may thus be viewed as a centre of power (*commissures*).

In short, I consider that the cineritious portion of the nervous system stands in the same relation to the rest of that system as the secreting portion of a gland does to the rest of that organ; for the one portion would be useless without the other, and the central portion possesses its power independently of the peripheral; this is proved by the fact, that in the case of a patient being paralytic from disease affecting the motory tract, the individual as perfectly retains the power of willing the motion of his limbs as previous to the occurrence of the disease, though his will is no longer conducted to the point where it would be executed; but this illustration does not of course afford the slightest explanation of the mode of action of these two parts, nor need it imply a belief in the existence of a physical change being necessary to the production of nervous action.

Meckel[1] says that "the most probable hypothesis is that which represents the grey and medullary substances as two masses, the opposition or contrast of which results from the difference which exists in their structure and chemical composition, and is necessary to the accomplishment of the functions of the nervous system; and that, however incontestable the importance of the grey matter, it does not authorize us to believe that it is more noble than the medullary; that is to say, that in this portion the spiritual changes corresponding to the material pass into one another, as Wengel appeared to believe when he says: 'Cinerea singularum cerebri partium substantia videtur præcipuè id esse, quo propriæ cuivis istarum partium sensationes efficerentur[2];' and that the office of the medullary is not simply that of a conductor."

Various opinions might be stated on this subject, but they appear to me too vague and undefined to be worthy of particular attention; such, for instance, as the office of the cineritious neurine being that of a gland for the secretion of a nervous fluid, &c. It is true that the action of a gland affords us a good illustration of the relation which these two portions, the cineritious and medullary

[1] Vol. i. page 256.

"[2] *De Penitiori Cerebri Structurâ,* cap. vi. p. 69."

matters, bear to each other, but not the slightest explanation of their mode of action.

These opinions regarding the vital powers of the cineritious neurine in distinction to that of the medullary, appear to me to be strongly supported by the relative proportion of the cineritious matter and the medullary in the different portions of the spinal cord. For instance, the cineritious is abundant in that part of the cervical portion of the cord with which the large axillary nerves are connected, as reference to the diagram of these parts will prove; while in the dorsal portion of the cord it forms little more than a narrow streak, which the small size of the dorsal nerves seems to account for. In the lumbar region the cineritious matter is again abundant, even to its very termination, and the nerves connected with it are very large, while the medullary matter, in this situation very scanty, forming little more than a thin layer, and uniformly though slightly increasing from this point upwards, confirms the idea of its office being that of a conductor; for as each nerve of sensation joins the cord, it increases the layer of medullary matter, in the same ratio as each motory diminishes it on quitting the cord; for I think that no one in the present day will doubt that each medullary filament of sensation is continuous from its peripheral extremity in all tissues to the cineritious matter of the hemispheres, and that each motory filament is continuous from the hemispheres to the muscles they are intended to supply.

Tiedemann adverts to the fact which I have just stated in the following manner; and though his opinion on the use of the cineritious neurine does not coincide with mine, still I consider that his reasoning rather serves to confirm than weaken it: "The quantity of grey substance," says Tiedemann, "in those parts of the spinal marrow from whence issue the large nervous trunks, and which receives so many vessels that Ruysch imagined it entirely vascular, contributes certainly, during life, to increase and exalt the nervous action, according to this general law, that an organ possesses more force and energy as it receives more arterial blood. M. Gall is deceived in saying that the grey substance, which he terms the womb of the nerves, is the first formed, being the producer and nourisher of all the nerves. I allow, with him, that it strengthens and fortifies the action of those parts of the brain and nerves which emanate from it, in as much as this effect is produced by the arterial blood which it contains, and by the greater rapidity with which it repairs the loss which the exercise of the vital action produces. I admit, then, an intimate relation between the volume of the spinal nerves and the enlargements of the spinal marrow in those points from whence these nerves issue. It is very easy to be convinced of this in fishes, where the origins of the nerves produce particular ganglia, always when the nerves and the organs to which they are distributed have acquired a greater development, or when there are particular organs not found in other fishes. The remarkable and regularly disposed enlargements observed immediately behind the cerebellum in the flying-fish (*Trigla volitans**) are the origins of the nerves destined to the digitiform prolongations peculiar to these fishes, observed in front of the ventral fins, and provided with numerous muscles, serving at the same time as organs of touch and progression†; of this I have been convinced for some years. We find also in the torpedo (*Raia Torpedo*) two large ganglia, situated also behind the cerebellum, the size of which they much surpass, and from whence issue the nerves analogous to the eighth pair, which furnish a great number of branches to the electrical organs of these fishes. The *Raia clavata, Raia Batis, Raia Pastinaca,* and other species of the skate properly called, present but a very small swelling, giving origin to the eighth pair, which in these animals are only distributed to the gills. In the sheaf-fish (*Silurus*) the origin of the fifth pair of nerves forms a very voluminous mass, because this pair sends large branches

"* Samuel Collins has described and represented them,—System of Anatomy, vol. ii. tab. 70. fig. 3.

"† This I have demonstrated in a Memoir addressed to the Academy of Sciences at Berlin.

to the long barbules which cover the superior maxilla, and to the muscles of these appendages. We find similar enlargements along the spinal marrow of most fishes*. Thus, for example, in the carp there are behind the cerebellum two swellings, united together by a middle tubercle, and representing in some degree a second cerebellum. We cannot then doubt that the local augmentation of the mass of the spinal marrow, by the addition of a greater quantity of this substance, is to exalt the action or activity of the nerves which emanate from these ganglia[1]."

Dr. Fletcher[2], of Edinburgh, in his Lectures, when speaking of the distinction between a plexus and a ganglion, says, "The abundance of grey matter which they contain, and *which there is good reason to believe is always a primary source of some distinct faculty or power*, &c.[3]" And again, in another part of the same course of lectures he says:

"It is probable that no impediment whatever is offered to the function of a ganglionic nerve by

"* Arsakay, *loc. cit.* p. 16. *De posteriore Gangliorum Encephalum constituentium Parte.*

[1] Tiedemann on the Fœtal Brain, translated by Bennet.

[2] It is with great pleasure that I embrace this opportunity of expressing the high opinion I entertain of the late lamented Dr. Fletcher's talents and philosophical mind. Dr. Fletcher had the honour of being among the first, if not the very first lecturer in the kingdom who taught human physiology on the wide and scientific basis of comparative anatomy.

[3] Ryan's Journal, April 18, 1835, page 961, note.

such a division as entirely paralyses the cerebro-spinal. Such is the case with the latter only; because the white matter of the nerve, being dependent for its energy upon the grey matter of the central parts of this system, becomes of course inert when separated from it: but no such line of demarcation exists in the ganglionic system, every point of every nerve of which contains white and grey matter intimately interwoven together, and may be considered, therefore, as a centre of nervous energy to itself; and it is in this way only that we can explain how the total removal of a muscle from the rest of the body, which implies a division as well of its blood-vessels as its nerves, is not for some time effectual in destroying its irritability."

If it be true, then, that the cineritious matter alone is endowed with the faculty of generating or producing power, while the medullary is simply capable of conducting it, we must conclude that the nerves are not only the instruments of conduction, but that those portions of the human brain which are formed of medullary neurine must perform exactly the same function, and that the great transverse commissure or corpus callosum, the longitudinal commissure or fornix, and in fact all those commissures into whose texture the medullary neurine alone enters, must necessarily be conductors and not originators of the peculiar powers by which the nervous system is distinguished from every other. Is it not then extremely probable that the office of the commissures is to enable the individual to compare those impressions which are conducted to the hemispherical ganglia, the seat of judgement, memory, &c., by the nerves of sensation from the especial organs of sense in which they originate, as the eye and the ear, &c.?

The vital phenomena which living beings present to our observation are of two kinds.

The one comprehends all those functions which tend to the maintenance and preservation of their individual existence and the reproduction of their species; while the other class of phenomena brings them into relation with the external world, informs them of the existence of surrounding objects, and, manifested in the activity of the intellectual faculties, teaches man in particular the properties of bodies and the laws which regulate them.

Those functions by which the nutrition and growth of individuals and the reproduction of species are effected, are common to all living beings, vegetables as well as animals, and there can be no life without them; but the second order of functions, the manifestation of which proves to us that the individual is capable of receiving impressions from external nature and of reacting upon these impressions, showing thereby a consciousness of their existence, is peculiar to animals.

And all true physiologists, even from the time of Aristotle, have observed more or less accurately the distinction between these two classes of phenomena, and arranged them accordingly. Aristotle conceived that they might be classified under three heads, vital, natural, and animal; the first two comprehending those which we now combine under the head of vegetable life.

Galen adopted the same arrangement, but added the hypothesis that these functions were superintended or controled in their operation by presiding spirits; something in the same way that some physiologists of the present day believe in the existence of a single *vital principle,* whose office it is to effect all the various vital phenomena which are presented to our observation by living beings.

Bichat arranged the functions, like many of his predecessors, under two heads; but instead of referring the power, which appears to regulate and preside over these phenomena, to some mysterious spirit, he considered it to be dependent for its very existence on the nervous system; and this led him to divide the nervous material into two systems, the one of which he called the nervous system of organic, perhaps better called *vegetative life,* and the other of *animal life.*

The first of these systems used in man to be designated the sympathetic *nerve,* from a belief that it arose from the brain in a similar manner to the cerebral nerves in general. Its title of sympathetic was owing to the idea that the sympathy which exists between all the vital organs was dependent for its existence on this nerve. The idea that it arises from the brain is erroneous; for it differs from the cerebral nerves as completely as the brain and spinal cord themselves do from the nerves which arise from them. And the notion being rejected, it has since been called the ganglionic system, a name which I think objectionable, in as much as it might lead the student to imagine that those nodules of neurine called ganglia were peculiar to this system, which as he advances in his studies he would find to be erroneous.

It has appeared to me that in describing this portion of the nervous system in man, it would be better to designate it the *Cyclo-ganglionic* system, as corresponding in its mere anatomical arrangement with the nervous system of the cyclo-gangliated or molluscous division of the animal kingdom.

Some physiologists even of the present day are divided in opinion as to which of the two systems, the cyclo-ganglionic or the cerebro-spinal, the nervous apparatuses of the lower orders ought to be referred. Before the cyclo-ganglionic system had been acknowledged in man and the lower animals as distinct from the cerebro-spinal system, every appearance of a nervous system was very naturally considered as corresponding to the cerebro-spinal.

But after the cyclo-ganglionic system was admitted to be independent in its powers in man and the higher animals, physiologists, looking only to resemblance in outward appearance and not to analogy of function, began to maintain that the nervous system of the lower orders corresponded exactly to this, the system of vegetative life of the upper.

It is now, however, generally believed that where a distinct nervous system is present, and there is an evident separation of the animal from the organic or vegetative functions, in all probability there are two corresponding nervous systems.

And though it is difficult, most probably on account of its minuteness, in many of the lower animals to demonstrate the existence of the nervous system of vegetative life, as distinct from that of animal life, there is very little doubt that it always exists; and it has in fact lately been demonstrated in many of the lower orders where its presence was not previously even suspected.

Dr. Grant, in speaking of the nervous system as developed generally in the animal kingdom, says, "The nerves of sensation and motion closely accompany each other, forming by their union cords or columns, or a cerebro-spinal axis; but the sympathetic nerves, appropriated to the more slow and regular movements of organic life, form a more isolated system, and these three systems are developed together, almost from the lowest animals [1]."

The following literary history, from Dr. Fletcher's Lectures, of the opinions held concerning the uses of the ganglionic nerves from Galen to Brachet is so excellent and comprehensive that I think its introduction in this place will be acceptable to my readers. "Before the time of Galen the ganglionic system of nerves was entirely unknown; and although by him and his followers, the Arabians, the existence of this system, as well as its supposed origin from the superior maxillary branch of the trigeminal nerve, was pointed out, as well as its other supposed origin from the abductor nerve was subsequently by Eustachius, it was not till the time of Willis that the ganglionic nerves were generally considered as a part of the nervous system at all.

"Willis, however, still looked upon them as merely an appendage to the cerebro-spinal system, and represented them, both in verbal descriptions of them and in his curious diagrams of their distribution, as growing upon the latter "ut frutex super alio frutice." And this notion having been adopted by Vieussens (*Neurograph*, 1684), Lancisi (*Opera Omnia*, 1745), Meckel senior (*Mémoires de Berlin*, 1745), Zinn (*ditto*, 1753), Hoare (*De Ganglia Nervorum*, 1772), Scarpa (*De*

[1] Outlines of Comparative Anatomy, Part II.

Nerv. Gangl. 1779), Monro (On the Structure and Function of Nervous Ganglia, 1783), Blumenbach (*Inst. Physiol.* 1786), Chaussier (*Exposition, &c.* 1807), Le Gallois (*Sur le Principe de la Vie*, 1812), Beclard (*El. d'Anat. Gén.* 1823), Wilson Philip (On the Vital Functions, 1817), Mason Good (On the Study of Medicine, 1825), and numerous other writers, both before and since the time that their independence was insisted on by Winslow, it has become a very prevalent custom to regard these nerves as of very secondary importance; and the names imposed upon the system in general, as well as the uses assigned to it, have generally corresponded with this idea.

"The ganglions of the sympathetic nerve were supposed by Galen, their discoverer, to act as buttresses, in order to strengthen them as they recede from their reputed origin;

"By Willis as a kind of diverticula to the animal spirits received from the brain, and also as a means of keeping up a sympathy between distant organs: Vieussens and Meckel adopted the same opinion.

"Lancisi looked upon them as forcing-pumps adapted to propel the animal spirits along the nerves.

"The doctrine of the independence of the ganglionic system was espoused by Cuvier (*Leçons d'Anat. Comp.* 1799), and particularly insisted on, with his accustomed eloquence, by Bichat (*Sur la Vie et la Mort*, 1802), who represented all the ganglions of this system as "des centres particulièrs de vie organique, analogues au grand et unique centre de la vie animale qui est le cerveau;" and who further demonstrated, not only that all these ganglions were collectively independent of the cerebro-spinal system, but that each ganglion was independent of every other; nay, that each nerve proceeding from such a ganglion was in a great measure independent of that ganglion, and even that each point of such nerve was independent of all the rest, and constituted, *per se*, a distinct focus of nervous influence.

"Richerand (*Phys.* 1804) and Gall (*Anat. et Phys. du Syst. Nerv.* 1810) adopted similar tenets; and they are further inculcated by Wutzer (*De Corp. Hum. Gangl.* 1817) and Broussais (*Journal Univ. des Sc.* 1818), the latter in particular describing the ganglionic system of nerves as possessing a peculiar kind of sensibility (*i. e.* irritability), with which it immediately endows all the organs destined for nutrition, secretion, and the other organic functions, and, by means of its repeated connexions with the cerebro-spinal system, all organs of the body.

"Brachet in an especial manner (*Sur les Fonctions du Syst. Nerv. Gangl.* 1823) distinctly represents the ganglionic system of nerves as the seat of "imperceptible sensation," and as presiding in an especial manner over the several viscera of the body[1]."

In the animal which we have last described, the Star-fish, it is evident that one of the earliest forms of nervous system which is cognisable to our senses, presides over the functions of animal life; and its nerves, like the spinal nerves in man, may most probably be divided into the two classes presiding over sensation and motion respectively, the motor nerves going to the arms, the sensory to the stomach. In this individual all the ganglia are of equal dimensions, none predominating in size over, or differing in function from, the rest: there is no concentration of power; all is equally diffused.

The nervous ring which we observe surrounding the œsophagus in the Star-fish, constitutes in the two next classes, namely, the *Articulata* and *Mollusca*, the most uniform and apparently the most important portion of their nervous systems. Everything like further development appears in the first instance to be merely in correspondence with the general form and shape of the animal: thus, in the long-bodied insects, as the Caterpillars, Sandhoppers, &c., which consist of a succession of rings, we find the nervous system putting on the lengthened form; while in the molluscous tribes, where external

[1] Lecture xviii. Ryan's Journal, vol. vii. p. 360.

form appears, as it were, sacrificed to the advancement of their internal organization, all the ganglia are scattered about without much apparent regularity, though the whole still preserves a very obvious circular arrangement.

In directing our attention to the relation which the development of the nervous system bears to the manifestations of consciousness in each individual of the animal kingdom, it is interesting to observe the relative position which the nervous system, in its simplest form, holds to the alimentary canal: we must not, however, attempt to account for this circumstance by supposing that the presence of a nervous system is necessary to the solution, digestion, and assimilation of the alimentary matter; for these processes are perfectly executed by the freshwater Polypus or *Hydra viridis*, in which there is not the slightest trace of a nervous system. Almost the whole existence of the lowest orders of animals appears devoted to the acquirement of food and the reproduction of their species; apparently they answer no other end in creation than that of elaborating a nutrient material for others that hold a higher rank in the animal kingdom; and the whole of their vital energies being devoted to this object, we cannot be surprised that those organs which are expressly constructed for its fulfilment should be surrounded by, and thus intimately connected with, that system (the *nervous*) by which the animal is informed of the existence of surrounding things, and is fitted to act upon these to the extent of its limited necessities.

The next specimen of a nervous system to which we shall direct our attention is taken from the second subkingdom; the Diplo-neurose or Articulated animals of Cuvier. This is almost as simple in its arrangement as that just referred to, although in general appearance it approaches more nearly to that of the higher orders.

Plate I. fig. 5., taken from Dr. Grant's Outlines of Comparative Anatomy, represents the nervous system of the common Sandhopper, or *Talitrus Locusta*; and it will be seen that here likewise all the ganglia are of equal size and nearly at equal distances: this form of nervous system is seen in the embryos of the higher orders of the Crustacea.

The next step onwards in the evolution of the nervous system consists in the approach and close connexion of the two longitudinal cords and their accompanying ganglia, or to concentration of these into a single cord as well as single ganglia. This form is beautifully illustrated by that of the Cymothea, Plate I. fig. 6.

In the Lobster we meet with the same arrangement of neurine into single ganglia as we observe in the Cymothea; but in addition to this, we perceive that those which are placed nearest to the head of the animal are much increased in size, a circumstance of which I shall consider the reason very fully when I come to describe the nervous system of some of the insects in whom it is even more decided, though the general arrangement is equally simple. The structure of the nervous cord of the lobster is particularly interesting to us as affording a very perfect type of the spinal cord in man, in as much as distinct columns for motion and sensation are capable of easy demonstration after the parts have been immersed for some time in alcohol; an arrangement which, though not susceptible of proof in the Asterias, in all probability exists as perfect as in the specimen before us. For, as Mr. Newport, in the interesting papers which he laid before the Royal Society, very justly observes, "the same train of reasoning which led Sir Charles Bell to his discoveries in the nervous system of the higher animals, must long ago have taught us, that since the laws of nature are simple and uniform, the same principle exists through the whole series of animated beings;—that however altered in arrangement or appearance in different parts of the series, structures corresponding to those which are endowed with especial properties in man and his immediate affinities, exist in every organized creature having the powers of locomotion and sensation."

"In the month of August, 1833," says Mr. Newport, "after many dissections and examinations of the animal [the lobster] in its recent state, I began first to hope for success; and in the beginning of September completed a preparation of the nervous system of the lobster, which I still possess, that appeared to show the two motor and sensitive columns, and I immediately communicated the circumstance to my friend Dr. M. Hall. Early in October a second preparation was completed, which showed these columns far more distinctly than the first. Fearing the possibility of a mistake, I showed the preparation to Dr. Hall, and a few weeks afterwards to Professor Grant, and many others: it is now in the possession of Sir Charles Bell.

"The nervous system of *Crustacea* has been examined by many anatomists,—Edwards, Carus, Home, and others. In the lobster it is formed upon the same general plan as that of insects. It consists of two longitudinal cords, corresponding to the halves of the body, united at certain distances by ganglia (fig. 7. Plate I. 1 to 14). These cords are double, each being composed of two tracts, lying one over the other (fig. 8. Plate I.), analogous to the motor and sensitive tracts in the spinal column of *Vertebrata*. These tracts, however, are not readily distinguished until after the cords have been kept for a short time in alcohol, when they become very evident even to the naked eye. The ganglia (fig. 8. Plate I.) are fourteen in number, one cerebral (A) and thirteen subœsophageal (C D). Seven of these are thoracic (C), and the remainder are post-abdominal or caudal ganglia (D). They all belong entirely to the sensitive tract, which lies nearest to the under or exterior surface of the animal. The tracts are in close apposition until they arrive at a ganglion. The motor then becomes more distinct and passes over the ganglion without uniting with it, and immediately afterwards is again closely approximated to the sensitive. A distinct line between the two tracts extends along the whole lateral surface of each cord, and is more or less evident in different parts of its course. It will thus be seen that the ganglia are situated almost entirely along the under surface of the cords, and it is from these that the sensitive* portion of the double or symmetrical nerves (*o, o, o, o, o,*) of the body take their origin. The manner in which the nerves from the motor tract unite with those from the ganglia of the sensitive in the lobster to form

"* While engaged upon the anatomy of the lobster I obtained a large living specimen, which, although apparently vigorous and healthy, appeared to suffer but very little pain when pricked or pinched, and was of a much lighter colour than usual, its whole covering being quite blue, instead of the usual blackish purple. Upon killing the animal and examining its spinal cords, the motor columns and nerves were of the usual size and appearance; but all the ganglia of the sensitive columns, particularly those in the post-abdominal region, were exceedingly small, and each inclosed only a very small nodule of grey matter. May we not infer from this fact that the degree of sensation in the nerves belonging to the spinal column very much depends upon the size of the ganglia and the quantity of grey matter they contain?

these symmetrical nerves, is not at first very apparent. Upon close examination it seems to be by fibres coming off laterally from the motor tract, just above the anterior margin of each ganglion, passing backwards and outwards, and immediately uniting with those from the ganglion in distinct trunks. The ganglia in the thorax are rounder, larger, and closer together than the caudal or post-abdominal ones, and give nerves to the true organs of motion, the legs; to the claws, mandibles, and feelers; to the glandular structures, and the circulatory vessels in the branchiæ and thorax. The caudal ganglia are of a much smaller size, and are of an oval shape. Each of these gives off two pairs of nerves (*o*, *o*), which again divide into two branches, and pass outwards close to the under surface of the body, supplying the large trunks of circulatory vessels which pass along the same course with them, and the external layer of muscles. The posterior division of the second pair from each ganglion is larger than the others, in consequence of its again dividing into two branches as soon as it reaches the lateral margin of the body. The largest of these branches (*p*, *p*) descends to supply the muscles of the false feet, the other ascends to those of the lateral surface of the segments. This is analogous to the means by which the false feet are supplied in the larva of *Sphinx ligustri* and other lepidopterous insects, in all of which they are supplied from the ganglia in the abdominal region, which are analogous to the post-abdominal of the lobster. The terminal ganglion (Plate I. fig. 7.) is the largest, and gives off four pair of large nerves, and, as in insects, was originally formed of two ganglia. The two terminal nerves (S) from this ganglion, which has coalesced longitudinally, pass on each side the rectum, and divide each into two branches. The terminal branch supplies, and is entirely lost in, the rectum and sphincter ani; and the other supplies the muscles which elevate and expand the anus in the expulsion of fæces, and the middle lamella of the tail in which the anus is situated. The remaining pairs of nerves (W) are given to the other lamellæ of the tail.

"All the nerves I have now described in the lobster belong to what Sir Charles Bell calls the regular or symmetrical, and come directly from ganglia; but there are others (fig. 7. *q*, *q*, *q*) which come directly from the upper surface of the cords, unconnected with those from ganglia. In the caudal region there are two sets of these, posterior to each ganglion. They arise from the tracts by single trunks, each dividing into five or six branches, that ramify in every direction, and are given entirely to the muscles. Although at first sight they do form ganglionic enlargements (*q*, *q*) before dividing into branches, there are no ganglia upon them. This appearance is occasioned by the approximated fibres which constitute the trunk being spread out, instead of rounded like a cord. The two last of these nerves (Q) originate singly from the tracts, and are given to the under surface of the rectum. In the thoracic region they come from the tracts (Plate I. fig. 7. L, L) immediately above the posterior part of the ganglia, and are given to the muscles of the branchiæ[1]."

From this beautiful arrangement in the organization of the lobster let us turn to one which will serve to instruct us how wonderfully Nature varies her resources according to the task she has to execute, always maintaining real simplicity amidst an almost boundless variety; teaching us also that the shape alone and general outline of the component parts of a nervous system in the lower animals will guide us very imperfectly to its analogues in man, and that we must search deeper for a clue to unravel the structure of the human brain. Instead of simply directing our attention to the shape of the ganglia, we must rather consider how far the distribution of the nerves which we believe to be the conductors of the power generated by the ganglia or centres, corresponds in the specimens we select for illustration. Guided by this principle we can always discriminate the masses of neurine or optic ganglia in which the optic nerves terminate in each individual in whom

[1] Philosophical Transactions, 1834, Part II.

optic nerves exist, and so of all the other centres or ganglia which in the higher tribes of animals especially are found so closely united that the whole mass appears but as one, when it is called the brain. On the same principle, in the specimen which we shall next attend to, we must observe that the collection of neurine from which the nerves of the extremities arise, though wholly dissimilar in shape, is analogous to the spinal cord of the *Vertebrata* [Plate I. fig. 9.], and that in the common Crab the neurine, which in the last-described species was deposited so as to form a chain of ganglia spread along the surface of the abdomen, is collected into only two masses, the one situated in the head, and the other in the thorax.

The anterior of these ganglia, the *supraœsophageal* or brain, is small as compared with the posterior; for the organs of sense, whose nerves terminate in this centre of power, are as yet but imperfectly developed, while the muscular system, deriving its supply almost entirely from the posterior or thoracic ganglion, is large and powerful.

The anterior ganglion is connected with the posterior by two slender commissures in the form of mere nervous threads, which, passing on each side of the œsophagus, form with the ganglia the same œsophageal ring we have before observed.

Advancing from this, one of the most concentrated forms of the nervous system in the *Crustacea*, we next meet with a very decided step towards the concentration of the higher orders in some of the insect tribe; for the nervous ring round the commencement of the alimentary canal receives additional ganglia on its superior surface until the whole mass formed by the union of these nervous centres, or instruments of consciousness, assumes the appearance, and seems entitled to the appellation, of a *brain*.

The intimate connexion and apparent dependence of the organs of sense, as the eye, &c., upon those appropriate masses of cineritious or pulpy neurine in which their nerves terminate, and to which, therefore, we suppose the impressions of light, &c., received on their peripheral expansions transmitted in order to become perceived by the animal, is beautifully illustrated by the various alterations which take place in the nervous system of the Moth as it advances from the caterpillar to the perfect insect, or imago.

In this part of my task I shall again avail myself of the excellent descriptions of that most trustworthy and indefatigable inquirer Mr. Newport.

"The cerebral mass of neurine in the caterpillar lies above the œsophagus, and is formed of two lobules closely united, convex upon their upper, and a little concave on their under surface, so as in the middle line to accommodate themselves to the anterior part of the dorsal vessel which passes immediately beneath them, and to the œsophagus along which this is directed. The longitudinal cords originate from the under surface of these lobules, and passing a little backwards meet beneath the œsophagus, and by their uniting form the heart-shaped or first ganglion [Plate I. fig. 1. (1)]. From this they are continued close to each other into the next segment or true collar of the future moth, and here connected from the second ganglion [fig. 1. (2)], which is nearly of a spherical form. The cords then gradually diverge and proceed apart from each other, passing on the outside of and inclosing between them the insertions of some of the diagonal muscles of the future thorax, until they again unite in a third and distinctly bilobate heart-shaped ganglion [fig. 1. (3)]. From this they are continued in the same manner into the fourth segment, and uniting, form a similarly shaped fourth ganglion [fig. 1. (4)]. They then pass close to each other into the anterior part of the fifth segment, and form a ganglion [fig. 1. (5)], the distance of which from the fourth, like that of the second from the first, is scarcely more than half of what exists between any of the other ganglia. From the fifth they are continued to the sixth, seventh, and so on to the eleventh segments, forming in the middle of each one nearly spherical ganglion [fig. 1. (5, 6, 7, 8, 9, 10, 11)], which has scarcely any appearance of having originally been formed of two lobes. The eleventh ganglion, however, is distinctly bilobate [Plate I. fig. 1. (11)], and at this period of the larva's existence is in reality a double ganglion, with a constriction in its middle, which is more or less apparent in different individuals [1]."

It would be inconsistent with my purpose if I were to expect the student to follow the description of the various nerves connected with these ganglia in the present stage of his knowledge; nor do I conceive that such a proceeding would diminish his difficulties in reference to the study of the human brain: at the same time, however, as he may find it interesting to refer to them when he has investigated their distribution in man, I will here introduce Mr. Newport's accurate description.

"*Nerves of the Head.*—When viewed from above, the cerebral lobes are pretty uniform in appearance, and are clearly distinguished from each other by a depression between them. This is more apparent on the anterior than posterior surface, and arises from the lateral part of each lobe being carried a little forwards, so that they lie across the œsophagus in a curved or semilunar direction. From the anterior and lower part of each lobe originate four remarkable nerves.

[1] Philosophical Transactions, 1832.

"Two of these are distributed towards the front of the head, near the flexor muscles of the mandibles; a third passes a little forwards, descends, and uniting with its fellow from the opposite lobe, forms a circle round the œsophagus, to the under surface of which it distributes a few filaments; while the fourth, which originates rather higher up than the others, forms what has been called by Lyonnet the recurrent ganglion and nerves.

"From its origin this nerve is directed forwards and downwards along the side of the œsophagus, or rather posterior part of the mouth, but gradually altering its course, inclines upwards and inwards, and then a little backwards, until, by meeting its fellow of the opposite side, above the roof of the mouth, the two by their union form a semilunar ganglion[1] immediately below the bifurcated portion and distribution of the dorsal vessel. From the front, or most convex surface of this ganglion, originates a small branch that distributes filaments in the direction of the superior lip, while a large nerve is produced from the posterior surface, which passes backwards beneath the cerebral lobes, along the middle of the œsophagus, covered by the dorsal vessel. On

[1] The presence of this ganglion at the central extremity of the pneumo-gastric nerve, supports the opinion which I have stated further on regarding the ganglionic character of the corpus olivare in man, to which body I have no doubt it is perfectly analogous.

arriving at the stomach it divides into three branches, which are distributed chiefly to that organ. Throughout the whole of its course, from the ganglion to this division into branches, it distributes filaments to the dorsal vessel and to the œsophagus. I have not yet succeeded in tracing it in this insect beyond the anterior part of the stomach; but in the *Gryllus viridissimus*, Linn., I was once enabled to follow its central division along the whole of the stomach and part of the small intestine, from which, with a little care, it was readily detached. Its length from the ganglion to the trifid division in the Sphinx is much increased during the changes of the insect, and corresponds precisely with the elongation that takes place in the œsophagus. The form of the ganglion undergoes no alteration.

"From the analogy that exists in the distribution of this nerve to that of the eighth pair in the vertebrated animals, it is probable that its functions are of a somewhat similar nature, — that in reality it is the par vagum, or pneumogastric nerve of insects. The other nerves from the cerebral lobes arise nearer the lateral surfaces. The first of these are destined for the future antennæ, and proceed from the front near the origin of the cords. At the last period of the larva state they are of considerable size and length, and lie packed in sigmoid folds on each side the head, within the cranium. The next are the optic nerves. These come from the upper part of each lobe, and in the larva are scarcely more than slender cords directed diagonally outwards to the six minute eyes. In addition to these nerves from the cerebral lobes there are also two minute pairs which form very remarkable ganglia, similar to those described by Straus Durckheim, in his Anatomy of the Melolontha. These ganglia I have ventured to call anterior lateral ganglia. The two pairs of nerves originate, one from the base of the nerve to the antennæ, the other from the posterior surface of each lobe, and they are directed backwards and outwards, and after passing some distance unite and form an irregular lunated ganglion, which is closely connected to another of an oval form. Both these ganglia distribute filaments to the muscles of the neck and to a lateral branch of a dorsal vessel, and are connected with a system of nerves derived from the large ganglion in the second segment. All the nerves which supply the organs of motion belonging to the head and mouth, excepting only those to the antennæ, derive their origin from the first ganglion. There are four distinct pairs, three of which proceed from the anterior and one from the lateral surface of the ganglion. The largest pair from the anterior surface are divided into three branches, and go directly to the mandibles; the next to the palpiform spinnerets; and the third apparently to the inferior lip, while the lateral pair are given exclusively to the silk bags, which afterwards are the salivary vessels of the perfect insect.

"*Nerves of the Thorax.*—They arise from the second, third, fourth, and fifth ganglia, and their intervening cords [Plate I. fig. 1. (2, 3, 4, 5)].

"The first pair from the second ganglion are remarkably small in the larva, and their distribution is not easily traced. The second are large, directed forwards, and divided into many branches, which supply the muscles of the head and neck, [fig. 1. (*c*, *c*)]. The third are carried backwards for a little distance, and then turning forwards enter the first pair of legs [fig. 1. (*d*, *d*)]. Both the cords between the second and third ganglia produce a single nerve, which is directed backwards, and unites at an angle with the first nerve from the third ganglion [fig. 1. (*f*, *f*)]. These form a single trunk, which goes to the first pair of wings in the perfect insect. It is now of small diameter, but is carried forwards and distributes filaments among the muscles at the anterior part of the segment. This trunk is also connected with a system of nerves of which we shall speak more particularly hereafter. The second pair from the third ganglion, [Plate I. fig. 1. (3. *g*, *g*)], distribute from their base a small branch, which looks like a distinct nerve, while their main trunks, at a distance from the ganglion, divide into two branches, and are given to the second pair of legs. The cords between the third and fourth ganglia also produce a nerve that unites, in a manner similar to the preceding, with the first nerve from the fourth ganglion, [fig. 1. (4. *i*, *i*)] and forms a trunk which ramifies among the muscles of the fourth segment, and is destined for the second pair of wings. The second pair of nerves from the fourth ganglion [fig. 1. (4. *k*, *k*)] are given to the third pair of legs. The nerves from the fifth ganglion [fig. 1. (5. *l*, *l*)] belong also to the thorax, and are those which are given to the muscles of the hinder part of the thorax in the perfect insect.

"*Nerves of the Abdomen.*—All the nerves from the sixth to the termination of the eleventh ganglion, belong to this division of the body; and, with the exception of those from the latter, are pretty nearly uniform both in number and distribution. Each ganglion produces one pair of small nerves, and one of large. The small ones are given to the flat and minute tracheæ of the ventral surface. The large ones pass transversely across the segments, and divide each into two branches. One of these passes over the inner range of fibres and between the layers of abdominal muscles, and following the course of the trachea gives its branches to the dorsal muscles, and to the integuments of the back; while the second, [fig. 1. (*r*, *r*, *r*, *r*)] passing also between the layers of ventral muscles, distributes its branches to their inner surface and to the integuments of the under surface of the body. The eleventh or terminal ganglion [Plate I. fig. 1. (11)] produces five pairs of nerves, four of which are of considerable size. These are arched backwards, and three of them are given to the remaining segments of the body, while the others supply the colon, rectum, and organs of generation.

"Besides the nerves thus described as constituting those of the head, thorax, and abdomen, there are others which merit some attention, as they seem to form a distinct or superadded series. Lyonnet has accurately delineated them in his excellent anatomy of the larva of the *Cossus*. There is a plexus of them lying transversely in every segment, attached by apparently a single filament, passing between the longitudinal cords to the posterior part of every ganglion, [Plate I. fig. 1. (*e*, *h*, *o*, *o*, *o*, *o*, *o*)]. Some of the nerves from each plexus in the abdomen unite with the principal nerve from the next ganglion, while others ascend and ramify among the tracheæ and dorsal muscles. The principal branch [fig. 1. (*p*, *p*, *p*, *p*)] goes directly to the tracheæ which come from the spiracula. In the thorax, the plexus from the hinder part of the second ganglion [Plate I. fig. 1. (2. *e*)] unites some of its filaments with the nerve destined for the first pair of wings, while others are distributed among the muscles. The nerves from the plexus attached to the third ganglion give, in a similar manner, some of their filaments intended for the second pair of wings, and some to the muscles. The second ganglion has the transverse plexus from the first, attached pretty closely to its anterior surface. This plexus distributes its nerves laterally to the muscles of the head and neck. It is also united by a small branch with the anterior lateral ganglia, and with the first pair of nerves from the second ganglion, so as to form a complete link or medium of communication between the nerves and ganglia of the head, neck, and second segment. From the distribution of these nerves it seems probable that they may constitute the origin of a distinct system; but whether this system in insects be analogous either to the sympathetic or to the respiratory system of vertebrated animals, is yet a matter of inquiry. From the principal branches from each abdominal plexus being always distributed among the tracheæ, near the spiracula, there seems reason for inclining to the latter opinion.

"Such is the arrangement of the nervous system when the larva has attained its full growth, and ceased to eat, preparatory to its changing into a pupa. Thirty days after the insect has become a pupa the change in the nervous system is very evident. (Plate I. fig. 11.) The cerebral lobes are increased in size, the optic nerves a little extended, and the first ganglion has been brought so very close to the lobes as to appear to constitute with them a single mass, through which there is a small aperture for the passage of the œsophagus. All the ganglia of the thorax are much enlarged, and the first pair of nerves which belonged to the second ganglion in the larva now appear to take their origin from the cords, and after anastomosing with the second pair, to form with them a plexus which supplies the neck and collar; while the third pair passes before to the muscles of the first pair of legs. The first pair from the third ganglion, and the roots they derive from the cords, are much enlarged, as also are the second pair given to the second pair of legs. But the greatest alteration is in the fourth ganglion, which is now more than double its former size, is elongated and bilobate, and gives off four pairs of nerves. The first, including the roots they derive from the cord, are given to the inferior wings; the second, to the third pair of legs; the third pass backwards to the muscles of the abdomen; and the fourth are directed upwards, divided into three branches, and are distributed to the posterior muscles of the trunk. The fifth ganglion is close to the fourth, and coalesces with it; the nerves last described being those that originally belonged to it. The sixth ganglion, much decreased in size, is sometimes found at this period close to the fifth, from which it is separated only by a slight indentation. It is more frequently, however, at a short distance from it. The longitudinal cords are no longer irregularly folded in the abdomen; they now lie in a direct line between the ganglia, but neither these nor the cord itself are increased in diameter."

Without following out each different stage in the gradually progressive change which the nervous system of the pupa undergoes previous to its attaining its full development in the imago, we will advance at once to it in its most perfect form, as represented in Plate I. fig. 12.

The cerebral ganglia are now extended transversely, and form, with the first subœsophageal ganglion, and the enlarged crura which connect them, one continuous mass around the œsophagus and anterior part of the dorsal vessel. The second ganglion has entirely shifted its position, and receded towards the middle of the thorax, and has coalesced with the third, which has entirely disappeared, and seems to have joined in part with both the second and fourth, and the intervening cords. This aggregation of ganglia and cords is situated in the middle of the thorax, and supplies all the muscles in that part of the body. The longitudinal cords are continued from the hinder part of the fifth ganglion, and just before leaving the thorax to enter the abdomen, they give off the nerves which formerly belonged to the sixth ganglion, which is now entirely obliterated. The cords then descend into the abdomen, and immediately give off the nerves that belong to the seventh ganglion, which, with part of the cord that existed between the sixth and seventh ganglia, is also obliterated. The cords are then continued in a direct line along the abdomen, the eighth, ninth, tenth and eleventh ganglia being situated as in the previous stages. Such is the state of the nervous system at the period antecedent to the development of the perfect insect, which usually takes place about the middle or latter end of June. Mr. Newport details some further points of interest as regards the distribution of the nerves and the obliteration of a ganglion in the thorax, but it would be foreign to our purpose to dwell upon them at present.

The nervous system of the Sphinx in its perfect condition differs but little in its general arrangement from that of the pupa in its last stage. Thus, there is no further alteration in the cerebral ganglia, nor in those which constitute the thoracic mass, from which nerves to the organs of locomotion are distributed; but the whole are covered in by a new structure, and do not lie, as in the larva, in the open cavity of the thorax.

In the *Cyclo-gangliata* or *Mollusca*, where we find the organs of sense and the external form sacrificed, as it were, to the more perfect development of the organs of vegetative life generally, and of the digestive and circulating systems in particular, the nervous apparatus is commonly found scattered in an irregular manner throughout the interior of the animal. The nervous collar surrounding the œsophagus, however, still maintains its station; and the accompanying diagram of the *Aplysia fasciata*, or Sea Hare as it is called, which in many respects approaches very closely to the Slug tribe, from the *Annales du Museum*, affords us a very good specimen of this cyclo-gangliate form of the nervous system generally. [Plate II. fig. 1.] The supra-œsophageal ganglion is connected with two lateral ganglia, and there is in addition a fourth ganglion beneath the bulb of the œsophagus. From the right lateral ganglion there is a considerable nerve detached, which descends towards the heart, near which organ it becomes connected with a fifth ganglion, from whence branches are given off to the heart and to the organs of digestion and of generation in its neighbourhood. This ganglion and its branches are evidently analogous to the sympathetic or vegetative system of nerves in man and the higher animals.

From the supra-œsophageal or cerebral ganglion nerves are given off to the muscles of the head, and to the superior tentacula and eyes, while the branches from the lateral ganglia are distributed to the muscular parietes. In this form of nervous system we must not neglect to remark the curious mode in which the nervous system of organic or vegetative life is bound up with that of animal life: so complete, indeed, does this connexion appear to be, that we cannot decidedly point out the distinction, if there be any, between the centres of power and the conductors of the two systems; in other words, and as we should say in the ordinary language of human anatomy, the line of demarcation between the ganglionic system and the cerebro-spinal system is nowhere clear and well defined among the *Cyclo-gangliata*.

Our attention having been directed, in the instance of the Moth, to the progressive development of the organism from the larva to the imago, and to the striking increase in the size and greater complexity in the form of the nervous system when the animal becomes fitted to receive impressions from the objects which surround it, which it does through the medium of especial organs of sense, and not by the whole surface of the body, as in the *Medusæ* and lowest forms of animal existence, we are prepared to appreciate similar changes in some of the Molluscous tribes, and to inquire how far the nervous organization of these creatures will countenance the opinion that there is an intimate relation between the bulk of cineritious neurine in which each individual nerve of sense terminates, and the perfection of the organ of sense from which that nerve arises.

However much we may have had reason to be gratified with the evidence which our investigations into the development of the Moth has afforded us of the existence of such a relationship, we shall be even more delighted with the clear proof of the universality of such a law, which one very interesting class of the Molluscous division of the animal kingdom in particular has lately yielded to the physiologist: I allude to the admirable Memoir of Mr. Owen on the Pearly Nautilus[1], and to his account of the structure of the Cuttle-fish, published a few months ago[2]; and whilst I do so, I gladly express my thanks to this philosophical anatomist, for several kind and valuable hints during the progress of this work.

We shall first consider the relations that exist between the perfection of the organs of the senses and the bulk and complexity of the central portions of the nervous system in the Pearly Nautilus, and afterwards in the Cuttle-fish, in which they will be found to be still more strikingly displayed than in the former.

[1] Memoir on the Pearly Nautilus (*Nautilus Pompilius*, Linn.), by Richard Owen, Esq.; published by direction of the Royal College of Surgeons in London, 1832.

[2] Descriptive and Illustrated Catalogue of the Physiological Series of Comparative Anatomy contained in the Museum of the Royal College of Surgeons in London; Vol. III. Part I. Nervous System and Organs of Sense, 1835. From one or other of these publications the following particulars, and the figures in Plate III. are entirely derived.

"The brain or supra-œsophageal mass in the *Nautilus* [Plate III. fig. 1.] consists of a transverse cord-like ganglion, from the ends of which three nervous trunks are continued on each side. The anterior pair pass downwards and forwards by the sides of the œsophagus to unite below it, forming a ganglion on either side, which supply the digital processes and tentacles, and give off nerves to the organ of smell and the funnel. The middle and superior trunks dilate into the optic ganglia; the retina, which terminates that of the left side, is shown. The posterior cords surround the œsophagus in a manner analogous to the anterior pair, forming also two ganglionic swellings, from which the nerves of the great shell-muscle and those of the viscera are given off; the latter nerves are of small size, and are continued down by the side of the great perforated vein, and are analogous in their distribution to the sympathetic nerves and par vagum."

The organization of the *Sepia officinalis*, or Cuttle-fish [Plate III. fig. 2.], is peculiarly interesting, not only from the fact that it offers to our notice the first appearance of an internal skeleton, an apparatus, which in the *Vertebrata* is constructed in intimate relationship with the nervous system, and is often entirely appropriated to its protection; but we find this rudimentary skeleton supporting a central ganglion of unusual dimensions, and a nervous system very highly developed in many of its parts. In its general arrangement, however, the nervous system differs but little except in the quantity of neurine composing the cerebral ganglia from that of the Nautilus, as will be apparent by turning to Plate III. fig. 2., in which the differences between them are exhibited and made apparent to the eye. In Plate III. fig. 2. the bristle is placed in the situation of the œsophagus, around which the nervous masses are aggregated[1].

"As the supra-œsophageal cerebral mass," says Mr. Owen, "is principally in communication with, and is developed to receive the impressions transferred by the optic nerves, it must be considered as analogous to the bigeminal bodies in the brain of *Vertebrata*; which parts are first developed in all the higher classes, and from their constancy and magnitude in the cold-blooded *Vertebrata*, are evidently among the most important parts of the cerebral organ." A small spherical body, considered by Mr. Owen as probably analogous to the corpus geniculatum, is appended to the peduncle of the optic ganglion on either side.

"The medulla oblongata, from which the auditory and respiratory nerves are given off, is, in the Cuttle-fish, situated below the œsophagus.

The anterior subœsophageal ganglia give off

[1] The relation of the brain to the alimentary canal is more distinctly shown in Plate II. fig. 2.

nerves to the brachial and labial processes; the posterior subœsophageal ganglia send off laterally the large nerves which pass outward to the mantle, and then form on either side the great ganglion, which, from the radiated distribution of its filaments, is termed ganglion stellatum." In addition to these there are a pair of nerves which, like those in the Aplysia, descend to the region of the heart, and there form a plexus for the supply of the organs of digestion and circulation, and exhibit a very perfect analogy to the cardiac and solar plexuses of the sympathetic nerve in man.

This very general review of the nervous system in these two members of the cephalopodous class of Mollusca, shows us, in the first place, that the supra-œsophageal ganglion in the Nautilus has no cranial cavity constructed for its protection, and that instead of being a distinct rounded mass, as in the Cuttle-fish, it seems little more than a rounded cord or commissure connecting the ophthalmic ganglia, and placed transversely to the œsophagus. These facts by themselves would be of little value as affording data for reasoning on the offices and relations of the nervous system, did we not at the same time discover an imperfection in the structure of their brain corresponding with imperfect development of the organs of locomotion and sensation generally. The peculiarities in the structure of the Nautilus are in complete correspondence with this principle. "The eye," observes Mr. Owen, "is far from presenting those complexities of structure that render it so remarkable an organ in Dibranciate Cephalopods. Indeed, it here appears to be reduced to the simplest condition that the organ of vision can assume, without departing altogether from the type which prevails throughout the higher classes. For although the light is admitted by a single orifice into a globular cavity or *camera obscura*, and a nerve of ample size is appropriated to receive the impression, yet the parts which regulate the admission and modify the direction of the impinging rays are entirely deficient." This state of the eye appears to be in harmony with the habits and aptitudes of the animal so far as they are known. On the other hand, the superior locomotive powers of the Cuttle-fish demanding more perfect vision, we find not merely the eye more complex and perfect in its construction, but the "centre to which the impressions of the optic nerve are referred, more highly developed."

In fact, as Mr. Owen observes, (p. 51,) "The inferiority of the more intellectual senses, sight and hearing, is in correspondence with the simplicity of the brain. If, as I believe, a distinct organ for the latter sense is altogether wanting, the Pearly Nautilus exhibits, in this respect, an obvious approximation to the inferior Mollusks.

"As the Pearly Nautilus, like the latter group of Mollusks, is also attached to a heavy shell, and participates with them in the deprivation of the locomotive instruments of the Cephalopods, we may thence deduce the more immediate principle of their reciprocal inferiority with respect to the visual organ; for what would it avail an animal to discern distant objects, which could neither overtake them if necessary for food, nor avoid them if inimical to its existence?"

The following difference in the distribution of the nerves of the *Nautilus Pompilius* and *Sepia officinalis* is also highly instructive.

"In those Cephalopods, whose shells are rudimentary and internal, and whose bodies are enveloped in a naked, and, as we may suppose, sensible mantle, the nerves which supply that part radiate from a ganglion, which, as in the posterior roots of the spinal nerves in the *Vertebrata*, is interposed on the cord which brings them into communication with the central mass. In the Nautilus, on the contrary, whose body is incased in an insensible calcareous covering, the analogous nerves are wholly expanded on the largely developed muscles which attach the shell to the body; and these nerves, like the motor filaments of the spinal nerves, pass into the muscles directly from the brain without the interposition of any such ganglion[1]."

[1] Memoir, &c. p. 51.

The nervous system in the *Spini-vertebrata*, or Vertebrated class of animals, which derive their name from that beautiful piece of mechanism constructed expressly for the purpose of protecting the central portions of this system, will next engage our attention. This subkingdom includes Fishes, Amphibious animals, Birds, and the Mammalia.

In these animals the whole skeleton is developed in relation to the nervous system; and we find, as might be expected, the axis or central portions become by an increase of bulk and gradual concentration of parts more decidedly elevated above the peripheral. The supra-œsophageal ganglion now having an appropriate organ, the cranium or skull, for its protection, uniformly passes by the name of brain; while the remaining ganglia with their commissures are so closely united that all appearance of a chain is lost, and one nearly uniform cord supplies its place, which, from the situation it holds in relation to the skeleton, namely, within the spinal column, is called the medulla spinalis or spinal cord.

We have already observed in some of the *Articulata* how the gradual union of several ganglia constitutes a tolerably uniform cord, and how also the addition of ganglia to the single pair above the œsophagus which we saw in the Sandhopper, so far increased the entire mass of neurine in that situation as to procure for it the title of cerebrum or brain; so also, even in the *Vertebrata*, whose organs of sense, the instruments by which the individual is brought into relation with the external world, are so much more perfectly developed, we do not find that the brain is separated from the spinal cord by any other line of demarcation than that of a greater disproportion in the size of the ganglia composing it. The further we advance, indeed, we meet with fresh proofs that the brain, even of the highest order of animals, is no more than a series of ganglia or collections of cineritious neurine, though without any peculiar uniformity of size in which the nerves from the different organs of sense terminate, and from which the nerves of volition originate. That these ganglia are larger and more numerous at the anterior than at the posterior extremity of the spinal cord is simply in accordance with the evident marks of consummate design upon which every living being has been constructed. For all the organs of especial sensation, as sight, smell, hearing and taste, are placed in that situation in the body where they have the greatest range for the exercise of their powers, either in the anterior, or that portion which is in advance of the rest of the animal as he moves over the face of the globe, or, as in man, placed so completely above the rest of his frame, that they receive no impediment from it in the performance of their functions. These organs, from the high office they have to fulfill in the sphere of animal life, appear to require a large quantity of cineritious matter to accomplish their functions; in consequence of which the anterior extremity of the spinal cord is larger than the posterior. In this simple manner may we account for the relative proportion of the brain and spinal cord throughout the vertebrated class of animals up to man himself.

In *fishes* the common division of the nervous system into a brain and spinal cord, though arbitrary, it is nevertheless convenient to retain. The two portions in fact exhibit but a slight disproportion in general dimensions, although the mass of the spinal cord, as a whole, is very much more considerable than that of the brain or cerebral ganglia.

The spinal cord in fishes bears a very great resemblance to that of man, differing from it only in the circumstance that the superior and inferior grooves which separate the cord into two lateral portions are much deeper. The superior groove indeed is so deep that it forms an imperfect canal, the internal surface of which is covered with a layer of grey matter. This canal exists in the human fœtus, and communicates by the calamus scriptorius with the fourth ventricle, which in reality is nothing more than a permanent dilatation of it.

The spinal nerves arise from the cord in fishes, by anterior and posterior filaments, an arrangement similar to that which is found in man, the posterior roots having in like manner a small ganglion connected with them.

The cineritious neurine in which the nerves of sense, as the optic, auditory, &c., in the Butterfly and Sepia, terminate, and which in these animals is collected into one rounded mass, the supra-œsophageal ganglion, in the fish is divided into several separate masses, so that almost every nerve terminates in a distinct and appropriate ganglion; hence the peculiar appearance, as compared with that of man, which the brain of the fish presents.

There is in fact no set of organs in the human being which have less resemblance to the corresponding ones of the fish, in mere external appearance, than the masses of neurine contained within the cranium; and I will venture to assert that there are few circumstances more startling to the anatomist who has confined his attention solely to the examination of the human brain than the first appearance which the brain of a large fish presents to his view on removing the upper surface of the skull. Its minuteness as compared with the great size of the body, the number of its component parts, and their want of that concentration which is so peculiarly striking in the human brain,—a concentration, let it be remembered, deeply interesting, but which can only be duly appreciated by him who traces with attention the structure of the nervous system through the chain of beings,—all give a mystery and confusion to the subject, which can only be solved by seriously considering and carefully drawing inferences from those facts which rest upon comparative as well as human anatomy for their support.

Among these facts there are none more important to us than these, viz.

That every nerve of sense, whether it be of the sense of smell, sight, hearing, taste, tact, or of simple sensation, has at its central extremity a collection of cineritious neurine, or ganglion. By the central extremity of a nerve we mean that which in the ordinary language of anatomists is called the *origin of the nerve*, but which in strict accordance with physiology ought to be called its termination; for the term origin is not merely incorrect as regards the function of the nerves of sensation, but also as regards their development, all the nerves being formed in the extremities and trunk previous to their connexion with the brain and spinal cord, in conformity with the law of concentric development, or development from the circumference to the centre. In the human embryo, for example, we find that when the nerves first engraft themselves upon the spinal cord the external layer of medullary matter is extremely thin, and the nerves appear to be simply in contact with the cord, but that in proportion as new fibrous layers are deposited the nerve is enveloped by them, and becomes, as it were, dovetailed into the fissures of the fibres.

But the brain of fishes does not consist simply of ganglia, in which the nerves of sensation terminate; there are other parts which must, I think, be viewed as a decided advancement, in accordance with their manifestation of higher instinct and an approach to the intellectual faculties of memory and judgement. These parts are therefore, in all probability, the instruments by which some further process is effected, approaching in its nature to the mental operations of man, such as judgement, of course extremely limited in its nature, remembrance of sensations, &c. If this view be correct, these parts must be analogous to the hemispheres of the human brain, for most physiologists of the present day agree with the opinion given by M. Cuvier in his report to the Academy of Sciences at Paris on M. Flourens' work, namely, that the cerebral lobes or hemispheres are the organic parts in which the impressions made on the organs of sight and hearing become perceptible to the animal, and that probably there too all the sensations assume a distinct form, and leave durable impressions; that the hemispheres, in short, are the abode of memory, and from this circumstance therefore a source to the animal of the materials for judgement.

Besides these parts, which in all probability are analogous to the hemispheres of the human brain, there is a structure which corresponds to the cerebellum. Its office has not yet been clearly ascertained, though, for reasons to be mentioned hereafter, there can be little doubt that it is in some way or other connected with the production of that combined action of the muscles which is essential to progressive motion, and which would seem to require appropriate nervous parts for its direction and control.

If we do not take this view of the composition of the brain of the fish, we must remain satisfied with the obscurity in which all writers on comparative anatomy have left this subject, and be content to see the chain of progressive development from the lowest animals up to man broken, by which the study of the nervous system in these animals, instead of assisting us in unravelling the structure of the human brain, would only plunge us into fresh difficulties.

Serres[1] was well aware of the backward state of information in regard to the anatomy of the brain of fishes. He thus expresses himself:

"Considered in its ensemble, the enkephalon of the fish is the most simple in nature: it is the most complicated in our writings; it is an inextricable labyrinth in our books. Why this con-

[1] *Anatomie Comparée du Cerveau*, tom. i. p. 184.

tradiction between nature and our writings? There exist many reasons for it; the principal one, that from which all the others flow, is the infinite variety which the brain of the fish presents to our notice. Nature seems to have employed all her riches upon these animals. Their brain does not only vary from family to family, but essentially differs from genus to genus and even from species to species; there is continued metamorphosis going on. These variations do not consist solely in changes of form, of position, or of relation in the same elements: some entire parts are transformed, left out, and again reproduced."

Notwithstanding these prefatory observations of Serres, I confess that he does not appear to me to have considered the structure of the brain from that simple point of view from which I conceive it may very readily and very advantageously be regarded.

In order to prove the correctness of this view, and justify all that has just been said, let us direct our attention to a few individual specimens of the brain of fishes, commencing with the more simple forms, and proceeding gradually to the more complicated. For this purpose I have intentionally selected the brains of those species which are most easily obtained in London.

But before proceeding to the description of the brain of any particular fish, let me remark that there is a striking peculiarity in the brain-case or cranium of fishes as regards its relation to the dimensions of the cerebral mass. In most species of fishes the cavity of the skull is nearly double, and in many instances nearly treble, the size of the included brain. In the head of the skate and cod this difference is particularly obvious: the space which is left between the surface of the brain and the walls of the cranium is filled up with a loose cellular membrane containing a quantity of gelatinous fluid, and evidently answers the same purpose as the arachnoid in those instances where the brain is closely surrounded by the bones of the skull. In the sturgeon again there is no such vacancy, a circumstance which it is important to bear in mind in order to avoid injuring the brain when opening the skull of this cartilaginous fish.

The Whiting[1].—If in this fish we view the cerebral mass from above, proceeding from before backwards, we observe three rounded masses or nodules of neurine, and a triangular-shaped medullary leaflet which overlaps that fissure of the cord called the fourth ventricle.

The first pair of these nodules are the olfactory ganglia, and, lying immediately on the cribriform plate of the ethmoid bone, are seen to be joined by the filaments of the olfactory nerves, precisely

[1] See Plate II. figs. 3, 4, & 5.

as they are in the human subject. They are about the size of large pins' heads, and being situated at some distance from the rest of the cerebral mass have escaped the observation of most anatomists, and are not included by Serres in his description of the component parts of the brain in this fish. To me they nevertheless appear to be as decidedly a portion of the cerebral mass as the optic tubercles or ganglia, in which the optic nerves terminate, and which are always included in the description of the fish's brain. The commissure or apparatus of union which connects this ganglion with the rest of the encephalon is thin and threadlike, resembling a nerve in its appearance, and about an inch in length. Some authors have stated that the olfactory tubercles in the osseous fishes are generally in contact with the cerebral mass; but the brain of the whiting, as well as of many others, forms an exception to the rule. The next masses, connected together by a transverse commissure, and about the size of a small pea, are analogous to the human hemispheres, and may be designated the hemispherical ganglia. It is particularly interesting to observe how closely these hemispherical ganglia of the whiting correspond with the cerebral hemispheres of the human embryo at the seventh week. These bodies, however, are described by Tiedemann[1] as

[1] Tiedemann on the Fœtal Brain; translated by Bennet, p. 230.

analogous to the corpora striata rather than to the hemispheres of the brain, and by Desmoulins to the optic thalami. With all deference to the talented authors of these opinions, I must say that I do not imagine either of these analogies to be founded in fact. The corpora striata and optic thalami in man and the Mammalia, are structures formed so entirely of fibres intermingled with cineritious neurine, either terminating in, or arising from, the hemispheres, that I cannot conceive how they should exist where the hemispheres themselves from which they derive their origin, and in which they terminate, are absent.

The next pair of nodules are the optic ganglia or tubercles, analogous to the tubercula quadrigemina in man[1].

[1] By the translator of Carus's Comparative Anatomy (Mr. R. T. Gore) it is said, in page 240, that the identity of these middle cerebral masses with the corpora quadrigemina is fully proved by a reference to the progress of formation of the same parts in the fœtus of man and other Mammalia. In the early periods of the existence of the human fœtus the corpora quadrigemina contain a capacious ventricle, subsequently filled up by the deposition of nervous matter, so as to leave only the narrow passage known as the aqueduct of Sylvius. This ventricle is covered over by two thin medullary laminæ, in contact with each other, though not united, along the mesial line, and contains elevations or ganglia similar to those here described. (Tiedemann, *l. c.* 186.) According to him, however, they represent not merely the anterior, but rather both pairs of the corpora quadrigemina. Their size is directly proportioned to that of the eyes and optic nerves, being small in the conger eel and burbot, of moderate size in rays and sharks,

The next division of the Whiting's brain is the triangular leaflet, the analogue of the cerebellum, or little brain, in man.

and considerably larger than the first cerebral mass in the trout, pike, garpike, salmon, carp, uranoscopus, sparus, scorpœne, perch, &c. In the genera *Sparus*, *Scorpœna*, *Clupea*, *Mugil*, *Scomber*, *Zeus*, *Trigla*, &c., the optic nerve, arising on each side from the middle cerebral mass or optic tubercles, consists of a membranous expansion, disposed in longitudinal folds like the leaves of a closed fan, though inclosed within a cylindrical neurilema, which, however, adheres so loosely as to allow the folds to glide one upon another. In the *Trachinus Draco*, where the diameter of the nerve is about a line, there are nine or ten folds, which, when expanded, form a membrane eighteen or twenty lines wide. In the pleuronectes, murænæ, rays, sturgeons, &c. the optic nerve is almost in a rudimentary state, its length and the thickness of the neurilema being proportionally very considerable. In a sturgeon four feet long the diameter of the nerve was not above three fourths of a line, and the medullary matter contained within it less than one fourth of the whole, the rest being formed by neurilema. In the Ammocetus the nerve is wanting, though there is a rudiment of the eye. (Desmoulins, *l. c.*, p. 325, &c.) In the *Cyclopterus Lumpus*, the nerve on each side consists of from twenty-five or thirty parallel filaments, each covered by a separate neurilema, and collectively inclosed within a common cylindrical sheath so loosely as to allow of motion one upon the other. The most remarkable circumstance, however, is that the cerebral termination of each nerve is continuous with that of the other; the extremity of the neurilema of each filament and the ends of the common sheath of each inosculating, as it were, together. The point of union of the common sheaths of the filaments of each side is connected with the brain merely by very fine cellular tissue, without the interposition of any medullary matter, and so loosely as to admit of being separated by the least effort (Desmoulins, *l. c.* 330, Plate IX. fig. 3.) The nerves in this case do not decussate.

These parts comprise the whole of the nervous masses which can be observed by merely looking upon the upper surface of the cerebral mass of the Whiting; but if we raise the optic tubercles, we find that instead of their being solid, as they appear, they are hollowed out internally; and by turning them back, we observe two small rounded projections, which appear to be merely continuous portions of the same ganglia, bearing some resemblance to the posterior of the quadrigeminal bodies called the testes in the human subject. By raising the cerebellum we also observe that the spinal cord lying beneath it is much thicker than the same part lower down; in fact, that fresh neurine has been added to it on each side, in the shape of two oval bodies, the nature of which, or the analogy they bear to particular portions of the human brain, it is not easy to discover in the Whiting; but, as will be seen afterwards by reference to other fishes, it is highly probable that they correspond to the posterior pyramidal bodies or auditory ganglia, together with the olivary bodies or ganglia of the pneumogastric nerves in man, the branchigastric nerve in the fish actually taking its rise from, or being in direct communication with them.

If the whole encephalic mass of the Whiting, having been removed from the skull, be reversed, and the under surface exposed (Plate II. fig. 4.), two oval-shaped cineritious bodies may be observed. "These bodies," says Spurzheim[1], "probably correspond to the grey tubercle (tuber cinereum) of Mammalia. This tubercle, in the higher classes of animals, always sends fibres to the optic nerves, which after this accession advance in their course of increased size." Carus entertained the same opinion, while Cuvier regarded them as the true optic tubercles. The use of the tuber cinereum in man certainly has not yet been ascertained; but it is much more probable that these oval-shaped cineritious bodies of the fish are analogous to them, than to the corpora mammillaria, as conjectured by Serres; for the corpora mammillaria being portions of the fornix in man, cannot be supposed to exist where that structure is wanting, as it is in the fish.

The brain of the Cod so closely resembles that of the Whiting that it will not require any particular description; but I have introduced two drawings of it, one to show the optic ganglia turned back, and exposing what seems to correspond to the testes in man [Plate II. fig. 5.], and the other [Plate II. fig. 9.], which is copied after Serres, to exhibit the connexion of the olfactory nerves with their hemispherical ganglia.

The Carp. [Plate II. fig. 8.]—On first exposing the brain of the Carp, we are struck with the great dissimilarity which it presents to that of

[1] Anatomy of the Brain, 1826, p. 83.

the species of fish last described. Instead of only four divisions we here distinctly observe no fewer than seven. A little consideration, however, will convince us that there is no essential difference between the brain of the whiting and that of the Carp, but that the analogy is perfect, and the chain of structural uniformity yet unbroken. The first pair of nodules, which are small, are the olfactory ganglia, and, like those of the whiting, situated on the ethmoid bone at some distance from the remainder of the encephalon. The commissure connecting them in a Carp seven inches in length was a little more than one inch long. The second pair are the hemispherical ganglia, but extremely small as compared with the same parts in the cartilaginous fishes. The third and fourth pairs are the optic ganglia, the anterior corresponding with the first pair of the corpora quadrigemina or nates in the human brain, while the posterior resemble the testes. The cerebellum is the next mass; and immediately behind it is the auditory ganglion analogous to the posterior pyramidal bodies in man. On each side of this ganglion are placed those bodies from which the branchio-gastric nerves arise, analogous, as before stated, to the corpora olivaria in the human subject. [Plate II. fig. 10.]

In the common Eel[1], we have an appearance of

[1] The description which is given by Carus (Comparative Anatomy, translated by Gore, vol. i. p. 237.) of the brain of

variety, which simply arises from the circumstance of the *olfactory tubercles* (which in the whiting, carp, &c. are situated on the cribriform plate of the ethmoid bone, at the distance of nearly an inch from the rest of the cerebral mass,) being placed close to the hemispheres; this, and also their being slightly grooved transversely on their upper surface, gives to the whole cerebral mass the appearance of a long chain of tubercles, which have no resemblance to the component parts of the brain in the last-mentioned fish, so that there appears at first sight to be no analogy; the number of essential parts is, however, in reality the same, and the analogy between them perfect; the only real difference consists in their relative size and the distance at which they are situated from one another. [Plate II. fig. 7.]

In the cartilaginous fishes the form of the brain approaches so much more nearly to that of the higher orders of animals, that at first sight the cerebral mass in one of the Rays, as the common Skate [Plate II. fig. 11.], appears to differ essentially in its component parts from that of one of the bony fishes which we have hitherto been describing particularly. There is, however,

the osseous fishes would give the reader the idea that a considerable difference must exist between the brain of the eel genus and that of the carp or whiting, &c.; and this error seems to have arisen from his having omitted in his description of the central mass of the carp, that of the olfactory ganglia, merely because they are not closely connected to the rest.

no essential distinction; the difference arising solely from the greater concentration of similar or nearly similar parts.

The olfactory ganglia in the Skate are extremely large, as will be seen by referring to the diagram [Plate II. fig. 11.]. The peduncles are long, and the cerebral hemispheres form a more considerable mass, slightly irregular upon its surface, and thus assuming an approach to a convoluted arrangement of the superficies. The optic tubercles have also increased in size, and are connected with the hemispheres by distinct medullary bands.

But the cerebellum is found to have undergone the greatest alteration of any part; for it is no longer a mere triangular leaflet, but is divided into lobes, and partly overlaps the optic tubercles.

On each side of the cerebellum there is an extensive layer of folded neurine, which I consider to be analogous to the corpora olivaria, from which a considerable portion of the branchio-gastric nerve arises; in addition to which we find a portion of the nerve corresponding to the fifth nerve of Mammalia connected with it. Serres considers this structure as forming a portion of the cerebellum. Spurzheim does not agree with him, though he does not form the same conclusion which I have done.

On reversing the position of the brain [Plate II. fig. 12.], we observe the two small tubercles of medullary neurine, believed to be analogous to the tuber cinereum in man, a part whose character, as before stated, has not yet been ascertained.

From the fish let us direct our attention to some specimens of the cerebro-spinal axis in the

AMPHIBIA.

As the brain of the Turtle is extremely simple we shall commence with it. [Plate IV. fig. 1.] The olfactory ganglia, instead of being situated on the cribriform plate of the ethmoid bone, are placed, as in the eel genus, almost close to the hemispheres, and the commissures connecting them are therefore extremely short. The olfactory nerves pass towards the cribriform plate of the ethmoid, where not forming any bulbous enlargement as in the skate and the Mammalia, they split into small filaments which pass through separate foramina. The cerebral lobes or hemispheres are larger and more perfectly developed than in any of the finny tribes.

The optic tubercles, placed immediately behind the hemispheres, are joined to the cerebellum by two medullary processes, the analogues of which, in the human brain, are called the *processus è cerebello ad testes*; and as these parts form a commissure between the anterior portion of the cerebral mass and the cerebellum, I have in my description of it in the human brain called it the inter-cerebral or oblique commissure. It is from this part that the fourth pair of nerves arise both in man and the Vertebrata generally.

The cerebellum of the Turtle is distinctly formed, but the auditory ganglia and olivary bodies are scarcely perceptible. The first circumstance is accounted for by the sense of hearing in these animals not being acute; in fact, all their sensations are peculiarly dull, and, in the second place, the "besoin de respirer," as the French express it, is not the violent uncontroulable sensation which is evidently experienced by fishes and the higher order of animals when the access of air is by any accident impeded. Now I have shown elsewhere that this peculiar sensibility is entirely annihilated if the pneumogastric nerve be divided; and it is therefore very evident that on this nerve, as a nerve of sensation, the high degree of sensibility peculiar to the respiratory organs in the higher animals depends. The deficiency of a perfectly developed system of respiratory muscles in these animals, as in most of the Vertebrata, viewed in connexion with the diminutive size of the olivary bodies, supports the opinion advanced elsewhere, that from these bodies issue the orders for the respiratory muscles to act; and as they are evidently the points in which the nerves conducting those sensations which constitute the protecting sensibility of the lungs terminate, the supposition is rendered still more probable.

It is worthy of remark in confirmation of the views regarding the office of the cineritious neurine, which I have laid before the reader elsewhere, that the spinal cord of the turtle is immensely enlarged opposite to the anterior and posterior extremities, whilst between these points it is contracted to a mere thread.

BIRDS[1].

The brain and spinal cord in Birds are developed after one uniform type, notwithstanding the amazing diversity of external form, habits and instincts of the different species of these creatures.

The evident advancement in intellectual powers which this interesting tribe of the animal kingdom exhibits to us, is found to correspond with a greater development of the hemispheres of the brain. The proportion of these to the size of the body, to the other cerebral ganglia, and lastly to the spinal cord, is far superior to anything we have met with in the preceding classes. The different ganglia composing the encephalic mass are not placed one after another as in the skull of fishes and reptiles, but on the contrary, are rather placed under one another, and the hemispheres or cerebral lobes are so much increased in size that they cover all the different ganglia of the nerves of sensation; so that on viewing the cerebral mass of birds from above we observe only two divisions,—the hemi-

[1] Plate IV. fig. 2.

spheres or cerebrum, and the cerebellum; in some instances too the cerebrum is so large as even partly to overlap the cerebellum. [Plate IV. fig. 2.]

The cerebral lobes still present a smooth surface, not putting on the folded or convoluted appearance which is so characteristic of the brain of the highest order of animals. And let me here again observe that this convoluted arrangement is adopted simply for the purpose of obtaining a larger surface of cineritious neurine in a smaller space. The amount of surface presented by a convoluted brain if extended evenly would cover a very large space, and take up a great deal of room; it would consequently require a skull of corresponding dimensions to contain it, with proportionally large muscles to move the head; folded backwards and forwards, however, in the beautiful manner in which we find it arranged in man and the Mammalia generally, the brain takes up but little room, and is packed into a comparatively small box, which does not then interfere with the active powers of locomotion, so important to all the higher animals in maintaining their relations with the external world.

The cerebellum in Birds is peculiarly large, a fact which tends to confirm thevi ews of many intelligent physiologists of the present day, that it presides over and combines the action of separate muscles so as to produce an harmonious result; for the perfection which the organs of locomotion attain in this class very far surpasses all that we have yet observed among fishes and reptiles, and equals at least the degree of development exhibited by the same organs in any other species or class of living beings.

Nevertheless the cerebellum of the Bird differs from the same organ in the Mammalia in one important particular. The lateral lobes of the cerebellum, which in man are so much developed that the central portion, consisting of the superior and inferior vermiform processes, has even been described by Reil as constituting a mere commissure, are almost wholly deficient in birds. The cerebellum of the Bird consists in many species, of little more than the middle lobe, which, corresponding to the vermiform processes of the Mammalia, proves that these processes, instead of constituting a commissure, form the fundamental, and consequently, we may suppose, the most essential portion of a cerebellum. Serres[1] remarks, that this analogy, which was first observed by Haller, was rejected by Malacarne, and neglected by most subsequent anatomists. The lateral hemispheres, observes the same author, in some Birds are so small as scarcely to be visible, for instance, in the common fowl, the duck, the goose, the wren, canary bird, and sparrow: but they are very distinct in partridges, pigeons,

[1] *Anatomie Comparée du Cerveau*, vol. ii. p. 372.

swallows, birds of prey, the ostrich, the cassowary and the storks. In general, in Birds which elevate and sustain themselves a long time in the air, as the stork, and those whose wings or feet have great power, as the emu, cassowary, and parrots, these hemispheres appear most developed.

The olfactory ganglia are small in Birds, and, as in some fishes, are placed close to the cerebral hemispheres, so that the commissures, or peduncles as they are sometimes called, are peculiarly short, presenting little more than a white line, which runs to the outer side of the hemispheres.

The optic tubercles, on the contrary, are very large, as are also the nerves which arise from them.

The medulla oblongata is more than double the size of the spinal cord both in width and depth, but the olivary bodies do not project in the same distinct manner as they do in fishes.

The hemispheres of the brain are connected together by a commissure, consisting of cineritious matter on the exterior, of filaments of medullary matter, of the size of a thread, in the interior. On the internal surface of the hemispheres (those two surfaces which are opposed to each other, and in the human brain are separated by the falx major,) we observe some diverging fibres of medullary neurine, which present themselves as a sort of footstalk at the under part of the hemispheres, but really commence by two portions, the one from the outer edge of the tractus opticus, the other from the inner. That which takes it course to the outer side is connected with the tractus opticus, while the internal appears to terminate in the tuber cinereum. This structure appears to me analogous to the fornix in man.

It is in the brain of the Bird that we first distinctly observe those collections of cineritious neurine through which the fibres of the anterior and posterior columns of the spinal cord proceed in their passage towards their termination in the hemisphere. These nodules or tubercles, which in the human subject are called the corpora striata and thalami nervorum opticorum, may be seen in the bird by separating the hemispheres and breaking down the commissure which connects them. They will then be observed partly covered by the optic tubercles. As they are more perfectly developed in all the genera of the succeeding class, I shall not at present dwell longer upon the character they exhibit.

BRAIN AND SPINAL CORD IN THE MAMMALIA.

The advance which the brain makes in this class of animals is very striking. [Plate IV. fig. 4.] The spinal cord no longer competes with it in point of dimensions. The hemispheres, except in the very lowest members of the class, begin to take on a convoluted appearance, and the optic tubercles, instead of remaining merely a single pair, have, appended to their posterior surface, two additional and smaller masses of medullary neurine, called the testes. But still we do not find any sudden transition from one form of brain to another; there is no great chasm between the brain in Birds and that of the Mammalia, for when we direct our attention to the brain of the Rodentia, or gnawing animals, we find almost as much difference between its anatomy in them and in man as between that of the feathered race and the lord of the creation. The upper surface of the hemispheres in the rat, mouse, marmot, beaver, and even in the rabbit, is as smooth as in birds; the hemispheres in most of these animals do not cover the cerebellum, and in some instances not even the optic tubercles.

When the upper part of the skull of the *Rabbit* [Plate IV. fig. 8.] is removed, we observe that the cerebral mass consists of three grand divisions; the first and smallest of these comprises the olfactory tubercles; the second, the hemispheres; the third, the cerebellum; the other ganglia remain entirely concealed.

On separating the hemispheres we find them connected together by a broad band of medullary neurine, called in the human subject the *great transverse commissure*, or *corpus callosum*.

If the great transverse commissure be now divided and the hemispheres separated from each other, several parts of importance beneath it will be exposed. Commencing from the posterior part, we observe just in front of the cerebellum four rounded bodies, the posterior of which are small, not being more than a fourth part as large as the anterior. These four bodies are analogous to the single pair of optic tubercles in the bird, and in man are called the *tubercula quadrigemina,* or the posterior the testes, and the anterior the nates. Immediately anterior to these bodies we find two other rounded projections, the anterior of which is the larger. The posterior is formed by a body which in the human brain is known by the name of the *thalamus nervi optici,* from an idea now exploded, that it gave origin to the optic nerve. This projection, though principally formed by the optic thalamus, as I will continue to call it for the present, is not solely formed by it; for covering the thalamus we find a thin layer of medullary neurine, the outer edge of which corresponds to that of the thalamus, so that in this stage of the dissection the thalamus is not really exposed. This band of medullary neurine consists of two sets of fibres; one set, connecting the hemispheres, crosses the mesial line, and appears to correspond to the *tenia semicircularis* in man, which is a portion of the transverse commissure. By tracing the other set carefully, we find it passing forwards and winding over the surface of the thalamus, till, reaching the under part of the brain, it terminates in that portion of the spinal cord which in the human subject is known by the name of the *crus cerebri.* The beautiful structure just described forms a communication between the anterior and posterior portions of the hemisphere of the same side, running along the course of the mesial line, and in the brain of man has hitherto gone by the absurd name of *fornix,* which I would gladly see changed to that of the *longitudinal commissure.* If an incision, commencing at the optic ganglion, be made completely through this commissure, the optic thalamus will be exposed.

The projection which is immediately anterior to the thalamus is analogous to the *corpus striatum* of the human brain, a part that has received its name from the striated appearance which it presents on a section being made of its substance in consequence of the deposition of cineritious neurine between the white fibres which are passing from the hemispheres to the anterior columns of the spinal cord. The corpus striatum and thalamus are deposits of neurine through which the component fibres of the anterior and posterior columns of the spinal cord pass in their course from and to the hemispheres, and have been characterized, I think advisedly, by Spurzheim as ganglia. The corpus striatum should be entitled the *anterior,* and the thalamus the *posterior cerebral ganglion* of the cord. Running near the edge of the thalami towards the nates, are two white lines, which, turning off at a right angle to cross the mesial line, meet with a very small cineritious body about the size of a pin's head. This little body is the pineal gland; the whole structure forms a commissure between the two opposite thalami, and may be called the *pineal commissure*. Situated immediately beneath the pineal gland, and between the thalami, is a transverse band, which in the Rabbit is not much thicker than a thread, called the *posterior commissure*, immediately in front of which is a middle band of cineritious neurine, and still further forward is another; these are respectively called the *anterior* and *middle commissures* of the brain, in distinction to the posterior commissure.

The hemispheres having been completely turned back in the performance of this dissection, the student cannot fail to observe that they form a sort of cap to the anterior and posterior cerebral ganglia of the cord, covering them something in the same way that the head of a mushroom does the footstalk; and he will undoubtedly perceive the ingenious contrivance by which the immense quantity of neurine composing the large central or cerebral ganglia in these animals is lodged in such a circumscribed space as the cranial cavity.

If the brain be now removed from the skull, reversed so as to expose the under surface, and the eye carried along the spinal cord, it will be observed that the cord becomes of nearly double the thickness it possessed within the vertebral canal. This thickened portion of the cord is called the *medulla oblongata*, and contains within its substance the olivary bodies or pneumogastric ganglia, and the posterior pyramidal or auditory ganglia. Crossing the medulla oblongata transversely is a band of medullary neurine, which, running from one side of the cerebellum to the opposite, forms the commissure of that part, and is usually known by the name of the *pons Varolii* or *tuber annulare*. The spinal cord beyond this commissure splits into two portions, which, running to the two corresponding hemispheres, are called the *crura* or legs of the brain. Between them is the collection of cineritious neurine called the *tuber cinereum*, and immediately anterior to it the commissure of the optic nerves. The hemispheres appear divided into two lobes on each side, and the fissure of separation is called the *fissura Sylvii*. The commissure between the olfactory ganglia and the hemispheres is of considerable width, consisting of cineritious and medullary neurine, but it is short when compared with that of the carp and whiting.

I have been thus minute in my description of the brain of the Rabbit, because this animal is always easily to be procured, and because I am sure that whoever will take the trouble to go over this dissection once or twice before attempting that of the human brain, will find his path much facilitated by the knowledge and the manual dexterity he will have acquired. He will be prepared, too, to take a more correct view of the character of the human brain, and his mind will be divested of many of those feelings of awe and mystery which have unfortunately been hitherto so constantly associated with the structure of the human brain.

The facility of procuring the brain of the *Sheep*, and the slight cost at which multiplied dissections of it may be made, induce me to bring it under the notice of the student, as affording another characteristic link in the chain of cerebral complication, from the lower to the higher tribes of creation and its termination in man. Investigations of this kind indeed ought to be pursued through as extensive and varied a series of animals as can be procured; each offers some peculiarity well worthy of attention, and all confirm the important truth in the science of zoological anatomy, without which human anatomy is but a limited and unsatisfactory pursuit, that every one of the organs through the whole of the animal kingdom, is constructed on one uniform and simple plan. The brain of man, which had so long been, and even now remains an obstacle in the path of the teacher and student, who restrict themselves to the limits of human dissection, may be shown to have been formed with the same attention to the beautiful simplicity which distinguishes all the varied forms of organized existence. The minute description which has been given of the anatomy of the brain of the rabbit, makes it unnecessary to dwell with the same attention to detail on each point in that of the Sheep; so that I shall merely mention those particulars in which they differ, and thus point out some others in which the brain of the sheep approaches more in its structure to that of man.

The upper surface of the cerebral mass of the Sheep presents only two divisions, the cerebrum, consisting of two hemispheres as usual, and the cerebellum. The olfactory ganglia can no longer be seen in front of the hemispheres, as in the rabbit, these last having here increased so much in size as completely to cover and conceal them. The hemispheres are not merely of larger relative dimensions, but their shape is altered: they have lost the pyriform character they presented in the rodent animal, and have assumed more of the oval form which they possess in the human being. Their surface, instead of being smooth, is convoluted, looking exactly as if it were formed by the folding up of a soft but tenacious substance. The cerebellum is not much changed in appearance; it is only somewhat larger in proportion to the cerebrum.

The great transverse commissure has increased in accordance with the greater development of the hemispheres, and when we divide it in the middle and turn either half back, in order to expose the optic tubercles, the thalami and corpora striata, we find the latter appearing as if they were placed within a circumscribed cavity, so much have the hemispheres increased in size in every direction. The space which is left between the corpora striata and thalami, and the under surface of the hemispheres, has actually been described in the human brain as if it were a cavity or chamber scooped out of the substance of the brain, under the name of *lateral ventricle*. The erroneousness of this description and of the views which have led to it, must be evident to every one who has followed the gradual development of the hemispheres from before backwards. We find, in fact, that the spaces denominated lateral ventricles are the necessary effect of the drawing back, if I may so express it, of these extensive surfaces of neurine covering the crura cerebri or anterior productions of the medulla oblongata. By the addition of the anterior and posterior cerebral ganglia of the cord (the corpus striatum and thalamus,) the structure comes to bear a considerable resemblance to a head of cauliflower included within its capsule of leaves, or, as I have said elsewhere, to the nodulated head of a walking-stick, over and around which a piece of cloth has been tied, and then reflected forwards upon itself.

The edge of the fornix or longitudinal commissure may be seen lying in the groove between the anterior and posterior cerebral ganglia; the posterior ganglion or thalamus, being however so completely covered that it cannot be seen until the commissure is completely divided and reflected outwards. If after doing this the hemispheres be turned forward, the cerebral ganglia on both sides will be exposed, with the pineal commissure, and tubercula quadrigemina; crossing the fissure between the posterior cerebral ganglia, (absurdly called the third ventricle,) the commissura mollis, or middle commissure, will also be brought into view.

On the base or under surface of the brain we observe that the olfactory ganglia or tubercles are very highly developed; they are, in fact, nearly three times as large as those of the human subject, a size which appears to correspond with the complicated structure of the nose in this animal, and to be in proportion to the acuteness of their sense of smell. The olfactory commissures are short and thick, scarcely a line's breadth being left between the tubercle and the point where they are united to the under surface of the hemispheres. These commissures appear to extend backwards some way further than the point where they are first attached to the surface of the cerebrum. The olfactory tubercles themselves are composed of medullary and cineritious neurine.

The pons Varolii, or tuber annulare of Willis, is small in the sheep compared with the same part in man: here it is not more than three lines in breadth. The corpora mammillaria are united so as to appear like a single body. The tuber cinereum is not particularly distinct; through its centre we find a sort of funnel-shaped tube passing, called the *infundibulum*, which joins a rounded structure situated on the sphenoid bone called the *pituitary gland*. The character or analogy of the last-mentioned parts is extremely obscure, and there is a mystery here which has not yet been unravelled;—the medulla oblongata, like that of the rabbit, is very thick in comparison with the spinal cord.

The origin of the nerves occurs in the sheep precisely as in the human being, and need not, therefore, be dwelt upon in this place; although in dissecting the brain of the sheep, reference may be very advantageously made to the base of the human brain for assistance in discriminating several of the particular pairs of nerves. In Plate V. a sketch of the under surface of the brain of the horse has been introduced, merely for the purpose of showing the amazing development of the olfactory ganglia in one of those animals in which the sense of smell attains a high degree of perfection, and also for the sake of demonstrating the impropriety of classifying analogous parts in the human being under the head of nerves with bulbous extremities. A section of the olfactory ganglia in the sheep further illustrates the same anatomical truth by exhibiting the arrangement of the pulpy and medullary neurine, fig. 2. same plate.

Having now followed out the various changes which the cerebral ganglia undergo from their first appearance in the insect tribe up to their relatively high development in those animals whose nervous system approaches very nearly to that of man, both in complexity and concentration, the student might, without detriment, abandon the assistance which comparative anatomy has hitherto afforded him in preparing his mind to enter upon the study of the human brain. Nevertheless, I cannot resist the temptation of bringing before him a brief account of the anatomy of the enkephalon of the *Porpoise*. This creature, which to the vulgar is no more than a large fish, the enlightened physiologist admits into the same grand division of the animal kingdom to which man himself belongs. Bringing forth its young in a state requiring long after birth the protecting care of the mother, higher moral and intellectual endowment are implied than we can expect in fishes and reptiles, whose spawn is generally abandoned by the parent as soon as it is shed; and in accordance with these manifestations of higher powers, we find the cerebral mass developed upon the same plan and presenting nearly the same appearances and arrangement of parts as some of the most perfect of the terrestrial mammalia, and even as the brain of man himself.

BRAIN OF THE PORPOISE.

Looking at the superior part of the cerebral mass of the Porpoise, as represented in Plate V. fig. 3, we observe two divisions, the cerebrum and cerebellum ; the whole surface is convoluted as in the human brain, and although the convolutions are smaller, the sulci between them are of considerable depth; its shape is peculiar from its great lateral width as compared with that of the human being or sheep, for the cerebral hemispheres taken together are even longer from side to side, than from before to behind. The dimensions of the cerebellum are great in comparison with those of the cerebrum, the whole cerebellum bearing a proportion to one hemisphere of the cerebrum as two to two and a half. The posterior lobes appear to be wanting as in the sheep, by which the cerebellum is left wholly uncovered.

The great transverse commissure or corpus callosum is strikingly short from before backwards, measuring a little more than one fourth of the whole length of the hemisphere, if we except that portion which curves downwards in front, and which is about a third of the length of the horizontal portion, so that the tubercula quadrigemina or optic tubercles are entirely uncovered by it, and on removing the arachnoid and pia mater are to be observed between its posterior edge and the cerebellum, nearly a third larger than those of the human brain; the posterior pair or testes are nearly double the size of the anterior or nates.

The pineal gland is small but distinct, as well as its commissure. A perpendicular section having been made through the transverse commissure a little to the left side of the mesial line, and a horizontal one carried through one of the hemispheres on a level with it, the thalamus nervi optici and corpus striatum are exposed, the latter scarcely a fourth part as large as the former. The fornix, which is small, is divided, and with the exception of its anterior pillars and the septum lucidum, is removed in making the above section. There is no posterior cornu to the lateral ventricle.

Base of the Brain.—The fissura Sylvii is deep; the middle lobe very large and projecting more than in the sheep.

The pons Varolii or commissure of the cerebellum is large in proportion to the whole cerebral mass, and is about the same size as this part in man.

The medulla oblongata presents more points of interest and instruction than any other part. In the first place it is more than double the size of the spinal cord, a circumstance which partly depends on the large size of the corpora olivaria, and partly on the magnitude of the posterior pyramidal bodies.

The corpora olivaria are so amazingly developed that instead of being separated from each other, as in the human being, by the corpora pyramidalia, they overlap and cover these so completely as even to come into contact with each other in the median line. The pneumogastric nerves are developed in the same proportion, being about double the size of those of man. If the corpora olivaria be carefully elevated, the anterior columns of the spinal cord will be seen decussating beneath and posterior to them, according to the usual anatomical nomenclature.

The arrangement of the fibres of the anterior and posterior columns, as regards their course towards the cerebellum and the share they take in the formation of the corpora restiformia, is perfectly identical with the disposition of the same parts in the human brain, which will be found described so fully further on that it will be unnecessary to dwell upon it here. The accordance is, nevertheless, extremely interesting as confirming the new views I have advanced on the subject of the communications between certain parts of the medulla oblongata and the cerebellum.

Origin of the Nerves in the Porpoise.—The olfactory nerves are entirely absent.

The optic are smaller than those of man; their origin is the same.

The 3rd, 4th, 5th, and 6th are also exactly similar.

The 7th, or facial, is the same both in size and origin.

The 8th, or auditory, is nearly double the size of that in the human being.

The 9th, or glossopharyngeal, is large.

The 10th, or par vagum, is at least double the size it presents in man.

The spinal accessory is rather small. Its origin is the same as in man.

The 11th, or lingual, is rather large. Its origin is from the anterior columns of the cord immediately below the corpora olivaria.

PART II.

THE HUMAN BRAIN.

MEMBRANES, &c.

THE cerebro-spinal axis in man is situated in a long bony canal, which is expanded superiorly into a cavity of considerable size. The difference in the dimensions of the two portions of this canal has led anatomists to divide it in their descriptions, the upper portion being called the skull or cranium, the lower the vertebral or spinal canal. Now though in man this division seems even natural, the two portions differing so entirely in size and general appearance, still if we observe the same parts in the lower orders of animals, and trace their alterations of form and capacity as the organs which they contain increase in size and require a change in the shape and extent of the cavity which contains them, we shall find that the bones composing the human skull are simply vertebræ in a more expanded form, and exhibiting those alterations in shape which adapt them to the increased size of the organ they are formed to protect[1].

[1] This opinion, that the cranium is formed by a series of vertebræ, originated with Peter Frank (see Edinb. Med. Surgical Journal, vol. xliii. p. 288), (*Epit. de Curand. Hom. Morb.*, lib. ii. p. 42), and Burdin (*Cours d'Études Médicales*, Paris, 1803, tome i. p. 16); and was afterwards espoused by Kiel-

As the following description of the anatomy of the cerebro-spinal mass in the human being is not intended to supersede the necessity of dissecting it, but rather to assist those who are commencing their studies, as well as to give clearer and more correct views of the real character of the parts to those who have already dissected them according to the old system, I will enter rather fully into the best mode of opening the skull and vertebral canal, to reach without injury and to expose the structure of the nervous masses contained within them.

The student should place the subject on its face, and raising the head rest the chin upon a block so as to fix it in a horizontal position.

meyer (Ulrich, *Annotationes quædam de Sensu ac Significatione Ossium Capitis*, Berlin, 1816, p. 4), Dumeril (*Magazine Encyclopédique*, tome iii. 1808), and Goethe (*Zur Naturwissenschaft*, Band i. p. 250), and more or less fully illustrated by Oken (*Ueber die Bedeutung der Schädelknocken*, Jena, 1807; *Isis*, 1820, No. VI. p. 552), Spix (*Cephalogenesis*, Munich, 1815), De Blainville (*Bulletin de la Soc. Philom.* 1816, p. 111, and 1817), Geoffroy St. Hilaire (*Philosophie Anatomique*, Paris, 1818–22), Carus (*Lehrbuch der Zootomie*, Leipzig, 1818, p. 164), Meckel (*Beyträge zur Vergleichenden Anatomie*, Band ii. Stück ii.), Schultz (*De Primordiis Systematis Ossium, &c.*, Halle, 1818, p. 13), Bojanus (*Isis*, 1818, p. 301; 1819, p. 1364), and Burdach (*Vierter Bericht von der Anatomischen Anstalt zu Koenigsberg*, Leipzig, 1821). Arnold also adopts this principle, but confines himself to the views given by Oken, Cuvier, Carus, Spix, and Meckel, considering that the cranium consists of three vertebræ only; not therefore agreeing with Geoffroy St. Hilaire, who believes that he can there demonstrate the parts of nine vertebræ.

An incision must then be made through the scalp extending across the vertex from ear to ear. The anterior part of the scalp may then be forcibly torn instead of being dissected from the skull over the face, and the posterior over the occiput, which will save much time; but some force is required to effect this reflection of the integuments.

A deep groove must be made with the saw through the outer table and diploë, commencing half an inch above the superciliary ridges anteriorly, and extending round the entire skull to the protuberance of the os occipitis posteriorly.

A small axe should next be used to break the inner table, which is much better than sawing it entirely through, as being less likely to injure the dura mater and brain, and as permitting the skull to be more firmly fixed again when replaced after the dissection is completed.

The skull-cap being removed, a dense fibrous membrane is perceived beneath it, rough on its surface owing to the torn extremities of the vessels which connected it to the internal table of the skull; for this membrane, which is the internal periosteum of the cranial bones, and in the young subject is connected at the edges of the several bones with the external periosteum, adheres to the bones so closely that they are with difficulty separated. The glistening membrane exposed is called the *dura mater*, from the density and firmness of its texture, and from an idea that it was the origin or mother of all the other membranes of the body[1].

On the surface of this membrane are some small rounded bodies which certainly were undeserving of notice if they had not received the grand title of *glandulæ Pacchioni*. These are scarcely observable in the young subject, and in the old are most probably a morbid appearance. The dura mater should next be cut through carefully all round with a pair of scissors, on a level with the divided edge of the skull. On being turned back over the upper part of the brain, we discover that its under surface is smooth and polished; a circumstance which does not arise from any peculiarity in the texture of its internal surface as opposed to the external, but from the presence of a serous membrane called the *tunica arachnoidea*, which, like all serous membranes, is a thin diaphanous web covering the contained viscera and reflected from thence on to the internal surface of the walls of the containing cavity. The next membrane, therefore, which we observe covering the brain when the dura mater is raised, is that portion of the arach-

[1] Portal, iv. 2. The membranes of the brain, by the Greeks, were called meninges, the Greek word μήνιγξ simply signifying a membrane. The term *mater*, or mother, originated with the Arabs, and the credit of having shown that the dura mater does not accompany the nerves in their passage from the skull, and that the membranes in general are therefore not continuous with it, is due to Ludwig.

noid[2] which, from its investing the brain, may be called the *tunica arachnoidea cerebralis* or *investiens*, in contradistinction to that portion which lines the dura mater and is called the *tunica arachnoidea reflexa*. The further description of this membrane will be postponed until we have completed that of the dura mater. The dura mater forms several processes in the interior of the skull, some of which are best seen after the removal of the brain as directed at p. 114, but which it will be in order to describe at once.

The dura mater consists of two layers united by cellular tissue, the external of which forms, as described, the internal periosteum of the bones of the skull. The internal layer is inflected downwards between the two symmetrical halves of the brain, forming what has been called from its sickle-like appearance, the *falx major* of the dura mater. This structure may be said to commence from the crista galli of the ethmoid bone, where it is generally about half an inch in width, though it varies in different subjects; from this point it extends backwards, gradually becoming wider in its passage, and being connected through the medium of the periosteal portion to the frontal, parietal, and occipital bones. On reaching the

[2] Portal, iv. 2. The arachnoid derives its name from its extreme delicacy and its resemblance to a cobweb; it was first discovered in 1565, by the Dutch Society, among the members of which was Swammerdam, the celebrated naturalist.

transverse ridge of the occipital it splits into two lateral portions, which are attached posteriorly and laterally to the transverse ridge of the occipital bone, while anteriorly it is attached to the superior angles of the petrous portions of the temporal bone, from which points it stretches itself up to the posterior clinoid processes of the sphenoid, leaving a space between its under surface and that portion which covers the superior angles of the temporal bone, through which pass the fifth pair of nerves.

This portion of the dura mater is called the *tentorium*, and forms an extended surface on which the posterior lobes of the hemispheres rest; and by which the cerebellum, which is situated beneath, is protected from the superincumbent pressure of the brain; consequently, the tentorium so far resembles in its office the falx major, which prevents one hemisphere from pressing on the other when the head is inclined to either side.

Extending down along the mesial line of the occipital bone beneath the tentorium, there is another process analogous to, but much smaller than, the falx major; it separates the two lobes of the cerebellum, and has received the name of the *falx minor*: it commences on the internal surface of the occipital bone at the point where the transverse and longitudinal ridges meet, and extends to the edge of the foramen magnum.

The veins which return the blood from the substance of the brain are protected from the pressure of that organ, which they would otherwise be exposed to, by the mechanism of the falciform processes and tentorium of the dura mater, through the internal lamina of which they pass immediately after quitting the pia mater: the spaces formed for their reception by this peculiar arrangement of the dura mater are called *sinuses*, and require the attention of the student. There are fifteen sinuses in all.

The *superior longitudinal*, which is the largest, commences at the foramen cæcum of the frontal bone, and passing back along the upper edge of the falx major reaches the transverse ridge of the os occipitis, where it usually enters the right lateral sinus. Its shape is triangular, and the openings of the veins, which enter contrary to the course of the blood within it, may be distinctly seen on the interior, and surrounding each of them the small fibrous cords (the *cordæ Willisii*) so admirably adapted to keep the openings permanently free for the regular passage of the venous blood, any obstruction to the normal circulation of which endangers the life of the individual, by producing congestion of the brain. Running parallel with the superior longitudinal sinus, but along the inferior edge of the falx, we find a much smaller sinus called the *inferior longitudinal.* This also terminates generally in the left *lateral* sinus; previously, however, to its reaching this sinus, and when it is passing between the two layers of the tentorium, it receives the name of the *straight* sinus.

The course and extent of the *lateral* sinuses are distinctly marked in the dry skull; for they groove the transverse ridge of the occipital bone, and then crossing the posterior inferior angle of the parietal, reach the internal surface of the mastoid portion of the temporal bones, in which they are deeply imbedded, and thus effectually protected from the pressure of the cerebellum; they again cross a small portion of the occipital bone, and finally terminate at the foramina jugularia, beyond which they form the internal jugular veins: these sinuses have frequently another outlet for their contents, by means of the foramen mastoideum, and the vein which commences at this opening usually joins some of the deep-seated veins of the neck.

On each side of the sella turcica a considerable space is left between the dura mater and the bone, called the *cavernous* sinus; this cavity is not, however, constructed solely for the protection of the venous circulation, but also guards some of the cerebral nerves, in their passage to their destination in the orbit, from the pressure of the brain. The nerves which are thus protected are the third, fourth, first division of the fifth, and the sixth.

The blood of the cavernous sinus, separated from the nerves by the lining membrane which is common to the whole venous system, flows into a sinus called the *inferior petrosal*, a name derived from its proximity to the petrous portion of the temporal bone. The inferior petrosal sinus takes its course along the edge of the basilary process of the os occipitis, and terminates in the internal jugular vein. This sinus is connected with its fellow by a short sinus the *transverse*. The *superior petrosal sinus* deeply grooves the posterior edge of the superior angle of the temporal bone, and terminates in the lateral sinus.

Surrounding the pituitary gland in the sella turcica there is a circular sinus communicating with the cavernous sinus called the *circular sinus of Ridley*.

The *occipital* sinuses, the last we have to mention, are situated on each side of the foramen magnum, and terminate at the point where the straight sinus and lateral sinus become conjoined; the triangular space left just before their junction is called the *torcular Herophili*.

The arachnoid membrane does not merely line the dura mater and cover the convoluted surface of the brain without dipping between the convolutions, but it also covers the figurate surface[1], and the point where these two portions are continuous is at the foramen of Bichat, as it is called, after the justly celebrated man who first de-

[1] The difference between the two surfaces of the brain will be thoroughly explained hereafter.

scribed it. The situation of this opening is between the superior and anterior portion of the cerebellum and the under and posterior part of the cerebrum, as will be better understood when these parts have been described, and the relations of the arachnoid explained.

Beneath the arachnoid is situated the pia mater, a membrane which is constructed solely for the purpose of supporting the vessels distributed to the superficies of the central masses of the nervous system, which are so numerous that they require an especial tissue for their support. This structure dips between the convolutions of the brain, at the same time closely investing its external surface; it passes also over those surfaces, which, from the old method of slicing the brain from above downward, appear as if they formed the walls of cavities in the interior, and in some of these situations it has received peculiar names; among the most remarkable of its portions thus indicated, we may mention the *plexus choroides.*

Otto, in his Compendium of Pathological Anatomy, translated by Mr. J. F. South, p. 373, note (1.), states in general that these two membranes, the arachnoid and pia mater, are inseparably united in the greatest part of the circumference of the brain in adults, and that they are at all times in organic connexion throughout, by means of fibro-mucous tissue of various length.

It will be instructive to dwell for a few moments upon the admirable adaptation of these three cerebral membranes to the ends of their formation. The dura mater forms a support which is sufficiently firm and unyielding to retain the brain accurately in its normal position, while its processes are still capable of yielding to a certain extent, like the strong springs of a carriage, under any violent concussion.

The arachnoid, lining the dura mater and covering the surface of the brain, wholly prevents friction, which would otherwise be inevitable, and thus answers in its situation the same end as the synovial membranes with their lubricating secretion in the various joints of the body, for the brain is never in a quiescent state, but is constantly rising and falling with slight pulsating motions.

The immediate agents in the production of these movements appear to be the circulating and respiratory systems, and the motions are therefore twofold; the one occasioned by the pulsations of the heart, the other by the movements of the chest; for at the moment that cavity begins to be contracted for the expulsion of the air, the return of the blood from the brain is temporarily impeded; and, on the other hand, when the chest begins to be expanded, and during inspiration, its flow is in a corresponding degree accelerated. This subject has been much and carefully investigated, as a reference to the following catalogue of authors who have written expressly on it, given by Meckel, in vol. iii. p. 722. of his Anatomy, will prove. Schlichting, *De Motu Cerebri*, in the *Mém. Prés.* tom. i. p. 113; Lorry, *Sur les Mouvements du Cerveau et de la Dure-mère*, same collection, tom. iii., Mém. i. p. 277., Mém. ii. p. 344; Haller, *Experim. ad Motum Cerebri à Refluxu Sanguinis natum*, in his *Opusc. Phys.* tom. i. p. 231; Lamure, *Sur la Cause des Mouvements du Cerveau*, in the *Mém. de Paris*, 1753; Richard, in the *Jour. de Méd.* tom. xxix., 1768, Août, p. 140; Ravina, *De Motu Cerebri*, in the *Mém. de Turin*, 1811; Portal, *Mém. sur un Mouvement qu'on peut observer dans la Moëlle épinière*, in his *Mém. sur plus. Maladies*, tom. ii. p. 81; Magendie, *Sur un Mouvement de la Moëlle épinière isochrone à la Respiration*, in his *Jour. de Phys. Expér.* tom. i. p. 200.

The *pia mater* in the skull is of just sufficient thickness to support the vessels without interfering with the motions of the brain; but in the vertebral canal it is much denser, affording a better support to the cord, and thus performing the same office that the neurilema, or investing membrane of the nerves, does to these organs in their extended course through all parts of the body.

REMOVAL OF THE BRAIN.

The next step in the dissection is to remove the brain from the skull, which must be done with great care, as the nerves which are passing from the cavity of the cranium are easily torn through, unless divided with a very sharp knife or pair of scissors.

The fingers of the operator should be insinuated under the anterior lobes, and the cerebral mass raised with great care; the *first* pair of nerves which he will observe are the *olfactory*, running forward to the cribriform plate of the ethmoid bone, from which they must be carefully detached. The next pair are the *optic*, which are observed gliding under the anterior clinoid processes, and quitting the skull at the optic foramina, where they may be divided, as well as the internal carotid arteries which are situated immediately on their outer side. The next are the *third* or common *oculo-muscular* nerves; these penetrate the dura mater midway between the anterior and posterior clinoid processes. Immediately after their division, a structure called the *infundibulum*, which runs directly down to the pituitary gland in the sella turcica, must be cut through.

The next pair are the *fourth*; these will be best seen by gently raising the edge of the tentorium, and being the smallest of the cerebral nerves they require great care when they are divided. The tentorium itself must next be cut through; and the nerves situated in the fossæ of the skull under it will be discovered in the following rotation, namely, the *fifth*, to the outer side of the posterior clinoid processes, just crossing the superior angle of the petrous portion of the temporal bone:

The *sixth*, situated on a plane internal to and beneath the 5th, penetrating the dura mater about half an inch below the posterior clinoid process:

The *seventh* and *eighth*, or facial and auditory nerves, pass on a plane beneath and to the outer side of the 5th through the foramen auditivum internum.

The *ninth* and *tenth*, or glosso-pharyngeal, and par vagum, with the spinal accessory, are immediately below the last; and the *eleventh* or lingual, lie rather lower down, but to the inner side. These being divided, the spinal cord and vertebral arteries must be cut through by pushing the knife as low down into the vertebral canal as can be conveniently effected.

The left hand of the operator (his right being engaged in supporting the brain) must then be placed beneath the cerebellum, leaving the spinal cord between his middle and ring finger, and the whole enkephalon be removed[1].

REMOVAL OF THE SPINAL CORD.

For the purpose of removing the spinal cord, the student had better make an incision through the skin directly over the spinous processes of the

[1] These last directions only apply in those cases where the pupil is unavoidably prevented removing the spinal cord in connexion with the brain.

whole vertebral column; and next, dissecting the muscles from them and the surfaces of the arches, he will be able to use the saw, with which he must cut completely through the arches of the two or three lowermost cervical vertebræ on both sides; having entirely removed these, he can easily divide the remainder of the arches by means of a pair of strong bone scissors made expressly for the purpose.

Having thus opened the whole of the vertebral canal, he will observe the dura mater completely investing the cord, but not in contact with the arches of the vertebræ, though it is attached anteriorly to the intervertebral substance, as he will discover when he proceeds to the removal of it together with the cord.

The dura mater forms a complete canal for the medulla spinalis, and also branches off with each of the spinal nerves, which it accompanies as far as the vertebral foramina, to the edges of which it is attached, each attachment performing to the whole the office of ligaments, which retain the cord accurately in its normal situation.

The cord may next be removed in connexion with the brain by cutting through the dura mater, and each spinal nerve as it quits the canal, commencing with the lowest sacral and then drawing it through the *foramen magnum*.

Having removed the *cerebro-spinal axis* from its canal, the dissector must proceed carefully to divide the dura mater along the mesial line, and he will then observe the *arachnoid* loosely investing the cord, and forming, by the addition of some tendinous fibres, a tooth-like ligament between the anterior and posterior roots of each of the spinal nerves, called from its appearance the *ligamentum denticulatum*. This is evidently a continuation of the arachnoid with some superadded fibres, and serves the purpose of hanging the cord to the interior of the canal of the dura mater. It also affords additional protection to the soft and yielding neurine of which the whole spinal nervous mass consists, retaining it in its situation, and supporting, but without exerting the slightest pressure upon it.

The arachnoid being now carefully removed, the dissector will find a tolerably firm membrane underneath it; this is the *pia mater*, which is so much less vascular than that investing the cortical structure of the brain, that some anatomists have considered it as a distinct membrane. When, however, we consider that the exterior of the cord is formed of medullary, and not of cineritious neurine, which is so much more vascular, we can understand the reason of the vessels being fewer in number, and thus account for the existence of a pia mater altered in its general appearance.

CONFIGURATION OF THE ENKEPHALON.

Before the student begins to trace the medullary fibres of the cerebro-spinal axis, in order to ascertain the connexions and relations of one part with another, as well as those of the cineritious with the medullary neurine, it will be desirable to take a general view of the external form and appearance of the entire brain and spinal cord, that he may become acquainted with the different elevations and depressions observable on its surface; for although our predecessors, till lately, confining their attention almost entirely to external appearances, and to such as are produced by section, obtained but an imperfect idea of the real structure of the organ, we must not fall into the opposite error and neglect the observation of outward form as wholly unnecessary or unphilosophical. We must only be on our guard at the same time not to confound the study of mere outward configuration with a knowledge of internal structure.

In studying the configuration of the cerebral mass we shall find it advantageous to divide its surface into two portions, the one external and *convoluted*, the other internal and presenting appearances of so precise a character that it may be called the *figurate*; the convoluted, as will be explained afterwards, forming a sort of envelope or wrapper to the figurate.

After removing the brain and spinal cord from the skull and vertebral canal, by dividing the nerves as they pass through their appropriate foramina, the student should place the brain upon its upper surface, which will expose what is usually called the base of the brain, and the anterior surface of the spinal cord. By the term *spinal cord* we mean all that portion of the cerebro-spinal axis which is contained within the vertebral canal, and which it will be seen occupies the whole of the cervical and dorsal regions ; but in the sacral and the lower portion of the lumbar its place in the canal is occupied by the nerves supplying the lower part of the trunk and the inferior extremities ; the appearance produced by the collection of the large nerves in the interior of the canal, from its resemblance to a horse's tail, is called the *cauda equina*. The size of the cord varies ; in the cervical region it is widest, and in the middle of the dorsal narrowest, widening again at the lower part of the dorsal, and then gradually tapering off to a point opposite the second lumbar vertebra, where it terminates in a single nerve. Anatomists have rather differed in opinion as to the exact limits of the cord superiorly ; physiologically speaking, it extends to the hemispheres ; but guided by its external configuration we may describe its superior boundary as formed by the corpus olivare, with which the medulla oblongata commences. After passing through the foramen magnum into the skull the spinal cord becomes very much enlarged, and changes its name to that of the *medulla oblongata*. At the upper edge of the medulla oblongata a large knot or thick band of medullary fibres of about an inch in width will be observed passing over and bounding it; this structure is the *commissure of the cerebellum*, or pons Varolii. The *cerebellum*, or little brain, is the oval-shaped body to which this structure is attached laterally, and which lies beneath the tentorium when in its normal situation in the skull.

At the upper edge of the commissure of the cerebellum we observe two rounded bands, about half an inch in thickness, emerging from behind the commissure, and spreading as they pass forwards and outwards to be lost beneath the convolutions of the hemispheres; these are called the *crura cerebri*. At the point where the crura are first covered by the convolutions, we observe on either side a thin band of medullary neurine, about three lines in width, crossing them; these two bands gradually approach each other, and, apparently joining, form what is called the *commissure of the optic nerves*; the bands themselves go by the name of the *tractus optici*. A space is thus left between the divergence of the crura cerebri and the convergence of the tractus optici, of a diamond shape, within which we observe two white rounded bodies, called from their appearance the *corpora mammillaria seu albicantia*, anterior to which bodies, and partly surrounding them, we observe a layer of cineritious neurine, the *tuber cinereum* or *pons Tarini*, in the centre of which is a funnel-shaped body, the *infundibulum*.

Behind these bodies is a layer of medullary neurine, called the *substantia perforata*, from its being perforated for the passage of vessels.

On either side of the diamond-shaped space described we observe the mass of convoluted cineritious neurine, denominated the *hemispheres of the brain*. These are considered as divided into three *lobes* on each side; the division between the anterior and middle lobe is well marked by a fissure called the *fissura Sylvii*; the division between the middle and posterior lobe is more arbitrary, and corresponds to the superior angle of the petrous portion of the temporal bone in the interior of the skull.

The different pairs of cerebral nerves may also be seen in this view, but their exact connexions will be minutely described after the student has become accurately acquainted with the real structure of the cerebral mass.

The dissector may now reverse the position of the brain by placing it upon the base; he will then observe the upper surface of the hemispheres divided by a *deep fissure*, into which the falx major of the dura mater passes; and by separating the hemispheres he will perceive at the bottom of the fissure a wide band of medullary matter, called the *great commissure of the cerebrum*, or *corpus callosum*.

After this general view of the external appearance of the whole cerebral mass, we shall proceed to an examination of its intimate structure, though the observations which have been already made on the composition of neurine will obviate the necessity of dwelling for any length of time on this subject.

STRUCTURE.

The white portion of the cerebral mass, or that which is commonly designated the *medullary*, has a fibrous appearance dependent on the manner in which the cellular membrane is arranged which supports it. Vieussens was one of the first anatomists who demonstrated the fibrous arrangement of the medullary portions of the brain. In 1684 he published his work entitled *Neurographia Universalis.* The mode he adopted in order to show the white fibres was the same as that pursued in our own day by Gall and Spurzheim, namely, that of scraping its surface in the recent state[1].

Dr. Macartney, of Dublin, has among others been very successful in unravelling the texture of the medullary portion of the brain, and he says that "In order to perceive the real structure of the brain recent specimens are necessary. The sight should be aided by spectacles of a very high magnifying power; and as the different parts are exposed in the dissection, they should be wetted with a solution of alum in water or some other coagulating fluid. By these means it will be ob-

[1] See Observations on the Structure of the Brain, by Dr. Gordon, 1817.

served that all the white substance, whether appearing in the form of bands, cords, or filaments, is composed of still finer fibres, which have a plexiform arrangement, and that all those fibres, to the finest that can be seen, are sustained and clothed by a most delicate membrane."

Reil, Professor of Anatomy in the University of Halle, preceded Gall and Spurzheim in adopting a scientific method of dissecting the brain; and as he always conducted his researches on brains that had been immersed for some time in spirits, he was enabled to trace the course of the fibres with much greater facility than can be done in the recent specimen.

Reil first published the result of his researches in 1807 in the Archives of Physiology, conducted by Autenreith, his attention having been principally directed to the structure of the cerebellum. In these inquiries Reil had himself been preceded by Vincenzio Malacarne, professor of surgery in the city of Acqui, who published his observations in 1780. Reil acknowledges that in his description of the cerebellum he has closely followed Malacarne[1].

[1] The intention of this work would be counteracted if I entered minutely into the researches of these and other physiologists of eminence who have devoted their time to this subject; the reader who is interested in its literary history will find a very good account of the state of cerebral anatomy in 1824 in the 21st volume of the Edinburgh Medical and Surgical Journal.

Though all anatomists of the present day are now perfectly aware of the difference between the texture of the white- and the grey-coloured portions of the brain, still the white retains the name of medullary, and the grey that of cineritious ; and if in the course of this work I continue to use these terms, it will be understood that I merely do so in accordance with general custom, not as implying any doubt as to the real fibrous texture of the white, or the pulpy texture of the grey substance.

The most important difference between the two substances is that the cineritious or pulpy is much more vascular than the fibrous; it also presents a sort of granulated structure, supported by the vascular plexus, though it has a slightly fibrous appearance just at the point where it is joined to the medullary.

The membrane mentioned as pervading the entire substance of the brain and supporting its delicate organization in every part, had certainly not been clearly demonstrated before Macartney investigated the subject, though every rational physiologist must have felt convinced that the soft nature of the neurine required for its support a membrane arranged in the same manner as the interstitial cellular membrane in other situations in the body.

PART III.

DISSECTION OF THE HUMAN BRAIN AND SPINAL CORD.

SPINAL CORD, OR MEDULLA SPINALIS.

In conformity with the principles which induced me to preface the study of the cerebro-spinal axis in the human being with a demonstration of the progressive development of the nervous system by tracing it from some of the simplest forms of animated existence onwards, we shall commence this division of our labours with an account of the configuration and structure of that portion of this system which, protected by the vertebral column, is known by the name of *spinal cord.* Without an accurate knowledge of the component parts of the cord, no one can ever comprehend the intricate structure and mode of composition of the other portion of the system, which, included within the cranium, is therefore entitled the *enkephalon,* or *brain.*

The *spinal cord* consists of two halves or corresponding portions, placed, as regards the mesial line of the body, laterally to each other, and united anteriorly by a central commissure composed of medullary neurine. The fissures separating these two halves of the cord are designated the *anterior* and *posterior fissures* of the *spinal cord*.

The anterior fissure differs from the posterior in being wider, more distinct, and therefore more easily demonstrated, though it is not so deep at the upper part of the spinal cord as the posterior; it deepens, however, as we descend, and is the deeper of the two towards the sacral end of the cord. The pia mater, which closely invests the cord, dips into the anterior fissure, but nevertheless requires to be carefully dissected off before the cleft can be distinctly shown. As the sides of the posterior fissure are in closer contact than those of the anterior, more difficulty is met with in introducing the point of the scalpel into the posterior fissure without injuring the medullary substance. It is curious that so much difference of opinion should have existed among anatomists as to the character of these fissures, Haller almost doubting the existence of the anterior one, whilst Chaussier states that it is deeper than the posterior; and Gordon and others, again, stating that in point of depth there is scarcely any difference between them. See Plate VI. figs. 14 & 15.

SPINAL NERVES.

Connected with the spinal cord, there are no fewer than thirty-one pairs of nerves, each nerve being in communication with the medulla spinalis by two sets of filaments, which in the ordinary language of anatomists are called the *anterior* and *posterior roots* of the *spinal nerves*. But viewing the connexion of these nerves with the cord in strict accordance with the functions which they severally perform, it would be more correct to say that the anterior filaments alone *arise* from the cord, and that the posterior *terminate* there; for the anterior filaments have been proved by Sir Charles Bell and Magendie to be the conductors of the will to the voluntary muscles: they are in fact the instruments of volition, the experiments of the physiologists named having proved that after the division of the anterior filaments the limb to which their continuation as nerves is transmitted becomes perfectly paralytic as regards voluntary motion.

The posterior roots again convey sensation through the medium of the cord to the seat of consciousness, the cerebral hemispheres.

The anterior roots are much smaller than the posterior. The posterior are further distinguished from the anterior in the circumstance of their passing through a distinct ganglion previous to their connexion with the cord. See Plate XI. fig. 4.

Transverse section[1].—A transverse section of

[1] Plate VI. figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

the cord demonstrates clearly that, with the exception of the anterior and posterior fissures, it is solid throughout. Nevertheless different anatomists have maintained that there was a canal in the interior of it, some not giving it any precise situation, and others, as Portal and Morgagni, describing it as being situated in the middle of the cord, lined by a delicate membrane. Gall and Spurzheim in their folio work described two canals running through the whole length of the cord, not communicating with each other, nor with the ventricles, but terminating in a cul de sac about the size of an almond in the optic thalami. Spurzheim has since stated[2] that such canals were produced by the action of the blow-pipe. The canal which exists in the fœtal state is but a dilatation of the posterior fissure, and is gradually diminished by the deposition of neurine; for the pia mater by which it is secreted forms a deep fold posteriorly, as here represented, the secretion first commencing from the concave internal surface anteriorly, and being continued till this surface becomes level, and the whole cord solid.

The transverse section shows that the cord which externally seems composed alone of fibrous neurine, contains in its interior a considerable deposit of the pulpy matter.

[2] In the Anatomy of the Brain, 8vo, London, 1820, translated by Dr. Willis.

The quantity of grey matter included differs very much in different portions of the cord, as may be seen in figs. 3, 4, 5, 6, 7, 8, 9, 10, of Plate VI., a circumstance which I have before adverted to as throwing some light on the different offices of each kind of neurine. The arrangement of the cineritious neurine is definite and clear, the shape of the included mass, which is best seen by a transverse section, something resembling two C's placed back to back and connected by a narrow line thus,)-(. The anterior horns do not reach the surface of the cord; but the posterior, extending completely through its substance, attain the surface at those points where the posterior roots of the spinal nerves are connected with the cord.

If we attempt to divide the medullary neurine of each half of the cord into two portions or columns, the separation may be easily made without the slightest division of their component fibres; and in order to facilitate the description of the ultimate course of the fibres of the cord in that portion, to be spoken of hereafter under the title of *medulla oblongata,* we may consider them as separate parts under the name of *antero-lateral* and *posterior* columns, as these names seem calculated to excite attention to the exact relative position of these two tracts of medullary neurine. The antero-lateral is so much larger than the posterior, that it not merely constitutes almost the whole of the anterior portion, but also the side of the cord, as is seen in the diagram, Plate VI. fig. 14. The relative proportion of the antero-lateral and posterior columns varies, however, in different portions of the cord. In the cervical region, for example, the antero-lateral is nearly double the size of the posterior. In the lower part of the dorsal and upper part of the lumbar regions, again, it is not more than one fourth larger. The relative proportion of these two columns is seen in Plate VI. figs. 14, 15.

By a transverse section of the cord we are also enabled to observe a set of medullary fibres, which, running horizontally across the cord from one side to the other, connect the corresponding halves together. This is the *commissure* of the cord before spoken of, and bears a perfect analogy to the great transverse commissure of the brain. This commissure forms the floor of the anterior median fissure.

The fibres of the spinal cord are very simply arranged, lying parallel to each other, in consequence of which they are easily stripped off, leaving the surface beneath smooth and regular, so that, as Sir Charles Bell observes, "It appears that the superficial layers furnish the roots of the higher nerves, and that the lower layers go off to the roots of the nerves as they successively arise."

FUNCTIONS OF THE SPINAL CORD.

From the statement which has been made regarding the different functions of the anterior and posterior roots of the spinal nerves, the one being destined for motion, the other for sensation, it follows as a necessary consequence that the anterior and posterior fibres of the cord with which they are respectively in communication must perform corresponding offices; in other words, that the constituent fibres of the anterior and posterior portions of the cord are themselves implicated, the one in the production of motion, the other in the perception of what is called common sensation.

These two portions of the cord are however so closely united together that they seem to constitute no more than a single organ, although performing as distinct offices in reference to the nervous system as the arteries and veins do in the vascular, the anterior columns of the spinal cord, in fact, commencing from the cineritious matter which forms the cortical or exterior portion of the convolutions of the cerebrum and cerebellum, and terminating in the substance of the voluntary muscles; the posterior columns, commencing in every texture of the body, and ending in the same points from whence the anterior arise, to wit, the cineritious matter of the cerebrum; just as the arteries convey the blood to all parts of the body and the veins return it; the arteries, commencing at the heart and ending in the capillary tissues; the veins, commencing in the capillary tissues of every organ, and terminating in the heart.

Anatomists used to dispute the question as to whether the spinal cord should be considered as arising from the brain, or the brain be regarded as an enlargement of the spinal cord. Of those who held the first opinion, we may mention Hippocrates, Vesalius, Willis, Varolius, Haller, Zinn, Winslow, Sabatier, Portal, Chaussier, and Cuvier. On the other hand we find Tiedemann and Serres maintaining the second opinion, from a belief that the spinal cord is formed before the brain, which opinion is decidedly refuted by Rolando, who states that the rudiment of the cerebro-spinal system from its earliest appearance is always larger at its anterior or cerebral extremity than elsewhere, and that Tiedemann was deceived in consequence of the cord arriving more rapidly at a state of perfection from the greater simplicity of its structure. As a third opinion I may mention Gall and Spurzheim's, who consider that the brain no more arises from the spinal cord than the spinal cord does from the brain,—that they are in fact several existences. This last opinion appears to me correct as regards the *cineritious* neurine, but not in reference to the *medullary*. Indeed, when we consider the different offices performed by the two columns, it is clear as regards the functions of the cord that the anterior columns ought to be described as *commencing* in the brain, and the posterior as *terminating* there.

The exact point of connexion of the posterior roots of the spinal nerves with the cord is not positively ascertained, but we find Sir Charles Bell stating that if "we follow the sensitive or posterior roots towards their origins we find them entering and dispersing in the substance of these lateral columns. Some authors describe these roots as derived from the cineritious matter: this is quite at variance with my dissections. It is not, however, impossible that the posterior columns may be connected with the sensitive roots of the spinal nerves, though I have not hitherto succeeded in tracing the connexion."

"Formerly I believed," says Sir Charles Bell, "that the nerves of sensation, that is to say, the posterior roots of the spinal nerves, came from the posterior columns of the spinal marrow, and consequently from the cerebellum. Whilst entertaining that belief I found my progress barred; for it appeared to me incomprehensible that motion could result from an organ like the cerebrum and sensation from the cerebellum, for there was no agreement between them[1]."

Bellingeri, in two treatises which he published

[1] Philosophical Transactions, 1836.

at Turin in the years 1823 and 1824, states that the spinal cord consists of six whitish or medullary strands instead of only four as usually described. The two anterior he speaks of as being divided, in the manner above mentioned, by the anterior fissure; and he says that they are united by means of the medullary neurine which I have described under the term *commissure of the cord.* The divisions between the anterior columns and the lateral, again, he thinks are made by the anterior peaks of the cineritious neurine; but they communicate on the surface, as the anterior peaks do not advance to the surface of the cord. The posterior columns he describes as separated from the lateral by the posterior peaks of cineritious neurine, which advancing to the surface of the cord form a complete division between them.

By comparing the relative thickness of these columns or strands, it appears that the lateral are the widest, the posterior the next in size, and the anterior the narrowest of the whole.

Considering the relations and connexions of these strands with the brain, he designates the anterior the *cerebral* strands, the lateral the *restiform,* and the posterior the *cerebellar.*

He also considers that the posterior roots of the spinal nerves have three different origins: 1st, from the posterior collateral furrows; 2nd, from the posterior peaks of the grey matter; and 3rd, from the posterior strands of the cord: and though all these different origins are collected together so as to issue at one point from the cord in the human subject, in the ox he has seen the filaments which arise from the lateral strands issue separately from the posterior.

The anterior roots have likewise three origins: 1st, from the anterior columns; 2nd, from the anterior peaks of grey matter; 3rd, from the lateral or restiform strands.

The anterior columns, Bellingeri agrees with Sir Charles Bell and Magendie, in considering as the conductors of volition, and devoted therefore to the production of voluntary motion; but he confines the kind of motion to simple flexion, so that volition, in fact, is conveyed solely to the flexor muscles through the medium of the anterior columns. His opinion regarding the functions of the middle columns agrees with Sir Charles Bell's, that it regulates all the organic, involuntary, or instinctive movements, such as the action of the respiratory muscles, &c.

Among other reasons for these opinions he adduces the fact of the spinal accessory, pneumogastric, and glosso-pharyngeal nerves arising from the middle columns.

Thus it is clear that in his views regarding the office of the middle strands or columns of the spinal cord, Bellingeri agrees to a certain extent with Sir Charles Bell, in as much as the latter maintains that the nerves which supply especially the muscles of respiration, namely, the par vagum, spinal accessory, phrenic and intercostals, have their appropriate origin from the middle columns of the spinal cord, which he calls the respiratory tract.

When we consider the amazing extent and complication of the respiratory actions, and consequently the immense number of muscles which must necessarily be associated in their production, we can perfectly understand how these muscles should require to receive their stimulus to action from one common point. Nevertheless, I do not consider the evidence for the existence of this respiratory tract as strong enough to warrant me in admitting and speaking of it as an established fact.

The posterior strands, Bellingeri holds to preside over the voluntary motions of extension; in other words, he imagines that all the extensor muscles in the extremities receive the mandates of the will through the medium of the posterior columns. The facts which he brings forward in support of this view are derived from experiments on living animals, and pathology. Did we consent to confine our attention to his illustrations, without comparing them with those of other physiologists, we should come to the same conclusion that he does; but we ought to be cautious in deciding as to the worth of opinions which are so entirely in opposition to those of many of the first physiologists of the present day. Without then being enabled to disprove or absolutely to confirm the truth of these opinions of Bellingeri, we must content ourselves, for the present, with stating that there seems some reason in his views, but that further investigation is required to establish or overthrow them. Their promulgation may, however, be attended with this advantage, that the attention of the profession will be called to the importance of noting down, with more accuracy than is usually done, the exact extent of lesion in the spinal cord in relation to the symptoms of disease or functional lesion exhibited during life[1].

The functions of sensation, and volition in reference to motion, which are now usually considered to be executed by the anterior and posterior columns of the spinal cord, do not constitute its sole office; for if so, it would then be simply a conductor analogous in every respect to the nerves themselves; but it is evidently a point from which power emanates, like the brain itself, though we may not yet have ascertained truly in what that power consists. The experiments of Flourens

[1] An excellent review of the works of Bellingeri will be found in the Edinburgh Medical and Surgical Journal, vols. xlii. and xliii.

tend to prove that it combines the action of certain orders of muscles; for irritation of any portion of it produced an harmonious regularity of action in the muscles of the limb which derive their supply of nerves from that particular portion of the cord, while, on the other hand, irritation of a nerve simply produces a convulsive irregular action. Is it not most probable that this power, which the cord seems to possess, of combining muscular action, depends on the presence of the cineritious neurine in its composition? Had the office of the cord been that of a mere conductor, as in the instance of the nerves, we should then, in all likelihood, have found it made up of medullary neurine alone.

Mons. Rullier relates a case in the 3rd vol. of the *Journal de Physiologie* of Magendie, which, to a certain extent, confirms the opinion of M. Flourens, that the spinal cord is more than a mere conductor of impressions and motory volition; though I cannot help thinking that a part of the morbid appearances met with on dissection, must have taken place very shortly before death, otherwise all our notions regarding the office of the posterior columns must be erroneous.

The patient I allude to above died at the age of forty-four; having suffered for seven years previously from paralysis and contraction of both upper extremities, but without loss of sensibility. These symptoms followed from disease of the spine with curvature, aggravated by the effects of a fall from a considerable height. The sufferings of the patient were dreadful; his intellect remained unimpaired; he had perfect use of his lower extremities; he was immoderately addicted to sexual intercourse.

On the inspection of the body after the man's death, which was conducted in the presence of Magendie and others, no morbid alteration was found in the brain; the spinal cord was also perfectly healthy as far as the fourth pair of cervical nerves, as well as the two inferior thirds of the dorsal and the whole of the lumbar portion. But between these two portions, that is, for the extent of about six or seven inches, including from eight to nine pairs of nerves, the cord was soft and diffluent, so that the canal of the dura mater was filled with fluid, containing flakes of medullary neurine, all being disorganized with the exception of two medullary cords corresponding to the anterior columns, and to which the anterior roots of the spinal nerves were attached.

The experiments detailed by Dr. Marshall Hall in his interesting lectures on the nervous system, prove that the spinal cord possesses very considerable power over the action of muscles independently of the brain. That it is an instrument or generator of power, and not a mere conductor, is proved by the following simple experiment: He divided the spinal cord of a frog just below the occiput; all spontaneous motion of course ceased immediately, and the animal would have remained without motion, until all signs of vitality had been extinct; but on pinching the toe with the forceps both posterior extremities were moved, thus proving that the power to move remained, and was capable of being brought into action, not by exciting the nerve conveying the mandates of the will, but, as I believe, by exciting the nerve of sensation, which must have conveyed that impression to the cord, and there produced some phenomenon the intimate nature of which we can never know, as in all probability it does not depend on any physical change, but from which resulted the contraction of the muscles. And that this contractility did not result from mere irritability of the muscular fibre was proved by his then destroying the spinal cord entirely, after which pinching the toes produced no effect, though the application of a slight galvanic shock caused the muscles to contract forcibly, thus showing that they were still irritable and capable of contracting freely. Mayo in his Outlines of Physiology[1] refers to this circumstance, and considers it explained by the fact that "the nerves of motion take their rise from the same region or segment with those cerebral nerves which transmit the impressions by which their action is usually

[1] 2nd edit., page 343.

regulated;" and in illustration of this point he adduces the origin of the cerebral nerves, which will be again referred to when we come to their description. Dr. Marshall Hall's opinion, however, goes beyond that of simply attributing to the cord a power resident in it, and of which the agents are the nerves of sensation and motion. Though not agreeing with Dr. Hall in his explanation of facts, I feel that this is by far too important a subject to dismiss lightly; I shall therefore extract from his preface the outlines of his views, referring my readers to the original for the arguments he brings forward in support of them. He imagines:

"First, That there is a source of muscular action *equally distinct* from voluntary motion, and from motion resulting from the irritability of the muscular fibre. Second, That there is a series of incident *excitor nerves*, and of reflex *motor nerves*, which, with the true *spinal marrow* as their centre or axis, constitute the *true* spinal system, as distinguished from the *cerebral*, through which that muscular action is excited. Third, That the *ingestion* and *egestion* of air and of food, and the action of the *orifices* and *sphincters* of the body, are dependent upon this system. No physiologist has observed that the action of the *larynx* and *pharynx* in *deglutition* and *vomiting*, and in *respiration*, and that of the *sphincters*, continually depends upon the *spinal marrow* and certain *excitor* and *motor* nerves[1]:

"The eyelids close when the eyelash is touched, through the same agency of *excitor* and *motor* nerves and of the spinal marrow:"

Respiration has been shown to depend upon the medulla oblongata. But this part of the *spinal marrow* has been erroneously supposed to be the *source* and *primum mobile* of this function; whereas Dr. M. Hall believes he has ascertained that the pneumo-gastric is that *primum mobile*, as the principal *excitor nerve* of respiration:

"The action of the ejaculators obviously depends upon the same *excito-motory* or true *spinal system.*"

The fourth of Dr. Hall's views is, "That the true spinal system is the *exclusive* seat of *convulsive diseases.*"

The fifth is, "That the same system is the seat of action of certain *causes of disease* and of certain *remedial agents.*"

Legallois[2] and Mr. Mayo[3] have shown "that distinct portions of the spinal marrow have distinct functions; but these functions have been con-

[1] In order to see the proofs of this remark, the reader need only turn to the justly popular works of Mayo, "Physiology," ed. 3. pp. 113, 114, 361, &c.; and of Magendie, ed. 3. & 11. pp. 65—68, 132, &c.

[2] *Œuvres*, Paris, 1824. p. 62, &c.

[3] On Human Physiology, pp. 230, 231.

founded with *sensation* and with *voluntary*[1] and *instinctive*[2] *motion*, and have remained both unexplained, and without any application to physiology or pathology."

CRANIAL DIVISION OF THE CEREBRO-SPINAL AXIS.

The spinal cord must now be followed into the skull and its connexion with the cerebral mass investigated. In strict accordance with the course of the nervous influence we ought to describe the voluntary or motory strands from above downwards, and those for sensation, or the sensory, from below upwards. But as this mode of proceeding, even if the exact line of demarcation between them had been ascertained, would greatly increase the difficulties which unavoidably surround every mode of study in this complicated organ, we must not attempt a plan which, however correct in a physiological point of view, would not assist us in our endeavours to obtain correct ideas of its anatomical structure. At the same time it must not be forgotten that when we speak of the anterior columns as running up to be connected with the cerebrum and cerebellum, our language is not merely metaphorical, but is positively physiologically incorrect.

MEDULLA OBLONGATA.

The spinal cord shortly after its entrance into

[1] Legallois. [2] Mr. Mayo.

the skull becomes considerably enlarged, and changing its name to *medulla oblongata*, will be found upon section to be entirely altered as regards the arrangement of the cineritious neurine contained in its interior. And here let it be distinctly understood that this enlargement is not occasioned by any swelling of the fibrous or medullary portion, but by the deposit of cineritious neurine in greater quantity than it is met with in the composition of the cord; by the deposition, too, of this constituent of the nervous system in separate and isolated points or masses, a circumstance which does not appear to me to have received the attention which I cannot help thinking it deserves. The view I am inclined to take of the character of the parts comprising the medulla oblongata is simply this: in addition to the columns for motion and sensation, there are here deposited, and imbedded to a certain extent in its substance, four ganglia, two on each side. The most anterior of these are the ovoid bodies, which derive the name of *olivary* from their form. We have already observed their analogues in moths giving origin to the par vagum, in the fish to the branchio-gastric nerves; in like manner, in man they seem to me to be the appropriate ganglia of the pneumo-gastric nerves.

The posterior ganglia are found in the fissure at the back part of the cord, which is known by the absurd name of fourth ventricle. See Plate VI.

fig. 13. They form two projections of a pyramidal figure, and are usually designated the *posterior pyramidal bodies*[1]. In these bodies terminate the auditory or eighth pair of nerves. These also we have remarked in the fish under the title of tubercles of the fourth ventricle.

The arrangement of the cineritious neurine in the olivary bodies will be understood by referring to Plate VI. figs. 11, 12, 13, where the beautiful contrivance which has been adopted in the arrangement of the cineritious neurine of this ganglion is exhibited. It is of exactly the same kind as that employed in the hemispherical ganglia, namely, a contrivance by which an extensive surface of neurine is packed into the smallest space. The cineritious neurine of this ganglion appears indeed as if it were crumpled up to accommodate it to its confined situation.

The corpus olivare[2], I have little doubt, is an important organ in the function of respiration, for the pneumo-gastric, which both terminates and originates in it like the spinal nerves, is a compound nerve ; it is a nerve of sensation in relation

[1] Ruysch described the restiform bodies under the name of posterior pyramidal; and Rolando describes the internal laminæ of the restiform bodies by that name, and even warns the reader against confounding them with the restiform bodies.

[2] Spurzheim in his Anatomy of the Brain, 1820, p. 154, calls the olivary bodies ganglia. Prochaska and Vicq d'Azyr also described them as such, but without attempting to explain their office.

to the sensibility of the lining membrane of the respiratory organs,—the "besoin de respirer" is dependent upon it; it is also a nerve of motion, in as much as the muscles of the larynx and the muscular tissue of the trachea, bronchi and stomach is under its control. So far, then, the opinion of Mayo, referred to further on, that nerves of sensation and motion supplying the same parts are connected with one deposit of cineritious neurine at their central extremity, is confirmed in this instance. It is therefore highly probable that the corpus olivare is a central point, from whence emanates that peculiar power which the system of respiratory nerves conduct, and by which they call the respiratory muscles into action independently of volition. In support of the opinion that the respiratory muscles are dependent on the corpus olivare for their stimulus to contraction, the results of two or three experiments may be related.

A section of the spinal cord made above the origin of the intercostal nerves simply annihilates, as regards the respiratory movement, the power of the intercostal muscles. A section above the phrenic nerve induces paralysis of the diaphragm; while a section exactly at the origin of the par vagum, and therefore through the corpus olivare, occasions a total cessation of every respiratory movement and instant death. If the section, however, be made above the corpus olivare, then the whole of the respiratory movements take place as usual. Is it not, then, from this point, and this only, that they draw their power of motion? A section of the par vagum produces no such effect; the section must destroy the corpus olivare before total interruption to the respiratory action can take place.

For the proofs that the sensibility of the air-passages are dependent on their connexion with the brain through the intervention of the par vagum, I must refer my readers to Braschet's[1] researches on this interesting subject.

With these facts regarding the power, if I may so call it, of the corpus olivare, it appears to me that it would be well to abandon the term medulla oblongata altogether, for it is extremely indefinite, scarcely two writers agreeing as to its exact limits[2]; besides which, an importance is attached to the whole of this segment of the cord which in all probability belongs alone to the corpus olivare.

Some authors, among whom I may mention Gall, describe a fasciculus of fibres ascending from the olivary bodies through the pons Varolii. I have not been able to satisfy myself of their ex-

[1] *Recherches Expérimentales sur les Fonctions du Système Nerveux Ganglionaire*, par J. L. Braschet, 1834, p. 135.

[2] Meckel, for instance, applies the term medulla oblongata not merely to the upper portion of the cord, as most writers do, but includes also the pons Varolii and crura.

istence. Rolando[3] distinctly denies that any such fibres are to be met with; at the same time he suggests that the fibres so described are most probably "the anterior cords of the medulla spinalis, which are compressed, as it were, between the peduncles of the cerebellum and olivary bodies." This view quite agrees with my own observations.

The relation of the antero-lateral and posterior columns of the spinal cord to these ganglia of the medulla oblongata must next be studied, as this will be the clearest method we can adopt for arriving at a knowledge of their connexion with the cerebral mass.

For this purpose let the pia mater be carefully dissected off from the surface of one half of the spinal cord, and in so doing, all the nerves on one side may be removed; those on the opposite, however, being sedulously avoided. In removing this membrane, where dipping into the anterior fissure, as described in the directions for dissecting the cord, the student will find about an inch and a half from the pons Varolii several medullary bands crossing the anterior median fissure obliquely from one side of the cord to the other; these bands belong to the anterior columns; and this crossing of their fibres from one side to the other is technically called the *decussation* of the *pyramidal bodies.*

[3] *Saggio sopra la Vera Struttura del Cervello,* 2nd edit. vol. i. p. 53. Toreno, 1828.

This fact of the decussation of the anterior columns or motory tract of the spinal cord is extremely important, and particularly interesting in a pathological point of view, explaining as it does the fact that disease of the right side of the brain almost uniformly produces paralysis of the left side of the body, and *vice versâ.* Hippocrates himself mentions the fact, that lesions on one side of the head were often observed to occasion palsy on the opposite side of the body; but Aretæus was the first who attempted to explain it, by supposing a decussation of the nerves at their origin in the brain. Dion Cassius is the next who speaks of a decussation of the cerebral nerves and spinal cord; but with him the subject dropt, and the attention of the medical world was only recalled to the fact in 1581, by Fabricius Hildanus. The true decussation of the pyramidal bodies, however, was first described by Mistichelli in 1709; it was noticed by Petit in the year following, and at a later period by Lieutaud, Santorini, and Winslow. The same authors also speak of other decussations, but probably on mere supposition.

"Modern anatomists," says Dr. Spurzheim, "before Dr. Gall and myself, were divided in opinion upon the subject of decussation. Many admitted the fact, but no one pointed out the place of its existence. Vicq d'Azyr, for example, confounds the simple transverse fibres between the two halves of the spinal cord with the true decussation of the pyramidal bodies. Many others, among the number Prochaska, Barthez, Sabatier, Boyer, Dumas, Bichat and Chaussier, have in the most positive terms denied the decussation of the pyramidal bundles altogether, as we have shown in our reply to the Report of the Committee of the French Institute upon our Anatomical Memoir[1]."

Rolando entertains some curious ideas on the subject of the pyramidal bodies: for he states, page 60 of the work referred to, that "the pyramidal bodies must not be considered as a division of the principal cords of the spinal marrow, since these fasciculi of medullary fibres are not in any way continuous with the fibres of the medulla, which it is easy to see. The fibrous fasciculi, and the roots, so to speak, of the pyramids, begin on the anterior face of the medulla spinalis fourteen or sixteen lines below the annular protuberance, and the anterior columns run behind them. It seems that Tiedemann has been led to admit the continuation of the pyramids with the anterior columns, from the decussation observed at this point: however, the fact that the fibres of the pyramids only have their *origin* from that point at which the crossing is perceptible, forms a strong argument against the received disposition;

[1] See Spurzheim's Anatomy, p. 147.

since it is very evident that if they only arise from this point, they cannot pass to the opposite, or be continuous with the fibres of the spinal marrow." In addition to which, Rolando states that his observations on the chick confirm his opinion that the pyramidal bodies are merely placed upon the spinal marrow.

There are, it is true, a few cases on record in which no decussation of the pyramidal bundles has been discovered; but such cases must be viewed as exceptions to a general rule. Let the student, then, distinctly understand that the pyramidal figure which appears drawn, as it were, on the anterior surface of the cord, and gives rise to the term *corpus pyramidale*, is simply caused by the crossing over of the constituent fibres of the anterior columns from one side to the other, but that it is not occasioned, as is the projection of the corpus olivare, by the addition of fresh masses of either medullary or cineritious neurine as supposed by Rolando.

LINE OF DEMARCATION BETWEEN THE TRACTS OF SENSATION AND MOTION.

Although the different offices performed by the anterior and posterior roots of the spinal nerves have been, I think, clearly ascertained, and as it is also evident that the spinal cord consists of tracts of neurine whose office is the same as the nerves which are connected with them, and therefore that there are portions of the cord which perform functions as distinct from each other as the arteries and veins, still anatomists are not yet agreed as to the line of demarcation between them. Sir Charles Bell, for instance, in a paper published in the 135th vol. of the Philosophical Transactions, states that he regards the lateral portion of the antero-lateral columns as a part of the tract for sensation: and the circumstance of there being no decided anatomical line of division between the two columns is not of itself an argument against the correctness of this view; for it is quite possible that perfect distinctness of parts, as regards their function, without any visible line of separation between them, may exist. We must always bear in mind that the neurine which composes the cord is supported and clothed by a perfect though delicate membrane, which, pervading its substance in every direction, is undoubtedly as capable of separating masses of neurine endowed with distinct powers, and ordained by nature to execute distinct offices from each other, as any fissure however wide, or membrane however thick. The presence of such gross and palpable partitions, it is true, would save us some trouble in discovering the line of demarcation, but would not necessarily make it in any way more efficient.

That the boundary line between the two organs of sensation and voluntary motion comprised within the spinal cord (for they are not the less distinct organs because of our ignorance of their respective limits, any more than a nerve of motion is one of sensation because we are incapable of unraveling the fibres of each from their common investing membrane,) cannot be formed by the posterior peak of grey matter, is very decidedly proved by the fact that a portion of the fifth pair of nerves, which we know to be a nerve of sensation from the beautiful experiments of Mayo and Sir Charles Bell, is not connected with, or, in the common language of anatomists, does not arise from, the posterior, but from the lateral columns. This is seen in Plate VI. fig. 2.

THE ANTERIOR COLUMNS OR MOTORY TRACTS.

The antero-lateral columns within the spinal canal consist of fibres, which simply lie parallel to each other without interlacing like the filaments of a nerve; so that if a portion of the cord (previously hardened in alcohol) be taken up in the forceps, it splits up without any difficulty, and the fibres themselves do not appear to be torn, but merely the membrane connecting them. If this mode of proceeding, however, be attempted on the medulla oblongata, we find that the fibres, no longer maintaining an even parallel course, easily break off, and great care therefore is required to trace them to their destination, for some begin to take one course and some another.

Of the fibres which run from the antero-lateral columns to the cerebellum, there are evidently two sets, one superficial and one deep.

The *superficial* may again be divided into two sets: the first cross the surface of the cord immediately below the corpus olivare, and may generally be seen without dissection; they are more distinct in the sheep, bullock, and horse than in man, in whom they form a very thin layer emanating from the corpora pyramidalia, and I have no doubt that they actually decussate with their fellows of the opposite side, forming in fact part of the apparatus of decussation, though I have not yet positively ascertained the fact.

The *second* of the superficial set of fibres take the same direction; only, instead of crossing the cord immediately below the corpus olivare, they run to the inner side of the corpus olivare, and then ascending to the cerebellum they form the outer part of the corpus restiforme.

The *deep* set of fibres from the antero-lateral columns to the cerebellum, are the most posterior of the whole mass of fibres composing this portion of the spinal cord. They are separated from the posterior columns by the posterior fissure, from which the posterior roots of the spinal nerves emerge; this fissure they cross in their passage to the cerebellum, obliterating it entirely.

Thus it will be perceived that one portion of the antero-lateral columns,—for there is yet another portion of these columns to be described,—on reaching to within a small distance of the corpus olivare, splits into three sets of fibres, one, and the most anterior, of which passes through the pons Varolii, as will be described presently, and may be designated the *cerebral* fibres of the anterior columns; a second set, which may be entitled the *superficial cerebellar* fibres of the anterior columns, passing over the surface of the medulla oblongata are usually seen without dissection. Rolando[1] describes the superficial cerebellar fibres of the anterior columns, those which are seen without dissection, (the processus arciformes of Santorini,) under the name of "filamenti arciformi," saying, "I believe that I ought to give such a name to numerous filaments which are seen to issue from the transverse fibres of the annular protuberance precisely at the same spot where the anterior cords penetrate into its centre. The filamenti arciformi nevertheless descend and partly cover the above-mentioned cords, expanding on the corpora olivaria, and extending even to the median fissure by which they remain separated from each other. Such a disposition is constantly observable in quadrupeds, in which the said filaments are extremely distinct, although no mention has hitherto been made of them." Rolando does not, however, trace them as he might

[1] *Op. citat.*, vol. i. p. 147.

have done to the cerebellum instead of describing them as descending from the pons Varolii. The third or *deep cerebellar* fibres of the anterior columns, proceeding in company with those of the posterior columns, form about a fourth part of the whole diameter of the restiform bodies.

RECAPITULATION.

From the above description it will be remarked that the anterior columns of the cord, which have hitherto been spoken of as simply passing up through the pons Varolii or commissure of the cerebellum to be connected with the cerebrum[2], are described as passing also to the cerebellum. In a paper which was read before the Royal Society in May 1836, I proved that they were connected with the cerebellum as well as with the

[2] Meckel speaks of the anterior columns as dividing into two halves, an anterior and posterior; these he describes as running up to the inner side of the corpora olivaria, on a plane with the fourth ventricle. Besides which, he states that a smaller fasciculus, which Gall describes as being occasionally absent, after touching the above bodies ascends to the corpora quadrigemina. Mr. Mayo is almost the only author who points out the fact, that the restiform bodies are not alone formed by the posterior columns, though the exact course of the additional fibres he was not aware of, for he describes the superficial fibres spoken of above, as descending instead of ascending. In his second edition of his Outlines of Physiology, p. 273, he says, "On cutting through and stripping down the corpus restiforme, it is found to carry with it the posterior lateral furrow; the anterior lateral furrow terminates among fasciculi which are continuous with the corpus olivare."

cerebrum, as allowed by Mr. Mayo and Mr. Owen, to whom my preparations were referred. Since this time I have had the opportunity of showing the same preparations to many of the first anatomical teachers in England, who consider the point fully established. They have been since deposited in the Museum of the College of Surgeons. The corpora restiformia, or the processus è cerebello ad medullam oblongatum, are not, therefore, as they have usually been described, bodies which are formed solely by the *posterior* columns; nor are they bodies which consist of fibres from the posterior columns, to which some fibres from the anterior columns are added, the additional fibres lying perfectly parallel to those of the posterior columns; but they are bodies which consist of fibres that interlace in rather an intricate manner, the interlacing fibres consisting of some from the antero-lateral, and some from the posterior columns.

It is rather curious that Rolando should have approached so nearly to the discovery of the fibres above described, as connecting the anterior columns with the cerebellum, and yet have just fallen short of understanding them, as is even more evident by the further perusal of other passages in his writings; for at p. 142, he remarks: " All anatomists agree in saying that the posterior surface of the olivary body is in contact with the superior surface of the peduncles of the cerebellum. Malacarne observes, however, that they are separated from them by means of a medullary layer of the shape of a half-moon. To my thinking, this question has been too superficially examined. No anatomists who have especially studied the brain have detected that between the said olivary bodies and the inferior peduncles of the cerebellum are placed fasciculi of medullary fibres which are *continuations of the anterior cords* of the medulla spinalis. This omission appears to me to have arisen from their not having paid sufficient attention to the direction of the fibres and filaments of which these are composed. If the anterior cords of the medulla spinalis be carefully examined a little below the pyramids, we see that they send fibres from the anterior median fissure to the posterior lateral fissure, which forms the line behind which issue the posterior roots of the spinal nerves, and as the said columns advance upwards they contract. The fibres that were previously expanded become convergent, and are found compressed between the pyramidal bodies and the cineritious tubercles[1]; and following them upwards, they are found strongly compressed, and as it were hidden between the corpora olivaria and the inferior peduncles of the cerebellum, on which account they have eluded the minute investigations of anatomists among these parts.

[1] The cineritious tubercles are described as bodies situated on the lower part of the restiform bodies.

For in order to see these fibrous cords distinctly, which are flattened externally and at the same time a little curved, it is necessary to separate the olivary bodies from the inferior peduncles of the cerebellum: in this place they are covered by the arciform filaments, to be spoken of shortly. Then above this point, if you wish to follow the fibres of the said cords downwards, it is easy to see that anteriorly they are directed towards the inferior extremities of the olivary bodies and the pyramids, in order to form that portion of the medulla spinalis which folds into the anterior median fissure; whilst these find themselves in contact with the inferior peduncles of the cerebellum they bend backwards, carry themselves towards the posterior surface of the cineritious tubercles, and go to form the posterior lateral fissure. *It is more difficult to follow the anterior cords towards the superior region of the medulla oblongata.*" At this point his observation has failed him, for instead of tracing them, as he might have done, to the cerebellum, he goes on to say: "But one may often succeed in seeing them when they bend over the superior extremity of the olivary bodies, where is formed that space which Malacarne has called the fossa quadrilatera. Nevertheless it is only by means of transverse sections, made and repeated at like distances, that the anatomist will obtain an exact idea of their arrangement at the part in question; in this manner they may get behind the above-mentioned cords, although hidden in the cineritious substance of the annular protuberance[1]."

The best method of dissecting the medulla oblongata with a view of demonstrating clearly the existence of these fibres which connect the anterior columns with the cerebellum is, either to split the posterior column from the antero-lateral column by raising only the posterior columns, or in other words that portion which is between the posterior lateral and posterior median fissure, about two inches below the pons Varolii; and drawing the portion thus separated very carefully up towards the cerebellum, the dissector will find that the splitting will be stopped before the cerebellum is reached by the superficial cerebellic fibres of the anterior columns, unless so much force is used that the superficial fibres are torn through without observation. Or another mode of dissecting them is to trace the sensory root of the fifth pair of cerebral nerves through the pons Varolii down to its connexion with the posterior portion of the antero-lateral column, in doing which a layer of fibres will be met with in the medulla oblongata about the thickness of hogs' bristles running, from beneath the olivary bodies on the outer side of the above-mentioned root of the fifth pair of nerves, to the cerebellum, forming

[1] *Op. citat.*, p. 149.

a portion of the restiform body in their progress.

The first set of *superficial cerebellic* fibres are represented (Plate VI. fig. 1.) passing upon the surface of the corpus restiforme. The second set of the superficial cerebellic fibres are represented cut through in their passage to the cerebellum just as they cross the sensory tract of the fifth pair (Plate VI. fig. 2.).

The fibres just described as connecting the antero-lateral columns of the cord with the cerebellum are peculiarly interesting when viewed in relation to the functions of the cerebellum. For although it is true that its functions have not yet been clearly ascertained, the experiments of Flourens, Bouillaud, Magendie, and others, and the numerous cases on record in which disease of the cerebellum has been followed by paralysis, all tend to prove that the cerebellum is in some way or other connected with the regulation of muscular action, most probably, as before hinted at, that it has the power of combining the action of individual muscles so as to effect an harmonious result, such as is necessary to enable us to stand, walk, &c. Even Broussais in his lecture on Phrenology, published in the Lancet, July 30th, 1836, acknowledges that the cerebellum is an instrument connected in some degree with the combined action of the muscles, though merely in relation to the act of copulation. Their presence also proves the weakness of Mr. Walker's theory of the function of the posterior columns as derived from the supposed fact that the posterior columns alone are connected with the cerebellum.

The circumstance is also at variance with the opinions of M. Foville, who reasons that the cerebellum must be concerned in the phenomena of sensation because the posterior columns are alone connected with it[1]; while Dr. Prichard in his treatise on Insanity and other disorders of the mind, p. 482, after speaking of Foville's doctrines and their foundation upon what he considers an established fact in anatomy, says with the usual caution of such a highly talented observer: "In the present state of these researches it would be a rash attempt to draw inferences with any degree of confidence; but I may be allowed to remark that the general bearing of facts seems to direct towards the conclusion that the two great organs inclosed within the skulls of vertebrated animals belong respectively to the two principal functions

[1] *Dict. de Méd. et de Chirurg. Prat.*, tome vii. p. 202, art. ENCEPHALE. "Or nous voyons les cordons posterieurs de la moëlle, affectés à la sensibilité, se prolonger dans le cervelet; les cordons anterieurs, affectés au mouvement, s'entrecroiser dans les pyramides, poursuivre apres cet entrecroisement leur marche vers le cerveau, dans l'epaisseur duquel ils pénétrent très profondement; et nous trouvons ainsi une raison anatomique de supposer que le cervelet doit avoir à remplir un rôle tres-important dans les phénomènes relatifs à la sensibilité, tandis que le cerveau jouirait d'une influence directe et centrale sur la production des mouvements volontaires."

of animal life, which are, first, sensation, conscious perception, and the physical phenomena related to intelligence; and, secondly, those of voluntary motion. This however can only be considered as a probable opinion. Such it has long been thought by many physiologists; and though the grounds on which this conclusion rests appear to be more secure than they formerly were, the proof is still defective."

Besides those fibres of the antero-lateral columns which have been described under the title of cerebral and cerebellar fibres of the anterior or motory columns, there is another set which in the spinal cord occupies a completely lateral position, being separated from the posterior columns by the posterior peaks of grey matter. These are regarded by Sir Charles Bell as the *cerebral* strands of *sensation*; cerebral, because, as will be explained a little further on, they terminate in the cerebrum; of *sensation*, because the posterior roots of the spinal nerves are connected with them.

The fibres of the posterior columns, or those columns which are separated from the rest of the cord by the posterior peaks of cineritious neurine and the groove of the posterior roots of the spinal nerves, take their course directly and entirely to the cerebellum; none of them whatever can be traced to the cerebrum. Both these portions of the sensory tract will be traced to the cerebrum after the description of the course of the anterior columns is concluded.

The anterior portion of the anterior columns, that which is usually called the corpus pyramidale, may now be traced through the pons Varolii[1] by dividing those fibres to the depth of about the eighth of an inch in the mesial line, which form the inferior surface of that body, and then by scraping them back towards the cerebellum, remembering at the same time that the fibres which are thus scraped back form the commissure of the cerebellum. The fibres of the anterior column will now be perceived distinctly to cross through the pons Varolii, and emerging beyond it, or from its upper edge, to form the under portion of a structure which has been already noticed under the old name of the crus cerebri, and which, diverging from its fellow of the opposite side, forms the outer and posterior boundary of the diamond- or lozenge-shaped space of the base of the brain. See Plate VII., and Plate VIII. fig. 1.

These anterior columns, or the motory tract, in their passage through the pons Varolii are separated from each other by a peculiar structure, first described by Sir Charles Bell, and represented

[1] The celebrated anatomist from whom this commissure of the cerebellum derives its name was the first to trace the anterior columns of the spinal cord through it to the substance of the hemispheres.

in the Philosophical Transactions for 1834 as resting with its edge on the commissure of the cerebellum, and extending its fibres directly backwards so as to form a striated leaf, separating the two great longitudinal tracts which pass between the medulla oblongata.

In making sections of the pons Varolii, it is a curious fact that those parts which appear grey on a transverse section, are white on a longitudinal, and *vice versá.*

The next step in the dissection is to remove the arachnoid and pia mater from the fissura Sylvii, through which fissure the dissector may insert his fingers, and raising the middle lobe tear through its connexions with the anterior so completely as to enable him to turn it back over the posterior, after which he will be enabled to trace further the motory tract of fibres of the anterior columns. By gradually removing the neurine which still covers them he will expose some medullary fibres, running from before backwards; these belong to the great transverse commissure or corpus callosum. On removing these he will come to a large deposit or bed, if we may so express it, of cineritious neurine, through which the anterior columns pass, exactly in the same manner that the sensory fibres of the fifth pair do through the semilunar ganglion already referred to in the sphenoido-temporal fossa. This collection of neurine is the ganglion of the anterior columns or motory tract, and is commonly known by the name of the *corpus striatum.* Gradually scraping the substance of this ganglion away will expose the exact course of the motory fibres. In the course of scraping the cineritious neurine away, a rounded band of medullary neurine will be exposed, taking its course forwards and inwards: this band is the commencement of the anterior commissure.

The motory fibres, which are thus traced into the substance of the corpus striatum or anterior cerebral ganglion of the cord, spread as they emerge from its external edge, and pursuing their course in different directions like the rays of a fan, some passing forwards, others outwards, and others backwards, terminate ultimately in the cineritious neurine composing the convoluted surface of the hemispheres, the *hemispherical ganglia.*

The anterior division of the anterior columns of the spinal cord or the motory tract of neurine having been thus traced from the point where, going by the name of corpus pyramidale, it forms part of the medulla oblongata, 1st, through the pons or commissure of the cerebellum; 2ndly, forming the inferior part of the crus cerebri; 3rdly, plunging into the anterior cerebral ganglion; and 4thly and lastly, quitting this ganglion in order to reach the hemispherical ganglion or the cineritious neurine of the convoluted surface of the hemispheres. The posterior division of the same column, again, has been traced to the cerebellum.

We should here return to the medulla oblongata, and in like manner pursue the tract of sensation to its destination. This would unquestionably be in strict accordance with the functions of the spinal cord and its relations to the brain; but in describing the anatomy of the brain it should be an object with the anatomist so to arrange his description as to economize the material which the student has to work upon. With the latter view, therefore, the attention of the dissector will now be called to the anatomy of the *commissures* or *apparatuses of union*, parts which, in point of physiological connexion, ought not to be studied at present. Should, however, the student prefer tracing the posterior columns at once, he has only to refer to the section after the description of the commissures, where he will find them described.

In commencing this new inquiry the student must remember that the commissures or apparatuses of union, can only be thoroughly understood, and their exact connexions and relations appreciated, after a diligent consideration of the exact relative position of the different ganglia which it is the office of these commissures to connect together, and also to bear in mind that his attention to these media of connexion is now required solely that they may not be destroyed and lost sight of in the further pursuance of this dissection of the columns of the cord.

COMMISSURES[1].

Let the brain be now laid upon its under surface, when of course the upper surface of the hemispheres will meet the eye. Let the membranes be removed from these, and the depth of the fissures separating the convolutions, as well as the general exact correspondence or symmetry of the hemispheres of the brain, be remarked. The great fissure separating them longitudinally is deep; at the bottom of it a broad band of fibrous or medullary neurine will be observed: this is the *great transverse commissure*, or corpus callosum. Before entering on the description of this part, let me remind the student of the simple form in which a commissure was first presented to his notice in the nervous system of the star-fish, where it appeared as a slender cord of neurine connecting one ganglion with another.

In the description of the human brain I shall consider under the head of commissures all those collections of medullary neurine which are so arranged as to connect either corresponding parts

[1] Spurzheim confines the word *commissure* to designate structures which connect corresponding parts, and applies the term *instruments of communication* to those which connect different parts on the same side; a distinction which, as it does not appear to me to be attended with any advantage, I have taken the liberty of rejecting.

which are placed on each side of the mesial line, as, for instance, the right and left hemispheres; or different structures on the same side, as the various convolutions of each hemisphere; or two distinct structures, as the two grand divisions of the cerebral mass, the cerebrum and cerebellum; thus following out to its fullest extent the principles which have been laid down elsewhere, that a ganglion is a collection of neurine of any size and any form, and that the cerebro-spinal axis, of which the brain is a part, is no more than a collection of ganglia of immense size connected together by commissures of corresponding dimensions.

TRANSVERSE COMMISSURE.

The great *transverse commissure*[1], or corpus callosum, is a body consisting of fibres of medullary neurine, the extremities of which are everywhere in contact with the internal or central surface of the cineritious layer which forms the con-

[1] Vicq d'Azyr was the first anatomist who described the corpus callosum as a commissure, while, on the other hand, Rolando denies that it is entitled to the name of a commissure; for, says he, "laying together the observations of Wenzel and Tiedemann upon the formation of the corpus callosum and my own observations on the union of the cerebral vesicles,—the point of union constituting the future corpus callosum, this is obviously in the first instance no more than a contraction of superior and inferior margins of the vesicles; the part cannot at any rate be justly described as a commissure."—*Op. cit.* p. 72.

volutions of the hemispheres,—the hemispherical ganglia. These fibres consequently establish a communication between the cineritious neurine of the whole convoluted surface of both sides of the cerebrum.

Strictly speaking, the fibres of the great transverse commissure do not commence on one side more than another; but in the hope of assisting the mental eye in following their course from hemisphere to hemisphere, we will describe these fibres as originating on the right side and crossing over to the left. The fibres from the front, sides and superior part of the anterior lobe, then, pass backwards and inwards to the distance of an inch and a half from the anterior extremity of the cerebrum, where they cross the fissure which divides the two hemispheres. The anterior edge of the commissure consequently forms the posterior boundary of the anterior part of the fissure. In this situation the fibres are folded one upon another; so that on a transverse section of the commissure the anterior edge appears thicker than the centre, though it is not so thick as the posterior edge. (See Plates IX. and X.)

The fibres from the convolutions of the upper part and sides of the middle lobes run downwards and inwards, being joined by those from the convolutions at the base of the brain.

Those, again, from the upper, under, and posterior surface of the posterior lobe run forwards and inwards to cross the fissure at the distance of nearly three inches from the posterior extremity of the cerebrum. The fibres from such extensive surfaces are necessarily numerous, and give a considerable thickness to the posterior edge of the commissure[1].

All these fibres may be easily demonstrated in a brain that has been immersed for some time in spirits, and they may also be shown, though not so readily, in the fresh brain. The best method of exposing them is gradually, by tearing, to remove the upper part of the hemispheres, the handle of the knife being pushed into the horizontal fissure through which the commissure creeps, as it

[1] M. Foville, of Rouen, in the article referred to above, gives a very different account of the nature of the corpus callosum and the origin of its component fibres. He considers that they commence from the corpus striatum and thalamus, and says they have nothing to do with the hemispheres, but in reality form a commissure between the two crura cerebri of a vaulted form. In his Outlines of Physiology, Mayo has very clearly proved the manner in which that mistake has occurred, and shown that Foville in producing the appearance which induced him to adopt the opinion stated above, breaks through the point where the fibres from the columns intersect the commissural fibres, and then follows the columnal fibres in their course to the striated bodies. Rolando advances the same opinion regarding the composition of this commissure as Foville, quoting the opinions of Tiedemann in support of his own. Notwithstanding such weighty testimony, I am convinced from repeated dissections that they have been deceived, most probably as explained by Mayo in his Physiology.

were, under the convolutions on both sides of the hemispheres. The dissection here had better be confined to the right side, in order to reserve the left entire for other observations.

Let me again repeat that I consider these connecting fibres of the great commissure as performing the same office, and that they ought to be considered as perfectly analogous structures to the single commissural cord which we met with in the star-fish. Their vast number, which is only in proportion to the great extent of surface from which they originate or which they connect, ought not to deceive us as to their similarity, and thus withdraw attention from the illustration of their real character afforded in the simple type of the nervous system as it exists in the star-fish.

The mode of tracing the fibres of the transverse commissure recommended will open what, at first sight, appears to be a circumscribed cavity (the *lateral ventricle*). This space must not however be viewed by the student in the light of a cell or cavity situated in the interior of the brain, the walls of which are formed by the cerebral mass; he must consider it as resulting merely from the contact of the different surfaces of the brain: the external surface of the anterior and posterior cerebral ganglia or the figurate surface[1] is here

[1] The character of the figurate surface, and meaning we attach to the term, will be explained a little further on.

in contact with the internal smooth surface of the superficial cerebral convolutions or hemispherical ganglia. It is quite true that in one sense it is a cavity with walls sufficiently perfect to be capable of containing fluid; but the important point for the student to understand is, that these walls are not entirely formed by neurine, and that its power of containing fluid arises simply from the mode in which the arachnoid membrane is reflected from the figurate surface on to the convoluted surface. It is in this way that we have a circumscribed cavity, formed from a mere accident in structure, which in the constitution of the brain amounts to no more than an irregular but extensive fissure, analogous in all respects to the fissures between the different convolutions of the cerebrum. Though it may not, perhaps, be possible for the student who has only advanced thus far in the dissection of the brain to have a clear idea of the difference between the figurate and convoluted surfaces, I have considered it advisable to arrest in the very first instance any ideas that might arise in his mind as to the ventricles of the brain being perfect cavities, whose walls are wholly formed by the substance of the organ itself. The term *ventricle* alone is sufficient to mislead whoever dissects these parts for the first time.

FIGURATE SURFACE.

The figurate surface of the brain is so named, in distinction to the convoluted surface, from the projections which compose it presenting regular forms and having received individual names, generally derived from some trifling peculiarity of appearance, some fancied resemblance to another part, or erroneous views of their functions; nevertheless, however incorrect these titles may really be, it would not be advisable to attempt any sudden and total rejection of them; all we shall do will be to couple with them other appellations which have relation to the structure and function of the part they are used to indicate.

Commencing anteriorly, the first of the component parts of the figurate surface which presents itself to our observation is the *anterior cerebral ganglion* or *ganglion of the anterior* or *motory columns,* whose under surface we have already examined; it is pear-shaped, the base of the pear being forwards and inwards, and the apex or small end lying backwards.

Posterior to this anterior cerebral or motory ganglion, and, as it were, embraced by the curve it forms, there is another large ganglion, the *posterior cerebral,* presenting a white surface and rounded form, called the *thalamus nervi optici,* through which the posterior or sensory column passes previously to its expansion in the hemisphere and termination in the *hemispherical ganglion*, as shown in Plate VIII. fig. 2.

Between these two ganglia is situated a narrow band of medullary neurine called, from its appearance, the *tænia semicircularis*; the fibres composing this band are derived from the great commissure, and are considered by Spurzheim as the media connecting the converging fibres, or fibres of communication between the two hemispheres and the anterior and posterior cerebral ganglia, commonly called the thalami and corpora striata.

Lying upon the superior surface of the posterior cerebral ganglion we find a vascular membrane called the *plexus choroides*; this membrane, notwithstanding its grand name, is merely the continuation of the pia mater, as will be seen a little further on. Overlapping this membrane at the internal or posterior part of the posterior cerebral ganglion or thalamus, there is a sharp band of medullary neurine; this structure is a portion of the *inferior longitudinal commissure* or *fornix*. The connexions and precise character of this commissure I shall not describe at present, being anxious to give a connected and uninterrupted view of the figurate surface, merely remarking that the width and extent of the inferior portion of the fornix or inferior longitudinal commissure may be observed by dividing the transverse commissure about one third from its posterior edge in the direction of its fibres. On removing a portion of the transverse commissure, the fornix will be found to extend on each side nearly an inch from the mesial line, narrowing considerably towards its anterior extremity. The right side of the longitudinal commissure must next be completely divided, cutting towards the upper surface of the cerebellum, and the divided portion turned over to the left side: the consequence of this section will, in the first instance, be the further exposure of the pia mater, and a view of the exact point where it quits the *convoluted* to join the *figurate* surface; the convoluted surface, which the pia mater quits, is the upper surface of the cerebellum. The narrow space left between the under surface of the posterior edge of the inferior longitudinal commissure and the upper surface of the cerebellum, used to be called the foramen of Bichat, and the pia mater in this situation is known by the name of *velum interpositum*. This membrane, the *velum interpositum*, must now be very carefully raised, and immediately underneath and connected with it will be found a small rounded body about the size of a pea, consisting of cineritious neurine, and frequently containing in its interior some gritty matter called the *pineal gland*; it forms, together with two white bands, hitherto known by the title of the *peduncles* of the *pineal gland,* connected to it, a commissure between the optic thalami. The whole structure may be called the *pineal commissure.* Beneath this commissure are situated the *optic tubercles,* which in man are four in number, instead of being simply binary as in fishes; these tubercles are usually known by the term *corpora quadrigemina.* The anterior of these are the largest and are frequently called the *nates,* the posterior the *testes.* By gently raising the anterior edge of the cerebellum with his knife, the student will observe, passing from the optic tubercles backwards and downwards to the cerebellum, a broad band of medullary neurine, thick laterally, but extremely thin in the centre; so great is the difference in the texture of these two portions, that the central has been called the valve of the brain or the valve of Vieussens; the direction of the component fibres is however longitudinal in both. This structure in the aggregate must be regarded as a commissure connecting the cerebrum and the cerebellum, and I shall designate it therefore the *oblique* or *intercerebral commissure*: a more minute description of its fibres will be found under the head of the commissures.

This view of the figurate surface of the brain (for I see no advantage to be derived from including such parts as the hippocampi, &c., the true nature of which will be shown when we describe the commissures, and the introduction of which in this place would only serve to burthen the memory unnecessarily,) will remind the student of the tubercular form of the brain of the fish, to which it bears some resemblance. It, in fact, consists of the anterior and posterior or motory and sensory ganglia of the spinal cord, of the optic tubercles, the intercerebral commissure and the cerebellum, the olfactory tubercles being concealed, as indeed were the rest until the hemispheres were divided and turned back. The relation of the hemispheres to the ganglia of the cord or corpora striata and optic thalami, will be easily understood by referring to the accompanying diagram, where the convoluted surface is represented as commencing at the fissura Sylvii, from which it is traced, first forwards then upwards, then backwards to the posterior extremity, and then forwards again under the striated bodies to the fissura Sylvii.

We may thus compare the corpus striatum and thalamus nervi optici, or anterior and posterior cerebral ganglia, to the head of a stick, to the neck of which just below the knob is attached a piece of folded linen (represented by the hemispheres, in the human subject an immense surface), which is first drawn forwards, next turned backwards, and again brought forwards so as to form a complete covering to the head.

Fig. 1.

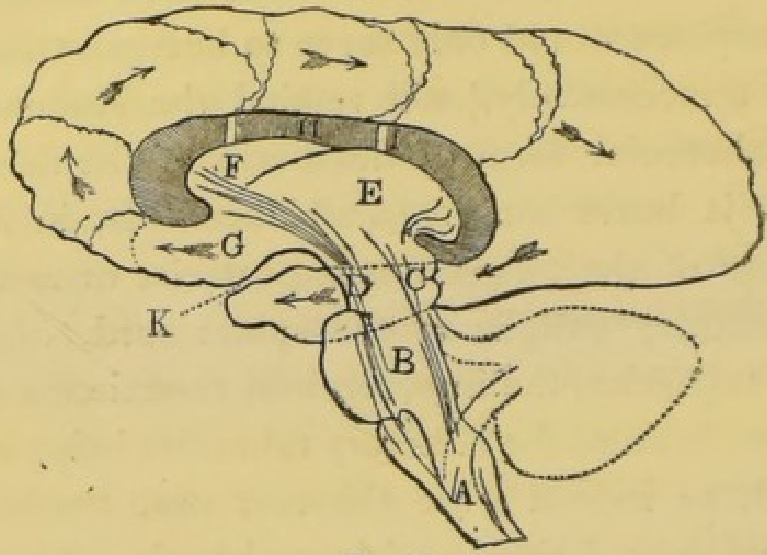

Fig. 2.

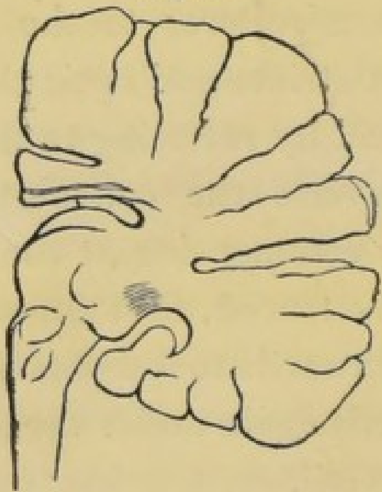

Fig. 1. A, represents the medulla oblongata; B, pons Varolii; C, tubercula quadrigemina, with the fibres of the posterior columns passing in front; D, crus cerebri, fibres of the anterior columns; E, thalamus, or posterior striated body; F, anterior striated body; G, substance of the hemisphere springing out from the front of the anterior corpus striatum; H, space between the striated bodies and the hemispheres caused by the introduction of a small piece of wood; I, the two surfaces, being in contact in the natural state; K, fissura Sylvii.

Fig. 2. represents the same parts shown by a transverse section through the centre of the brain.

INFERIOR LONGITUDINAL COMMISSURE, OR FORNIX.

In pursuing the dissection of this commissure, where we have not more than one brain at our command, a difficulty arises from the circumstance of the longitudinal commissure, or fornix, lying over and concealing from view the transverse commissures which remain to be studied. This makes it necessary that the longitudinal commissure should be divided and turned back in order that the others may be seen; as this proceeding interferes with that perfect and minute dissection which can only be accomplished on a brain almost entirely devoted to it, a drawing of the fornix has been introduced in Plate IX. with the view of assisting the student to a knowledge of its complicated relations. The longitudinal commissure must now be divided in the middle just opposite the divided end of the transverse commissure; this being done, the posterior portion must be turned back, when the optic thalami on both sides may be distinctly brought into view with a fissure of some depth between them (*third ventricle*).

COMMISSURA MOLLIS.

Crossing this fissure, in the centre, is the *commissura mollis*, consisting almost entirely of cineritious neurine.

PINEAL COMMISSURE.

Running along the inner edge of the thalami a white line may be seen formed by a collection of medullary fibres, which are connected to the pineal gland in the centre; these, through the intervention of that body, form the *pineal commissure* before mentioned.

POSTERIOR COMMISSURE.

The pineal commissure may now be divided; beneath it, and just anterior to the optic tubercles, a narrow band of medullary neurine will be perceived; this is the *posterior commissure*; its fibres may be traced in the thalami on each side.

ANTERIOR COMMISSURE.

The whole extent of this commissure cannot be perfectly seen in this stage of the dissection, the only portion of it brought into view being that which runs across the small fissure left between the anterior pillars of the longitudinal commissure; its dissection will be most conveniently conducted at the base of the brain, where it will be found (having been already exposed in the dissection of the passage of the motory tract through the anterior cerebral ganglion of the cord,) to be about three lines in width, and commencing in the middle of the hemispheres to pass through the substance of the corpus striatum or anterior cerebral ganglion, apparently receiving additional fibres from the cineritious neurine of the most external portion of this ganglion: near to the internal edge of the ganglion, however, the anterior commissure becomes quite distinct from it, and crosses over to the corresponding ganglion of the opposite side, in front of the anterior pillars of the longitudinal commissure. From the outer part of this commissure some fibres may be traced to the olfactory nerves: these were first discovered by Spurzheim in 1821, and are mentioned in his thesis entitled *Encephalotomie.* The portion running to the olfactory nerve forms an arc, the convexity of which is turned backwards, the concavity forwards[1].

INFERIOR LONGITUDINAL COMMISSURE, OR FORNIX.

The commissure to which we must next direct our attention is the *longitudinal commissure* or *fornix,* which having been divided in the centre in the course of the preceding dissection, must be replaced in its normal position. This part has

[1] Chaussier and Tiedemann both regard the anterior commissure as a continuation of the cerebral crura; but with all due respect to such high authorities, I cannot agree with them; for in pursuing the dissection which has been already described, tracing the course of the anterior fibres through the corpus striatum, and giving the utmost attention to the relations of the anterior commissure, it will be found that there is no continuity of fibre between the peduncles of the brain and the anterior commissure.

not been generally described in the light of a commissure. By Vieussens it was considered simply as the under surface of the corpus callosum; but the direction of its fibres being so entirely different, that is, being longitudinal instead of transverse, it is impossible to agree with that celebrated author in this view of the relations of the fornix, the name of which is derived simply from its vaulted figure, for it forms in the centre of the cerebral mass a surface which is convex superiorly and concave inferiorly, bearing, therefore, some resemblance to an arched or vaulted roof. By the German anatomists it is called the twain band. If the student will here refer to Plate IX. he will find the following description considerably elucidated.

The general form of the fornix may be described as that of a vaulted roof supported upon four pillars, which, unlike pillars in general, are bent nearly double, the anterior pair presenting their concavity forwards, the posterior pair theirs backwards. Its real character and the direction of the fibres composing it will be ascertained by making a section of the brain, so as to obtain a side view of it; and in order to effect this, the crus cerebri on the right side should be divided by an incision just between the optic tubercles and the posterior cerebral ganglion; and the scalpel being kept quite close to the inner side of that ganglion, the incision may be carried forward, running also on the inner side of the motory ganglion, and then cutting through the anterior lobe into the anterior fissure, as has been done in the dissection from which Plate IX. is taken. This commissure, like every other commissure, cannot, strictly speaking, be described as commencing in one part more than another; in describing it, therefore, as commencing in the crus cerebri, it must be remembered that it would be equally correct to describe it as terminating there; but being obliged to suppose it to commence at some point, we shall speak of it as arising from the cineritious neurine, or *locus niger*, which in the centre of the crus cerebri separates, as has been shown, the sensory from the motor columns.

From the centre of the crus cerebri the fibres of the longitudinal commissure may be traced to the corpora mammillaria, at which point they are joined by a band from the interior of the thalamus, which can be most easily dissected when the brain rests on its upper surface and the base is exposed. (Plate X.) The right thalamus having been removed in the previous dissection, the part in question must be searched for on the opposite side. From the corpora mammillaria the fibres are collected so as to form two rounded cords; the course of these is first forwards, then upwards, and afterwards backwards, thus forming a semicircle, the concavity of which facing backwards, used to be called the anterior pillars of the fornix, and is free and unattached, whilst the anterior or convex edge receives fibres from the anterior lobes and from the under part of the great transverse commissure, by which means a thin delicate septum is formed, called the *septum lucidum*[1]. The longitudinal commissure in its passage backwards under the great transverse commissure (corpus callosum), to which it is attached, spreads laterally, and at first is nearly of the width of half an inch; but afterwards, becoming much wider, it descends to be connected with the convolutions, first of the back part, and afterwards of the inner and under part of the posterior lobes. While tracing its fibres in this portion of its course two projections are observed, which have received the absurd appellation of *hippocampus major* and *hippocampus minor*; they are usually described as being situated in the descending and posterior cornua of the lateral ventricles.

In this division of our subject it will, I think, be advisable to inquire into the real character of these hippocampi, and the relation they bear to other parts of the brain, and thus do away with

[1] Rolando describes the septum lucidum as a folding in of the fibres of the hemispheres from the corpus callosum. The direction of its component fibres convinces me, however, that such cannot be a true view of its construction, and the fornix as a whole he views as merely a portion of the corpus callosum.

the mysterious importance which they have received in consequence of their being considered as isolated or individual structures entitled to an especial appellation.

If the hippocampus major be examined carefully in a brain that has been thoroughly hardened in spirits of wine, it will be found to consist of cineritious neurine covered by a thin layer of medullary fibres. The cineritious neurine is on the same plane, and continuous with the convolutions at the base of the brain, and is in reality a true convolution; the medullary fibres come from the under part of the cerebrum in various directions, and being collected at the inner edge of this body, form what have usually been called the posterior pillars of the fornix, or the tænia hippocampi, but which we must regard as the posterior and descending extremity of the longitudinal commissure.

The cineritious neurine over which these fibres of the longitudinal commissure, run from before backwards, and from below upwards, is, in fact, nothing more than a continuation of that neurine which constitutes a portion of the convoluted surface of the brain, neither more nor less, therefore, than a part of the hemispherical ganglion, but in this situation covered by the inferior fibres of the longitudinal commissure. It is in this way that the real character of the part entitled hippocampus has been obscured, and the necessity been imagined for conferring upon it an independent and absurd title[1].

The hippocampus minor is in some respects analogous to the hippocampus major; for it is formed by the projection of one of the fissures dividing the convolutions at the inner side of the posterior lobe, where it is covered by the posterior fibres of the longitudinal commissure. It differs from the hippocampus major in this respect, that the projection is caused by the *central* surface of the convolutions, and not by the *peripheral* surface, as is the case in the hippocampus major.

This account of the fibres which enter into the composition of the longitudinal commissure will prove to the student that this structure connects the cineritious neurine or *locus niger* of the crura cerebri with the convolutions of the hemispheres, as well as most of the convolutions of the same hemisphere together, and is in this respect distinguished from the transverse commissure, whose office is to connect the two opposite hemispheres together. It must be regarded, therefore, as an apparatus of union between different points of the same hemispherical ganglion.

There is another portion of cineritious neurine

[1] Mr. Mayo, in the edition of his elementary work on Physiology lately published, describes a cavity in the interior of this body which, however, appears to me to be no more than one of the ordinary fissures of the convoluted surface.

which I am compelled to mention in consequence of its being uniformly described in all descriptions of the brain under the silly name of *corpus denticulatum*; I say silly name, because it would have been equally wise to have given a particular appellation to every square inch of the convoluted surface as to this portion, which is partly covered by the posterior pillar of the longitudinal commissure. The *corpus denticulatum* is neither more nor less than a portion of the hemispherical ganglion, which, being brought into view according to the old method of dissecting the brain by cutting through the posterior pillar of the fornix, appeared to be a distinct part deserving an appropriate title.

SUPERIOR LONGITUDINAL COMMISSURE.

The fibres which have been thus described as forming the inferior longitudinal commissure, and connecting together distant convolutions situated on the same side of the mesial line, are not the only fibres devoted to this office; for if such were the case, those convolutions which are placed on a plane superior to the transverse commissure, would be unconnected either with each other or with those below the plane referred to, and would therefore differ most essentially in their anatomical relations from those which are placed below the said plane; there is, however, no such curious anomaly, but here, as everywhere else, Nature is consistent with herself, though anatomists generally have neglected to observe the fact. We do not find in most systematic works any mention whatever made of some fibres which, from their correspondence to those of the *fornix*, I shall designate in the aggregate, the *superior longitudinal commissure*, in distinction to the *fornix*, or *inferior longitudinal commissure*. Mayo, with his usual accuracy of observation, has delineated them in his Plates of the Brain, showing on their external aspect, what I have exhibited on their internal, in Plate X., where they are represented as they run above the transverse commissure on the edge of the longitudinal fissure. These fibres may be easily seen by removing the surface of the convolutions where they form the lower part of the outer wall of the above fissure; and from the centre of it these fibres may be traced either backwards or forwards. In tracing them forwards, we find them turning over the anterior edge of the transverse commissure, and running down to those convolutions at the base, which, forming the under and back part of the anterior lobe, are placed close to the *fissura Sylvii*: these fibres do not, however, form merely a narrow band, but an extended plane, the exact width of which cannot be defined, as its constituent fibres are in opposition to the internal surface of all that part of the hemispherical ganglion which is to the outer side of the longitudinal fissure. The posterior fibres run backwards in the same manner in which the anterior run forwards, terminating in like manner in the convolutions at the back parts of the hemispheres. No one, I think, can trace these longitudinal commissures without acknowledging the justice of Spurzheim's observation, when, after describing and reasoning on the composition of the fornix, and the apparatuses of communication in the brains of the lower animals, he says, "Thus, the especial pains which nature has taken to establish communications between cerebral parts cannot be overlooked, and it is this arrangement which enables us to understand the mutual influence of their functions respectively[1]." Nevertheless, it is rather extraordinary that he should make no mention of the fibres above described as constituting the superior longitudinal commissure.

OBLIQUE OR INTERCEREBRAL COMMISSURE.

The remaining commissure which demands our attention consists of medullary fibres connecting the two great cerebral masses, the cerebrum and the cerebellum together, as well also as the optic tubercles and the cerebellum; these fibres have been briefly noticed before under the name of the *oblique* or *intercerebral commissure*, consisting of

[1] Spurzheim's Anatomy of the Brain. London, 1826.

fibres thick and strong on each side, but extremely thin and delicate in the centre; the fibres are arranged longitudinally in both situations.

The constituent fibres of this commissure are not so simply arranged as we might in the first instance be inclined to suspect. To me they appear to be divisible into three sets; and as they are all collected together at the point where they enter the cerebellum, we shall describe them from that point forwards.

1st, The most *superior*, those in fact which form the surface of the processus è cerebello ad testes, and the valve of Vieussens, may be traced distinctly to the optic tubercles.

2ndly, The *external*: these form the external surface of the processus è cerebello ad testes, and may be traced to the side of the optic tubercles, and from thence to the optic thalami, and as far as I can discover, though I cannot speak decidedly, through that ganglion to the hemispheres.

3rdly, The third and last set are the deep or descending fibres: these may be seen by first dividing the cerebellum into two halves, then dividing close to the cerebellum that portion of the pons Varolii called the crus cerebelli, and the corpus restiforme. If the cerebellum be now raised, tearing up the intercerebral commissure, it will be found that some of its fibres descend, and in so doing interlace with the ascending fibres of the sensory tract: these descending fibres may be traced through the locus niger of the crus cerebri till they become continuous with the motor tract, and also with the portion of the longitudinal commissure or fornix which takes its origin at that point. See Plate XI. fig. 2 and 3, representing the relation of the fifth pair of nerves to this commissure.

A perpendicular incision having been made through the centre of the cerebellum, the course of this commissure into its interior may be next demonstrated, and at the same time that beautiful appearance, which from its resemblance to the branches of a tree is called the *arbor vitæ,* observed distinctly exposed.

RECAPITULATION.

On reviewing what has been said on the commissures it will be found that they may be arranged under three heads; the transverse, longitudinal, and oblique.

The *transverse commissures,* six in number.

1. The great transverse commissure of the hemispheres, or the corpus callosum.
2. The pineal commissure.
3. The posterior commissure, or commissure of the posterior cerebral ganglia.
4. The soft commissure, or commissure also of the posterior cerebral ganglia.

5. The anterior commissure, or commissure of the corpus striatum or anterior cerebral ganglia.
6. The commissure of the cerebellum or pons Varolii.

The *longitudinal commissures*, two in number.

1. The superior longitudinal commissure.
2. The inferior longitudinal commissure or fornix.

The *oblique commissure* is single; it consists of,

1. The intercerebral commissure, or processus è cerebello ad testes, with the valve of Vieussens.

CEREBELLUM.

The cerebellum having been thus divided, the two halves must be turned completely to each side; and then the posterior surface of the medulla oblongata being exposed, it will be seen that the posterior fissure of the cord has here expanded to a considerable size, the posterior columns as they pass under the cerebellum diverging so as to leave a space or fissure, already referred to as existing permanently in fishes, and named, from its resemblance in shape to a writing pen, the *calamus scriptorius* or *fourth ventricle.*

Covering the floor of this space and running at right angles to the mesial line some bands of medullary neurine may be seen, which are the terminations of the auditory nerve in their appropriate ganglia.

The general configuration of the cerebellum is all that need engage the student's attention at present, in as much as the minute description of each convolution and a lengthened account of their peculiar arrangement would not in the existing state of our knowledge lead to any useful result, either by enabling us to trace their analogy to corresponding parts in the lower orders, or by elucidating the share which the cerebellum has in the offices of the nervous system. Reil has entered with great minuteness into a description of its structure in the *Archiven für die Physiologie,* translated by Mayo in his Physiological Commentaries; and though I am anxious that the student should not burthen his memory at present by investigating the curiously complicated structure of this organ, he may hereafter consider it interesting to inquire further, in which case he will find the descriptions of Reil, as translated by Mayo, and introduced a little further on, to be his best guide.

Reil held, with Gall and Spurzheim, and I have no doubt he was correct in his opinion, that the "cerebellum is not composed of elementary portions essentially different, but is one homogeneous organ." As I understand the cerebellum, it is one instrument for the production of power, and not many instruments united together. It consists, like the cerebrum, of two hemispheres united anteriorly by a commissure called the pons Varolii; and by Reil it is described as being united posteriorly by another commissure, which, projecting on its upper and under surface, forms what have been called from their appearance the *processus vermiformis superior and inferior.* I confess this portion of the cerebellum does not appear to me to be an apparatus of union, but rather a centre of power placed in the mesial line and connected laterally with the two hemispheres, perfectly analogous to the cerebellum of the bird and hare, Reil himself stating that in the brain of the hare there is little more than a vermiform process. Indeed a mere section of it ought to be sufficient to convince us that it is no true commissure.

The surface of the cerebellum is analogous to that of the cerebrum, in so far as it consists of an extensive layer of cineritious neurine requiring, like the cerebrum, to be folded in order to pack it in the small space devoted to its reception: its appearance is, however, rather laminated than convoluted, the laminæ being divided by furrows of greater or less depth, more or less parallel to each other, and constituting each a segment of a circle, the convexity of which is turned backwards, and the horns forwards. The following minute description of its configuration by Reil, translated by Mayo, is the one alluded to. Let it be remembered, it is not intended for the perusal of the student who is only commencing the study of the brain, it will be more advisable for him to return to it when he has obtained clear but general views of the whole enkephalon.

"The cerebellum consists of laminæ of medullary matter [Mark Blätter], which are enveloped in cortical substance [Rinde], and are attached to medullary stems [Markstämme]. The medullary stems, on the one hand, branch into lobes [Läppen] and lobules [Läppchen], the subdivision ending with the laminæ; on the other, they unite to form central medullary nuclei [Markkerne]. From the latter, three processes are given off on either side, comprising two to the cerebrum, the pillars of the Vieussenian valve, two to the medulla oblongata, the corpora restiformia, and a third pair situated between the two former, passing to the annular protuberance.

"The cerebellum lies below the posterior lobe of the cerebrum, in a cavity, which is inclosed below and behind by the sphenoid and occipital bones, laterally by the petrous portions of either temporal bone, and above by a process of the dura mater. The cerebellum measures transversely, at its greatest breadth, from three inches and ten lines, to four inches; longitudinally, above, and in the centre, twenty lines: either lateral portion is about two inches long, and about sixteen lines thick at its middle. The lateral parts are called hemispheres [Seitentheile, Hämisphären]. The central part is called the general commissure [Mittelstück, Nath, Total-commissur, Wurm], and consists of two portions, the superior and inferior vermiform processes. The superior of these terminates at the commissure of the upper and posterior lobes. When viewed from above, the two hemispheres are externally circular; internally, where they approach to join the general commissure, their margin is deeply notched both before and behind. Thus two fissures [Ausschnitte] are formed, one looking forwards towards the cerebrum, and receiving the tubercula quadrigemina, termed the semilunar fissure [vordere halbmondförmige Ausschnitt]; the other backwards, which receives the falx cerebelli, termed the purselike fissure [hintere beutelförmige Ausschnitt], from its narrowness at first, and subsequent enlargement: in the latter is the line, at which the superior and inferior vermiform processes meet.

"The upper surface of the cerebellum is not horizontal, but raised a little anteriorly towards the tubercula quadrigemina, and depressed laterally and behind. The under surface is somewhat hemispherical, having along its middle a deep and broad depression, the valley [Thal], extending from before backward, in which the medulla oblongata is lodged, as well as the inferior vermiform process: the latter is separated from the hemispheres on either side by a furrow. The valley is broadest at its middle, where the pyramid is placed: behind this point it is contracted by the inner extremities of the lower and posterior lobes, and before by the almondlike lobes.

"I employ the term horizontal or lateral fissures [seitliche horizontal-Furche], to designate those depressions, which extend transversely across the fore part of the cerebellum, and contain the processes passing to the annular protuberance. These fissures are continuous with the intervals between the upper and under posterior lobes, which extend as far as the purse-like fissure: thus a deep furrow may be traced all round each hemisphere, dividing the cerebellum into an upper and an under portion.

"Either surface of the cerebellum is composed of that laminated structure, in which the medullary processes rising directly from the nuclei ultimately terminate: the laminæ are divided by furrows of greater or less depth, which are more or less parallel to each other, and constitute each a segment of a circle, the convexity of which is turned backwards, and the horns forward and towards the horizontal fissure. The deeper furrows pass down to the medullary nuclei, and form the boundaries of lobes: the shallower furrows, which are not continued over the entire surface of a hemisphere, form the boundaries of lobules. This structure is best understood from the vertical section of a hemisphere.

"In some places, particularly in the deep furrows between the lobes, and in the shallower furrows of the lower and posterior lobe, several laminæ are sometimes found united, so as to form an irregular band of short extent [ein Schwanz]; sometimes an abrupt and tonguelike projection [eine Zunge] arises from the bottom of a furrow, consisting of a few laminæ, not directly connected with any neighbouring lobe or lobule.

"Each hemisphere has five lobes, of which two compose the upper, three the under surface: these are, first, the square, or anterior and upper lobe [vierseitigen, vörderen oberen Läppen], which is seen on either side of the superior vermiform process, forming the fore part of the upper surface of the cerebellum. This lobe extends from the tubercula quadrigemina to the commissure of the upper and posterior lobe, and is united to the vertical process of the general commissure, and to all those portions of the horizontal process, which are given off above the single commissure. Secondly, the posterior and upper lobe [hinteren oberen Läppen] which forms the upper and posterior surface of the cerebellum, extends as far as its margin. The limits of this lobe are easily defined by tracing its union with its fellow, by means of the single commissure, and following from thence the furrow, which is continued outwards to the horizontal fissure betwixt this lobe and the next. Thirdly, the lower and posterior lobe [hinteren unteren Läppen]; this is united to its fellow by the short and exposed commissure, and by the long and hidden commissure; and sometimes it adheres to the posterior surface of the pyramid. The fourth, or slender lobe [zarten Läppen], is joined to its fellow, sometimes by the last laminæ of the long and hidden commissure, but for the most part by the laminæ of the posterior part of the pyramid. The fifth, or biventral lobe [zweibaüchigen Läppen] lies between the slender lobe and the almond-like lobe. The latter is pressed inwards towards the valley, while the biventral lobe is the last, which conforms to the circular arrangement of the parts upon the under surface of the cerebellum. This is distinguishable by its wedge-like form, by the direction of its furrows, which are nearly parallel with the medulla oblongata, and by its union with its fellow, through the anterior laminæ of the pyramid, in the valley.

"If we examine the contents of the valley, beginning at the upper part of the purse-like fissure, we find that they occur in the following order: above is placed the single commissure [einfache quer Commissur], by which the upper and posterior lobes of either hemisphere are connected; immediately below this the short and exposed commissure [kurzen und sichtbaren Commissur], by which the under and posterior lobes are united; below this again the long and hidden commissure [langen verdeckten Commissur], by which the under and posterior, as well as the slender lobes are joined together; next the pyramid [Pyramide] in the broadest part of the valley, a tongue-shaped body, somewhat flattened, and marked with transverse furrows on either side: then the spigot [Zapfen], a body smaller than the pyramid, towards which its base is turned, and the nodule [Knotchen], the last and least.

"On either side of the forepart of the valley, between the concave surfaces of the biventral lobes on the outside, and the spigot and nodule on the inside, and in contact with the posterior velum, lie the almond-like lobes; these are covered in part by the medulla oblongata: it is equally difficult to class these lobes as portions of the hemispheres, or as parts belonging to the valley.

"The medullary matter of the cerebellum exists in greatest volume in either hemisphere, constituting the medullary nucleus of each, whence the primary processes arise, which are expanded in an arborescent form to constitute the laminated circumference. Anteriorly the nuclei advance towards the medulla oblongata, inclosing laterally the fourth ventricle; each then divides into three processes or peduncles [Arme, Schenkel], of which one pair passes forwards to the tubercula quadrigemina, termed the peduncles of these bodies [Arme zu den Vierhugeln]; a second pair to the medulla oblongata, being its peduncles [Arme zum Rückenmark]; the third pair passes under the annular protuberance, constituting again its peduncles [Arme zur Brücke].

"Between the two superior peduncles, which pass to the tubercula quadrigemina, a medullary membrane is expanded, which adheres to the inner edge of either peduncle; this I call the anterior medullary velum [vördere Marksegel]: over against it is situated the posterior medullary velum [hintere Marksegel], which has a middle portion attached to the nodule, and two free semilunar portions attached to the flocks of either side.

"The flocks [Flocken] are a pair of additional processes found in the human cerebellum, and not in that of animals, which emerge obliquely from between the almond-like processes, the medulla oblongata, and the peduncles of the annular protuberance, and are connected by the posterior medullary velum; they seem as if they were the germs of two other lobes, and the posterior velum their intended commissure, which nature has not completed for want of room."

"*Vermiform processes*, or general commissure by which the two hemispheres of the cerebellum are united.—Under this title I include all those parts which are divided by a vertical section carried through the median plane of the cerebellum, viz. at the upper and fore part, the anterior medullary velum, the superior vermiform process ending at the single commissure, the short and exposed commissure, the long and concealed commissure, the pyramid, the spigot, and the nodule, which occur in the above succession.

"The following sketch may serve to give a general idea of the double arrangement of parts which is met with in the structure of the cerebellum: externally there would seem to be an apparatus, partly composed of vessels and cortical substance, in part again of the medullary matter immediately subjacent, which may be followed in its curvilinear course to the annular protuberance: this apparatus may be compared to the plates of a voltaic pile; the cortical and medullary laminæ, which compose it, are merely in apposition, and may easily be drawn asunder, leaving smooth surfaces. Internally, there would seem to be an apparatus, more or less analogous to the conductors of a voltaic pile; this internal part is continuous above with the tubercula quadrigemina, by means of the peduncles, which pass to these eminences; and below with the medulla oblongata, by the peduncles frequently termed corpora restiformia.

"This general plan seems to be followed on all occasions; in the cerebellum of the bird it is adopted in its simplest form: in this instance there is one erect pyramidal process, with double laminæ before and behind, in the medullary nucleus of which there exists a narrow conical hole, directed outwards, giving passage to the peduncles. The cerebellum of the bird represents indeed a vermiform process alone, and wants the lateral parts, which are superadded in animals more nearly allied to human beings in their anatomical construction, possessing in their place little germs or shoots scarcely discernible.

"The successive additions, which may be traced to this simple form of a cerebellum, consist but of parts of similar structure with the elementary part; sometimes these cohere with the primitive portion, by continuity of their medullary substance alone, being otherwise separate and distinct; in other cases the separation is slighter, and the new parts are continuous with the old, both through their medullary and their cortical substance; the former may be termed offsets (Ansätze), the latter wings (Flügeln) of the vermiform process. Among the lower animals, there are but few and simple offsets; higher in the scale, these become more numerous; the vermiform process extends itself laterally and receives wings, and in proportion as the wings are developed, the offsets diminish. The first improvement in the cerebellum takes place at its anterior and upper surface; while on its under surface the parts remain contracted and shrunken. The vermiform processes predominate even in quadrupeds, in length, breadth and depth; the fore part only of the cerebellum possesses distinct wings; laterally and behind, there are only offsets. In proportion as the fabric improves, the offsets are changed into wings, till at length in human beings the hemispheres are completed; and with the exception of the flocks, the offsets have wholly disappeared. All the parts are now brought together in compact order: the vermiform processes, with their wings, constitute one whole, between the parts of which the freest communication seems to exist, which the employment of offsets would interrupt.

"In the brain of the hare there is little more than a vermiform process: there are but few wings, and these slight and short: the lateral offsets are small. In the brain of the sheep the central lobe is large, firm and broad, but has neither wings nor offsets: the anterior velum is somewhat depressed upon the fourth ventricle. The next lobe in order is broad, of some length and depth, but has laterally short projections, not equal in their breadth to half the length of the vermiform process; these, however, may be viewed as wings. In the third lobe the organ is contracted, and has longer and larger wings; there follow, upon the under surface, a pyramid, spigot, and nodule, which have no wings, but a large bundle of lateral offsets; between the wings and offsets the peduncles of the annular protuberance emerge, and mark the place of the horizontal fissure. The whole cerebellum has a globular form, which results from the projection of the vermiform processes. The latter stand more or less vertically over the medulla oblongata, and have an anterior and a posterior surface, which correspond with the superior and inferior surfaces of the same parts in the human brain. The lateral offsets in the higher animals are more and more driven from the fore to the back part of the cerebellum, until at length, in the human brain, they are exchanged for the lobes of the inferior surface, which unite with the inferior vermiform process. The whole cerebellum seems indeed pressed backwards, as its parts become more complex; so that the central lobe continually emerges more and more from between the peduncles of the tubercula quadrigemina, and in the human brain lies fairly behind these bodies, the common anterior stem being directed upwards, and the posterior horizontally. In the brain of the ox the central lobe is large, and without wings; the remaining lobes of the anterior surface are of inconsiderable dimensions: on the posterior surface, the pyramid, spigot and nodule are barely separable; they are without wings, and have scarcely offsets. Lastly, in the brain of the horse the central lobe is large, and without wings, but of less size than in the ox, and more compressed from above downwards. The next lobes of the vermiform process have anteriorly larger and longer wings, which are bent forwards, contracted in their middle, and at their ends have a clublike thickening. The upper and posterior lobe is distinct; but the under and posterior, the slender, the biventral, and almondlike lobes are wanting, and in their stead a large bundle of irregular offsets is found on either side of the pyramid, the spigot, and the nodule.

"Thus the enlargement of the cerebellum proceeds from the central primary portion; to which new processes, as wings or offsets, are continually added, in proportion as the scale of its improvement rises. In quadrupeds, and even in the human brain, traces of the simplest type of a cerebellum are to be seen in the central lobe, illustrating further the principle on which its improvement proceeds. The furrow between this lobe and the lateral processes connected with it, is so deep, as to leave it doubtful whether the latter are properly wings or offsets.

"In the human brain the wings form the principal part of the cerebellum, viz. the hemispheres. On the upper surface these are immediately prolonged from the vermiform process; on the under surface they seem incomplete, being separated by a deep furrow from the inferior vermiform process on either side. It is remarkable that the human cerebellum, the most complex in its structure of any, should yet exhibit a resemblance of the clearest kind to the primitive and elementary form. When the human cerebellum is placed with its usually horizontal axis in a vertical direction, it may be rigorously compared with the cerebellum of birds: what in the latter case is a single lamina, is here subdivided, and has become arborescent; in the one case single leaves, in the other, lobes, lobules, and finally leaves, are raised around the nucleus, forming a dense investment to it, from under which the peduncles project on each side, like the finlike feet from under the shell of the turtle.

"In proportion as the lateral parts increase in the shape of offsets or wings, the vermiform processes become smaller, as if compressed towards the centre. This circumstance is most apparent in the human brain: the vermiform processes are there comparatively diminutive in every dimension, in length, breadth, and depth: before them spring out the horns of the semilunar fissure, behind them the projecting margin of the purse-like fissure: within the latter, and at the place of the spigot and nodule, the inferior vermiform process is scarcely a few lines in breadth. In animals the vermiform processes overtop the lateral portions; in man the upper surface of the general commissure is only on a level with the hemispheres, while below it is contracted and shrunken to the bottom of the valley. This compression of the general commissure on all sides in the human brain, accounts for the difference observable in its structure as compared with that of the hemispheres; a difference which is not found in the brains of quadrupeds. In its texture this part in the human brain is softer, and its membrane firmer and more vascular than is the case in the hemispheres. The medullary matter is here again in thinner layers than in the hemispheres: thinly spread out in the anterior velum, it forms a thicker mass at the meeting of the vertical and horizontal process, where the nucleus of the general commissure begins: in the former process it exists in greater quantity than in the latter, and finally it forms an extremely thin layer in the posterior velum. In the anterior fissure the general commissure has its greatest breadth, becoming narrower as it passes towards the purselike fissure: in the single commissure, where it has shrunk to a single lamina, and in the short commissure, it continues still narrow; it becomes broader again at the pyramid, and finally tapers to a point in the spigot and nodule. On either side of the superior vermiform process there are furrows of greater or less depth, at which the laminæ are thinner, and indented, and their direction altered; so that whereas the convex margin of the laminæ of the hemispheres is directed backwards, that of the laminæ of the superior vermiform process looks forward. In these furrows, by which the lateral limits of the superior vermiform process are defined, blood-vessels are lodged: these furrows are continued along the valley, where they become deeper.

"Looking generally at the vermiform processes, we observe that they are composed of corresponding portions on either side of the median plane, that there is no material difference in the structure of the upper and under portions, and thus that the whole is one homogeneous organ. We may observe further, that whereas in birds these parts constitute the whole of the cerebellum, and in quadrupeds the principal portion; in human beings, where their relative bulk is trifling, compared with that of the hemispheres, they are, on the one hand, parts of the same composition and nature with the latter, and on the other may be considered as the general commissure, by which the lateral portions are intimately united."

PEDUNCLES OF THE CEREBELLUM.

The medullary fibres, which may be described as either emerging from or terminating in each side of the cerebellum, consist, as already stated, of three sets: 1st, the commissural fibres of the two hemispheres, called where they emerge the *crura cerebelli*, in the centre *pons Varolii*; 2ndly, those of the oblique or inter-cerebral commissure; and 3rdly and lastly, those from the anterior and posterior columns of the cord, the *corpora restiformia*. These three sets are described by Reil as the three peduncles of the cerebellum.

"The three peduncles," says Reil, "on either side may be considered as forming by their union two medullary columns, which are directed at first backward and outward; these enlarge into coarsely fasciculated masses, which contain, near the middle of each hemisphere, the ciliary bodies, and are finally inclined inwards in a circular course towards the general commissure; the central mass on either side is surrounded by a laminated stratum, and, in union with the latter, constitutes the medullary nucleus: upon the exterior or laminated stratum the lobes and their subdivisions are placed: in the history of the latter two distinct points claim our notice, viz. the structure of each part, and the manner of its articulation with the neighbouring surface. As the same plan is everywhere followed in these respects, the complete understanding of any single portion of the surface involves a knowledge of the whole.

"The lobes, lobules, and their subdivisions, consist of medullary plates, which are arranged in succession, one behind the other, and are parallel to the outward furrows; each medullary plate again consists of fibres, which are radiated, and converge from the circumference, generally towards the centre of each hemisphere; but sometimes, as in the almondlike lobes, another imaginary centre is produced by the peculiar form of the part towards which its fibres converge. In the stems and branches of the lobes, that is to say, when nearer the nucleus, the fibres are found to be coarser and stronger than at the surface of the cerebellum.

"In consequence of their radiated structure, the medullary plates tear very readily in the direction of their fibres, but do not yield any regular fissure when an attempt is made to tear them transversely. The fibres have a glittering, bubblelike appearance, when viewed through a microscope.

"In brains which have been long in alkohol, and appear thoroughly hardened, threads as fine as those of the silkworm may be raised from the stems, particularly in their middle: whether the substance of these threads correspond in any respect with the cellular texture between the fibres of muscles, is extremely uncertain.

"The particular contrivance, which I call an articulation [Articulation], exists, wherever subdivision or branching occurs, as of the stem from the nucleus, or of branches from a stem, as well as when a slighter medullary layer lies upon a larger: it may be mentioned here, that the parts of the cerebellum are rather contiguous to, than continuous with, each other: the truth of this position will appear in the sequel. The articulations are disposed in lines parallel to the course of the laminæ, and consist of a projecting linear ridge on one surface, and a corresponding furrow on that opposed to it: the ridges are more or less acute or rounded: the surface between any two ridges is slightly hollowed..... It is necessary to distinguish from this mechanism those sharp and minute projections which exist in the angle at which any two branches of equal bulk meet; such projections are acute, and consist of two portions adhering without an intermediate furrow. Every lamina is naturally separable into two equal lateral portions: at the centre of the base of each lamina is found an angular furrow, which receives the ridge of the surface below. If a lobule be divided in its axis, and from the exposed surface of either half, the medullary plates be successively raised in a direction from the base towards the apex, to that, on which the ridges exist for the articulation of the laminæ; and this last lamina, instead of being raised as the preceding, be peeled off crosswise, medullary plates are seen extending from the ridge into the centre of the lamina. Similar ridges exist on other occasions where medullary plates are joined: the ridges are slighter, in proportion as they are remote from the nucleus. A rent made from the outer surface of a lamina towards the centre, does not pass directly to the nucleus, but from the lamina, through the branch on which the latter is placed, from this branch again through its stem, and so on towards the nucleus. The middle medullary plates of the laminæ do not pass to any adjoining branch, but are continued down the branch on which the lamina is placed. A similar disposition is observed in the connexion between minor branches and larger branches, and in that between the latter and their stems: the exterior plate alone skirts accurately the margin of each subdivision, and may be traced re-ascending, and lining in succession those beyond: the internal plates follow the course of the stems and branches. These facts may be ascertained when a lobe is opened from its base and everted. The medullary plates of the stems pass into the branches and their subdivisions, and even into the laminæ.

"Having made these general remarks, I will describe specifically each part, beginning at the circumference, and passing inwards to the nuclei: and first of the laminæ*.

"The cortical external covering of the laminæ consists of two layers; the outer of which is grey,

"* By laminæ [Blättchen] I mean the ultimate subdivisions of the lobes of the cerebellum, which are composed of a central medullary, and an external cortical portion; for the most part they project at an acute angle; they vary in form, magnitude, and direction. The cortical matter is not confined to the laminæ, it is equally spread over the furrows between them; it is however limited to the surface, with the exception of its contributing to the ganglions within the medulla. The medullary substance of the cerebellum again is everywhere covered with cortical matter, excepting on the surfaces of the fourth ventricle, the stems of the flocks, the medullary vela, and the peduncles; which parts, it may be presumed from this circumstance, have an office different from the rest.

the inner of a dirty yellow. The outer layer may be removed from the inner, and the inner again from the medulla, leaving smooth surfaces, and apparently without the rupture of an intermediate substance. By immersion in alcohol the cortex becomes white, the medulla yellowish, but more so in the laminæ than elsewhere. The cortex is of a looser, more spongy texture than the medulla. These circumstances, and what I have mentioned above, of the continuity of the layer of medulla immediately within the cortex, may lead to the conjecture that the latter is formed as if by precipitation from the investing pia mater, and that its colour changes gradually to yellow, and then to white; and it may even be worth inquiry, whether the whole substance of the cerebellum be not thus formed. One circumstance I would mention in connexion with the preceding remarks, that the pia mater in the fœtus is unusually firm, when there is no distinction between cortex and medulla in the substance of the brain.

"The central part of the laminæ consists of slender plates, which lie in close apposition, and admit of being separated. These plates are composed of fibres, which are nearly parallel, are directed towards the extremity of the laminæ, and are covered on every side with cortex. The external plates are reflected from one lamina to another. If the external plates be followed to the centre of the base of any lamina, from the interval on either side intervening between this lamina and the next above and below, they will be found to meet abruptly; and at an angle with their former course, and parallel with each other, and in the axis of the lamina, to pass to its extremity. Where these plates meet is the angular furrow belonging to their articulation, beginning at which it is easy to separate the lamina into two equal and similar portions. Intermediately between the external plates thus described, other medullary plates, derived from the medulla of the branch itself, enter each lamina, which may be distinctly traced for at least half the length of the lamina.

"From the lateral surface of a lobe or lobule, lamina after lamina may be successively removed with the handle of a scalpel and the forceps; along with each lamina a medullary plate is torn down; the first of which, that namely corresponding with the lamina nearest the base, may be traced reflected along the opposite surface of the adjoining branch. At the point where the lamina is first raised, and at the place of its natural articulation, a ridge is seen: if the next lamina be raised, another ridge is seen, belonging to the articulation of the second; and if this be then drawn towards the base of the lobe, along with its corresponding medullary plate, the ridge is lost, on which the former lamina had been placed, but remains still distinct upon the plate last separated. In this manner the laminæ on each side of a lobule may be removed to the central plates. Every lamina, however, does not bring away with it a medullary plate: whether it be, that all the laminæ have not a plate derived from the centre of the branch, or, that if they have, its slightness renders it often impossible to remove it singly. Thus a lobule is peeled from the outside to its central plate, much in the manner of various parts of plants.

"If a lobule be selected, the laminæ of which pass off at a right angle nearly, and one of these be pressed towards the apex, and upon its thus exposed surface a slight incision be made, the thin medullary plate, which may then be raised, will not pass from the base of the lamina along the axis of the lobule; but will be found continuous with, or reflected so as to form the outer medullary plate of the lamina next in order towards the base of the lobule. A similar result ensues, if an incision be made upon the external margin of a sufficiently broad lamina in the direction of its axis, and either lateral portion be pressed towards the adjoining lamina; the separation will continue down the first parallel to its axis, and then ascend the second lamina in the like direction. If again the cortical matter be removed from a few laminæ, and from one surface of a thus denuded lamina a fine layer be drawn with the forceps, the rent will first descend parallel to the axis of the denuded lamina, then run at an angle along the interval leading to the next lamina, which it will in turn ascend.

"If a thin lobule be torn asunder in its axis, and its layers be raised in a direction from the base towards the apex in succession, so as to leave the external layer only, there is an appearance as of cylinders lying in close lateral apposition: the projections in this case correspond with the intervals between the laminæ; and the angular furrows, to the axes of the laminæ: each lamina will open at these furrows, and finally divide into two equal portions. If care be taken not to complete this separation, each lobule, and even each entire lobe, may in this way be unfolded, and its arborescent appearance converted into that of an expanded membrane. The better mode of thus unravelling a lobe is the following: a portion about an inch broad is to be cut out of a fresh cerebellum, and placed for from twelve to twenty-four hours in a weak solution of caustic potass, then in distilled water for some hours more, and finally left for from twenty-four to forty hours in pure alcohol. Very little force is necessary to unfold the parts of such a preparation in the order above described. By a somewhat similar process the medullary plates of the lobes and lobules may be shown: an indurated cerebellum is to be placed in a weak solution of caustic potass, for from twenty-four to forty-eight hours, and subsequently reimmersed in alcohol for a few days, if the solution of potass has rendered it too soft. From a lobe thus prepared, the laminæ, with their adherent medullary plates, may be easily separated in succession. When several laminæ have been removed, it may well be seen how one or more plates of the central medulla of each lobule enter the furrow at the base of each lamina, and proceed towards its margin. The same observation may be varied by drawing off, in the direction of the furrows, the external medullary plates. If a lobule be split from its base, the fissure does not always proceed to the circumferential extremity, but often breaks short off into the centre of a lamina.

"The composition of the lobes and lobules is accurately the same as that of the laminæ; only that the medullary axes of these larger parts are larger in proportion; but they equally admit of a central division, and their outer layers are reflected in a similar manner along the opposite surfaces of the adjoining similar parts. For the articulation of a branch with a stem, a lobule with a lobe, the latter shows at the line of separation a slight projecting ridge, which is received into a furrow in the latter. If the square lobe be broken off from the nucleus, and the laminated stratum be peeled from its internal surface, an appearance of apposed cylinders, or of parallel raised surfaces, with intermediate furrows, is seen; resembling, though on a larger scale, the internal surface of the laminæ. The entire lobe may be then unfolded, the separation commencing at the intermediate furrows: the parallel raised surfaces again correspond to the interval between the lobules; they are not always rounded, but sometimes angular and wedge-like. Finally, the lateral plates of the lobules are reflected to the opposite sides of the neighbouring lobules, and the entire lobe itself, as well as the lobules, laminæ, and their investing cortex, seem as if they might be the result of successive depositions from the surface. Hence it is that rents from the circumference toward the centre do not penetrate the nucleus, with the exception indeed of that carried between the upper and under posterior lobes. In this case the rent is successfully carried through, in consequence of striking an interval between the circularly disposed fasciculi, which inclose the ciliary bodies; the rent has every appearance of doing violence, and the radiated fibres of the lobes meet those of the nucleus at an angle.

"The lobules are articulated by means of ridges and furrows with the nucleus. To the square lobe there are mostly but three strong ridges, and several lobules attach themselves to the anterior of these; hence the ragged appearance of this ridge, when the lobe in question is broken off. When the square lobe is raised from the horizontal fissure towards the superior vermiform process, a similar appearance is seen to what occurs in stripping the medullary plates crosswise from the laminæ; viz. that of medullary plates entering the central furrows from the ridges, which correspond with them.

"From what has been said it appears, that in the structure of the lobes, plates composed of medullary fibres are merely laid in successive layers upon the nucleus; a remark which is confirmed by these additional facts; that there is no relation between the volume of the hemispheres and that of the medullary columns; that the medullary substance of the branches does not diminish in proportion to the minor branches given off from them; that the radiation in the lobes has in many places a different direction to that in the nucleus; and lastly, that the lobes and lobules of either surface overlap the medullary columns on either side of the horizontal fissure. It appears that the fibres from the circumference crowd together towards an imaginary centre, and thus exhibit internally an irregularly fissured surface, when they reach the nucleus, the next part for our consideration.

"Immediately within the lobes a laminated stratum exists, which forms, on the one hand, the surface supporting these processes, and on the other, the exterior shell of the nucleus. This it is, which requires to be peeled from the internal surface of the square lobe, after its removal, as above alluded to, in order that the alternate risings and furrows at the base of its lobules may be seen. I have been able frequently to raise two, three, and more medullary plates in succession, between one ridge and another, especially between the posterior ridges. It would seem as if the component fibres run across each intermediate furrow, and meeting, form each ridge, and mount together into the lobules. There are found, besides, some coarser fibres in the direction of the ridges, which cannot be raised without breaking up their adhesion to the sides of the medullary columns; perhaps these are but layers, which serve to fill up the intervals: the stratum itself seems, as the preceding parts, to be formed in layers, as by successive depositions.

"The last part is the stratum of coarse and curvilinear fasciculi, which is specially continuous with the lateral peduncles of the cerebellum, and together with the anterior and posterior peduncles and the ciliary body, constitutes the central part of the nucleus of either side. The lateral peduncles ascend backwards and outwards in the horizontal fissures, expand themselves in the upper and under portions of the hemispheres, and at the same time incline inwards, being curved more abruptly at the fore part than near the posterior margin. The anterior division of fibres throws itself over the anterior peduncles, and with the next set pursues a course towards the general commissure: a third set of fibres passes parallel to the medulla of the general commissure, towards the purselike fissure, to the posterior margin of the posterior lobes, the radiated fibres of which are placed at an angle upon them. If, on the removal of a portion of the posterior lobes, part of the nucleus is brought away besides, the two portions either naturally separate, or are only retained by their mutual indenting, the furrows for which are parallel to the circular course of the fibres of the nucleus. Between the middle peduncles, which form the capsule of the ciliary body, (which consists of lobes again, and may be raised from this capsule,) and the anterior peduncles, the posterior plunge; and along with the middle peduncles, mount over the anterior. The anterior peduncles pass directly backwards, pierce the lobes of the ciliary body with delicate fibres, and lie close upon and parallel to the anterior velum, and the nucleus of the general commissure."

TRACTS OF SENSATION, OR SENSORY TRACTS.

We must now return to the medulla oblongata for the purpose of tracing those tracts of neurine which Sir Charles Bell has proved to be employed in conducting sensation. It has been already stated that in the composition of the spinal cord we can observe no line of demarcation by which the tract of sensation may be distinguished from that of motion, but that a portion of the cord anterior to the posterior fissure is distinctly ascertained to be appropriated to this function; I shall assume therefore that the line of demarcation is about the middle of the lateral aspect of the cord, and that the sensory column, or tract of sensation, consists of two portions, the one posterior to the fissure referred to and consequently named the posterior column, the other anterior to it, constituting part of the antero-lateral column. These two portions had better be traced separately. Commencing with the posterior division, or, in other words, the posterior columns, we find them ascending to the cerebellum, and in their course to that mass forming a portion of a body previously noticed in describing the anterior columns, viz., the *corpora restiformia.*

In their passage to the cerebellum, as a portion of the constituent fibres of these bodies, they are partly overlapped by, and partly interlace with, those fibres from the anterior columns which, ascending to the cerebellum, connect the motor or voluntary tract of the spinal cord with the cerebellum as well as with the cerebrum; and let me again repeat that the fibres which compose the corpora restiformia are not arranged in the simple, regular, parallel manner in which we find them in the body of the cord, but interlace, forming rather an intricate plexus.

The remaining portion of the tract of sensation, or that portion of the sensory column which is anterior to the fissure from which the posterior roots of the spinal nerves emerge, and whose line of demarcation with the motor tract has not yet been decided, but is supposed to be about the middle of the lateral aspect of the cord, must next be traced to its destination. In the first place we find it sending some fibres, like the posterior columns, to the cerebellum; the rest of its fibres ascend principally to the outer side of the *corpus olivare* or *pneumogastric ganglion*, and plunging into the *commissure* of the *cerebellum* or *pons Varolii* pursue their course to their appropriate ganglion, the *posterior cerebral ganglion*, better known, as before stated, by the name of the *thalamus nervi optici*. On their emergence from the pons Varolii, the fibres of the sensory tract form the upper part of the crus cerebri, separated in that body from the motor tract by that deposit of cineritious neurine called the *locus niger*, as previously mentioned: the sensory tract where forming the upper layer of the constituent fibres of the crus cerebri is covered superiorly by the optic tubercles and the intercerebral commissure.

The course of the fibres through the *posterior* *cerebral* ganglion is not so distinctly marked as that of the motor tract through the anterior; for here the medullary fibres are not so decidedly separated from the cineritious; the two appear more intimately mingled. From the outer side of the posterior cerebral ganglion the medullary fibres issue forth, spreading in every direction until, meeting with the convoluted surface of the brain or the cineritious neurine of the hemispherical ganglia, their progress is arrested and their course terminated.

The course of this tract through the *posterior cerebral ganglion* or thalamus nervi optici and its expansion in the hemispheres is beautifully shown in Plate VIII., which has been copied from Gall's large work, representing a side-view of these columns.

The relation of the motor and sensory columns of the cord, as forming part of the cerebrum, with their appropriate ganglia, is thus described by Sir Charles Bell in his paper in the Philosophical Transactions above referred to: "The thalamus forms a nucleus round which the corpus striatum bends, and when their respective layers of stria make their exit beyond these bodies to form the great fan, or solar-like expansion into the hemisphere of the cerebrum, their rays mingle together. A rude representation of these two parts of the cerebrum as we have traced them may be made with the hands. If I place my wrists together, parallel, and closing one hand embrace it with the other, I represent the two portions of one crus. The closed fist is the thalamus, and the other is the corpus striatum. If I then extend my fingers, interlacing their points, I represent the final distribution of the portions of the nervous matter which are dedicated to sensation and volition."

The best mode of dissecting these parts, for the purpose of tracing the sensory columns, as just described, and which perhaps will give the most correct ideas of their relative position to the parts with which they are connected, is to lay the brain upon its under surface, and then to make a perpendicular section through the mesial line, from before to behind, of the whole cerebral mass: this section will divide, it is true, all the transverse commissures; all those structures, in fact, which connect together corresponding parts placed on opposite sides of the mesial line; consequently, these apparatuses of union must be studied in another brain, should they not have been previously traced as suggested above. This section will bring the following parts into view, and in the following order. The similarity of the parts exposed to those composing the cerebral mass of the turtle, cannot fail to arrest the attention of the student.

Let me remark, that though most of the parts to be observed in the following view have been already described under a different aspect, I speak of them again without reference to the previous notice. Commencing from behind, and proceeding forwards, may be observed,

1. The *medulla oblongata*, divided in the mesial line. Anterior to this, and rather superior to it, is

2. The *pons Varolii*, or commissure of the cerebellum; above and behind the pons is

3. The *cerebellum*, presenting that curious and beautiful appearance resulting from the disposition of cineritious and medullary neurine, before mentioned as the *arbor vitæ*. If the student carry his eye along that portion of the medullary neurine which corresponds to the stalk of the tree, he will find it emerging from the cerebellum, and turning up to a little rounded body about the size of a small pea; immediately anterior to which is another of rather larger size; the two together are

4. The *optic tubercles*, or *corpora quadrigemina*, the posterior being the testes, the anterior the nates.

The structure which has been likened to the stalk of the tree, will be recognised as the commissure connecting the greater cerebral mass to the lesser, in other words, the cerebrum to the cerebellum; this is

5. The *intercerebral commissure*, or, from its oblique position in the skull, the *oblique commissure*.

Beneath the optic tubercles we observe, rising up, as it were, from the pons Varolii, a structure previously mentioned, namely,

6. The *crus cerebri.* A section of this part shows it to consist of medullary neurine above and below, with cineritious interposed between the two. The medullary neurine, which is above the cineritious, is the sensory tract, that below, the motor tract. The cineritious neurine has been long known to anatomists by the name of *locus niger*. Immediately in front of the crus and optic tubercles is a rounded nodule of considerable size, being about the same dimensions as the pons Varolii, called

7. The *thalamus nervi optici* by anatomists of the old school, the *posterior cerebral ganglion* of the cord by more modern teachers.

Anterior to this ganglion, and partly overlapping it, will be observed some fibres, which, appearing to spring from the under part of the brain, run backwards and upwards; these fibres form a portion of a longitudinal commissure or fornix.

If these fibres be removed, another rounded nodule of neurine will be exposed, which has been already observed upon its under surface; this is,

8. The *corpus striatum*, or *anterior cerebral ganglion*, in front of and behind which, are

9. The hemispheres, formed of the fibres of

the cord, commissural fibres, and hemispherical ganglia. For a view of these parts see Plate X.

TUBER CINEREUM. INFUNDIBULUM. PITUITARY GLAND.

The only structures which now remain to be noticed are situated at the base of the brain, namely, the *tuber cinereum*, *infundibulum*, and *pituitary gland*. The tuber cinereum is so called from its consisting entirely of cineritious matter; and whether it should be classed among the apparatuses of union—the commissures, or the centres of power—the ganglia, I do not feel capable of deciding; but from the circumstance of the optic nerve sending some filaments into its substance, and the longitudinal commissure deriving several from it, I am inclined to view it as an instrument of power connected in some way or other with the phenomena of vision. Its general form has been already noticed in the description of the base of the brain.

Neither can the *infundibulum*, a funnel-shaped tube, which evidently derives its name from its shape, be indubitably arranged under either head; nor shall I attempt any explanation of its nature. The pituitary gland is involved in the same mystery, and though no physiologists in the present day consider it to be a secreting organ, none have given any rational explanation of its real nature, or the relation which it bears to other parts of the nervous system.

RECAPITULATION.

The description of the course and termination of these tracts of medullary neurine being now concluded, and all the fibres composing the extensive convoluted layers of cineritious and medullary neurine which form the hemispheres, made known, it will I think be useful to take a general review of their character, by a recapitulation of what has been stated in detail separately.

In the first place, we have an extensive surface of cineritious neurine, the *hemispherical ganglion,* which, in the higher orders of animals, is convoluted or folded in a peculiar manner.

In apposition to the whole of the *central surface*[1] of this ganglion, there are medullary fibres which always present their extremities to the cineritious substance, as represented in Plates VII. and VIII.

These fibres which have their extremities in contact with the central surface of the ganglion are disposed of in three different ways; 1st, some of them, commencing[2] from the convolutions of the

[1] By the *central surface,* I mean that surface which is the most internal as regards the exterior of the skull.

[2] I make use of the term 'commencing' here merely for the sake of simplifying the description of their direction with reference to function.

anterior, middle, and posterior lobes, pass through the corpora striata, and forming the inferior layer of the crus cerebri, pass through the pons Varolii, so as to form the anterior columns of the cord, as previously described, the *motor tract*: 2nd, others commence in the cord, and after passing the pons Varolii, and emerging from the substance of the thalamus, terminate in the same neurine that gave origin to the last; this is the *sensory tract*: 3rd, others, passing from one side of the brain to the other, and in apposition with the internal surface of all the convolutions, are those fibres which, collected into a mass, form between the hemispheres that wide bridge, if I may so call it, the *great transverse commissure*, or *corpus callosum*. But these are not all, for, 4thly and lastly, in contact with all the convolutions, are the fibres of the superior and inferior longitudinal commissures, which, connecting together those convolutions which are situated on the same side of the mesial line, so far differ from the transverse commissure, which connects those situated on opposite sides.

From all that has been thus stated regarding the composition of the hemispheres, I think it will be seen that they are principally composed of fibres, which radiate from the extreme surface of the two large ganglia of the anterior and posterior columns, as from a common centre, forming, however, in their radiation, only half a circle. The description of their gradual development in the fœtus will assist the student very much in his endeavour to form a correct judgement as to the relation which they hold to the upper part of the cord, which I have elsewhere likened to the head of a walking-stick, around the neck of which a piece of cloth being attached, has been drawn over so as to surround it: for even so do the hemispheres envelop the thalami and corpora striata.

From the above description the student will also perceive that the enkephalon or brain in the human subject is not a large solid mass of matter, in the interior of which are cavities scooped as it were out of its substance to be appropriately denominated ventricles, but that it really consists of nodules or collections of cineritious neurine, placed on each side of the mesial line, some of them being the appropriate ganglia of the nerves of sensation; as, for instance, the olfactory tubercles, the optic tubercles or tubercula quadrigemina, the auditory tubercles or posterior pyramidal bodies, the pneumo-gastric tubercles or olivary bodies, and others, being the motory and sensory ganglia, as the corpora striata and thalami nervorum opticorum. The hemispherical ganglia again, that they might present the greatest possible extent of surface, are folded up into innumerable plaits, and thus cover or surround every other ganglion within the cranium, so that on first removing the skull-cap nothing can be seen but the convoluted surface of these extensive ganglia.

And here let me insist upon this important principle in the study of the brain, which is also one of the first ideas that the student should acquire regarding its composition, namely, that it consists of corresponding or symmetrical parts on each side of the mesial plane, and that instead of regarding the fissures of separation between its different portions as forming ventricles or cavities, he must direct his attention to the ganglia which bound the fissure, and the structures called commissures, which, connecting them together, cross the fissure and necessarily alter its character in different points, masking it, it is true, but not at any place changing the fissure into a true bag or circumscribed cavity, for the 3rd, 4th, and 5th ventricles, and the iter a tertio ad quartum ventriculum, are in truth no more than the posterior fissure of the cord, considerably dilated, viewed in different situations, difficult enough to be understood when seen in the ordinary mode of dissecting the brain, but which seem necessary and obvious when its parts are traced in connexion with one another.

In conclusion let me express the hope that these views, or analyses, if I may be allowed so to call them, of the component parts of the enkephalon will really simplify the whole of its anatomy, and materially assist the student in acquiring a knowledge of its true character, without requiring him to burthen his memory with fanciful and unmeaning names, for it will be perceived that instead of learning a long catalogue of the contents of the lateral ventricles as they are erroneously designated, and puzzling his brain with the absurd titles of hippocampus major and minor, pes hippocampi, ternia hippocampi, cornu Ammonis, &c., &c., he has simply to observe how the spinal columns appear to terminate superiorly in two large tubercles, *the corpora striata* and *thalami*, from the sides and under parts of which the hemispheres springing out, and being afterwards reflected so as completely to envelope this bulbous extremity of the spinal cord, a space is necessarily left which requires no peculiar title to remember it by. The third ventricle, as a fissure separating the two halves of the brain, he cannot fail to observe; and his particular attention is left free to be directed to the commissures which pass across it to connect the different cerebral ganglia with one another. It will thus be seen that the description of the relative position of these ganglia, the commissures connecting them, and their relation to the ganglia and columns of the spinal cord, comprehend all the information which is either interesting or useful to the student.

PART IV.

CEREBRAL NERVES.

Having thus considered both individually and collectively the various centres of power which constitute the enkephalon in man, we shall next direct our attention to those organs which conduct the mandates of the will outwards and the different perceptions inwards, universally known by the title of *nerves.*

Connected with the enkephalic ganglia and that portion of the motory and sensory tract which is contained within the skull, there are, according to some authors, eleven pairs of nerves, in the opinion of others no more than nine. Each nerve is distinguished by an appropriate name in addition to its title derived from its numerical position. This difference in the number of nerves reckoned by different anatomists arises from the fact that some describe the 7th pair or facial, and the 8th pair or auditory, as if they were merely portions of the same nerve, whose office was analogous although their distribution might be different; whereas the fact is that they are as distinct instruments of two dissimilar kinds of nervous power as the optic nerve and the olfactory nerve, and are therefore equally well entitled to appropriate and distinguishing appellations. If it is often found convenient to employ numerical names in speaking of the cerebral nerves, it is still very important that no single number should be given to two nerves *physiologically* distinct, however closely they may be connected. The glosso-pharyngeal and pneumogastric nerves have also, like the auditory and facial, been till lately described as forming the 8th pair of cerebral nerves. In this instance we are not perhaps authorised to separate these two nerves from any decided proofs of their having distinct functions ; on the contrary, we are rather led to regard the two as mere portions of the conducting instrument of one and the same nervous power. Nevertheless as one division or root of the old 8th pair is now invariably described under the title of the *pneumo-gastric*, and the second division is constantly spoken of by the name of the *glosso-pharyngeal* when they have passed out of the cranium, it seems important that the two should still be distinguished by distinct numerical designations when within the skull. Upon these grounds I shall follow the arrangement of Soemmerring, who describes eleven pairs of cerebral nerves. Not indeed that I am altogether satisfied of the correctness, in a strictly physiological point of view, of this procedure, for if it be proper to separate the seventh and eighth pairs into two nerves each, it would be strictly correct to consider the third pair and the sixth as merely separate roots of the same nerve, and to describe the two together by the name of *the common oculo-muscular*; for the circumstance of the commissure of the cerebellum separating their roots is merely accidental to their arrangement in a physiological point of view; but the fact of their being described as if they were distinct nerves has frequently led the student to believe that they must be endowed with distinct offices, and wonder why the abductor muscle of the eye should be supplied by a peculiar nerve, while the other muscles, with the exception of the superior oblique, receive their supply from the same source. Again, I see no advantage in describing the glosso-pharyngeal otherwise than as a portion of the pneumo-gastric, for its office is evidently connected with the phenomena of respiration, as will be explained hereafter.

Most authors, with the exception of Spurzheim, who fell into the opposite mistake, have erroneously described all the cerebral nerves as originating in the brain. The fallacy of this idea, and the vicious method of description that resulted from it, have been pointed out in the section on Comparative Anatomy, where it has been remarked that the nerves of sensation should be described as terminating in their appropriate ganglia, as has actually been done by Spurzheim, whilst the nerves of motion on the contrary should be described as originating there, an extension of the legitimate mode of proceeding which Spurzheim neglected to enforce.

If after this statement regarding the most correct method in a physiological point of view of describing the connexion of the cerebral nerves with the enkephalon, the student is still desirous of information upon each of these individually, he will find it useful to make out a table for himself, in which he must carefully distinguish between the apparent origin,—more properly point of emergence from, or of entrance of the nerve between the fibres of the cerebral mass, and the actual point of union between the neurine of the nerve and that of the cerebral mass itself.

FIRST PAIR OF NERVES, OLFACTORY.

The first pair of nerves (the numeration commencing at the anterior part of the brain) encountered are the *olfactory* or nerves of smell; they originate on the lining membrane of the nose and entering the skull through the cribriform plate of the ethmoid bone, terminate in the olfactory tubercles or ganglia, which are situated in the cribriform fossæ of the same bone [1]. In

[1] MM. de Blainville and Rolando are almost the only mo-

man these ganglia, whose minuteness as compared with those of the horse and sheep is interesting in a physiological point of view, are entirely concealed by the enormously developed hemispheres[1]. Each ganglion is connected to the hemispheres by a long narrow commissure, frequently designated a *peduncle*, which, lodged in a triangular-shaped groove, passes backwards till opposite the fissura Sylvii, where it splits into three divisions. The most external of these, which is also the longest, and distinctly medullary, runs down the fissura Sylvii to be connected with the anterior extremity of the middle lobe: this portion of the olfactory peduncle is connected with the anterior commissure, as described by Malacarne in his *Encephalotomie et Microcephalotomie*, by Rolando, and by Gall and Spurzheim. The internal is connected to the posterior internal surface of the under part of the anterior lobe. The middle, which is the shortest, and strictly speaking no more than the internal portion of the external,

dern authors who seem to be aware of the absurdity of retaining the ordinary mode of describing these portions of the olfactory apparatus as a nerve; in fact, as Rolando remarks, we have in this particular retrograded from the knowledge of the ancients, who never described them by the title of nerves. Willis appears to have been the first to speak of them in connexion with the cerebral nerves.

[2] In describing each pair of nerves the description will generally be confined to one side only, as being simpler for the student to follow.

is connected with the posterior edge of the anterior lobe.

Thus we see the olfactory ganglion in the human brain connected by a commissure with the cineritious neurine of the hemispheres, as in the lowest animals, where we have invariably observed each individual ganglion in succession connected with the others.

The canal which Gall and Spurzheim believed they had discovered in the interior of the olfactory commissure in man was in all probability formed under the blowpipe by the breaking down of the cineritious neurine in its interior, in the same manner as a canal was formed in the spinal cord by the action of the blowpipe in the hands of these anatomists. Tiedemann observed the existence of a canal in the brain of two idiots, an appearance which I think must be considered merely as an arrest of development at a period corresponding to the permanent organization of the part in some fishes.

Second pair. OPTIC NERVES.

The *optic* nerves commence in the globe of the eye, from a nervous expansion called the retina. After penetrating the choroid and sclerotic coats of the eye, they enter the skull, through the foramina optica of the sphenoid bone, on the processus olivaris of which they form a commissure, consisting of fibres arranged in the manner represented in Plate XI. fig. 1, which is from a dissection similar to that figured by Mayo, who was, I believe, the first who described this peculiar arrangement, which is attempted to be accounted for on the following principles. The rays of light from any object, placed laterally, impinging upon the retina of both eyes, will strike the outer side of one eye and the inner side of the other; now, supposing the arrangement just depicted to be correct, and there is no reason for supposing it to be otherwise, it follows as a necessary consequence, that the outer and inner side of each opposite retina is formed by one and the same nerve, a peculiarity of structure that goes far to account for the circumstance so often reasoned upon, viz. that a single impression is conveyed to the sensorium, though each eye receives the impression. Whether this mode of accounting for it be satisfactory or not, the following facts are extremely interesting, and not sufficiently known, viz. that in those fishes whose eyes are placed so completely on the side of the head that the rays of light from any given object cannot impinge on both retinæ, as, for instance, in the cod and haddock, the optic nerves, instead of forming any union or commissure, cross each other completely, having a membrane interposed between them: in those fishes, again, whose eyes are situated so that even a small portion of their retinæ correspond, as in the carp, we find a few commissural fibres; and in those whose retinæ correspond in every point, as in the skate, we find the commissure as complete as in the human being. While engaged in the investigation of this interesting subject, by the dissection of those animals which I thought would best elucidate it, I was informed by Mr. Wheatstone, Professor of Natural Philosophy at King's College, that Professor Müller, of Berlin, had given great attention to the same subject, and had carried his observations much further than I have had any opportunity of doing, but uniformly confirming the opinions stated above.

The commissure of the optic nerves is not alone formed of fibres derived from the retina of the eye; for, in addition to these, we find a set of fibres highly interesting to the physiologist, and wholly unconnected with the organ of vision. These are strictly commissural, and were first pointed out to me by Mr. Mayo; they run from one side of the brain to the other, forming in their course a curve convex anteriorly and concave posteriorly; they may easily be seen in a human brain that has been hardened in spirits. In the mole, in which the optic nerves are well known to be wanting, these commissural fibres are found distinctly crossing the base of the brain, opposite the usual situation of the optic commissure; while the small black speck, evidently the rudiment of the eye, is supplied by a minute branch from the fifth pair.

Muller denies it. —

Tracing the fibres of the optic nerve in man from its commissure, we find it sending a few fibres into the tuber cinereum. From the side of the tuber cinereum, the nerve takes its course over the crus cerebri, flattened like a ribbon, and spreading laterally. To this body it is, so far as I can make out by the most careful dissection, only connected by cellular membrane: I have always failed to trace any fibres of neurine between the two parts, as described by Spurzheim.

Reaching the posterior edge of the crus cerebri, the nerve winds round it, ascending to the posterior extremity of the thalamus, where it meets with two oval bodies, which, taken together, were first called by Santorini[1] *corpus geniculatum*, but which have more recently been described by Soemmerring as the corpus geniculatum externum and corpus geniculatum internum. At this point of its course the nerve splits into two parts, the separation being marked by a furrow or depression: the external portion, which is the largest, is lost in the external or greater geniculate body; the internal pursues its course over the internal geniculate body with which it is connected, and again dividing, runs directly to the *optic tubercles* or quadrigeminal bodies, one to the anterior, the other to the posterior. It is thus that the optic nerves terminate in these bodies, which are their own appropriate ganglia.

[1] *Observationes Anatomicæ*, cap. iii. §. 14.

I do not think it necessary to dwell upon the views of Rolando on this point, who denies that the optic nerves arise from or terminate in the tubercula quadrigemina, asserting that they take their origin from the thalamus alone[1]. This statement is altogether untenable with the parts before us.

Third pair, or COMMON OCULO-MUSCULAR NERVE.

The *third* pair of nerves, the *oculo-muscular* or common oculo-motor, emerges from the crebral mass at the inner side of the crus cerebri, the medullary fibres of which, as already explained, are continuous with the motory tract of the spinal cord. This is not, however, the real origin of this nerve; for if it be traced carefully it will be found not merely to be connected with the surface of the crus cerebri, but dipping beneath the surface, where it divides into two portions, to be connected by one of these which ascends through the pons Varolii, with the motor tract in its passage through that commissure. The other portion is partly lost in the locus niger, and partly mingled with those fibres which the intercerebral commissure or processus è cerebello sends through at this point (Plate XI. fig. 2.). From this origin the third nerve passes forwards on the outer side of the posterior clinoid process, and penetrates the dura

[1] Page 92, *op. citat.*

mater midway between the anterior and posterior clinoid processes, where it enters a space left between the under surface of the dura mater and the side of the sella turcica, which we have seen constitutes the cavernous sinus, along the upper part of which it runs, quitting the cavity of the skull at the foramen lacerum orbitale, and thus entering the orbit, within which it is distributed to the levator palpebræ, and to the levator, adductor, and depressor oculi. The more particular distribution of these nerves will be found described in most of the elementary anatomical works, to one or other of which I shall therefore refer my readers for further information[1].

Fourth pair, or INNER OCULO-MUSCULAR.

The *fourth* pair of nerves, also called the *pathetic*, and the smallest of the cerebral nerves, arise from the intercerebral commissure, close to the optic tubercles; the nerve proceeds, in fact, from those fibres which descend to the centre of the crus cerebri, so that we at once observe an immediate connexion between the fourth pair and the third, and, as we shall presently see, with the motor root of the fifth also. The fourth pair of nerves, at their origin, are connected together by

[1] Let me here particularly recommend the excellent practical manual of my friend and fellow-labourer Mr. F. Le Gros Clark, just published.

a distinct commissure, represented in Plate XI. fig. 2, and more evident in some brains than in others. From this origin they take their course, between the cerebrum and cerebellum, along the edge of the tentorium, by which membrane they appear to be conducted to the posterior clinoid processes, where, entering the cavernous sinus, they take their course, in the posterior part of that cavity, just below the third; but as they approach the foramen lacerum orbitale, they cross above the third pair, and, on their entrance into the orbit, are situated to the inner side of the third pair: they supply the superior oblique muscle of the eye.

Fifth pair, or TRIGEMINAL.

The *fifth* or *trigeminal* consists of two portions, the one for sensation and the other for motion. The sensory portion commences by numerous filaments from the surface of the mucous membrane of the nose, of the palate, from the pulpy structure of the teeth in both jaws, from the papillæ of the tongue, from many parts contained within the orbit, the lachrymal apparatus, the conjunctiva, &c., and from the skin covering the face. The numerous filaments from all these sources are collected into separate portions, which pass individually into the skull. The first division passes through the foramen lacerum orbitale; the second through the foramen rotundum; and the third, through the foramen ovale. Under the dura mater in the temporo-sphenoidal fossa, they enter the lower edge of the cineritious matter of the semilunar ganglion of the fifth nerve. From the concave edge of the semilunar ganglion other fibres arise, which, passing over the anterior surface of the petrous portion of the temporal bone, penetrate the dura mater on the outer side, and below the posterior clinoid processes. They then run direct to the upper edge of the pons Varolii, and, passing between the fibres of this commissure, descend completely through its substance, maintaining their individuality down through the medulla oblongata, till they terminate in the posterior columns of the spinal cord, about an inch and a half below the pons Varolii, as represented in Plate VI. fig. 2. and Plate XII. fig. 1.

The motory portion of the fifth nerve, again, arises, not as usually described, from the continuation of the anterior columns or motory tract while passing through the pons Varolii or commissure of the cerebellum, but from the intercerebral commissure, very close to the cerebellum, as designated in Plate XI. fig. 3., running from this origin, and concealed by the fibres of the commissure of the cerebellum. The motor root emerges from that body almost close to the spot where the sensory division enters it, after which it is applied to the sensory portion of the nerve. As it then passes through the same foramen in the dura mater, and enters the temporo-sphenoidal fossa, it slides behind the semilunar ganglion, to which it is connected by membrane, but not by neurine. It quits the skull at the foramen ovale, and is then distributed to the muscles concerned in the motions of mastication, viz. the masseter, temporal, pterygoid, and buccinator.

To recapitulate: the motory portion of the fifth nerve emerges from between the fibres of the pons Varolii, very close to the spot where the sensory portion enters; but in all cases in which I have dissected it, the motory is separated from the sensory portion by a bundle of fibres of the pons Varolii, about a line in thickness; the exact point of emergence is, however, variable. If the nerve be traced with great care,—which is necessary, for it is very thin and easily torn,—it will be found running backwards and upwards, towards the intercerebral commissure or processus è cerebello ad testes, to the fibres of which it is ultimately connected. Let me remind the student that the intercerebral commissure, the structure usually known as the processus è cerebello ad testes, consists of three sets of fibres, one of which, if traced from the cerebellum forwards, is found descending into the centre of the crus cerebri, and becoming continuous with the motor tract where that tract is forming the lower part of the crus cerebri. From the above description, it will be seen that the motor division of the fifth pair of nerves does not arise, as usually asserted, from the motor tract in its passage through the pons Varolii, but that its origin from the fibres as above stated seems to prove that those fibres must be a portion of the motor tract, though not usually considered in that light; for no doubt exists as to the function of this division of the fifth nerve, which is in connexion with them.

Sixth pair, or ABDUCENTES.

The *sixth* pair arises from the motor tract, at the inferior edge of the commissure of the cerebellum, just as it is about to pass through that structure, proceeding immediately from the portion of the anterior columns known as the pyramidal bodies; the nerve directs its course forward towards the upper edge of the basilary process of the os occipitis, at which point, or at the distance of about half an inch below the posterior clinoid processes, it penetrates the dura mater. It then advances upwards, and, crossing the superior angle of the petrous portion of the temporal bone, it enters the cavernous sinus, where it crosses the carotid artery at nearly a right angle, being joined at the anterior edge of the vessel by some filaments from the sympathetic nerve or cyclo-gangliated system, which accompany the sixth nerve into the orbit, and are connected with the lenticular ganglion.

The sixth nerve, in its course through the cavernous sinus, is situated the most internally; but under the transverse spinous process of the sphenoid bone, and just previous to its passage through the foramen lacerum orbitale, it is crossed by the ophthalmic division of the fifth pair in its course from the orbit to the semilunar ganglion. The sixth nerve is finally distributed to the abductor muscle of the eye. This nerve, let it be remembered, in a physiological point of view, is merely a portion of the third.

Seventh pair, or FACIAL.

The *facial* nerve, which emerges from the groove between the corpus pyramidale and olivare, just below the pons Varolii, may be traced backwards through the substance of that commissure in which it runs immediately to the inner side of, and in contact with, the sensory root of the fifth pair of nerves. See Plate XII. fig. 1. On arriving even with the posterior and superior surface of this portion of the fifth pair of nerves, the seventh appears to split into two parts, the one running inwards to be connected with the motor tract of the spinal cord in its passage through the pons Varolii, the other division proceeding outwards to be connected with that portion of the corpus restiforme which I have described as being derived from the motor tract of the cord. Plate XII. fig. 1.

From this origin the seventh nerve passes forward to the foramen auditivum internum, passing through which, and entering the stylo-mastoid canal, it quits the skull at the inferior orifice of this canal, where, becoming external, it is finally distributed to several of the muscles taking their rise from the styloid process of the temporal bone, to the platysma myoides, and to all the muscles of the face.

Eighth pair, or AUDITORY NERVE.

The *eighth* or *auditory* nerve commences from the pulp which lines the labyrinth of the ear. Its fibres gradually unite so as to form a single cord, which quits the temporal bone at the foramen auditivum internum and directs its course to the posterior part of the medulla oblongata, being connected to the facial nerve by cellular membrane. On reaching the medulla oblongata opposite the inferior edge of the pons Varolii, where the facial nerve emerges, the auditory splits into two portions. One of these passes through the substance of the medulla oblongata anterior to the corpus restiforme, and plunges into its appropriate ganglion, the posterior pyramidal body; Plate XII. fig. 1. The other, which is the posterior division of the nerve, winds round the restiform body, which is thus hid between the two portions of the nerve as in a fossa, and then crossing the posterior fissure of the cord or fourth ventricle, forms by its separation three or four white lines, which are usually very distinct. Meckel[1] states that he has sometimes found the whole of these lines deficient, sometimes on one side and sometimes on both, and that Prochaska and Wenzel have observed them to differ on the two sides of the brain. Meckel views these striæ as not merely the roots of the auditory nerve, but as connected both with the trigeminal and pneumogastric nerves.

Ninth pair, or GLOSSO-PHARYNGEAL NERVE.

The *ninth* pair, called also the *glosso-pharyngeal* nerve, arises from the corpus olivare immediately above the pneumo-gastric by one or two roots. It runs forwards to the foramen lacerum posterius, passing through which it quits the skull, separated from the jugular vein by a process of dura mater and a spiculum of bone; and passing down the stylo-pharyngeal muscle is finally distributed to the muscles of the pharynx and tongue.

Tenth pair, or PNEUMOGASTRIC.

The *tenth* pair, the *pneumogastric nerve* or *par vagum*, is a compound nerve, like most of the spinal nerves; that is to say, it consists of two tracts of neurine bound up together, the one for sensation, the other for motion. The motor fila-

[1] *Anatomie*, tome ii. p. 614. n.

ments of the nerve are not conductors of volition, for the muscular fibres that are brought into action by this nerve are independent of the will, with the exception of the muscles of the larynx concerned in the production of vocal sounds; and as one portion of the tract of volition runs close upon the posterior edge of the corpus olivare from which these filaments most probably arise, we have no difficulty in reconciling the fact of one portion of the nerve being destined for voluntary and the remainder for involuntary motion and sensation, as the constitution of this nerve is proved to be by the most accurate experiments and observations. Accompanying these nerves in their passage from the skull is a spinal nerve which, instead of quitting the vertebral canal like the spinal nerves in general, enters the cavity of the skull by the foramen magnum, and adding itself as it were to the glosso-pharyngeal and pneumogastric, is from this circumstance called the *spinal accessory*.

Eleventh pair, or LINGUAL NERVE.

The last of the cerebral nerves is the *lingual*, or the *eleventh* pair. This nerve arises from that portion of the anterior columns of the medulla oblongata usually designated the pyramidal bodies, about half an inch below the origin of the sixth pair. It commences by several filaments, which being collected together, the nerve they compose quits the skull at the foramen condyloideum anterius. It is distributed to the muscles of the tongue and also to those of the os hyoides, viz. the omo-hyoideus and sterno-hyoideus, which fix the bone inferiorly.

PART V.

VESSELS EMPLOYED IN THE CEREBRAL CIRCULATION.

THE brain is supplied with blood by four large arteries, the internal carotids and the vertebrals.

The internal carotid arteries are derived from the common carotids opposite the os hyoides: ascending from their point of origin, they reach the base of the skull, and enter its cavity by the *foramen caroticum externum* and *carotid canal*. The course of the vessel in this canal is worthy of observation. Changing the nearly vertical course they held at the external orifice for one almost horizontal in its direction, they advance forwards and inwards through the space of about an inch; they then form a curve, resume their nearly vertical course, and quit the carotid canal by the *foramen caroticum internum*. At this point the vessels bend forwards horizontally again, passing through the cavernous sinuses, groove the outer surface of the sella turcica, and at the inner side of the anterior clinoid processes they pierce the dura mater and enter the proper cerebral cavity. It is impossible to follow the two carotid arteries in this way without the peculiarity of their course forcing itself upon the attention. The changes from a perpendicular to a horizontal direction cannot have been ordained without some peculiar purpose to be fulfilled, and the end most probably has been to protect the delicate structure of the brain from any ill effects which the suddenly increased or hurried action of the heart would have been liable to produce had the tube been perfectly straight and the wave of circulating fluid been suffered to arrive directly, and with its force unbroken, within the cavity of the skull.

The branches of the internal carotid artery, as regards the brain, are three in number; two supplying the brain immediately, and one simply forming a communication or anastomosis with the branches of the vertebral artery. The two first are the *anterior* and *middle cerebral arteries.*

The anterior first runs inwards towards the great median fissure, where, approaching very close to its fellow on the opposite side, the two are united by a short transverse branch called the *transverse artery* of the cerebrum. The anterior cerebral artery continues its course in the anterior part of the median fissure between the two lateral hemispheres, giving off numerous branches in its course, winding round the great transverse commissure, and running backwards on its upper surface, where it receives the name of *artery* of the *corpus callosum.*

The *middle cerebral* runs deeply within the fissura Sylvii, through which it continues its course, and ultimately reaches the upper surface of the hemispheres.

The third branch of the carotid, called the *communicating artery*, is small but interesting; for running backwards, and joining with the posterior artery of the cerebrum, a branch of the basilary artery to be described further on, it connects these large arterial channels together, and lessens the danger of accident to the brain from obstruction to the circulation in one channel, and from an irregular supply of the vital fluid. When tracing the connexion of the two communicating arteries with the basilary branches, a perfect arterial circle will be observed to be formed, the sides being constituted by the communicating artery, the posterior part by the basilary, the front by the anterior arteries of the cerebrum and the transverse artery. This curious circle is celebrated under the title of the *circle of Willis*, who first described it.

The *vertebral arteries* arise from the subclavian at the lower part of the neck, immediately anterior to the passage of that artery between the scaleni muscles.

The vertebral has a long course from this point to the cavity of the skull, and nature has beautifully provided for its protection by sending it through a bony and ligamentous canal, bored, as it were, for it in the transverse processes of the cervical vertebræ. This vessel, though much smaller than the internal carotid artery, does not run in a direct course from the heart to the skull, nor begin to distribute its blood to the brain, till it has undergone a succession of curves by which the impetus of the contained blood must be materially diminished. On quitting the foramen in the transverse process of the first cervical vertebra, the artery courses round the articulating process of that bone, and, like the carotid, taking a horizontal direction, it enters the skull through the *foramen magnum*. Within the cranial cavity the two vertebral arteries approach each other, and on the basilary process of the occipital bone they inosculate at an acute angle and form a single trunk. The single artery thus produced is designated from its relation to the occipital bone the *basilary* artery.

The branches of the vertebral are three in number; two to the spinal cord and one to the cerebellum. The two arteries to the cord, called the *anterior* and *posterior spinal arteries*, though of small size at their origin, run the whole length of the vertebral canal to the os coccygis, giving off numerous branches in their course. Their calibre however is almost undiminished even to their termination, in consequence of their being reinforced by frequent anastomoses with the branches of the deep cervical, intercostal, and lumbar in particular.

The branch to the cerebellum is called the *inferior artery of the cerebellum*, and supplies, as its name indicates, the under surface of that portion of the brain.

The branches of the basilary artery are three in number on each side. One of these is not however distributed to the brain, but to the internal ear. Of the other two, one supplies the cerebellum, called in distinction to the last-mentioned cerebellic artery the *superior artery of the cerebellum*; the other is distributed to the cerebrum supplying the posterior surface of the hemisphere, and is called the *posterior artery of the cerebrum*.

PART VI.

DEVELOPMENT OF THE BRAIN.

The development of the human brain is a subject which every philosophical inquirer into the laws of organization will find invested with peculiar interest. The vast mass of facts which have been accumulated for its elucidation are amongst the most satisfactory and conclusive in proof of the existence of general laws instituted by an Almighty power, and in conformity with which every organ in the animal series is found to be framed on one beautifully simple and harmonious plan; and as it is only by the discovery of the general laws which regulate the phenomena of vitality that we can ever expect to raise the study of physiology to its legitimate rank among the natural sciences, we ought to recognise with especial gratitude the well-digested store of interesting facts contained in the works of Tiedemann, Serres, the Wenzels, and Doellinger, on the evolution of the brain. Newton, whose vast discoveries in another of the realms of nature have raised him so far above his fellow mortals that we almost reverence his name, showed us that true philosophy simply consists in the discovery of the universality of a fact. How abundant, since Newton's day, has been the harvest to those whose researches have been guided by this simple principle, to which alone we are indebted for any knowledge we possess of the laws by which the Creator governs the universe; for we perceive, as Dr. Paley finely expresses it, that "God has been pleased to prescribe limits to his own power, and to work his ends within those limits. The general laws of matter have, perhaps, the nature of these limits: its inertia, its reaction, the laws which govern the communication of motion, of light, of heat, of magnetism, electricity, and probably of others yet undiscovered. These are general laws, and when a particular purpose is to be effected, it is not by making them wind and bend and yield to the occasion, (for Nature with great steadiness adheres to and supports them,) but it is, as we observe in the structure of the eye, by the interposition of an apparatus corresponding with those laws, and suited to the inquiry which results from them, that the purpose is at length effected[1]."

This simple view of the existence of fixed laws, established by the Almighty, is not however confined to mere matter and its properties; the scientific physiologist has reason to believe that there are similar laws which regulate vital phenomena, and produce results, without the constant and immediate agency of the Supreme Being.

[1] Natural Theology, chap. iii.

It is told of Newton, that one day when meditating on the simplicity and harmony of the laws which regulate the universe, and struck particularly with the relations and uniformity of the masses of the planetary system, his thoughts reverting from thence to the animal kingdom, whose wonderful organization attests in no less degree the supreme wisdom and power of a creating Providence, he exclaimed, "I doubt not that animals are subjected to the same uniformity." The only truly philosophical plan upon which any branch of physiology can be studied is to follow out this idea of Newton, and strive to discover such an harmonious arrangement among its objects; for example, to attain a knowledge of the great principle which is in operation during the life, or which presides over and regulates the development of the individual beings composing the animal kingdom. And here we must carefully guard against being seduced by the vain attempt to gain a knowledge of the ultimate *cause* of vital phenomena; we must strictly content ourselves with observing those phenomena so as to ascertain their relations, their harmony one to another, and their effects. It is indeed only by studying physiology on these principles that it can ever truly deserve the name of a science, or afford us that clear and steady light which will guide us philosophically amid the intricate paths of pathology and therapeutics.

Physiologists in general have too much neglected to conduct their studies in accordance with this idea of Newton; they have too constantly amused themselves with creating theories on one or two isolated facts, or in vainly searching after the ultimate cause of vital phenomena: it is but of late that they have begun to content themselves with observing their uniform relations and with scrutinizing their effects, and that they have ceased from being the laughing-stocks of true philosophy.

If indeed we required proof of the present imperfect state of physiology, and the mean rank which it holds in comparison with the other branches of natural philosophy, we have only to refer to contemporary writers, where we still find such passages as the following, in which the writer, after stating how ignorant we are of the nature of the intellectual faculties in man, goes on to say: "Nay, the springs and wheelworks of animal and vegetable vitality are concealed from our view by an impenetrable veil, and the pride of philosophy is humbled by the spectacle of the physiologist bending in fruitless ardour over the dissection of the human brain, and peering in equally unproductive inquiry over the gambols of an animalcule." Surely we ought after this to see how absolutely necessary it has become to cast aside crude and ill-digested hypothesis, and to study physiology under the guidance of the general laws of nature deduced from an unprejudiced observation of fact and circumstance. Such a sweeping assertion of the fruitlessness of the labours of the physiologist as we have above is by no means applicable to the *nature* of his studies, though it is to the *mode* in which they have usually been conducted; for the physiologist is just as competent to inquire into the *causes* of *vital phenomena* as the natural philosopher is into those of *physical phenomena*: neither the one nor the other can ever ascertain the ultimate cause of anything. All that can be done in either natural philosophy or physiology is to study the mutual relations in which phenomena stand to one another, and thus to trace their connexion and possible dependence.

The mature human frame, which in its perfect adaptation to fulfil the ends of its existence strikes the philosophical anatomist with admiration, does not result from the gradual increase of an exact though minute representation of its perfect form; but during the course of its development, and while gradually progressing towards its ultimate perfection, its constitution temporarily assumes many forms which are permanently retained by one or other of the members among the lower orders of creation.

The facts which prove the existence of this law of progressive development are derived from observation of the different organs at different periods of the fœtal existence; and in no set of organs is its truth more clearly shown than in the various component parts of the nervous system, as the reader will discover by giving his attention to the observations on its development which follow. The same thing may also be said in regard to the law which governs the development of the vascular system; and as the circumstances are here peculiarly interesting, and may be made introductory to those of the subject we have especially in hand, I shall make no apology for presenting a few of them in this place.

For instance, the first appearance of the heart in the human embryo is that of a mere pulsating vessel without any division into cavities or thickening of its walls; an arrangement which in all its simplicity is met with as the sufficient instrument for effecting the circulation in the perfect insect.

The next step consists in the gradual dilatation of this tube into a sac, previously to its division into four cavities; and this corresponds with the single heart of the fish, consisting merely of an auricle for the reception of the blood, and a ventricle for its propulsion.

As the development advances, a second ventricle is added to the first on the right side of it, separated from the left by a septum, which is so imperfect that the aorta communicates with both cavities; and the very same arrangement is found to exist in the adult crocodile.

While the septum is being formed in the interior, a notch appears on the exterior, which, extending from the apex to the base, divides the heart in exactly the same manner as it is met with in the dugong.

In the respiratory system, again, we find some most extraordinary changes; those we have remarked in the vascular we could explain on the supposition that they were the necessary and unavoidable steps towards perfection; but when we find the human embryo assuming forms which are afterwards entirely discarded, we can only account for it on the supposition that one general law governs the developments of the whole animal creation. The lungs in the first instance are placed on each side of the vertebral column, like the air-bladders of fishes, without any appearance of trachea or bronchial tubes; an arrangement which though interesting, as being analogous to the permanent state in fishes, has nothing peculiarly extraordinary in it; but finding, in addition to this, and in perfect correspondence with it, branchial apertures on the sides of the neck, the aorta giving off a regular set of branchial arteries which take their course to the edges of the openings, some of which are afterwards entirely obliterated, while the others are converted into vessels corresponding with the regular distribution of the adult. As the organism of the human fœtus cannot be supposed to be formed with the idea of providing for aquatic respiration like the embryos of fishes, we can no longer doubt that the whole series of phenomena which are taking place during the development of the fœtus do not result from any special interference of Divine agency for each individual occasion, but from the action of fixed and general laws.

In the development of the nervous system, to which we must next direct our attention, we shall find even more decided proofs of this general harmony throughout the animal kingdom.

DEVELOPMENT OF THE NERVOUS SYSTEM.

Tiedemann states, that at very early periods of fœtal existence there is no appearance of any neurine; the parts corresponding to the head and vertebral column are transparent, and contain a limpid fluid; about the fifth or sixth week the pia mater is distinctly perceptible, forming the walls of the canal in which the fluid is contained, arranged in the head so as to form five vesicles. The two anterior of these represent the future hemispheres; the two middle, the optic thalami; and the posterior, the cerebellum: the spinal marrow is represented by a long canal communicating with the cerebral vesicles, which in reality are but swellings of a single sac. The description which I have already given of the pia mater, and the mode in which it first forms a continuous canal, may here be again referred to.

The brain of all mammalia has this vesicular form in the first instance; the embryos of the rabbit or cat are, perhaps, the best that the student can select for his own observation. Rolando gives a very accurate account of the vesicular form of the fœtal brain in the mammalia and in birds.

The peculiar form and general appearance of the fœtus at the seventh week, will be easily comprehended by referring to Plate XII. fig. 3., taken from Tiedemann, who represents it as an oblongated mass slightly curved upon itself, gelatinous, and semitransparent.

In this embryo, which was about seven lines in length, and about seven weeks old, Tiedemann was enabled distinctly to observe the structure and disposition of the brain and spinal cord.

The cavity provided for the cord was situated immediately beneath the integuments, the muscles and vertebral arches not being yet formed. On opening this cavity by means of a fine pair of scissors, he perceived the dura mater nearly dividing the cranium into two equal portions; the pia mater beneath it adhered so intimately to the substance of brain and spinal cord, that it was difficult to detach it without destroying the inclosed pulp, the general form of which may be clearly understood by referring to Plate XII. fig. 4 and 5.

On the posterior part of the cord a longitudinal fissure existed, into which the pia mater entered, which has received the name of the spinal canal; at the upper part, where in the adult it forms the fourth ventricle, a thin narrow plate or flattened fasciculus of neurine arose from either side, and inclining inwards, touched, without uniting with, its fellow; thus forming a sort of arch over the fourth ventricle, and constituting the rudiment of the cerebellum (*c*, fig. 4 and 5.) about one line and two thirds in breadth.

In front of the cerebellum were two membraniform productions, the first appearance of the optic tubercles or corpora quadrigemina, taken together about a line in breadth and one in length *d*. The rudiments of the thalami, *e*, in the shape of two rounded protuberances, were next in order, the space between them being that which corresponds to the third ventricle. In front of these eminences were two others, in apposition with them, about a line in length, and apparently the rounded extremities of the anterior part of the crura cerebri; these were the corpora striata, *g*, fig. 5.

From the corpora striata arose two thin membraniform productions of neurine curving backwards and inwards; these are the first commencement of the hemispheres of the brain, *f*, fig. 2.

At this early period there are no traces of the commissure of the cerebellum or of the cerebrum, or of the thalami, or of the longitudinal commissure, called the fornix.

The substance of the brain and cord examined with a glass presented no fibrous appearance; it seemed to be composed of extremely minute globules. It does not assume a fibrous appearance until the commencement of the fourth month. Tiedemann states that he could not perceive any appearance of the cerebral nerves, which he accounts for on the supposition that they were so delicate as to escape detection; but such a supposition appears to me unnecessary, when we recall to mind the facts which I mentioned in the early part of this work regarding the development of the nerves in the first instance in all the different tissues, and their subsequent union with the brain and spinal cord.

In the following details I have adhered generally to the plan of describing the gradual development of individual parts connectedly, as bringing the whole more simply before the eye of the student than of particularly detailing each change as it takes place from one month to another, which has been faithfully done by Tiedemann and Serres, to whom I must refer the reader for greater minuteness.

It may be laid down as a rule that the spinal cord is formed previously to brain, not merely in man, but in all the orders of vertebrated animals. At first it consists of two cords, not united posteriorly, by which a deep furrow is formed, which is soon converted into a canal by the union of the opposite halves.

This canal of the spinal cord, which is so distinct in the human fœtus until the fifth month, and in that of the horse and calf until the sixth, exists permanently of a certain width in fishes, reptiles, and birds. In the fœtal state of the human embryo it is obliterated by the deposition of successive layers of grey matter secreted by the pia mater. But what is, perhaps, more extraordinary is, that the cord in the human fœtus extends to the extremity of the coccyx until the third month, when it appears, according to the statement of M. Serres, to rise suddenly to the point where it is met with after birth, namely, opposite the second lumbar vertebra. The os coccygis, which previous to this period consisted of seven pieces, suddenly becomes reduced to its permanent number, four.

The spinal marrow is of equal calibre in its whole extent in the young embryos of all classes; it is without enlargement either anteriorly or posteriorly, as in those reptiles which do not possess extremities, as snakes, &c. This appearance corresponds with the absence of extremities at this period of existence; for as soon as they are developed, the cord enlarges at those points with which their large nerves are connected.

The corpora olivaria are not formed until the end of the sixth or beginning of the seventh month. The interlacement of the pyramidal fasciculi is visible in the human embryo from the eighth week. In reptiles and in fishes there is no interlacement at all.

The very gradual manner in which the cerebellum attains its ultimate complexity, is in perfect harmony with the gradation which it pursues in the animal kingdom.

About the third month the fasciculi, which we formerly observed just touching each other, are now united so as to form a concave mass internally, smooth and convex externally, but without any appearance of grooves or leaflets, thus accurately corresponding with the cerebellum in osseous fishes, such as the carp, cod, &c.

In the fourth month the commissure of the cerebellum is perceptible, and is about a line in width. About the fifth month the cerebellum, itself about seven lines in breadth, begins to assume the same appearance as that of the skate; for grooves appear upon the surface, which gradually increase in depth and number, till at the sixth month the stems and branches of the arbor vitæ become apparent, and the part then puts on the exact appearance of that of birds.

In conclusion, let it be remembered that the cerebellum proceeds, in the first instance, from the spinal marrow, in fact, from the two fasciculi which are earliest apparent, and which constitute the corpora restiformia.

The masses of neurine which correspond with the tubercula quadrigemina or optic tubercles in the adult, are in the embryo of the second month merely two plates bending upwards and inwards, but not yet covered by the hemispheres, and in apposition only in the mesial line, their union not being complete until the end of the third month, when, becoming convex externally, they gradually increase in size and become united. At this period they correspond in appearance with the optic tubercles in fishes and in birds; and it is not until the seventh month that we can perceive any division into nates and testes, or into four bodies instead of two; and even at this period they are scarcely covered by the hemispheres, so that they now resemble those of the Rodentia.

The anterior ganglions of the cord or optic thalami at the end of the second month, not being yet covered by the hemispheres, are clearly to be seen (Pl. XII. fig. 6.). Towards the end of the third month, however, when they measure two lines and a half in length (Pl. XII. fig. 7, 8, 9, and 10.), the membranous hemispheres are partially extended over them. These protuberances, which are solid throughout, are united by a transverse band representing the posterior commissure, and their increase from this period is in exact correspondence with the progressive development of the hemispheres. The commissura mollis was not observed by Tiedemann until the ninth month. The Wenzels are said to have met with this commissure in the fifth, and again in the seventh month.

The pineal gland is not to be seen previous to the fourth month, when it appears in the form of a small flattened round body, the peduncles of which, extremely thin, are seen arising from the inner edge of the superior surface of the optic thalami.

This body is not met with in fishes, though it is in many reptiles, as the hawk-bill tortoise, wall lizard, and ringed snake, as also in birds, and invariably in the brains of the mammalia, varying in size, figure, and structure.

In volume it is much larger in proportion to the size of the brain in the ruminating animals than in man.

The *corpora striata*, or *posterior ganglions of the cord*, are just perceptible at the second month. In the commencement of the third they become more voluminous, and are partly covered by the hemispheres, which structures, being in the first instance mere layers of neurine shooting out from the hinder part of the corpora striata and thalami, give to the corpora striata an appearance of greater size and prominence than they seem to possess afterwards when the hemispheres have become nearly as thick as themselves. At the period of birth they appear sunk amid the substance of the hemispheres, which then bound the anterior part of the space left between them and the corpora striata and thalami, and which has been so incorrectly designated a ventricle or bag.

In the fish, as we have already seen, there are no bodies which can positively be considered as analogous to the corpora striata. In reptiles, however, they exist, as well as in all the tribes above them.

The anterior commissure does not exist in the second month; but in the third it appears like a thin delicate thread, and its development proceeds in accordance with that of the corpora striata and thalami.

Although in the preceding descriptions of the corpora striata and thalami we have had frequent occasion to speak generally of those layers of neurine which ultimately form the hemispheres, it may be desirable to give a more detailed account of them. This is particularly important as calculated to do away with the false notions that have been entertained on the subject of the ventricles, as well as to convey clearer impressions on the difference between the figurate and convoluted surfaces of the brain. These ends, indeed, can in no better way be accomplished than by following out the development of the hemispheres of the brain. At any rate I think that if the reader will attentively compare the description which I have given on the subject of the adult brain, of the relations of the hemispheres to the ganglia of the cord, or corpora striata and thalami, no doubt will remain in his mind as to the correctness of the statement made at the commencement of this work, namely, that the ventricles are no more entitled to the name of bags than the space left between any two convolutions of the surface of the hemispheres.

In the fœtus of the second month we perceive springing out from the under part of the corpora striata on each side, a thin delicate membrane, consisting of medullary neurine, which is reflected backwards and inwards, scarcely covering them, invested with pia mater: this is the rudiment of the hemispheres (Plate XII. fig. 6.). In the commencement of the third month these membraniform hemispheres completely cover the corpora striata, and towards the end of the month they have extended over the thalami, not having yet reached the optic tubercles (fig. 7, 8, 9, and 10.). During the fourth month (fig. 11.) they have advanced as far as the anterior edge of the optic tubercles, but they do not cover them entirely until the sixth, when they have extended as far as the cerebellum (fig. 12). At this period we may perceive on the surface corresponding to the falx major, some grooves or furrows which are the first steps towards the formation of the convolutions. The upper and lateral surfaces still remain perfectly smooth. At the seventh month the convolutions are very imperfectly developed, though the hemispheres now cover the cerebellum entirely, and upon this division of the cerebral mass, depressions appear here and there, the rudiments of the convolutions and fossa, into which the pia mater dips. The fissuræ Sylvii are distinct, lodging the middle arteries of the brain, which send numerous branches into the interior.

In the eighth month the hemispheres which cover the cerebellum, and are prolonged even beyond its posterior border, are two inches eleven lines in length, two inches one line in breadth, and one inch ten lines deep. On examining their inferior surface, the anterior, middle, and posterior lobes may be distinctly seen, the boundaries of each being well marked.

At nine months the hemispheres are three inches and four lines in length, and two lines in breadth; they have now exactly the same form as in the adult, and are covered with convolutions and anfractuosities.

After these details, it must be evident that the hemispheres are formed from before backwards, and from without inwards; that at first they consist only of a thin membranous layer of neurine, reflected upon itself from behind forwards, and from without inwards; that they increase in thickness and volume very gradually; and that as they are developed they extend themselves, first over the corpora striata, and afterwards over the thalami, optic tubercles, and cerebellum, so that in the end they entirely cover all these parts.

We observe precisely the same plan adopted in the formation of the hemispheres of the brain throughout the Vertebrata, except that they are arrested at different stages of the development in different species, which the human embryo merely assumes for a short period and passes on to a more elevated type.

Having entered generally into the composition of the cerebral mass in fishes, reptiles, birds, and the mammalia, I consider it unnecessary to dwell more fully upon the subject at present than to point out a few of the analogies between them and the human fœtus.

The skate presents one of the most decided specimens of a structure analogous to the fœtal or rudimentary hemisphere of the higher classes, in the two tubercular enlargements which are placed immediately in front of the optic tubercles, and with which the peduncles of the olfactory nerves are connected as in the human subject.

These bodies are hollow, and the walls of the cavity are formed by a membranous layer of neurine reflected backwards and inwards, into which the fibres of the crura cerebri expand as in the human embryo.

In the carp we have also observed rudimentary hemispheres.

The rudimentary hemispheres of the reptiles are equally interesting when viewed in relation to this subject. In the crocodile, each hemisphere represents a membranous sack containing within it the optic thalami, the pineal gland, and the corpora striata, from which ganglia the hemispheres appear to arise, thus corresponding accurately with the same part in its state of evolution at the third month of fœtal existence in the human being, presenting the reflection of neurine which constitutes the hemispheres, extending to the same point behind, and covering the corpora striata and thalami, but leaving the optic tubercles exposed. And so we might in the same manner go on multiplying examples of the truth of the law of progressive development of the hemispherical ganglia: more than has been said seems unnecessary.

In the second month of fœtal existence the fasciculi of the spinal cord which are prolonged into the brain are curved downwards beneath the optic tubercles; this curve remains distinct until the third month. The bundles may be distinctly traced into the optic thalami, and having become more voluminous they then pass into the corpora striata, from the anterior surface of which they may be seen emerging, and spreading like a fan to form the hemispheres. From the internal and inferior side of the thalami, or from the continuation of each crus, a fasciculus of fibres is detached, which descends into the mammillary eminences. These reflected on themselves, and thus directing their course backwards, form the anterior pillars of the fornix, or, more properly speaking, the inferior longitudinal commissure.

All the other fibres of the crura, which are very numerous, are directed forwards and outwards, passing under the corpora striata forming the hemispheres; and at the posterior part they join, or more strictly speaking form, the posterior pillar of the fornix. In doing so they form a fold, which projecting on the internal surface of the ventricle gives rise to that appearance which is called the cornu Ammonis.

The corpus callosum or commissura magna does not exist in the brain of the fœtus in the second month, nor even in the early part of the third. Towards the end of the third, however, it makes its appearance; at first it is very narrow and nearly perpendicular. In its growth it passes from before backwards. By the seventh month its fibres may be traced in connexion with those of the spinal cord through the medium of the crura cerebri.

From the description already given of the brains of fishes, reptiles, and birds, the reader is aware that this commissure does not exist in them.

The corpora mammillaria do not appear until the end of the third month, and then not divided as they are after birth, but simple and homogeneous.

The pituitary gland is not in existence in the second month, nor even at the commencement of the third; but it appears towards the end of it, forming a rather large soft mass.

The above facts, which I have laid before my readers on the authority of Tiedemann, Serres, and others, will, I think, thoroughly convince them of the truth of the law which I stated at the commencement of this section regarding the gradual development of the brain and spinal cord on one simple and uniform type; and that the complicated structure which we meet with in the human adult, is, at an early period of fœtal existence, as simple in its general arrangement as many of the permanent forms of the lower vertebrated animals, and that in its development Nature appears to have pursued the same plan which she has adopted in the organization of each individual in her vast family, gradually adding one part after another, and at the same time concentrating the whole, so that each fresh addition is obscured, the appearance of the several parts being so entirely changed, that unless the chain be observed from its very commencement, all the analogies which are so palpable when we proceed step by step are obscured, and even made altogether incapable of demonstration.

Let me not however, be misunderstood, when speaking of the addition of fresh parts, for the brain of man even in its state of perfect development consists of the same number of *ganglia* as that of the Vertebrata in general, though the amazing size of the hemispherical ganglia and the cerebellum, with the addition of fresh commissures, give to the human brain an appearance wholly unlike that of the reptile and the fish.

PART VII.

PHYSIOLOGY OF THE BRAIN.

This is a subject which every candid physiologist must approach with great diffidence, for the extreme difficulty, nay, in many instances, the impossibility of procuring satisfactory evidence of the nature of the office performed by its various centres, either in man or in the lower animals, has still kept the whole subject in darkness; and this we fear no one in the present day would be justified in pretending he had the power to remove.

I shall therefore confine myself to a very brief outline of the best-supported opinions on this interesting subject, hoping that at some future period I may be enabled to pursue it more fully than I now feel competent to do, even if it were not inconsistent with the concise plan of the present work.

The sources of our information on the functions of the nervous system are threefold.

First, The observation of the parts composing it in the lower animals, and the relation which they bear to those of man, considered in connexion with their manifestations of consciousness.

This source we have already availed ourselves of in the section on comparative anatomy, and observed how clearly the development of the nervous centre keeps pace with the increasing power of the intellect.

Secondly, Experiments on living animals.

Thirdly, Pathological facts.

The errors to which all deductions made from experiments on living animals are liable, are so universally acknowledged in the present day, that little reliance is placed upon them as faithful or unerring sources of knowledge. Notwithstanding the hundreds of animals which have been sacrificed on the Continent particularly, with the view of clearing off some of the darkness in which this branch of physiology is enveloped, the results have been generally contradictory, and, with few exceptions, are therefore unproductive of facts that may be depended on. Nevertheless, we must not reject, as wholly without value, many of the points elucidated by experiments, particularly those of MM. Flourens and Bouillaud. In so far as this mode of investigation is admissible, the results obtained by these authors are perhaps the best authenticated and the most satisfactory of any.

If we were not bound to receive with the greatest caution the conclusions of every experimental physiologist, knowing how liable, even the strictly honest, among whom both the above-mentioned authors may be classed, are to see results as they expect them to be, and not as they really occur, we might be induced to believe, after reading their works, that a great deal more of the functions of the nervous system must be known than is actually the case. The relation of a few of their simplest and most conclusive experiments, together with the report made by the Académie Royale on M. Flourens' work, will place in the student's possession their facts and arguments in the most concise and appreciable form. Here, however, we must guard against extending the mischief which has been done by several recent authors, who have referred to the whole of the results and inferences as if they were so many firmly established facts in the science of physiology.

From pathology we might naturally expect surer evidence; but even here the physiologist who carefully examines its records is doomed to disappointment.

It is clear that if, in uniform accordance with the derangement or obliteration of individual functions during life, morbid alterations of individual portions of the nervous system were met with after death, no surer evidence could be procured of the connexion between function and organic structure. But, as will be proved hereafter, no certain light has yet shone on physiology from this source.

As much of the best-authenticated information regarding the functions of the nervous centres has been already embodied in the descriptive sections, as far as was consistent with clearness of detail, so important in descriptive anatomy, only those more debatable points which could not be consistently introduced before, will be now laid before the reader, commencing with the report on M. Flourens' work.

"Report made to the Royal Academy of Sciences of the Institute, on the Memoir read to the Academy in the meetings of the 4th, 11th, 25th, 31st of March, and 29th of April, 1822; having for its object the determination of the properties of the nervous system, and of the action of these and different parts of this system in the motions called voluntary, or of locomotion and prehension.

"The perpetual secretary of the Academy for the medical sciences certifies, that what follows is an extract from the minutes of the meeting held on the 22nd of July, 1822.

"The Academy has charged us, the Count Berthollet, MM. Portal, Pinel, Dumeril, and myself, to give it an account of a memoir of M. Flourens, entitled *Determination of the Properties of the Nervous System, or Physical Researches on Irritability and Sensibility.*

"This memoir may be considered under three aspects: 1st, the experiments made by the author; 2nd, the consequences which he draws from them; 3rd, the language in which they are expressed.

"He has repeated before us his principal experiments, and they have appeared to us correct. We have followed his reasonings with attention, and the greater number of them have appeared to us just; but the language which he has made use of differs in some important points from that generally received, and would give rise to objections and to misunderstandings, if we did not in the first place occupy ourselves with its correction. It is even with the intention of serving the author, and to give his results with more clearness, that we begin this report by a few critical remarks on his nomenclature.

"When a nerve is pinched or pricked, the muscles to which it is distributed contract with more or less violence, and at the same time the animal suffers more or less pain. When a nerve is separated from the rest of the system by ligature or by section, and is acted upon in the same manner below the ligature or section, the muscles again contract; but the animal experiences no pain, and the animal loses at the same time the power of commanding the contractions of the muscles which this nerve animates. These facts have been known from the commencement of physiological experiments. Herophilus and Erasistratus had performed them, Galen had left them in writing; and it is upon them that this fundamental proposition rests, that *the nerves are organs by which the animal receives sensations and exercises the voluntary motions.*

"A greater attention given to the various movements which take place in the animal body has shown that it is not by a mechanical traction that the nerves make the muscles contract. On the contrary, the nerves, during this action, remain in a quiescent state. And it is not even necessary to employ them as intermediate agents. A prick, any sudden irritation of a muscle makes it contract; this takes place for some time in a muscle whose nerve has been divided, even in a muscle detached from the body. Glisson and Frederick Hoffman had already drawn attention to this property, which became about the middle of the seventeenth century the subject of many experiments by Haller: the phenomenon is known at the present day by the name of *irritability.*

"These experiments indicated that this property of violent contraction, either by immediate irritation, or after irritating the nerve, exists in muscular fibres, and that it exists in no other element of the animal body. Their importance excited great interest; the pupils of this great physiologist repeated them, and even exaggerated the consequences.

" As the irritability is not proportional to the size of the nerves which are distributed to each muscle, and as it was then thought that there existed muscular parts entirely, or almost entirely, without nerves, some persons imagined that this property belonged to the fibre by itself, and independently of the assistance of the nerves; that a nerve may, perhaps, be one of the irritating agents, but that other irritants would act without it. It would be wrong to ascribe this opinion entirely to Haller himself. Many very pointed passages show that he was in no way ignorant of the cooperation of the nerve in the phenomena of irritability; and the more these phenomena have been studied, the more obvious has this cooperation appeared. In the present day, when the nerves of all the muscular parts are known, no muscular fibre is found unconnected with a nervous filament, and no one would now venture to maintain that this nervous filament was in a passive state during the contraction. All that is well proved is, that contraction may take place without the animal experiencing any sensation, and independent of all volition, which this sensation might have produced.

"This last proposition, which Haller first put in its proper light, and the natural application which resulted in reference to the involuntary motions, such as those of the heart and viscera, completely overthrew a physiological system which had been for a long time in vogue, namely, that of Stahl, who considered the mind as the promoter of all the movements of the body, not only of those which we feel and wish, but also of those of which we have not even the consciousness. Already forgotten in Germany, where systems disappear with the same facility as they make their appearance, the doctrine of Stahl was introduced at Montpellier by Sauvages, in opposition to the school of Haller; but here he was defended by changing the essentials of his system, and by introducing into the language of physiology an innovation which for a long time has made this science not only the most difficult, but the most mysterious and the most contradictory of all.

"This innovation consisted in generalizing the idea of sensibility to the point of giving the name to every nervous cooperation accompanied with motion, even when the animal has no perception of it. Organic and local sensibilities were established, upon which reasonings were made as if it had been ordinary and general sensibility that was the matter of debate. The stomach, the heart, the uterus, according to these physiologists, experienced sensation and will, and each organ was a species of small animal endowed with the faculties of the organism to which it belonged. This alteration in the use of terms was singularly favoured and even augmented by the double meaning which most of these terms had in our language. Indeed, *sensible* in French signifies at the same time that which can experience sensations, that which can give them, and that which can be their conductor. It is in the first meaning of the word that we say an animal is a sensible being; in the second, that we say a noise, a light is sensible; and in the third, that physiologists say the nerves are sensible.

"Some writers of great celebrity have deceived themselves by using this figurative language, these words of double meaning, to the extent that, when they thought they were explaining these phenomena, they were only giving the expression of their existence in a metaphoric style; and it must be confessed that this illusion has been communicated to a great number of their readers. Happily, it has not seduced men accustomed to rigorous reasoning; they give to each expression a fixed meaning by a positive definition; and they avoid its use with the greatest care in another acceptation, because they know that by so doing they expose themselves to fall into the same sort of sophism, one of the most common of all, and to which logicians have given the name of syllogism of four meanings.

"Indeed, it seems to us that this vacancy in the science had been sufficiently filled up in these later times by the rigorous physiologists in that which concerns the properties with which we are at present occupied, and that it was not necessary to change in this respect the language they had established. When they say, *the muscular fibre is irritable*, they mean that it alone can contract after being irritated. When they say, *a nerve is not irritable,* they mean that irritation does not cause it to contract: but, indeed, they do not pretend by this that irritation cannot be produced in a muscle; there is not one among them who has not always known to the contrary. When they say, *a nerve is sensible,* they mean that an animal receives all sensations through the medium of the nerves; but they assuredly do not mean that a nerve separated from the body can continue to give sensations to the animal, and much less can the animal experience any sensation.

"We will then begin by recommending M. Flourens to remove from his beautiful work a first part relative to this nomenclature, which cannot but confuse the ideas of his readers, without any advantage to science.

"As a nerve when pricked produces contractions in the muscles, he concludes that it is *irritable.* It is evident that in this proposition we are told nothing new; but he changes the meaning of the word *irritable.* A nerve separated from the system does not cause the animal to experience any sensation, and he concludes that a nerve is not *sensible.* This is merely a change in the meaning of a word, which tells us nothing which we did not know already.

"M. Flourens himself acknowledges that he introduces a new language, for he says: "I call *irritability* the property which a nerve possesses of provoking sensation and motion, without experiencing either sensation or motion itself." To give a known word a new meaning is always a dangerous proceeding. If we wish to express a new idea, it is much better to invent a new term than so to apply an old one.

"That which is true in this respect, that which is independent of any difference as to the meaning of words, is, that a fibre contracts whether it is directly irritated, or whether the nerve distributed to it is irritated; that the nerve is consequently a conductor of irritation. An animal feels impressions made upon the nerves when these are in free communication with the enkephalon, and consequently the nerves are *conductors of sensation*.

"These are the terms which might be used, were we inclined to increase the rigour of the language received; and these are, in fact, the terms which we shall make use of in the remainder of this report.

"To express, then, in general language, the true questions which M. Flourens has himself proposed, and which, perhaps, are not clearly explained in the title of his memoir, we will say, that he has endeavoured to discover by experiments:

"1st, From which points of the nervous system can artificial irritation depart, so as to reach the muscles?

"2nd, To which points of this system must the impression extend itself to produce sensation?

"3rd, From which points does voluntary irritation descend, and what parts of the system must be untouched to produce it regularly?

"We shall add, that in this first part he has only considered these questions in relation to vertebrated animals and to the nervous system of animal life; that is to say, to the brain and spinal cord, and the nerves which arise from them.

"To answer the questions the author begins with the nerves; and repeating with regard to them the known experiments, he establishes the two general effects of their irritation, such as we have stated them: he shows in a precise manner, that before contraction can take place there must be a free and continuous communication of the nerve with the muscle; and that for sensation, a free and continuous communication is necessary with the spinal cord and brain: he concludes that neither contraction nor sensation belongs to nerves; that these two effects are distinct; that they can be put into action independently of one another; and that these propositions are true to some point, to some branch of a nerve whose communication is intercepted.

"Making use of the same method for the spinal marrow, he arrives at the same results. When it is irritated at some point, it makes all the muscles which are supplied with nerves arising lower than this point contract, if the communications have remained free, though it produces no contractions if the communication is intercepted. It is exactly the reverse for the sensations; and as in the nerves, the empire of the will is in want of the same free communication as the sensations, the muscles beneath the intercepted part no longer obey the animal, and the animal no longer feels them. If the spinal marrow is intercepted at two different points, and if the space comprised between these two points be irritated, the muscles to which the nerves arising from that space are distributed alone contract; but the animal has no power over them, it receives no sensations from them.

"We shall not relate all the combinations with which M. Flourens has varied his experiments upon this subject; it suffices for us to say that they all tend to the result which we have just expressed.

"The author concludes that sensation and contraction belong no more to the spinal marrow than to the nerves; and this conclusion is certain for all unmutilated animals. It would be a great matter to know whether it is equally so in animals which have lost their enkephalon, and which in certain classes appear not to lose immediately their animal functions; but it is a question to which we shall have occasion to return in the sequel of this report, even with respect to the warm-blooded animals.

"M. Flourens, again, concluded from his experiments that it is from the communication established between all the nerves, by means of the spinal marrow, that what he calls the dispersion or the generalization of the irritations, or in other words, the general sympathies, are established; but he has not sufficiently unravelled this proposition to render the reasonings upon which he supports it appreciable.

"He then comes to the enkephalon; and it is in this central part of the system that we expect new ideas from experiments better directed than those of the ancient physiologists.

"Although Haller and his school had made many experiments upon the brain, to ascertain its vital properties, and whatever is peculiar in the functions of the various parts which compose this complicated organ, it may be said that his experiments did not bring forth results sufficiently rigorous; because, on the one hand, the different connexions of the brain were not sufficiently known at that period, neither the direction nor the communication of the medullary fibres having been ascertained; and, on the other, because they were not sufficiently isolated in the experiments. For example, when the brain was compressed, it was not known which part in the interior had been most compressed; when an instrument was thrust into it, the depth it had been introduced, and into which organ it had penetrated, was not sufficiently examined. M. Flourens, with some reason, has made this reproach to the experiments of Haller, Zinn, and Lorry, and he has endeavoured to guarantee himself against a like source of error, in operating principally by means of ablation, that is to say, by taking away in each instance, and as far as it could be done, the part whose particular function he wished to know.

"In order to place in a clearer light the facts which he has stated, we shall set forth in few words all the mutual relations of the parts of which we are speaking.

"It is at present known, and especially by the late researches of MM. Gall and Spurzheim, that the spinal marrow is a mass of medullary matter, white externally, grey internally, divided into anterior and posterior columns, the fasciculi of which communicate one with another by means of transverse medullary fibres; that it gives from each swelling a pair of nerves; that the *medulla oblongata* is the superior part of the spinal marrow, contained in the cranium, which also gives many pairs of nerves; that the fibres of communication between the two fasciculi interlace one with another, so that those on the right go to the left side, and reciprocally; that these fasciculi, after having been enlarged in the mammiferæ by a mass of grey matter which forms the prominence known by the name of *pons Varolii,* separate themselves, and are called the *crura cerebri,* continuing to send off nerves. They are again enlarged by a new mass of grey matter to form the masses commonly called *thalami optici,* and a third time to form those called *corpora striata*; and that from the whole external edge of these last swellings arises a lamina more or less thick, more or less convoluted externally, according to the species, covered entirely on the outer surface with grey matter, forming what is called the *hemisphere.* This lamina, after having bent back upon itself in the middle of the convolutions, unites on the opposite side by one or more commissures or fasciculi of transverse fibres, the largest of which, existing only in the mammiferous tribes, takes the name of *corpus callosum.* It is also known that on the crura cerebri, behind the thalamus opticus, are one or two pairs of swellings of different magnitudes, known, when there are two pairs, as in the mammiferous tribes, by the name quadrigeminal tubercles, from the first of which the optic nerves appear to arise; that the olfactory nerve is the only one which evidently does not arise from the spinal marrow or its pillars; that the *cerebellum,* as a single mass, white internally and cineritious externally, like the hemispheres, but often more divided by external folds, is placed transversely, behind the quadrigeminal tubercles, and over the medulla oblongata, to which it is united by transverse fibres which go by the name of *crura cerebelli*, and which are inserted into the cerebellum by the side of the pons Varolii.

" It was in these masses, so different and so complicated, that the place of departure of irritation and the arrival of sensation were to be looked for: their respective cooperation in voluntary actions was also a point to be ascertained; and this is what M. Flourens has particularly endeavoured to do.

" In the first place, he examined how far up he could proceed in order to excite powerful irritation in the muscular system; and he has found a point where these irritations were of no avail. Thinking then the brain itself was the seat of this insensibility, he irritated it more and more deeply, but still producing no action on the muscles; and when action did begin he found himself at the same spot where action had ceased as he proceeded upwards.

" This is also the spot where sensation, produced by irritation of the nerves, ceases; above the spot pricked, wounds produce no pain.

" M. Flourens has pricked the *hemispheres* without producing either contraction of the muscles or any apparent pain to the animal; he has removed them by slices. He has performed the same operation on the *cerebellum*. He has at the same time removed the hemispheres and the cerebellum:

the animal has remained impassive. The *corpora striata*, the *thalami nervorum opticorum* were attacked and removed without any effect. Contraction of the iris did not take place, neither was it paralysed.

"But when he irritated the *quadrigeminal tubercles*, shivering and convulsions commenced; and this shivering and these convulsions increased as he penetrated deeper into the medulla oblongata.

"The irritation of these tubercles as well as that of the optic nerves produced violent and prolonged contractions of the iris.

"These experiments are in accordance with those of Lorry, printed in the third volume of the *Mémoires présentés par les Savans etrangers.* 'Neither the irritations of the brain,' says this physician, 'nor those of the corpus callosum itself, produce convulsions. It can be removed with impunity. The only body situated among those contained in the skull, which has appeared to be uniformly and universally capable of exciting convulsions, is the medulla oblongata. It is this part alone which produces them, to the exclusion of all the other parts.'

"These experiments are at variance with those of Haller and Zinn, as respects the cerebellum; but, after what M. Flourens has seen and shown us, it appears that these physiologists had unconsciously touched the medulla oblongata.

"In his language, M. Flourens concludes that 'the medulla oblongata and quadrigeminal tubercles are irritable;' which, in our language, signifies that they are conductors of irritation, as are the spinal marrow and nerves; but that the cerebrum and cerebellum have not this property.

"The author also concludes that these tubercles are the continuation and termination of the spinal marrow and medulla oblongata, and this conclusion is in accordance with what their anatomical relations and connexions indicate.

"Wounds of the cerebrum and cerebellum produce no more pain than convulsions, and, in common language, it would from that be concluded that the cerebrum and cerebellum are insensible. But M. Flourens says that these tracts are the sensible tracts of the nervous system, which simply signifies that it is to them that the impressions received by the organs endowed with sensations must arrive in order that the animal may experience the sensations. M. Flourens seems to us to have well proved this proposition as regards the senses of sight and hearing: when the cerebral lobe of one side is removed the animal sees no longer on the opposite side, although the iris of this eye preserves its mobility; when the two lobes are removed it becomes blind, and cannot hear. But we cannot say that he has equally well proved it as regards the other senses. In the first place he has not nor could he make any experiments respecting the smell and the taste; then as regards the sense of touch itself, his experiments do not appear to us conclusive. In fact the animal so mutilated is quite drowsy; it has no will of its own, it makes no spontaneous motion, but when struck or irritated it rouses itself as from a sleep. In whatever position it is placed it preserves its equilibrium. If laid on its back it rises, it walks if pushed. When it is a frog it jumps if it is touched; when a bird it flies if thrown up into the air; it struggles if annoyed; if water is poured upon its beak it swallows it. Certainly it will be difficult to believe that these actions take place without being provoked by any sensation. It is very true that they are not rational. The animal escapes without any object in view; it no longer has any memory, and frequently stumbles against the same obstacles. And this moreover proves, and these are the expressions of M. Flourens, that such an animal is in a dormant state: it acts like a man asleep. But we are far from believing that a man asleep, who moves during his sleep, who in this state knows how to place himself in a more convenient position, is absolutely deprived of sensation; and because the perception of this has not been distinct, and that he has lost all recollection of it, is no proof that he had not possessed them. Instead of saying, as the author does, that the cerebral lobes are the sole organs of sensation, we shall restrict ourselves to the facts observed, and merely say that these lobes are the sole receptacle where the sensations of sight and hearing can be consummated and become perceptible to the animal: that if we wished to add more to this appropriation we should say that the cerebral lobes are the point where all the sensations take a distinct form and leave durable impressions and recollections; that they are, in fact, the seat of memory, a property by means of which the animal is furnished with the materials for its judgments. This conclusion, expressed in this way, would be sufficiently probable, although in the structure of these lobes and their connexion with the rest of the system, and in the constant proportion of the volume of these lobes with the degree of intelligence of the animals, comparative anatomy offers another confirmation.

"After the effects of ablation of the brain, properly so called, M. Flourens examines those of the extirpation of the quadrigeminal tubercles. The removal of one of the two, after a convulsive action which immediately ceases, produces blindness of the opposite eye, and an involuntary whirling round; that of the two tubercles renders the cecity complete and the whirling more violent and more prolonged. Yet the animal retains all its faculties, and the iris is still contractile. The entire extirpation, or a section of the optic nerve alone, paralyses the iris; from which circumstance M. Flourens concludes that extirpation of the tubercle produces the same results as a section of the nerve; that this tubercle is as regards vision only a conductor; and that the cerebral lobe alone is the limit of the sensation, and the place where it is consummated by becoming converted into perception. After all it must be observed that in too deeply extirpating these tubercles we interfere with the medulla oblongata, and then violent convulsions, which last long, make their appearance. What appears to us to be most curious and unheard of in M. Flourens' experiments, concerns the functions of the cerebellum. During the ablation of the first slices, only a little weakness and a want of harmony in the movements occur. At the removal of the middle slices an almost general agitation is the result. The animal, continuing to hear and to see, only executes abrupt and disorderly movements. Its faculties of flying, walking, standing up, &c. are lost by degrees. When the cerebellum is removed, the faculty of performing regulated movements has entirely disappeared. Placed on its back the creature could not get up; yet it saw the blow that threatened it, it heard noises, it endeavoured to avoid danger, and made many efforts to do so without accomplishing its object. In a few words, it retained the faculties of perception and of volition, but it had lost the power of making its muscles obey its will. It was with difficulty that a bird stood up, resting upon its wings and tail. Deprived of its brain, it was in a dormant state; deprived of its cerebellum, it was in a state of apparent drunkenness.

"'It is a surprising thing,' says M. Flourens, 'to see a pigeon, as he loses his cerebellum, gradually losing the power of flying, then that of walking, and at last that of standing up, which is also gradually lost. The animal begins by not being able to stand straight upon its legs; then its feet are not sufficient to keep it up. At last, any fixed position is impossible; it makes incredible efforts to attain some such position, without effecting it; and yet, when fatigued and exhausted, it appears as if it wished to be quiet; its senses were so acute that the slightest gesture reproduced contortions, without the least convulsive action, as long as the quadrigeminal tubercles and medulla oblongata remained untouched.' We do not know of any physiologist who has made known any of these singular phenomena.

"Experiments on the cerebellum of quadrupeds, and especially on that of adults, are very difficult to be performed, on account of the large masses of bone which it is necessary to remove, and the large vessels which must be opened. Besides, most experimenters have operated after systems imagined beforehand, and were apt to overlook whatever they did not wish to see; certainly no one had yet supposed that the cerebellum was in any manner the balancer, the regulator of the locomotive movements of the animal. This discovery, if experiments repeated with all due precautions establish its generality, cannot but confer the greatest honour on the young observer whose work we have analysed. From what has been said, the Academy, as well as ourselves, is in a position to judge, that independently of superfluous mutations of language, and of known facts, which the author was obliged to bring forward to give connexion to his work, this memoir offers, on many old facts, more concise details than any we possessed before, and contains others as new as they are precious to science.

"The integrity of the cerebral lobes is necessary for the exercise of vision and hearing; when they are removed, the will is no longer manifested by spontaneous acts. Yet if the animal is suddenly excited it executes regular locomotive movements, as if it constantly endeavoured to fly from the pain, and manifests uneasiness; but these movements do not effect the object in view, very probably because its memory, which has disappeared with the lobes, which were its seat, no longer furnishes a base or elements to its judgments.

"These movements, for the same reason, have no sequel, because the impression which has caused them leaves neither remembrance nor durable will. The integrity of the cerebellum is necessary to the regularity of the locomotive movements: let the cerebrum be entire, the animal will see, hear, and have volition of different kinds, very apparent and energetic; but if the cerebellum is removed, it will never have the power of preserving the equilibrium necessary for its locomotion. Yet the parts retain for a long time their irritability, without being in want of the cerebrum or cerebellum: irritation of a nerve is still followed by contraction of the muscles to which it is distributed; irritation of the spinal marrow produces action in the parts placed beneath the irritated point. It is altogether at the top of the medulla oblongata, at the spot where the quadrigeminal bodies are attached to it, that this faculty ceases of receiving and propagating, on one part irritation, and on the other pain. It is at least at this point that sensations must arrive to be perceived. It is also from hence that the mandates of the will must depart. Thus the continuation of the nervous organism, from this point to all parts of the system, is necessary to the execution of spontaneous movements and the perception of impressions, whether internal or external.

"All these conclusions are not identical with those of the author, and especially they are not expressed in the same terms. But they are those which have appeared to us to result the most rigorously from the facts which he has so well established; they, without doubt, will suffice to enable you to judge of the importance of the facts adduced to engage you to express your approbation to the author, and to invite him to continue to communicate to you accounts of whatever further progress he makes in a labour so very interesting.

(Signed) "Portal, The Count Berthollet,
Pinel, Dumeril,
"The Baron Cuvier, Reporter.

"The Academy approves of the report, the conclusions of which it adopts, and orders it to be printed.

"Certified in accordance with the original,
"The Perpetual Secretary, Baron G. Cuvier."

In consequence of the observations, in the *rapport* now laid before the reader, which go to question the sufficiency of the proofs adduced of the loss of the senses of hearing and smell, as well as of sight, M. Flourens was led to make further experiments, some of which are so highly interesting that I shall not hesitate to give an account of them, by way of supplement and continuation of what has already been stated.

Experiment of M. Flourens in proof of his opinion "that the cerebral lobes are the exclusive seat of the *sensations*, *perceptions*, and *volitions*."

M. Flourens removed, at the same time, the two cerebral lobes of a healthy chicken.

The animal, thus deprived of its cerebrum, survived ten whole months in a state of perfect health, and would in all probability have lived longer if M. Flourens had not been obliged to leave Paris.

During the whole of this time M. Flourens closely watched all the actions, habits, &c. of the animal, and the following is the result of his observations:

He had scarcely removed the brain before the sight of both eyes was suddenly lost; the hearing was also gone, and the animal did not give the slightest sign of volition, but kept himself perfectly upright upon his legs, and walked when he was irritated, or when he was pushed; when thrown into the air he flew, and swallowed water when it was poured into his beak.

He never moved unless he was irritated; when placed upon his feet he remained upon them; when seated on his belly, in the manner that chickens do when they sleep, he remained in that position; he appeared plunged in a sort of drowsiness, which neither sound nor light in the slightest degree disturbed; nothing but direct irritation, such as pinching, or pricking, or striking, had any effect in rousing him.

When the animal did move about, it seemed to do so without any motive or object, though there were no convulsions, nor any want of harmony in its movements; if it met with any obstruction it did not know how to avoid it.

The chicken was quite healthy, and five months after the operation the wound had quite healed, and a new layer of bony matter was forming.

Still it had no sense of smell or taste; neither had it any sensation of hunger or thirst; for after allowing it to fast for three whole days, and then placing food immediately under its nostrils, and afterwards putting it into its beak, and also putting its beak into water, it did not show the slightest disposition either to eat or drink, and would have died for want of nourishment if it had not been fed by force.

It seemed entirely to have lost its memory, for if it struck itself against any body it would not avoid it, but repeat the blow immediately.

Finally, it will be seen, that in a bird from which the cerebral lobes were removed, but in which the organs of sight, hearing, taste, and touch were perfect, the impressions received by them were not perceived by the individual himself; in short, that the bird was blind, deaf, and without taste or touch.

In opposition to the above experiment, the effect produced by the removal of the optic tubercles may be usefully brought forward.

The operation of removing the optic tubercles was invariably attended with convulsions. If the optic tubercle on one side only was removed, the opposite eye immediately became blind. In one bird, in which M. Flourens removed both tubercles, blindness immediately followed, and one bird thus mutilated[1], though perfectly blind, three or four days after the operation, went about in search of food, sought the place of rest in the evening, received the caresses of the male and responded to them, avoided the objects that it had once struck, advancing with precaution; it pecked the ground as it walked about, swallowing the grain and rejecting the pebbles; it soon learnt and remembered the places where it ordinarily received its food; the cautious animal conducted itself, in fact, under all the circumstances, with an intelligence more decided and continual, in as much as having lost the sense of sight, it was obliged to supply that loss by means of its other senses, directed by its intellectual faculties.

M. Flourens, in order to prove the office of the cerebellum, removed it in a pigeon by successive slices. The removal of the first pieces merely appeared to weaken the bird, and to produce some irregularity and want of harmony in the action of the muscles of the limbs. On reaching the middle of the cerebellum, it manifested a universal agitation, but heard and saw everything perfectly. When the whole was removed it no longer had the power of walking or flying, and placed upon its back it was unable to raise itself; but far from remaining quiet and calm, as in a pigeon from which the hemispheres were re-

[1] Page 92.

moved, it constantly made vain and ill-regulated attempts to rise: if it was threatened, or a pretence made to strike it, it endeavoured to avoid the blow. Finally, volition and sensation remained, as did also the power of exciting the contraction of the muscles; but the faculty of producing harmonious and regularly combined movements no longer remained.

Bouillaud, in a pamphlet entitled "Recherches cliniques et expérimentales tendant à refuter l'Opinion de M. Gall sur les Fonctions du Cervelet, et à prouver que cet Organe préside aux Actes de l'Equilibration, de la Station et de la Progression," advances some opinions which, to a certain extent, are at variance with those of M. Flourens on the same subject, in as much as he considers that the regulating power of the cerebellum is confined to the muscles of locomotion, and that it has no power over other voluntary movements.

It will not be necessary to detain the reader with any detail of the experiments of M. Bouillaud, for by confining myself to the summary of his observations I shall be enabled to convey all the information of importance his memoir contains.

"Mutilations of the cerebellum," says M. Bouillaud, "were not accompanied by paralysis or convulsions, properly so called, but merely by disorder of the locomotive functions; the faculties of equilibrium and progression were destroyed. The animals mutilated were still capable of reflection, of hearing, of moving their limbs in all directions, and most frequently these movements were executed with extraordinary quickness and violence; from which it follows, says M. Bouillaud, that we must admit the existence in the cerebellum of a force which presides over the association of the movements composing the different acts of locomotion and of station, a force essentially distinct from that which governs the simple movements both of the trunk and limbs, although there exists the most intimate connexion between the two.

"In this view of the subject it is impossible not to adopt the opinion of M. Flourens, namely, that in the cerebellum resides the power of coordinating the actions of walking, running, flying, standing, &c. But M. Flourens appears to have fallen into an error when he says that the cerebellum is the coordinator of all the movements called voluntary.

"Up to this time experiments only warrant our saying that the cerebellum is the central nervous organ which gives to vertebrated animals the faculty of preserving their equilibrium and of exercising the various acts of locomotion. Besides, I think I have proved in another memoir that the cerebellum coordinates certain movements, those of speech in particular, more marvellous than those of which we are here treating.

"The disorders of the functions of station and progression are not the same, whether the cerebellum is simply irritated or partly disorganized, or entirely destroyed. If the cerebellum is only irritated, its functions are not destroyed, but are thrown into confusion, if I may so express it, for a certain time. It is in this state that we observe jumping, falling heels over head, whirling, and all the puzzling movements which are executed with such impetuosity that the eye cannot follow them, which renders a description of these movements very difficult. It is also in this state that we observe that violent agitation so much like epilepsy. These phenomena do not appear to have been observed by M. Flourens in all their shades, undoubtedly because he always conducted his experiments by the ablation of parts. They have been found especially remarkable in birds; they are also to be observed in the mammalia. These phenomena evidently indicate a lesion of the functions of station and locomotion; they are irresistible. But this disorder, this species of *alienation* of the locomotive movements, soon disappears when the irritation is not continued; so that the animal gradually regains its proper attitude and normal gait.

"It is not so when the cerebellum is totally disorganized or entirely removed; the animal is then for ever deprived of the faculty of equilibration, of walking, and of flying if a bird; all the efforts it makes are useless, they merely demonstrate that though unable to perform any combined motions out of which station or locomotion results, it nevertheless retains the faculty of executing partial movements, and of moving its limbs in all directions.

"Between the total loss of equilibrium and progression, following the ablation or entire disorganization of the cerebellum, and the derangements of these acts produced by the simple irritation of the same organ, there exist many differences relative to the extent and depth of the lesions.

"When the cerebellum is only disorganized over a small extent of surface and to very little depth, the animal has some trouble to keep its equilibrium, and, when walking, staggers as if drunk: it can still take the food given it: it sometimes recedes, as if to regain its equilibrium, and to avoid falling forwards: its head and limbs straighten themselves; it rests against the surrounding objects. Some animals, rabbits for example, throw themselves forwards, and jump without motive; others whirl round, &c.

"Is the lesion more extensive and deeper, it is then that the most curious disorders in locomotion are observed. The animal, trembling and staggering as if in a most perfect state of drunkenness, consumes itself in fruitless efforts to stand; it falls in all sorts of ways, moves to the left when wishing to move to the right, recedes when wishing to advance, rolls upon itself, whirls round upon its belly, and seems to be under the influence of an infinite number of contrary powers, each of which solicits it to action, without, however, securing the preponderance or establishing equilibrium; so that the creature is tormented by its own wishes, and is made to suffer apparently extreme torture.

"As I have described, as distinctly as I could, these strange phenomena in particular experiments," continues M. Bouillaud, "I will no longer continue to speak of them here. M. Magendie has very well described the results produced by lesion of a single hemisphere, or of one of the peduncles of the cerebellum. It is known that then the animal rolls upon itself, and that this irresistible movement is executed from right to left and from left to right, according to the hemisphere which is wounded.

"M. Magendie has also accurately described the state of an animal whose cerebellum has been divided into two equal parts by a section directed according to the antero-posterior diameter of this organ. This is the state of the animal: 'It seems to be first pushed to the right, then to the left, without keeping any fixed position: if it rolls once or twice on one side, it soon gets up and rolls as often on the opposite side.' These are the phenomena *constantly* observed after lesions of the cerebellum.

"The sensations and intellectual faculties suffer no direct alteration from these lesions; but as the quadrigeminal tubercles (optic lobes in birds) are contiguous to the cerebellum, it is seldom that they are not wounded at the same time as the cerebellum, or that the irritation is not communicated to them; and then we observe that vision is troubled as well as the motions of the eyes. From the same cause a very singular state of the eyes, which I have often observed, and which is difficult to describe, is produced.

"When the tubercles are not injured, the sight and movements experience no lesion immediately produced by alteration of the cerebellum. In any case, a pure and simple lesion gives no pain.

"Such are the results of the numerous experiments which I have performed. I have neither observed erection nor ejaculation in animals having a lesion of the cerebellum, although many were examined during several days. If we read attentively the experiments of the different authors on the cerebellum, as I have done, we shall be convinced that all experiments, without even omitting those of physiologists whose opinions are in direct opposition to those of M. Flourens, are examples of disorder in station and locomotion. They are *unanimous,* if I may so express it, only on this point; and what is not less curious is, that the greater number of cases related by authors tend equally to prove, as I shall do in a subsequent memoir, that lesions of the cerebellum confuse the locomotive functions." So much for M. Bouillaud.

Rolando (in a work entitled *Saggio sopra la vera Struttura del Cervello dell' Uomo e degli Animali, e sopra le Funzioni dell' Sistema nervosa,* 1809, 2nd edit., Torino, 1828,) relates several experiments on the brain, resembling in some respects those of Flourens; and, although they were published prior to his, there is no ground for supposing that the latter author has in any degree been guilty of plagiarism. Rolando perceived to a certain extent the loss of intellectual power occasioned by injuries of the cerebral lobes; he also conjectures that the cerebellum is in some way connected with the power of locomotion; but he arrives at no positive conclusions on either of these points.

M. Foville* admits the facts adduced by Bouillaud and Flourens in proof of the coordinating power of the cerebellum over the voluntary motions; but reasons upon them very differently, as will be seen below. "The opinion advanced by some physiologists," says M. Foville, "that the cerebellum is the regulator of the voluntary movements, if we attentively consider the reasoning on which it rests, seems to me to strengthen the idea which places the central seat of sensibility in the cerebellum. After having injured the structure of the cerebellum extensively, we have observed

[1] *Diction. de Méd. Pratique,* art. Encephale, p. 204.

that animals preserved the power of moving their limbs, but had lost that of coordinating the movements of these in a manner convenient to station, progression, flight, &c. But when we *will* to perform, and actually perform, certain movements, do we not distinctly feel that we execute them? The man who, with his eyes shut, moves his hand or his arm, does he not also as distinctly feel that he moves these parts as if he followed them with his eyes? whilst the paralysed man who, with his eyes shut, is desired to move the paralysed limbs, may be very willing to do so, though incapable, and perfectly aware of his incapability of obeying; nor would it be possible to persuade the individual so circumstanced that he did move his limbs.

"If this be true (and no one, I think, will doubt it,) how can we expect that an animal deprived of the faculty of perceiving the sensation of the movements which it executes should execute them in the *ensemble* with harmony and in accordance with a proposed end? How can we expect it to walk deliberately and to keep its equilibrium if it does not feel the ground upon which it stands, if it is ignorant of the position in which its limbs are placed? I remember conversing with Sir Astley Cooper on this subject towards the end of the year 1830. Sir Astley cited to me the case of a man completely deprived of the faculty of sensation in one arm and hand, the muscular power of which was however preserved. When this man was desired to take hold of and to lift anything, he did so very well; but if, whilst holding the object, his attention was taken away from the hand, irregular contractions of the limb commenced, and very soon the object held fell to the ground: as soon as the patient ceased to follow the contractions of his fingers with his eyes, nothing remained to inform him that he held the object, when, of course, it escaped from his grasp.

"This and other cases of a similar description seem conclusive as to the fact of sensation being the true regulator of the muscular motions: it is by means of sensation that we are aware of the mode or degree of action of our muscles, that we have the power of coordinating their contractions in a suitable manner, and of executing a succession of voluntary movements in harmony with one another. The faculty of perceiving the movements being lost, we cannot answer for their precision or duration.

"The *exposé* of these facts, which prove that deep injuries of the cerebellum produce loss of regularity and harmony of the voluntary movements, supports very strongly the opinion of those who consider the cerebellum as the focus of sensibility; and if, in these same circumstances, we observe some phenomena which would make us think that sensibility is not entirely lost, it may be contested that there remains in the parts examined a sort of sensibility of which the animal is unconscious; the irritability or ordinary sensibility not being completely abolished, is so modified by alteration of its central organ that it only receives a few painful impressions, very different from the precise sensations which are necessary to the regular coordination of voluntary movements.

"In summing up the inquiry regarding the two functions of sensibility and movement, functions a knowledge of which is so very important in the practice and treatment of enkephalic affections, it seems to me that there is no doubt that the cerebrum, properly so called, is the centre of voluntary motion, and every reason to believe that the cerebellum is the central point of convergence for the sensations."

These arguments of M. Foville, though in my own opinion far from conclusive, are extremely interesting, especially when considered in connexion with Sir Charles Bell's views on the existence of a *muscular sense*; in fact the arguments and cases of M. Foville are very analogous to those of Sir Charles Bell. It seems to me that no physiologist can dispute the existence of that peculiar species of sensation by which we are informed of the state of the muscles during contraction. The seat of this peculiar *sense* seems to be considered by Foville as resident in the cerebellum, though he does not explicitly say so. A candid consideration of M. Foville's opinions must at any rate convince us that the views of Messrs. Flourens and Bouillaud cannot yet be regarded as established doctrines in the science of physiology.

From this field of experimental inquiry let us direct our attention to those facts which have been accumulated by the industry of the pathologists both in this country and abroad, in the hope that some useful information may accrue from an inquiry into the results of their labours.

PART VIII.

PHYSIOLOGICAL INFERENCES FROM PATHOLOGY.

CONTRASTED with the multifarious offices of the nervous system as the immediate agent in the various manifestations characterized by the terms *will, instinct* and *understanding*, it is obvious from what has now been said that a very scanty amount of information has been obtained, or seems likely to be obtained, by means of mutilations practised on the lower animals. Let us therefore next direct our attention to the field of *Pathology*, which has been repeatedly proposed as well calculated to extend our knowledge of the functions of the nervous system.

It happens unfortunately here that almost in the direct ratio of the value of pathological evidence when obtained, should be the difficulty of procuring it. Very rarely indeed do we find disease of the cerebral mass so isolated in its seat, or so concentrated in its influence, as only to affect what we might be inclined to regard as the particular instrument of a single function. From repeated experience I can myself state decidedly that there are few investigations more unsatisfactory and disappointing in their results than those which have diseases of the nervous centres for their subject, in reference to a connexion betwixt disordered function and diseased structure.

Dr. Abercrombie, whose invaluable work on diseases of the brain ought to be in the hands of every medical student, remarks, that "we find the same difficulty in attempting to ascertain the effect of *ramollissement* of particular parts of the brain in producing symptoms in particular organs, as in distinguishing *ramollissement* from other lesions of the brain. Convulsions in the same side with the disease, and paralysis on the opposite side, appear to be frequent symptoms, but are by no means uniform. In several cases the speech is remarkably affected, but they present no uniformity in the seat of the disease [1]."

And Lallemand, to whose admirable letters I shall have occasion frequently to refer, says, in relation to the study of diseases of the brain, "It is easy enough in *theory* to consider diseases in their simple state, to isolate them in our study, but in practice nothing is more difficult than to meet with a disease exempt from complication."

Otto, whose useful compendium of pathological anatomy Mr. South has made available to the English student by his faithful translation, says, "In no instance do we find greater difficulty than

[1] Abercrombie on the Diseases of the Brain and Spinal Cord, third edit. p. 116.

in the brain in making the results of dissection agree with the phenomena of disease previously exhibited [1]."

Bouillaud also adds his testimony to the insufficiency of pathological evidence, in the present state of our knowledge, for the solution of physiological problems. "It is but in accordance with strict truth to declare that a great many more researches are to be made before we can discover in all cases what are the constant pathognomonical symptoms which correspond exclusively to the lesions of such and such a portion of the cerebral mass. Nevertheless the great progress which this science has made for some few years, allows us to shortly expect something new [2]."

And when to the testimonies of these celebrated writers we add those inexplicable cases of injury and disease of the brain which are unaccompanied by any appreciable lesion of function, we are bound to confess that pathology is indeed a most uncertain guide in physiological investigations of the kind we are so anxious to further. Nevertheless we should not entirely reject such aid, but merely remember how imperfect it is at present, and not therefore expect too much from it.

Part of our ignorance regarding the connexion between diseased structure and impaired function

[1] Page 365.

[2] *Dictionnaire de Médecine et de Chirurgie pratiques*, p. 27, a. tome 7me.

has arisen from the superficial mode in which *post mortem* examinations are frequently conducted, from the omission of careful observation of the relative colour of the cineritious and medullary neurine, so that it frequently happens that we meet with reports of cases of paralysis during life being unattended with the smallest morbid appearance after death, when in all probability the change which really existed was passed over, namely, a much deeper colour than natural of the cineritious neurine, an appearance unaccompanied with any other change, not unfrequently found in connexion with paralysis, and one which we are therefore as much justified in considering as the efficient cause of that malady as *ramollissement*, extravasation, or any of the more palpable morbid alterations.

In the following case of paralysis which occurred in St. Thomas's Hospital, no morbid alteration was found beyond that referred to, viz., that the cineritious neurine was unnaturally dark, and the line of demarcation between it and the medullary peculiarly distinct: the dark colour of the cineritious neurine most probably was occasioned by its increased vascularity or an anormal state of its circulation.

James Panton, æt. 25, nightman.—Has been labouring under gonorrhœa and warts for some months, and was at the period of his attack under treatment for them; he states that for the last two months he has had pain at the top of the head and forehead, and his eyesight has gradually been diminishing; he could not see distinctly towards evening. Soon after the eyesight became impaired, he became deaf. The symptoms continued up to the present time. He has been noticed by the Sister to be very chilly, although the weather was hot.

On the 19th of August he was observed to have lost some power over both legs, but particularly over the left, and the sensation of the skin was impaired. Soon after (a few hours only) the arm of the left side became paralysed, and then the right arm. The sensation in all these parts was impaired.

August 20. The left side of the body is perfectly paralysed. He has lost sensation in the left arm and leg entirely, and slightly also in the right leg; in the right arm it is still less impaired. His breathing is sonorous, like ordinary snoring. He has some difficulty in swallowing. The face is paralysed. In the first of the morning it was drawn to the left side, but now it is drawn to the right. The pupils are dilated; the left is the larger; they do not contract readily to the stimulus of light. For the last two or three nights he has been delirious. He is now perfectly sensible, and answers questions quite correctly, and can even recollect events which have occurred some months back. The tongue is considerably coated, and when he puts it out, it points to the right side of the body. The bowels are freely open, and the motions are dark-coloured. He is very thirsty. The left cheek blows out during expiration. There is slight cough, and sonorous and mucous rattles are heard over the chest. Pulse 108. He complains of tenderness at the epigastrium and scrobiculus cordis. He has complete power over the rectum, and passes his urine naturally: he is perfectly aware of the calls of nature. He complains of considerable pain in the legs and arms. The arm over which he has power contracts, and resists extension somewhat. The paralysed arm is perfectly extended. The left leg is extended at times.

21st. He passed a sleepless night; he appears to be quite sensible. He says he has no pain in the head, and that he feels "quite nicely." He swallows with greater difficulty than he did, and he appears more stupid. The breathing is much more snoring. Tongue coated, dirty, dry. The right leg is more paralysed than it was. The other extremities remain in much the same state as at the last report. He appears to breathe more with the abdominal muscles. Pulse 125, small and weak: skin moist. He appears to pass his motions involuntarily.

22nd. Towards last evening he got worse. He became more stupid: breathing more snoring: features more contracted: face became more drawn to the right side. This morning I found him *in articulo mortis.* He has been getting worse and worse during the whole night. He breathes with much greater difficulty—about 38 in a minute. He appears sensible. He is bathed in sweat, and keeps groaning. There is still some rigidity in the affected limbs. The left arm is partially flexed. His pulse is so small and quick that I cannot count it. He died early the following morning.

In taking a view in their bearing upon physiology, of the pathological facts on record, whether consisting in injuries or diseases of the brain, a question naturally arises as to whether it is most advisable to classify the observations according to the genus of disease, or to take each individual portion of the cerebral ganglia, and then observe the effects of disease upon them.

As I am not aware that any advantage will be obtained by a strict adherence to either of these systems, I commence the subject with a narration of those injuries which produce a more general effect, as concussion, compression, &c., and then proceed with the effects of inflammation and *ramollissement*, and conclude with the general and local effects, as far as we can ascertain them, of extravasation of blood, depositions of pus, and pressure of morbid growths on individual portions of the encephalic mass ; confining myself strictly to the consideration of those circumstances which appear to illustrate the physiology of the organ; for if I were to attempt to consider them in a practical point of view, I should defeat the great object of this work. We shall begin by considering the more simple lesions in the first instance, and then proceed to those of a more serious and fatal character.

CONCUSSION.

Simple concussion or shaking of the brain obliterates, for a longer or shorter period, according to the degree of violence, the mental phenomena which are exhibited during a state of health. The patient who a moment before was in complete possession of all his mental faculties, receives a violent blow on the head, and in an instant loses his consciousness and lies dead to the world around him. This result we suppose to depend on the particles of neurine, of which the brain consists, being put into a state of vibration, an effect which interrupts for a time the natural functions of the organ.

The state of insensibility sometimes continues only for a few minutes, in other cases it will last for some days, the patient remaining in a kind of sleep, insensible to *ordinary* stimuli; the eyes, for instance, may be opened in a moderate light, and he will not apparently be aware of the presence of any one; but if a strong pencil of rays be thrown upon the iris it will contract, to prevent too many from impinging upon the retina, and he will perhaps turn his head away from the light.

A conversation may be kept up by his bedside without disturbing him; but if he be called loudly by his name he gives evidence that he is aware of the circumstance. As recovery gradually takes place the patient will answer questions, but incoherently, evidently neither understanding their import, nor able sufficiently to collect his thoughts to give a particular answer. If the case proves favourable, these symptoms disappear by degrees, the patient recovers, and no traces of the accident remain. If, however, inflammation supervene, another train of symptoms makes its appearance, and then the consequences are generally fatal.

No one who has once observed a case of concussion can doubt that the intellectual faculties are dependent in some way or other on the brain; but at the same time it is clear that this is the whole amount of evidence furnished by the phenomena; we have no guide in all we observe to the particular offices of the individual portions of the brain.

COMPRESSION.

The general symptoms of compression so closely resemble those of concussion that some authors assert, and, I believe, justly, that there are no unequivocal marks by which to distinguish them; but if the concussion be comparatively slight, and the compression severe, important differences may be observed. In severe compression the stupor will be complete, and the mind be, as it were, for the time, obliterated: the eye is insensible to light, the ear to sound, and the skin to touch; the breathing is slow and stertorous, and the heart's action is frequently oppressed. That these formidable symptoms are occasioned by pressure on the brain is proved by the cases in which almost immediate relief has been obtained by an operation by which the pressure has been removed.

Sir A. Cooper used to relate in his lectures on surgery one of the most interesting and unique cases on record, and though it has frequently been before the profession, I shall not hesitate to introduce it in this place.

"A man was pressed on board one of His Majesty's ships early in the late revolutionary war. While on board this vessel in the Mediterranean, he received a fall from the yardarm, and when he was picked up, he was found to be insensible. The vessel soon after making Gibraltar, he was deposited in a hospital in that place, where he remained for some months, still insensible; and some time after he was brought from Gibraltar on board the Dolphin frigate to a depôt for sailors at Deptford. While he was at Deptford the surgeon under whose care he was, was visited by Mr. Davy, who was then an apprentice at this hospital: the surgeon said to Mr. Davy, 'I have a case which I think you would like to see. It is a man who has been insensible for many months; he lies on his back with very few signs of life; he breathes, indeed, has a pulse, and some motion in his fingers; but in all other respects he is apparently deprived of all powers of mind, volition, or sensation.' Mr. Davy went to see the case, and, on examining the patient, found there was a slight depression on one part of the head. Being informed of the accident which had occasioned this depression, he recommended the man to be sent to St. Thomas's hospital. He was placed under the care of Mr. Cline; and when he was first admitted into the hospital, I saw him lying on his back, breathing without any great difficulty, his pulse regular, his arms extended, and his fingers moving to and fro to the motion of his heart, so that you could count his pulse by this motion of his fingers. If he wanted food, he had the power of moving his lips and tongue; and this action of his mouth was the signal to his attendants for supplying this want.

"Mr. Cline, on examining his head, found an obvious depression; and thirteen months and a few days after the accident, he was carried into the operating theatre, and there trephined. The depressed portion of bone was elevated from the skull. While he was lying on the table, the motion of his fingers went on during the operation, but no sooner was the portion of bone raised than it ceased. The operation was performed at one o'clock in the afternoon; and at four o'clock, as I was walking through the wards, I went up to the man's bedside, and was surprised to see him sitting up in his bed. He had raised himself on his pillow. I asked him if he felt any pain, and he immediately put his hand to his head. This showed that volition and sensation were returning. In four days from that time the man was able to get out of bed, and began to converse; and in a few days more he was able to tell us where he came from. He recollected the circumstance of his having been pressed, and carried down to Plymouth or Falmouth; but from that moment up to the time the operation was performed (that is, for a period of thirteen months and some days,) his mind had remained in a perfect state of oblivion. He had drunk, as it were, the cup of Lethe; he had suffered a complete death as far as regarded his mental and almost his bodily powers; but by removing a small portion of bone with the saw, he was at once restored to all the functions of his mind, and almost all the powers of his body."

Besides these usual and obvious effects of mechanical injury of the brain, it is proper to observe that this delicate organ occasionally receives very severe injury, and even sustains the loss of considerable portions of its substance, without any immediate serious consequences or apparent ultimate ill effects resulting.

The following case from the Edinburgh Medical and Surgical Journal, vol. xxxiv. p. 319, aptly illustrates this curious fact.

"William Conolly, 30, a blacksmith, on the evening of January 27, 1830, was firing at a mark with an old musket heavily loaded. The explosion retrograded, and shot the screw part of the breech deeply into his brain, an inch above the superciliary ridge on the left side. The whole of the breech, including the neck, was sunk beneath the surface, except the tail part, which projected nearly at right angles from the forehead, with the screw-hole in its extremity, by which the breech is fastened to the stock by a screw-pin, and through this hole it was necessary to pass the screw-pin to facilitate the extraction of the breech. This required a degree of force equivalent to what is sometimes found necessary in drawing a tight wine-cork. Very shortly after the accident, I accompanied the Rev. Mr. Duffy of this town to see him: he was then lying on a bed; the breech had been removed as I described; his face was scorched black; his eyelids swollen and closed; his extremities cold; pulse 50; he was collected, and very capable of muscular exertion, volunteering to sit up whilst I examined him. A wound, with uneven, swelled, and lacerated edges extended an inch and a half in length, and an inch above and parallel with the eyebrow. I removed several comminuted fragments of bone with great caution, as the least inadvertent pressure sunk them deeper in the broken pulp of brain in which they were imbedded. On passing the point of the forefinger round the inner edge of the aperture, several pieces of the inner table were found loosened. These were also removed with some necessary force between the point of the finger and the end of a probe. Being now satisfied of the firmness of the edge which bounded the aperture through the bone, and which was nearly oval and better than an inch in diameter, the external wound was with much difficulty, and only partly, closed with narrow straps of adhesive plaster. A bit of simple dressing was laid along the line of the opening, and over all was applied a pledget of wetted lint. About a dessert spoonful of brain escaped during the dressing. I should have observed that the membranes of the brain were quite destroyed to the extent of the opening of the canal. When I left him for the night his pulse was 56. The bowels had been open during the day; no medicine was ordered, but perfect quietude and silence were strictly enjoined.

"28th. Slept quietly; no pain; bowels open; pulse 60; tongue whitish; feels much annoyed from the quantity of discharge streaming down his neck and shoulders. It was a bloody serum, mixed with a great quantity of brain floating through it. The same dressing was continued, and he was enjoined low diet; but no medicine was ordered.

"29th. Passed a quiet night; bowels not open; general appearance heavy and apathetic; frequent sighing; tongue white and furred, with a black streak in the centre; pulse 60.—Continue the dressings.

"℞. Submuriatis Hydrargyri gr. viij. Pulveris Jacobi gr. v. Elect. Scammonii gr. xx. M. Fiat bolus nocte sumendus.

"30th. Brain still issuing in great quantity, mixed with serous blood and pus, in which bits of membrane and of the cortical substance might be distinguished; tongue white and furred; pulse 60; bowels open; still heaviness and apathy of expression.

"31st. Pulse 65, small; tongue still furred and white; wound erysipelatous round the edges; frothy discharge, mixed with brain; bowels open.

"February 1st. Some slight mental aberration; incorrect memory as to time; silliness in his talk; bowels not open.—Repetatur bolus. Dressing as usual.

"2nd. Pulse and tongue as usual; bowels open. I found great difficulty, as from the beginning, in approximating the lips of the wound, on account of the strong pulsatory bulging of the brain. Mind more collected, but excessively irritable and petulant.—Continue the dressings.

"3rd. He feels in better spirits and confident of recovering. With very great difficulty the edges of the wound are forced together.—Repetatur bolus.

"4th. The discharge of brain is becoming less, and the centre of the wound seems coagulating into something like a fungous consistence. The surface of it when cut close to its base with curved scissors presented a curved vermilion streak, which appeared to be composed of minute red points, lost in a surrounding cream-coloured edge. These little red points were probably the cut mouths of newly formed vessels commencing in the organization of a *fungus cerebri.* The whole surface and circumference of the wound were now freely touched with the lunar caustic, and a strip of dry lint was interposed between the wound and adhesive plaster today for the first time. He complains of some little intolerance of light, and slight pain in the back of the head.

"5th. Pain in the head gone; less intolerance of light; bowels open; pulse 64. The fungus looks firmer and contracted; it was again clipped and touched with the caustic. Dressings as usual. A small bladder of cold water was laid over the dressings and secured with a broad ribbon passed round the head. This was substituted for the wet pledgets, which were found to produce excoriation and tenderness.

"6th. The fungus begins to adhere to the edges of the wound; it was clipped as usual; and to it, and the wound generally, the nitrate of silver was applied. The inferior commissure of the wound next the temple, which had been hitherto flabby, irritable, erysipelatous, and excessively painful to the slightest touch, is now free from soreness, contracting and healthy in its appearance, which in my opinion is solely attributable to the free touching with the lunar caustic.

"7th. Some uneasiness in the head, which he attributes to his bowels not being open; expresses much comfort from the bladder of cold water, which is renewed every fourth or fifth hour.—Repetatur bolus.

"8th. Bolus neglected; bowels not open. He is childishly irritable, complaining of the most cruel infliction while the wound is dressed.

"9th. Bowels open; temper ridiculously irritable; upbraids me with unfeeling indifference to the alleged pain I inflict on him in dressing, yet, as if accidentally, bears without a murmur the most painful part of the process, that of forcibly drawing together the lips of the wound.

"11th. My absence from home prevented me from dressing him yesterday. He is, however, not worse; feels ashamed of his former unreasonable impatience; now cooperates in handing the plaster, sponge, &c., and putting himself in a convenient position. From this period his recovery was rapidly progressive. As I found great difficulty in closing the wound with the straps on account of the inversion of its lips over the edges of the bone, I had recourse to the insertion of a single point of suture in the centre. This trifling operation nearly produced fainting, and on removal of the ligature on the third day a complete syncope took place. It is remarkable, however, that although no immediate union took place at this point of insertion, it was very soon the first part skinned over; so that the wound presented for many days subsequently the appearance of two long ovals united at their narrowest parts. In the seat of the injury there is a pulsating depression, in which the point of the finger might be placed, and where moderate pressure produces no inconvenience. The man's intellects seem to be sound, and he has worked both at his trade as horse-shoer since February 26th, which requires necessarily the head to be in a dependent position, and at laborious agricultural work, without any inconvenience."

There is another case bearing upon this point related in the 12th volume of the same Journal, p. 22, by Mr. Crawford, Surgeon R.N.

In this case the patient was a boy betwixt two and three years of age. The skull was fractured and depressed to the depth of about an inch, and the cavity formed by the deepest part of the fracture was filled with protruded brain, and a portion of the medullary and cortical substance about the bulk of a walnut was lost. About the third or fourth day after the accident the brain was observed to protrude from the opening through the *dura mater*. When the protrusion rose above the scalp it put on the appearance of a mass of fungous granulations from a wound, and enlarged very rapidly for more than a week till it attained the size of a pullet's egg. The practitioner now determined to try the effect of pressure, and this being successful in gradually reducing the hernia the wound healed, and five months after the receipt of the injury, when again seen by the surgeon, he states that "the boy was then lusty and growing tall; the pulsation of the brain could be plainly seen. The vacancy in the bone appeared to be diminished in size. He is a very clever, healthy, apt child, and not in the least injured by the accident.

In addition to the above cases, which of themselves are sufficient to prove that considerable portions of the hemispheres of the brain may be removed or injured without an evident alteration of the intellectual powers, I may refer the reader to,—

1. *A case of injury of both hemispheres of the brain, by Henry Mansell, Medical Superintendent of the Letterpenny Dispensary, Ireland*[1].— In this instance the injury was occasioned by the

[1] Edinb. Med. and Surg. Journal, vol. xxxiii. p. 76.

bursting of a gun, and portions of the brain were lost, but without the patient ever losing his consciousness. The accident occurred in November 1829; and in July 1830 the report states, "that the patient is now in perfect health, attending to his ordinary business, and living in his usual manner, without ever suffering the slightest pain or uneasy sensation traceable to the injury. A considerable depression, in the bottom of which is a small T-shaped cicatrix, remains in the forehead, directly above the root of the nose, marking the spot first struck by the extremity of the gun-breach. This extends nearly equally on both sides of the central line, and is about ten lines in breadth. Above, and to the right of the cicatrix, the bone is deficient for an irregular space of more than an inch in diameter. In this spot the pulsations of the brain can be seen from a distance of several feet. By gentle pressure on the integuments, the fingers can be sunk into the aperture of the bone, but without producing any unpleasant effect."

2. *Case of fractured skull, and loss of a portion of the brain, occasioned by a fall from a horse, by C. Peak, M.R.C.S.*[1]—The boy to whom this accident happened was sufficiently sensible after it to inform the surgeon in what way it occurred. Some depressed portions of bone were

[1] Edinb. Med. and Surg. Journal, vol. xvi. p. 513.

removed, and during the performance of the operation the substance of the brain escaped in quantities sufficient to fill a large-sized tea-spoon, notwithstanding which the patient was perfectly sensible during the whole time of the operation. On the fourth day convulsive fits supervened, but they gradually gave way, and on the 29th of October he was reported in a state of convalescence.

"*Atrophy from injury*[1].—A man twenty-eight years of age, fell, when three years old, from a first story into the street: he fell on his head. After this fall he remained paralysed on the left side. By degrees an habitual extension of the left foot on the leg was established, so that, on the left, he walked only on the point of the foot. The left upper extremity was completely deprived of motion, no trace of contraction anywhere observed. This person had received some education, and had profited by it; he had a good memory; speech perfectly free; and his intelligence such as is ordinarily met with in the generality of persons. Having entered the infirmary of Bicêtre, where he lived, for a chronic affection of the chest, he was there seized with symptoms of acute peritonitis, of which he died.

[1] Andral, *Clinique Médicale*, translated by Dr. Spillan, Part I., p. 181. The value of this useful work has been much increased by Dr. Spillan's instructive notes, and additional cases from Olivier.

"*Post-mortem examination.*—The vault of the cranium having been removed, the meninges of the right side were found transparent, and fluctuating through almost their entire extent. They were cut into, and a clear, limpid serum, like spring water, gushed forth. Between these meninges and the ventricles there existed not the slightest trace of nervous substance; these membranes constituted the upper walls of an immense cavity, the lower wall of which was formed by the optic thalamus, the corpus striatum, and all the other parts situated on the level of these two bodies. Of the nervous mass situated above the ventricles, there remained only that, which, situated anteriorly to the corpus striatum, forms its anterior wall. Numerous tubercles were scattered through the two lungs, and several ulcers appeared on the surface of the small intestine. There was a perforation in the ileum, whence the peritonitis which terminated the life of the patient.

"*Remarks.*—The lesion discovered in this case, undoubtedly began to be formed after an external injury, twenty-five years before the period when it was examined by us. The atrophy of the brain was not probably here the primitive alteration; it succeeded to other alterations of an inflammatory nature, which commenced immediately after the fall."

The perfect preservation of the intellect up to the last moment is certainly a remarkable circumstance in a case where so great a portion of the brain had for a long time ceased to exist.

M. Breschet has published the remarkable case of a girl, fifteen years of age, in whom the two anterior lobes of the brain were wanting. At the bottom of and behind the membranous pouch which replaced them, the two corpora striata were seen exposed. The head was very well formed.

This girl was in a complete state of idiocy; it was necessary to dress her and feed her; she was disinclined to walk, though she had the power of moving the four extremities with ease and equal facility; she was usually observed in the sitting posture, and remained so for entire days, alternately inclining the head from one shoulder to the other; vision was intact; the most perfect indifference existed for agreeable or disagreeable odours.

Here was a case where atrophy of the two anterior lobes did not bring on paralysis properly speaking. Neither did this paralysis exist in two other subjects, who were still younger, for an account of which we are also indebted to M. Breschet.

In considering these extraordinary cases the question naturally arises how it is, if the brain be the organ of the mind, that the mind occasionally remains perfect, though the brain itself suffers severe injury, and even sustains the loss of a portion of its substance? Without pretending to be able positively to solve the question, I cannot help venturing on the following explanation.

The intellectual faculties in different individuals of the human race differ from one another as much as the human mind itself differs from that of the highest of the brute creation. The intellectual powers of a Newton are as much raised above those of the common hewer of wood and drawer of water as the mental faculties of the labourer are raised above those of the dog which follows him to the field. Now this difference of intellectual power, though no doubt arising partly from the original conformation of the brain, must proceed mainly from the circumstance of the faculties of the mind in the one case being highly cultivated and constantly exercised, while in the other case they have always remained dormant, and never being called into action, their loss is scarcely to be perceived. When the brain has been injured, and the faculties of the individual have not appeared to suffer, it is likely that the ideas of the individual have never been sufficiently abundant to attract notice to the loss of such of them as depended on that part of the instrument of intellect which has been injured. The circumstance has also been accounted for by the phrenologists upon the principle that the mental organs are double, and that the loss of one is not therefore easily perceived; and this opinion is certainly supported by the fact that there are no cases on record in which the mental faculties have remained undisturbed when the disorganization has extended to both sides of the brain.

Bouillaud[1], when speaking of the lesions of the moral and intellectual faculties from inflammation of the brain, makes the following interesting observations in connexion with the previous hypothesis.

"*Lesion of the moral and intellectual functions.* When inflammation only occupies a part, more or less extensive, of one of the cerebral hemispheres, and when the other hemisphere is in a healthy state, the intellectual and moral functions, at least ordinarily, present no notable lesion. It seems that in this case the healthy hemisphere suffices for the exercise of these functions. But if the inflammation of one hemisphere spreads itself over the other hemisphere, a *delirium* of variable form occurs, according to the extent and intensity of the inflammation, and perhaps also according to the part affected either in one or the other hemisphere. A general delirium always exists when the partial irritation generalizes itself, an accident unfortunately often seen."

The following case, abridged from vol. i. of the St. Thomas's Hospital Reports, p. 490, may be

[1] *Dictionnaire de Médicine et de Chirurgie pratique*, art. ENCEPHALITE, tom. vii. p. 262.

selected, among many others, for the purpose of showing that extensive disease of the enkephalon may exist, if the progress of that disease be slow and its whole course of a chronic character; it also demonstrates in conjunction and in contrast with this fact the striking effect of any *sudden change*; for the paralysis which occurred just previous to death must, I think, be accounted for not by the pressure of the medullary tumours, as these had existed for a long period, but by the extravasation of blood from the rupture of the diseased vessels.

"*Case.*—Alexander Forrest, æt. 64, shoemaker, Lazarus ward, St. Thomas's Hospital; admitted under Mr. Green, February 7, 1836, with large medullary bleeding fungus on the elbow-joint of four years' growth; the trunk also is covered with tumours apparently of the same nature, from the size of a small pea to that of a closed fist; there are several tumours on the opposite arm, and three or four about Poupart's ligament.

"The man's countenance is sallow, and he is emaciated; although feeble, he is still able to walk about.

"Feb. 14. Whilst eating his dinner he was suddenly attacked with paralysis, hemiplegia of the right side, and complete insensibility; shortly afterwards there was great heat of head, and his pulse became strong and full at 84. This attack was treated in the ordinary way, by bleeding, purgatives, injections, blistering and small doses of calomel.

"Feb. 25. Complete insensibility had continued three days, but he is now perfectly sensible, and able to move his right leg and arm; there is neither pain nor heat about the head; in fact he has nearly recovered the paralytic attack. The calomel has not affected his mouth. He was now ordered to omit it, and to have porter, beef-tea, &c.

"March 10. Remains in very much the same condition, not able to leave his bed; some of the tumours have enlarged considerably, especially those on the upper part of the chest; hæmorrhage has taken place from tumours situated upon the nape, arm and shoulder. His appetite and digestion are good; he has good nights, and makes no complaint of pain anywhere. Meat daily.

"April 4. His countenance very much depressed, and he is emaciating; loss of appetite, with nausea: pulse 100, small and feeble. The tumours have increased both in size and number, and there is an occasional hæmorrhage from several of them.—℞. Ammon. Carbon. gr. x. ex Mist. Camph. ter quotidie. Brandy ℥ iv. daily.

"April 12. Expresses himself as better, the irritability of the stomach having subsided; but he is evidently sinking.

"April 14. This morning he has had a second paralytic attack; complete insensibility; fixed and dilated pupil: pulse 120, very weak: heat of head.—Omittantur omnia. ℞. Ol. Croton. ♏ j. statim. Inject. Comm. Catapl. Sinapis pedibus. Lotio frigida capiti.

"April 15. Quite sensible, and answers questions rationally. The right extremities are again paralysed; and on protruding the tongue it is drawn to the right side; no dilatation of the pupils.—℞. Mist. Potass. Citr. 4tis horis.

"April 24. He has merged into very much the same state as before the second fit; on protruding the tongue it is still directed to the right side: pulse 108, feeble.—℞. Sulph. Quinæ gr. iij. ter die ex Infus. Rosæ. To resume the brandy, beef-tea, &c.

"April 28. Repeated hæmorrhage from the tumour, under which he is sinking.

"May 2. Died.

"Examination twenty-four hours after death.

"*Head.*—There were several tumours in different parts of the brain, varying in size from that of a pin's head to that of a large walnut, and they were all surrounded by cysts more or less perfect. One of the largest was situated in the left corpus striatum, projecting into the lateral ventricle. Another occupied the greater part of the posterior portion of the left thalamus opticus, and extended into the posterior lobe of the brain. These tumours were solid, and firmer than the cerebral substance. Upon section they presented the appearance of a clot of blood in part deprived of its colouring principle; some were firm and striated; others were traversed by vessels. Some, as the two following, contained a fluid in the centre resembling grumous blood; viz. one in the left middle, and one in the right posterior lobe of the hemispheres: the substance of the brain contiguous to the cysts was softened; in other parts it was quite healthy."

Although my object in introducing pathological facts in this work is to illustrate the physiology of the cerebro-spinal axis, and not immediately to instruct my readers in the character or treatment of the diseases which attack it, I cannot refer constantly, as I shall have occasion to do, to the morbid appearance called *ramollissement* or *softening* of the brain without a short detail of the opinions of the best pathologists on its real nature.

The term made use of to distinguish this peculiar disorganization of the brain, implies the appearance which it presents to the observer: it is, in fact, *softening* of *the substance* of the brain, generally isolated in its seat. By this the observer distinguishes it from the firmer portions of the brain which surround it, though, as it sometimes happens that the whole brain is softened and broken down into a pulpy mass, he has sometimes more difficulty in deciding whether it is truly a morbid appearance, or simply the effect of decomposition.

The portion thus broken down does not necessarily lose its natural colour, though frequently it becomes darker; however, it never resembles pus either in colour or in its disagreeable odour, so that it ought never to be confounded with suppuration.

The earliest observations on this peculiar lesion of the brain are to be met with in the fifth Letter of Morgagni *De Sedibus*, &c.[1], "which treats of the apoplexy as arising neither from a sanguineous nor a serous cause."

The patient whose case he relates was in her 59th year, and was seized with an apoplexy, followed by loss of speech and paralysis, with loss of sensation of the right side. She was not insensible, for "she gave of her own accord the sound arm to the physicians to have her pulse felt," and "she had no difficulty in swallowing fluids," but did not live many days after her admission to the hospital.

Of the *post-mortem* appearances I shall merely detail those which illustrate the lesion in question; and these I shall give from Dr. Alexander's translation in the author's own words:

"But let us now go on to the head, for the sake of which, principally, this dissection was performed. While the skull was sawed through, a quantity of serum came forth; and the upper part

[1] Translated by Dr. Alexander, 1769, p. 98., article 6.

of it being taken off, and the brain being dissected in its natural situation, we first observed that the dura mater was thickened. And the vessels that ran through the pia mater were all distended with blood, as if they had been filled by injection. This blood was such as that of the whole body, black, and not very fluid. And under the same membrane, in the convolutions of the brain, was seen a transparent water, of the same kind with that which was found in the lateral ventricles afterwards; yet the choroid plexuses were not at all discoloured, although they had vesicles upon them turgid with water, and one of these vesicles was equal even to the bigness of a grape. This was in the left plexus, which being taken off, the thalamus nervi optici appeared not of the same colour as the right thalamus, but brown. As I cut the brain into small pieces, I observed that every other part of it was natural and sound; but that the medullary substance, which was on the external side of the left thalamus, spoken of above, was very *soft* and *liquefied*, and was found to be mixed with a certain bloody fluid, of a colour almost effete; so that nothing but a disagreeable smell was wanting to make us pronounce it absolutely rotten. The space of the brain which this disorder occupied was larger than that which the largest walnut would have taken up; and that colour of the bloody fluid was most manifest in the middle thereof. It was more natural to take notice of this difference, because the cerebrum in general, as I said, was of its natural colour, and not only more hard than the cerebellum, but even endowed with a wonderful hardness everywhere, especially in the whole right hemisphere, and had only, in that place I have mentioned, a kind of bloody colour, and a loose ill-compacted substance.

"I believe that this was an *apostema sui generis*, which is agreeable to the opinion even of Avicenna, that an apoplexy might have its origin "from an apostem formed by repletion;" the violence of which was increased in the patient in question by the water being extravasated, and by the vessels being distended. But this apostem happened about the very place in which, as I have already said, organical injuries most frequently happen according to my observations."

The accurate account which Morgagni has given of the post-mortem appearances in this case can leave no doubt as to the real character of the lesion; and it is extraordinary that it should have escaped observation for so long a period after the celebrated author of the work "on the Causes and Seats of Diseases" wrote; for until Rostan published his "*Recherches sur le Ramollissement du Cerveau*," the second edition of which appeared in 1823, softening of the substance of the brain seems to have been entirely overlooked by the pathologists of Europe.

In the present day, however, no one ought to have any difficulty in distinguishing, after death, the morbid appearances designated *ramollissement* by the French writers, and *softening* by the English. But whether this lesion is the result of inflammation or whether it is a disease *sui generis* has not been so clearly decided. Lallemande believes that *ramollissement* is invariably the result of an inflammatory process, while Andral does not allow that this matter is yet decided. But we will quote Andral's own words: after pointing out the different appearances he says[1]: "Do these different appearances which may be presented by softening of the brain, refer to lesions of a different nature? Are they but degrees more or less advanced of one and the same disease? It is easy to prove that in a considerable number of cases the substance of the brain is first injected, then softened, then secretes pus. This has been excellently well established by M. Lallemand. The softening is then one of the anatomical characters of inflammation of the brain, as it may be of all other organs. But if in other cases we do find within the softening any trace either of sanguineous injection, or purulent infiltration; if we find there, in a word, no other alteration but softening itself, will it not be an abuse of analogy to conclude that in these cases

[1] *Op. cit.* page 160.

also, the cause which has deprived the brain of its consistence is inflammation? *A fortiori*, will not one be induced to admit it in those other cases where the softened part has become at the same time the seat of an anemia? Observe, besides, that among those cases of white softening, there are some which have formed very rapidly, after the manner of acute diseases, and in such cases it cannot be supposed that the softening has commenced by a sanguineous congestion, which would disappear, according as the affection would assume a chronic course. No doubt those who refer the proximate cause of every disease to a defect of the normal stimulation, must necessarily make cerebral softening enter into one or other of these states, and not finding in this alteration the characters of an asthenic disease, must regard it as an inflammation.

"In thinking so, they but follow their theories; but for us, who think that in a crowd of morbid states there is no more hypersthenia than asthenia, but mere perversion of the vital actions, we are no more obliged to consider the cerebral softening or any other softening as an inflammation than tubercles pneumonia. It is a specific alteration of nutrition, which may supervene under the influence of morbid conditions widely differing from each other. To endeavour to determine these different conditions is the task to be performed, a task, difficult no doubt, but of quite another importance from that on which medical men have occupied themselves in latter times, when they have wished to reduce every cerebral softening to one of the forms, or one of the degrees of inflammation of the nervous centres. We are convinced that by proceeding thus men have entered on a course diametrically opposite to that which should lead to the truth. We too might collect groups of facts to demonstrate that softening is capable of being produced by different causes of inflammation. Thus we might find some group from which it would result that commencing obliteration of the arteries which enter the brain, is one of the conditions which concur in the production of a certain number of softenings. We might cite other facts which would show us a remarkable coincidence between the *impoverishment* of the blood, or any other alteration whatever of this liquid, and the softening of a great number of our tissues. Are there really so many causes of softening? The future will decide, and will discover, no doubt, many other causes which, in the present state of our knowledge, we cannot even suspect. All that we affirm is, that it is necessary to seek elsewhere than in inflammation for the cause of all softenings. It does not even seem to us that the presence of an unusual quantity of blood in the midst of a softened tissue is a sufficient proof that irritation is the cause of its softening. May it not be that this superabundant blood has flowed into these softened parts but consecutively? See the case where after a limb has remained for a long time merely paralysed, it suddenly became rigid, convulsed and contracted; on opening the body we often find, in such cases, one part of the brain softened, and at the same time reddened with blood; reasoning may then lead us to admit that the sanguineous congestion occurred but as a mere complication of softening, and that it is this which caused the phenomena of excitement to succeed the simple loss of motion. In order to explain a cause which simultaneously softened and reddened a tissue, shall we never see anything beyond the mere fact of an irritation which has acted on this tissue? Is it then in the gums of a scorbutic subject that the cause resides which has brought them at the same time to a state of hyperæmia, and deprived them of their consistence?

Here no doubt are very many questions raised which wait till facts rigorously observed shall come to solve them. But it is enough, we think, that such questions can be put, and that in the future progress of science their solution is possible, to make one distrust very much the opinion which refers every softening to an inflammation. Because the brain is softened after a blow on the cranium, is that a reason for saying that every time it shall have lost its consistence it must have been previously irritated?

"If science refuse to admit inflammation as the sole cause of softening of the brain, if it see in this softening several other causes, for the proof of which it waits for new researches, it is quite clear that the term *enkephalitis* cannot be used as synonymous with the word *softening*. Neither do we think it correct to call this alteration capillary apoplexy, as M. Cruveilhier has done. In a certain number of cases, to be sure, the softening is accompanied or rather complicated with sanguineous infiltration, or effusions of blood more or less multiplied; but certainly it is not in the presence of this blood that the essence of the disease consists, and there are at least many cases in which we do not find the least trace of it. The softening may then be either a capillary apoplexy or an enkephalitis; but it is not necessarily either the one or the other."

Dr. Abercrombie,[1] in speaking of *ramollissement,* says, "When I formerly endeavoured to contribute something to the pathology of this remarkable affection I had no hesitation in considering it as one of the results of inflammation of the cerebral substance; since that time it has been investigated with much attention by M. Rostan and

[1] *Op. cit.,* p. 24.

other French pathologists, and a different view of the nature of the affection has been strongly contended for by these eminent individuals. They consider it as an affection of the brain entirely *sui generis*, and M. Rostan, in particular, seems to look upon it as a peculiar and primary disease of the brain, though he admits it is sometimes the result of inflammation. From all the facts which are now before us in regard to this interesting affection, I think we are enabled to arrive at the conclusion that it occurs under two modifications which differ essentially from each other. In the cases of M. Rostan the disorganization was observed chiefly in the external parts of the brain: it occurred almost entirely in very old people, many of them seventy, seventy-five, and eighty. It was found in connexion with attacks of a paralytic or apoplectic kind, many of them protracted, and was often found combined with extravasation of blood, or surrounding old apoplectic cysts. On the contrary, the affection which I had been anxious to investigate was found chiefly in the dense central parts of the brain, the fornix, septum lucidum, and corpus callosum, or in the cerebral matter immediately surrounding the ventricles; and occurred in persons of various ages, but chiefly in young people and in children. It took place in connexion with attacks of an acute character, chiefly the character of acute hydrocephalus; and it was in many cases distinctly combined with appearances of an inflammatory kind, such as deep redness of the cerebral matter surrounding it, suppuration bordering upon it, and deposition of false membrane in the membranous parts most nearly connected with it. We may even observe in different parts of the same diseased mass one part in the state of *ramollissement*, another forming an abscess, while a third retains the characters of active inflammation, and probably exhibits, as we trace it from one extremity to the other, the inflamed state passing gradually into the state of softening. Remarkable examples of this will be given in the sequel, and another of a different nature, in which an opening in the septum lucidum produced by the *ramollissement*, was entirely surrounded by a ring of inflammation. This is the affection which I have endeavoured to investigate, and which I consider as one of primary importance in the pathology of acute affections of the brain, and upon the grounds now shortly referred to, I cannot hesitate to consider it as a result of inflammation.

"When we compare the facts now alluded to with the observations of M. Rostan and his friends, I think we may arrive at a principle by which the apparent difference may be reconciled. The principle to which I refer is, that this peculiar softening of the cerebral matter is analogous to gangrene in other parts of the body; and that like gangrene it may arise from two different causes, inflammation, and failure of the circulation from disease of the arteries. The former I conceive to be the origin of the affection which I have described, and the latter to be the source of the appearances described by M. Rostan. If this doctrine be admitted the difficulty is removed; and I do not see any good objection to it.

"Gangrene from inflammation is familiar to every one; and equally familiar, though very different in its origin and concomitant symptoms, is gangrene from disease of the arteries of any particular part of the body. Ossification of the arteries of the brain to a very great extent is a common appearance in elderly people, and seems to be a very frequent source of apoplexy, with extravasation of blood, at advanced periods of life. It appears extremely probable that it may be the source of that particular condition of a part of the brain which terminates in the *ramollissement* of M. Rostan, and indeed he distinctly points at this explanation of it. On the other hand I am still disposed to contend that the *ramollissement* of young persons occurring in acute affections, and seated chiefly in the central parts, is one of the terminations of inflammation in that particular structure. I conceive it to be an affection of primary importance in the pathology of acute affections of the brain, and to mark a peculiar seat of the inflammation of very frequent occurrence. It is often combined with suppuration in other parts of the brain, and very often with effusion in the ventricles; but the peculiar interest of it is observed in those cases in which it is only the morbid appearance, and in which it is sometimes of small extent. Of this some remarkable examples will be given in the sequel, in which the perforation of the septum lucidum, by softening of a part of its substance, and similar softening of the fornix, were the only morbid appearances in cases which were fatal, with all the usual symptoms of acute hydrocephalus."

On reconsidering all these different opinions, and more particularly the simple but clear-sighted views of Dr. Abercrombie, we are warranted in concluding that the morbid appearance called *ramollissement* is usually the result of acute inflammatory action, but that in old people it frequently follows a total failure of the circulation, corresponding both in its consequence and in the cause producing it to asthenic senile gangrene in other parts. The question regarding its inflammatory character is peculiarly interesting to the physiologist, from deductions he may draw from the effects which its first stage produces on the functions of the brain, as distinguished from those exhibited after the disease has pursued its course to the actual destruction of its texture.

Among the various points which present themselves to us in investigating the office of the enkephalon as a whole, there is, perhaps, none more interesting than that of the relation which exists between the circulation or the supply of blood to the brain, and the dependence of the brain upon this circumstance for the due performance of its office. Every tyro knows that if the adequate supply of blood to the brain, from any circumstance whatever, be intercepted, the individual loses his consciousness for a time. The state thus induced is familiarly known by the name of *fainting*, or *syncope*. The occurrence of syncope, were we devoid of every other proof, is of itself sufficient to assure us that the brain, whose functions are so entirely different from those of every other organ in the body, is nevertheless quite as dependent as they are upon the vascular system for the means to execute its appropriate offices.

Even more interesting than the phenomena of syncope are the effects which that excitement of the circulation, called inflammation, produces upon different portions of the brain, although they have been less regarded, not having received the attention which in a physiological point of view they deserve. The phenomena of inflammation of the brain are more peculiarly instructive in those cases in which we have an opportunity of contrasting the symptoms of disturbed function with disorganization of the parts affected, as will be seen by the detail of a few cases. Those of inflammation of the arachnoid membrane are the best to commence with; for attentive observation of the symptoms which attend the progress of inflammation in this membrane may assist us in elucidating the office of that portion of the cerebral mass which is immediately connected with it; and I think it will be found that such observations carefully compared with those made on the lesion of functions with organic affections of other parts of the brain support the opinion of those who believe that the cineritious neurine of the convolutions more directly ministers to the mental operations than the rest of the enkephalon, as will be again adverted to when we come to consider the offices of individual portions of the brain.

The two first cases that I shall relate[1], most strikingly illustrate how a small alteration in the local circulation will produce great disturbance of function.

"A lady, aged 23, had suffered much distress from the death of a sister, and had been affected in consequence with impaired appetite and want of sleep. This had gone on for about two months, when, on the 4th of August, 1825, she sent for Dr. Kellie, and said she wished to consult him about her stomach. He found her rambling from one subject to another with extreme rapidity and considerable incoherence; and on the 5th she was in a state of the highest excitement, with incessant talking, alternating with screaming and singing: pulse from 80 to 90. In the evening she became

[1] Abercrombie, p. 65. Cases XVI. and XVII.

suddenly calm and quiet after an opiate; continued so for an hour or more, then fell asleep, and after sleeping two hours awoke in the same state of excitement as before. The same symptoms continued on the 6th; the pulse in the morning was little affected, but after this time it became small and very rapid. On the 7th, after a night of great and constant excitement, she had another lucid interval, but her pulse was now 150. The excitement soon returned, and continued till four in the afternoon, when she fell asleep. She awoke about eight, calm and collected, but with an evident tendency to coma: pulse 150, and small. She now took food and wine, and passed the night partly in a state of similar excitement, and partly comatose; and died about mid-day of the 8th, having continued to talk incoherently, but knowing those about her, and in general understanding what was said to her.

"Inspection.—The only morbid appearance that could be discovered was a highly vascular state of the pia mater, with numerous red points in the substance of the brain."

"A gentleman, aged 44, of a stout make, and very temperate habits, became suddenly affected, without any known cause, with extreme depression of spirits, accompanied by a good deal of talking and want of sleep. After this condition had continued for two days, it went off suddenly, and he recovered excellent spirits and talked cheerfully. This, however, was soon succeeded by a state of excitement, with rapid incoherent talking, and obstinate watchfulness, and the pulse rose rapidly to 160. This state continued without abatement for about four days, when he suddenly sunk into a state of collapse and died.

"Inspection.—The only morbid appearance was a highly vascular state of the pia mater and arachnoid, with slight serous effusion betwixt them."

There is a case related by Morgagni, Epist. LXII. No. 5, something similar to the last. The patient in the first instance was labouring under a false impression, which, producing excessive fear, was followed by tremors, convulsions, pain in the head, and loss of speech, but not of consciousness. He died seven days after the appearance of the first symptoms, and the morbid appearance discovered after death was merely congestion of the pia mater.

We will next consider attentively one of the most important laws of vital action which pathology has yet unfolded in relation to the nervous system, namely, that the first effect of inflammation of the neurine or essential material of the nervous system is to excite and exalt to an unnatural degree exactly the same kind of power which we have reason to believe resides in it in a normal state; for instance, the first effect of inflammation of the surface of the brain is to excite the mental faculties, to produce great irritability of temper, and constant restlessness or desire for action. If the inflammation be arrested at this point, the patient recovers his reason; but if it pursues its ravages undisturbed, limiting its destructive effects to the spot where it commenced, without extending to that portion of the brain which is beneath, it annihilates the intellect, but does not affect the muscular system; while, on the other hand, if the inflammation extend further, reaching the instruments by which the will travels to the muscles, it first produces *convulsive action* in these muscles, and they afterwards become perfectly paralytic; in this case the integrity of the neurine, through which volition traversed to call these muscles into action, is compromised, and its power, therefore, as an instrument for the production of voluntary motion, destroyed.

The same phenomena are presented to us by observations on the instruments of sensation, as far as we are at present acquainted with these instruments, for we generally find when inflammation attacks the tract of sensation, the first symptoms existing a sufficiently long time to be accurately observed, that previous to the obliteration of sensibility in any texture, the normal sensibility of the part is exalted, the patient suffering the most severe pain both at the spot where the nerves of sensation originate, and in the brain itself, in which they terminate.

Those cases in which the brain during life appears to have been simply *irritated* by the presence of foreign matter, as extravasation of blood, &c., though no appreciable sign of inflammation is met with after death, countenance the same opinions: it is true that such cases do not afford the same clear and unequivocal evidence as those of simple inflammation, in as much as the texture of the neurine and the membrane which supports it is so extremely delicate, that an effusion of blood usually destroys it, at the same time wholly annihilating its powers, unless the blood be effused upon the surface, or between its fibres, as supposed by some pathologists.

Olivier[1] says, "Paralysis may disappear in cases where the blood resulting from the hæmorrhage is effused *between* the medullary fibres, which it only separates, and which compresses without destroying them; whilst, if their *rupture* takes place, the cure is never complete; and whatever means may be employed, the effects still continue. I am certain," says Olivier, "that to this cause alone, already pointed out by M. Foville, and not to a cicatrization of the torn medullary fibres, we should attribute the disappearance of hemiplegia in certain individuals."

[1] Quoted by Dr. Spillan in his translation of Andral's *Clinique*, p. 131.

Without pretending to assume that the detail of a few individual cases is sufficient to establish firmly the truth of this or any other law of vital action, it cannot be denied that the consideration of those cases which, from the very fact of their being frequently met with, are the more adapted to our purpose, will be instructive and interesting in connexion with physiology.

By turning our attention to the effects of inflammation with its consequences in the first instance, and to those of extravasation of blood and mechanical injury afterwards, we shall gain much valuable information in a physiological point of view.

The following case from Lallemand's interesting Letters on Pathology combines the train of phenomena usually attending inflammation of particular portions of the brain, when they are unobscured by those symptoms which appear to result from the functions of other parts being affected through the agency of sympathy.

"*Case*[1].—Vailbain, a widow, fifty-four years of age, had for ten years suffered much and endured many family vexations, in consequence of which the intellectual powers became impaired, and she fell into a state of weakness, with general lowness of spirits, and complained of constant pains in the head. At her admittance into the Hôtel-Dieu, in

[1] *Recherches Anatomico-Pathologiques sur l'Encéphale*, par F. Lallemand, p. 25.

1816, the features betrayed great sadness; she almost always sat, because the pains in her head increased when she was in a horizontal posture; respiration was very difficult; the pulse was irregular, and presented after three pulsations two consecutive intermissions; the motions of the tongue were impeded, and she stammered when she spoke. The muscular strength was impaired; the limbs benumbed; the legs and feet infiltrated. Now and then the arms were convulsed, and there was frequent jerking of the tendons. The motions gradually became more difficult, especially on the right side, the diminished sensibility of which was replaced by a feeling of formication. At length, all of a sudden, during the night, about a month after her admittance, the paralysis of the right side became complete, except a slight sensibility in the leg. The mouth was drawn to the left; the stammering was increased to such a degree that we were unable to understand what the patient wished to say; she could not even put out her tongue. For a week we had recourse to bleedings, sinapisms, blisters, purgative enemas, emetics, &c., all without success. Eight or ten days after she had violent pains in the paralysed side, which caused her to scream and groan continually. When we tried to move her limbs there was a certain resistance, a sort of stiffness of the joints, and the pains became excessive.

"The eleventh day after the night attack, respiration became stertorous, the face cadaverous, the skin cold, the paralysed limbs excessively stiff. She died the next day.

"*Autop. cadav.*—The arachnoid and pia mater were injected and separated from one another by a sort of trembling jelly, half a line in thickness in certain places, very like that which is found under the epidermis in raising a blister. I removed these membranes with the greatest facility, without breaking them; but at the superior part of the middle lobe on the left side, I removed with the arachnoid a portion of the brain adhering to the pia mater, about two square inches in size; the corresponding convolutions were sunk and quite softened for about an inch and a half in depth; this softness was so much the more remarkable as I had not seen a harder brain. In the middle of this greyish and as it were liquid substance there was a collection about the size of a hazel-nut, of a dark brown colour, formed of blood partly extravasated and partly infiltrated and mixed with the substance of the brain."

In the above case life itself, and not merely the function of a part, was destroyed by the disease. The next case which follows, and which came under my own observation, the patient being under Dr. Williams's care at St. Thomas's Hospital, illustrates the same disease, but in a more chronic form, merely impairing function without destroying life, for the patient died of phthisis. In this as in every other case that I may relate, I shall only advert to those symptoms, post-mortem and morbid appearances, which bear upon the physiology of the brain.

John Ballard, journeyman tailor, admitted May the 5th, 1836, King's ward; Dr. Williams. Died the 15th. During the time he was in the hospital the only symptoms he exhibited of cerebral affection were general moodiness and irritability when spoken to. The following particulars of his previous history I obtained from a fellow-workman with whom he lodged, and who had been acquainted with him about two years. He described Ballard's general manner as having been so strange as occasionally to induce him to think that he was out of his mind; he was very irritable, subject to great lowness of spirits, and frequently cried like a child. He had drunk very freely before my informant became acquainted with him, but not latterly; he was much addicted to women, had occasionally had epileptic fits unaccompanied with the usual cry; for about a fortnight previous to his admission he had complained of severe headache and general restlessness.

Post-mortem. Chest.—Extensive disease of lungs. *Head.*—Arachnoid membrane opaque and thickened, particularly at the base of the brain, where there was slight effusion of pus and considerable effusion of serum. Vessels of the pia mater inordinately distended. Substance of the brain healthy.

The next case from Andral, though not containing the same amount of evidence in illustration of this law, is very decisive as far as it goes [1].

"*Acute meningitis limited to the convexity of the left hemisphere of the brain; delirium; convulsive movements of the face and extremities of the right side.*—A tailor, 37 years of age, had been sick four or five days when he entered the hospital, 17th July, 1821. On the 15th of this month, without any known cause, he was seized with violent pain of head, particularly seated in the frontal region. On the day after the headache continued, and the pain became more general, being extended now to the parietal and occipital regions. On this day he lost his appetite, and vomited some drink he had taken. In the evening constant nausea still appeared, followed from time to time by a throwing-up of some bitter yellow matter. On the 17th the headache continued, but the vomiting ceased; some nausea still. Having entered the hospital, he presented on the next day's visit the following state:—face remarkably pale; pain of head, the precise seat of which cannot be pointed out by

[1] Case 6, p. 6.

the patient; at intervals this becomes so very severe as to make him utter piercing cries; eyes dim and languid; slight involuntary motion of the muscles which move the commissure of the lips; his answers accurate; gives a perfect account of his state, and of everything which happened to him since the commencement of his illness; the pulse moderately frequent and regular; everything else natural.

"It was difficult to assign a precise seat to this group of symptoms: the first complaints however regarded the head; the vomiting might be considered as connected with a commencing cerebral affection, and the severe headache seemed to point out the head as the seat of disease. The absence of any morbid phenomenon with respect to the alimentary canal, repelled the idea that the headache was sympathetic of gastro-intestinal irritation. The absence of all febrile disturbance precluded the possibility of its being mere continued fever. The state of the patient, however appeared very alarming; the appearance of his countenance, and, amidst the absence of local symptoms, the great alteration already of his features obliged us to form a rather unfavourable prognosis. M. Lerminier suspecting a state of enkephalic congestion, applied, notwithstanding the extreme paleness of his face, twenty leeches across each jugular vein. Demulcent drinks, and sinapisms to the lower extremities. No change in the patient on the following morning.

"On the 20th he was very much cast down, and answered questions with difficulty and reluctance; light was painful to him, he kept his eyes closed and his head concealed under the bedclothes; face very pale; pain of head not great; the convulsive movements of the lips more frequent and more marked; pulse and skin natural; (blister to the nape of the neck.) In the night he emerged from a state of stupor in which he had been for the last twelve hours. He got up out of bed suddenly, saying that some persons were pursuing him to do him harm. He raved during the night, and occasionally uttered several piercing cries. On the 21st he was kept in bed by force. The face had now become red; the head was agitated by a continual movement, which carried it from right to left, and left to right; the muscles moving the lips, the alæ nasi, and the eyebrows, were in the highest degree of convulsive agitation; saliva, slightly frothy, flowed in great abundance from the mouth; he spoke incessantly and with energy, but his articulation was unintelligible; great subsultus tendinum, which prevented the pulse from being felt; its frequency did not seem very great. (Bleeding from the arm, twenty leeches to the neck, cold applications to the head.) No change on the 21st.

"On the 22nd, violent delirium; convulsive motions of the muscles of the face; risus sardonicus; continued motion of the right arm; subsultus increased; pulse more frequent; tongue moist and red. (Two blisters to the thighs; ice to the head.)

"On the 23rd, head turned back, and to the right; strong contraction of the right arm; respiration very irregular; occasionally accelerated: it then becomes slower than natural. The patient silent and quite still; eyes fixed, and void of expression; mouth open and unmoved; pupils neither contracted nor dilated; answers no questions; does not even seem to understand them; original paleness of face returned; pulse sixty a minute, and regular; bowels not free; tongue cannot be seen; teeth not dry. He remained quite torpid during the day, but at night violent delirium reappeared; uttered very loud cries.

"On the 24th this excitement was succeeded by profound coma; extremities cold; a clammy sweat covered the face; respiration *ralaut*. Died in the course of the day.

"*Sectio cadav.* On the upper surface a considerable difference in the colour of the two cerebral hemispheres, the right being pale, while the left present a well-marked red tint, which resided entirely in the subarachnoid cellular tissue, which was traversed by numerous vessels; neither serum nor pus in the tissue; the grey substance, constituting the most superficial portion of the convolutions of the left hemisphere, participates in the injection of the pia mater covering it. The ventricles contained scarcely two spoonfuls (*cuilleries à café*) of serum; nothing remarkable in the rest of the brain. The lungs infarcted posteriorly; the heart contained in its right cavity a large fibrinous clot, deprived of its colouring matter; the mucous membrane of the stomach very thin towards its great cul-de-sac."

From these cases, which seem to illustrate the truth of this law, in relation to the instruments of volition and the organs of intellect, let us next turn to the consideration of it in connexion with the instruments of sensation; for the following cases certainly demonstrate that the sensibility may be exalted first and impaired afterwards, as well as that muscular contraction may be excited first and destroyed afterwards, without the intellect being affected, when the inflammation is confined to that portion of the cerebral substance which is within the grey matter of the convolutions, that matter remaining itself unaffected; and let the student mark well the important conclusions which may be drawn from these facts, regarding the office of these two portions of the brain.

"*Softening of the right cerebral hemisphere; acute pains in the left extremities, which subsequently became paralysed, still continuing painful*[1].

[1] Andral, *Op. cit.* Case XV. p. 145.

"A woman, seventy-one years old, had felt, for about a year before entering the hospital, acute pains in the two extremities of the left side. These, which were at first transient, became lancinating, occupying particularly the anterior surface of the upper extremity, and the posterior surface of the lower extremity.

"When they were very intense, they gave rise occasionally to slight convulsive twitches of the fingers, and particularly of the index finger. Occasionally, too, but only after or during a pain, the thumb was flexed on the palm of the hand, the flexion never lasting beyond ten or twelve minutes. This was the first time the patient experienced such pains; by degrees they became more frequent, and at last continued; but at the same time, they abated of their original severity, and ultimately the patient only felt in the extremities of the left side, and particularly in the upper, a sensation of formication. She continued thus for five months; she then ceased to be able to sustain herself on her left leg as well as before; this limb seemed to her dull and heavy, and she dragged it a little in walking. At this time also the left upper extremity became weaker; she could no longer grasp or hold any weighty object with the hand of this side. By degrees this paralysis increased, and at the end of six weeks it was as complete as possible. But, what was extraordinary, from the time the muscles of the extremities of the left side were entirely deprived of voluntary motion, the pains which had marked the commencement of the disease returned with their original severity; and from time to time they increased so as to make her shed tears. This was the state she was in when she was submitted to our inspection. She was at this time emaciated and pale, eyes sunk, features drawn, and expressive of long suffering. Every two or three days the extremities were, as it were, furrowed by acute pains. The skin of these parts much more insensible than those of the limbs of the right side. Power of motion completely destroyed in them; right commissure of lips drawn up; tongue deviated sensibly to the left; skin of face on right side less sensible than on left; the intelligence perfect. She told us, that from her nineteenth to her twenty-third year she had been tormented with violent beating of the heart, accompanied with great difficulty of breathing. These symptoms, however, completely disappeared. After remaining about a month in hospital, a large eschar formed on the sacrum: she gradually wasted away; her feet became œdematous, and she sank exhausted, retaining her intellect to the last.

"*Sectio cadav.* On a level with and external to the optic thalamus and corpus striatum of the right side, we found considerable softening of the cerebral substance, which extended to the base of the brain. Anteriorly it was limited by a line, the internal extremity of which might terminate at the junction of the anterior four fifths with the posterior fifth of the corpus striatum. Posteriorly it extended nearly to the posterior extremity of the hemisphere. No injection in the softened portion. The softened cerebral substance is of a greyish white in certain points, and yellowish in others. The fornix and septum lucidum diffluent. The two lateral ventricles distended with serum. The great arteries of the brain ossified. Heart and lungs healthy; some ossifications in the aortic valves. The gastric mucous membrane visibly softened towards the great cul-de-sac in several points.

"*Softening of the anterior extremity of one of the hemispheres: at the commencement headache, and acute pains in different parts of the body; subsequently flexion and hemiplegia. Death by supervening pneumonia*[1].—A female, nineteen years of age, seven months before entering the hospital, felt a dull pain in the right temple, which becoming worse from time to time, then became general, and was accompanied with great depression; it often, when very acute, extended to the nape of the neck, thence descended towards the left side of the neck and involved the entire left upper extremity, extending occasionally to the left lower extremity. These pains were very changeable in character: some-

[1] *Op. cit.*, Case XVI., p. 146.

times she felt as if needles were thrust into her; sometimes as if subjected to very intense heat; pressing the muscles also sometimes gave pain; the skin of the left extremities sometimes, too, became painful. Such were the affections of the sensibility, when, in its turn, the power of motion also became affected: the fingers became flexed on the hand, the hand on the fore-arm, and the latter on the arm. The left lower extremity soon participated in this flexion. From the moment the latter supervened, the pains assumed increased intensity. In this state we saw the patient. She then complained of cruel pains in the two extremities; flexion was at its very highest degree. Headache continued, but less acute. (A seton was put in the nape of the neck, the flexed limbs rubbed with anodyne liniment.) From fifteen to twenty days passed on without any change; she then exhibited the following modification in her condition. Pain of head now changed into a sensation of weight in all the left side of the head; extremities no longer painful; the skin covering them now insensible; fingers and toes benumbed and cold; the flexion was now gone, and was replaced by the mere abolition of motion in the left extremities; the left side of the face participated in this paralysis, and the right commissure of the lips was drawn up. Whilst in this state, the patient was attacked with pleuro-pneumonia, of which she died.

Post mortem Examination.—The entire anterior lobe of the right hemisphere was changed into a greyish bouillie. The corpus striatum and anterior portion of the optic thalamus participated in this change, which did not, however, extend to the convolutions of the convexity, nor to those of the base. These convolutions were merely flattened. A mixture of red and grey hepatization of the inferior lobe of the left lung was also discovered.

Lallemand's opinions on the difference of symptoms exhibited along with inflammation of the *membranes* from those that occur when the *substance* of the brain is affected, powerfully support the view which I have given of the connexion between the normal state of the cerebral circulation and the healthy execution of its natural functions, and the disturbance of that circulation, with the symptoms of disturbed function, as well as of the office of the cineritious surface of the convolutions, as distinguished from that of the medullary neurine which is beneath[1].

"The substance of the brain," says Lallemand, "is irritated by inflammation of the arachnoid from its vicinity; its functions are exalted, and consequently those of the nervous system under its dependence, and consequently those also of the muscular system; and from hence arise convulsive movements, &c.: but, as the *tissue* of the

[1] p. 251.

brain is not destroyed, these symptoms are neither accompanied with nor followed by paralysis."

EXTRAVASATION OF BLOOD.

Let us next consider how far extravasation of blood produces the same effects as inflammation, and whether it confirms or invalidates the truth of the law I am anxious to investigate—that irritation of the cerebral substance, either by inflammation or mechanical means, first excites its normal action, though always with derangement of this, previous to its ultimate destruction.

Olivier[1], after detailing a case of "spontaneous hæmorrhage and rupture of the cephalic bulb of the spinal marrow and of the annular protuberance, accompanied with convulsive contractions of the limbs," says, "I have since had several opportunities of observing this apoplexy at the moment of the attack, and I have always remarked convulsive contractions in the upper extremities, with alternating movements of rotation inwards. The opening of the mouth underwent no change. The spasmodic convulsions observed at the commencement of the attacks of apoplexy in general, seem to me to depend on the irritation which the blood produces on the extremities of the torn medullary fibres with which it remains in contact, and on which it must act as an irritant."

[[1] Andral, p. 130.

The following Case, from Mayo's Outlines of Pathology[1], seems to be highly instructive, though the narrator does not appear to have duly appreciated its important bearing on physiology.

"W. Tucker, ætat. 42, brought into the Middlesex Hospital, and supposed to be intoxicated. He was drowsy, heavy, stupid, not insensible; answered some questions; the pulse small and slow. The left arm and leg powerless; face drawn to right side. When put to bed, he was seized with rigor, and complained of pain in the right side of occiput: in an hour afterwards the pulse rose, and the right side of the body became convulsed: v. s. ℥ xviij: the convulsions ceased for a time, then returned with extreme violence, threatening to suffocate him: v. s. ℥ xl: the respiration became more free, but the convulsions remained: he then became comatose. He continued insensible during the night, the breathing stertorous, right pupil dilated, left contracted, no pulse at the wrist: he died at 11 A.M. A large cavity filled with blood, partly clotted, occupied the centre of the right hemisphere of the brain: it did not communicate with the lateral ventricle, but opened between the sulci of the convolutions, which for a large extent were lined with it; between their summits streaks of clotted blood lay, resembling veins. There was slight sanguineous effusion on the surface of the anterior lobe of the

[1] Part I. p. 208.

left hemisphere. It is possible, but very unlikely, that this may have caused the convulsions of the right side of the body."

I confess I am surprised at Mr. Mayo's concluding observations, when cases like the following, related by Abercrombie, are to be met with so frequently[1].

"A man aged about 35, keeper of a tavern, and addicted to the constant use of ardent spirits, had been drinking to intoxication during the night betwixt the 12th and 13th of July, 1816; and, about seven o'clock in the morning, was found lying in a state of violent convulsion. No account could be obtained of his previous state, except that during the evening he had drunk a very large quantity of whisky, and that when he was last seen, about three o'clock in the morning, he was walking about his house, but unable to speak. He was seen by Dr. Hunter at a quarter before eight. He was then lying on his left side, in a state of perfect insensibility, with laborious breathing; saliva was flowing from his mouth; his eyes were much diffused and greatly distorted, the cornea of both being completely concealed below the upper eyelid; pulse 120, full and soft. While Dr. Hunter stood by him he was again seized with convulsion; it began in the muscles of the jaw, which was drawn from side to side with great violence, producing a loud jarring sound from the

[1] Abercrombie, c. x. p. 243.

grinding of the teeth. The spasms then extended to the body and extremities, which were first thrown into a state of violent extension and then convulsed for one or two minutes; they then subsided, and left him as before in a state of perfect insensibility. Similar attacks took place four times while Dr. Hunter was in the house, which was about half an hour; and he expired in another attack of the same kind about ten minutes after. Bloodletting and every other remedy that the time admitted of were employed in the most judicious manner.

Inspection.—On removing the scull-cap an appearance was observed on the surface of the dura mater of coagulated blood in small detached portions. These appeared to have been discharged from small glandular-looking elevations on the outer surface of the dura mater, which were very vascular and highly gorged with blood. There were depressions on the inner surface of the bone which corresponded with these bodies. On raising the dura mater there came into view a coagulum of blood, covering and completely concealing the right hemisphere of the brain; it was about two lines in thickness over the middle lobe, and became gradually thinner as it spread over the anterior and posterior lobes, and dipped down below the base of the brain. The coagulum being removed weighed about ℥ v. On the surface of the left hemisphere the veins were turgid with blood, on the surface of the right they were entirely empty; but the source of the hæmorrhage could not be discovered. There was no fluid in the ventricles, and no other disease was discovered. The stomach being carefully examined, was found to contain nothing but air and healthy mucus."

Lallemand's observations on the opinions which used to prevail on the subject of convulsions on one side of the body, and paralysis on the opposite, in connexion with wounds of the head, are so extremely apposite that I cannot resist quoting them[1].

"You have just heard many different opinions founded on observations more or less incomplete concerning injuries of the head: thus some have admitted that inflammation of the brain produced convulsions on the opposite side, others that it produced paralysis, and others that it sometimes occasioned convulsions and sometimes paralysis; so that the convulsions (always of the opposite side) were produced by inflammation, and paralysis by suppuration; that is to say, by compression of the brain. Another series of observations brings forth other opinions.

"Salmuthius[2] found in a patient who had had paralysis on one side and convulsions on the other, an abscess in the hemisphere opposite to the paralysed side.

[1] *Op. cit.*, p. 500.

[2] *Obs. Medicor. Centuriæ tres*, 4to, Bruns. 1648.

"Daniel Hoffman (*Dissert. de Sanatione rariss.*) relates the case of a child who, having had a fracture of the skull on the left side, with considerable destruction of the brain, had paralysis on the right and convulsive motions on the left side. These facts, after all, are very common, there are few practitioners who have not observed them.

"Berenger[1] says that he has most frequently seen convulsions on the sound side and paralysis on the opposite.

"It is to be observed," says Dr. Hennequin, "that when on one side of the body there are convulsions and on the other paralysis, the convulsions attack the side corresponding to the injured brain; but when convulsions alone are present, and on one side only, it is generally opposite to the injury."

"You will find these facts described by various authors very nearly in the same manner, among the most recent of which I will cite one to which the author's name attaches an imposing authority. This is what Boyer[2] says:

"'Paralysis is not the only disorder produced by compression of the brain and alteration of its substance. Convulsions are also sometimes caused by these affections. The greater number of observers who have remarked that paralysis always at-

[1] *Tract. de Fractura Cranii*, 4to, Venet. 1535.

[2] *Traité des Mal. Chirurg., &c.*, tom. v. p. 109.

tacked the side opposite to that which was injured, have at the same time observed that when in this case convulsions occurred, they attacked the side opposite to that paralysed, that is to say, the injured side, whilst the convulsive motions affected the side of the body opposed to the injury when no paralysis existed.'

"Amongst the authors who have spoken of these facts, some have contented themselves by relating them, without endeavouring to explain them; others have thought that the same affection could at the same time produce convulsions on the injured side, and paralysis on the opposite. Boyer seems to be of this number, when he says "paralysis is not the only disorder, &c." And others, persuaded that the convulsions were produced by inflammation, and the paralysis by the mechanical compression of the brain, have thought that in this case the hemisphere corresponding to the injury was at the same time inflamed, and compressed by blood, serum, or pus. But thus to explain these two orders of symptoms, required that the opinions of the ancients, generally received, should be rejected; and this is what is done. It is pretended that the symptoms of convulsions are quite different from those of paralysis; that the one manifested themselves on the injured, and the other on the opposite side. So inflammation and compression of the same hemisphere of the brain would show symptons in the first case, on the same side of the body, and in the other on the opposite. Although the mere relation of this suffices to show its absurdity, the notion has had a great many supporters.

"It appears that in Morgagni's time it was much accredited, for he speaks of it at great length, and combats it in many parts of his works[1]. After having called to mind the decussation of the fibres of the brain, admitted to explain the cause of paralysis on the opposite side, he finishes with this judicious reflexion, which naturally presents itself to the mind: 'Igitur quam decussationem ad paralysim in latere opposito explicandam agnoscere debeamus quare ad convulsionem non agnoscemus.'

"Morgagni's argument, very plausible at that period, fell the moment that we were able to demonstrate by the scalpel the interlacing of the fibres of the brain, which was then but an hypothesis more or less probable. That even has not hindered this opinion from being propagated to us, and I have heard distinguished practitioners defend it warmly. Others, always after the same observations of injuries of the head, have admitted that convulsions could occur on the side of the inflamed hemisphere, or on the opposite side, whether this last was free or paralysed, a circumstance much more difficult to be conceived.

[1] See *Epist. Anat.*, xiii., Nos. 14, 17, 18, & 22. *De Sed. et Caus. Morb. Epist.*, Nos. 46, 47, & 48.

"It has, indeed, been imagined that convulsions only occurred on one side, because the antagonist muscles were paralysed, so that the healthy ones drew the others to their own side; for example, pulled the mouth towards one or the other ear, bent the body laterally, &c. But without considering whether this action of the healthy muscles can be assimilated to the permanent contractions or tonic convulsions produced by inflammation of the brain, it is evident that paralysis of the muscles of the arm or leg of one side can have no influence over the limbs of the opposite side. Of all these explanations, the most reasonable, the nearest to truth, is that which was adopted by Mus, Donatus, Cesalpinus, P. Martian, Morgagni, &c.; they thought that in these injuries of the head the cause of the two orders of symptoms had equally its seat in the cerebral hemisphere which was opposite to the side of the body affected with paralysis or convulsions, but that this cause was of a different nature, that is to say, that it was a compression or a mechanical lesion of the one hemisphere which produced paralysis on the opposite side, and an inflammation of the other which produced convulsions on the other side. They were in that consequent with themselves, and they explained in a very simple manner contradictory facts; yet this opinion did not prevail generally, and for this reason:

"In many cases they indeed found on the injured side an effusion of blood, pus, or serum on the surface of the arachnoid, or an abscess in the brain, alterations which explained the paralysis of the opposite side; but they sometimes only found the dura mater and arachnoid injected, with softening of the subjacent brain: nothing then proved that there had been compression of the brain. There existed the great difficulty: they did not find in the hemisphere of the side opposite to that convulsed evident traces of inflammation of the brain, and the state of the arachnoid was thought of no importance for two reasons: the first, as you have seen, is that it is much more inflamed on the injured side than on the other; so that by comparison they thought it healthy when red, injected and opaque, &c.; the second is, that they did not think that inflammation of the arachnoid was more likely to produce convulsions than delirium.

"Some facts, certainly rather rare, threw into confusion the opinions of authors concerning convulsions and paralysis after injuries of the head. Paralysis was observed to take place on the side injured, and convulsions on the side opposite to it; and even Avicenna, who probably had seen many similar cases, thought (*De Fract. Cran.*) that these were more common than the reverse. They were for a long time very much embarrassed how to explain this singular phenomenon, which overthrew the received ideas; but when they opened the skulls of individuals who had died, they in a short time perceived that the lesion of the brain was opposite to that of the skull, and consequently opposite to the paralysis[1].

"These two series of symptoms, then, explain themselves in the same manner as in the preceding case. I have seen no other means of exhibiting to you in the most simple and clear manner possible, this rapid sketch of all these opinions, and of the facts upon which they are founded, than by reducing them to their most simple expression, by depriving them of that vainparade of erudition, which is very easily abused, and amid which it is so difficult to see one's way.

"Yet with this precaution you will perhaps find that the labour which such an extent of reading requires is not compensated by the benefit reaped from it; but I have thought that if others began to demolish before they build, or simply to pull down without leaving anything in the place of that which they destroy, I could, and I even ought, after endeavouring to build upon bases more ex-

[1] Amongst others, see the case of Paillot, continued by M. Ant. Petit, in his collection of Clinic. Observ., p. 223. He received over the left coronal suture a sword cut; the 18th day the left arm was paralysed, the paralysis increasing by degrees, and he died the 26th day. Under the wound the dura mater and brain where healthy; on the anterior lobe of the opposite hemisphere was a vast abscess which had penetrated many lines in its substance. See also Morgagni, *Epist.* LI., no. 42; and the *Observ.* of M. Dan de la Vauterie, Letter I. no. 19.

tended and more solid than have up to this time been assumed, to try to make everything disappear that might oppose your progress.

"After all, you see that the cause of the errors which have reigned concerning symptoms of inflammation of the brain, is that they have been studied in surgical observations; that great importance has always been attached to the external wound, and little attention paid to the symptoms, and this in considering pathological observations, which are so much more complicated than cases of spontaneous inflammation.

"You also see that all these opinions were founded upon facts which have been reproduced in our own days, because nature does not change; although so very contradictory, it is easy to explain them, and even to reconcile them one with another."

The following case from Ducrot, (*Essai sur la Cephalite*, 1812, Obs. 2.) quoted by Lallemand, illustrates the progressive effects of extravasation of blood.

"Mr. A., about 60 years of age, had a fracture with a depression into the left frontal region by a stone thrown with violence; he lost much blood, but was able to return home. The next day throbbing pains came on, with confusion of memory and inability to give proper answers to questions; power of speech not much impaired, but incapability of putting the tongue out. The pulse was feeble; oppression. (A liquid emetic.) The third day deglutition difficult, thirst, skin hot, pulse frequent. The fourth day, drowsiness, answers always correct. (A large blister to the nape of the neck.) Fifth day, drowsiness increases, loss of speech: he understands what is said to him, but can only answer by cries; the fæces and urine pass involuntarily. Sixth day, drowsiness still more increased, symptoms the same. Seventh day, no alteration. Eighth day, delirium, loss of sense, convulsive motions of the trunk and limbs, with distortion of the mouth and eyes; he had attacks every quarter of an hour. In the interval respiration difficult, snoring, eye fixed, gaping mouth. The ninth, at midnight the convulsions cease, the drowsiness diminishes, his senses return, but the alteration of memory and judgment continue; slight delirium, the left limbs begin to be paralysed. The tenth, complete paralysis of these limbs, with rigidity and slight pain when they were raised from the trunk; the countenance idiotic, answers not correct, optical illusions, convulsive jerkings during the night. The following days same state. The eleventh day, loss of sense, aphonia, immobility and general insensibility, coma, respiration loud and difficult, &c.; death at eleven in the evening.

Autop. cadav.—Depression two lines in depth for about two inches on the frontal region. At the internal and posterior part of the right lobe of the brain, inflammation an inch and a half in extent from above to below, and half an inch in the other direction, extending on one side as far as the corpus callosum, and on the other to the base of the brain. This inflammation was marked with a bright redness, sprinkled as it were through the substance of the brain. The arachnoid which covered the convexity of the brain was opaque, white, very thick, and smeared upon its internal surface by a thin layer of albuminous matter."

Bouillaud also bears testimony to the truth of this law, for in summing up his observations on encephalites he says [1], "We see that these symptoms have a diametrically opposite character, as Lallemand has already said, according as the encephalitis is in its first or second stage; and that the symptoms themselves differ according as the inflammation is general or local.

"1st, In the first period, or in that of irritation, we observe the exaltation of the intellectual, sensitive, and locomotive faculties.

"2nd, In the second stage, or in that of disorganization and compression, we remark on the contrary the diminution or complete loss of the same functions."

After this general view of the effects which the disturbance of the cerebral circulation, and the irritation of its substance as a whole, and of the

[1] *Traité Clinique et Physiologique de l'Encephalite*, par M.J. Bouillaud, Paris, 1825.

surface of the convolutions in particular, produces on its functions, we may now direct our attention to the results of more circumscribed lesions. And here we must not be disappointed if we cannot draw the same precise conclusions regarding the office of individual portions which we have had the satisfaction of doing in reference to the dependence of the enkephalon as a whole, in common with every other organ in the body, upon the normal circulation of the blood for the due performance of its office.

Lesions of the hemispherical ganglia or the cineritious neurine, usually designated the cortical substance of the brain.

From what has been already stated, when detailing the symptoms of inflammation of the membranes of the brain as distinguished from those which attend inflammation of the substance of the brain, it must be sufficiently evident that a considerable difference exists in the effects produced by these two affections. Upon what then do these differences depend? We cannot, of course, ascribe the mental disturbance, excitement, excessive pain, intolerance of light, delirium and insanity, which we have observed as the diagnostic marks of inflammation of the arachnoid and pia mater, to simple lesion of either a serous or vascular membrane; we are compelled to refer them all to the injury which that portion of the brain in contact with those membranes must have received from the disturbance of its circulation; hence it reasonably follows that the hemispherical ganglia are intimately connected with the intellectual powers, and that it is in them peculiarly and not in the whole cerebral mass that these powers reside; in fact, as before stated, that the medullary substance beneath is in all probability merely the passive servant, as it were, of the cineritious, either as the conductor of its commands to the muscles, or of the materials, namely, the various impressions made on the peripheral extremities of the nerves of sense, which the cineritious perceives, and with which it works.

Such, as elsewhere stated, appears to be the opinion of MM. Foville and Pinel-Grandchamp, and such also is the opinion of Bouillaud, who when investigating the localization of the cerebral functions, says[1], "If we reflect that disturbance of the intellect can exist independently of every other derangement of the cerebral functions, if we reflect moreover that disturbance of the intellect appears to coincide constantly with an alteration of the cortical substance of the brain, we shall be obliged to admit as very probable

[1] *Op. cit.*

this double opinion, namely, that the injury of the intellect depends upon that of a distinct part of the cerebral mass, and that the distinct part of the brain the injury of which produces derangement of the intellect is the cortical substance of that organ." He then refers to the following cases in support of his opinions.

"*Alteration of the intellectual functions, without lesion of the locomotive functions; then convulsions, grinding of the teeth, loss of intelligence: death the third day. Inflammation, with softening of the grey substance, arachnoiditis*[1].—Maintion, 43 years of age, house-painter, married, entered the 18th of November 1823, the hospital of La Charité: six years ago he left the military service, and had only been in Paris two months. Since two years he had shown signs of imbecility, and had completely lost all memory. Whilst he was a military man, he had shown at different periods derangement of the intellectual faculties. Last year, at Versailles, he had symptoms of acute meningitis: two months ago, these same symptoms having reappeared, a seton was inserted in the nape of the neck: besides, for two years he has complained of constant pain of the head and at the root of the nose, with a smell of putrefaction in this cavity. For a twelvemonth *he has been weak in his legs*. He

[1] *Op. cit.*, Case XV. p. 85.

has always had a good appetite. After having taken cold-baths for a month when he was in the hospital of St. Michel, he fell in a state of great exhaustion, and experienced lypothymiæ.

"The 17th of November he lost his mind, had repeated attacks of convulsions, with loud and unequal respiration. The 18th, at ten in the morning, general convulsions; eyes wandering; white froth from the mouth; rigidity of the limbs; sometimes grinding of the teeth and contortion of the mouth; sensibility remaining in the upper extremities, which he draws back when pinched, and makes grimaces; no motion in the lower extremities when pinched, but they are less rigid than the upper. Total loss of intelligence; respiration rattling; pulse pretty strong, full, regular and slow. (*Thirty leeches to the neck, ice to the head, sinapisms to the inferior extremities, a purgative enema.*) The agitation continued the remainder of the day; the convulsions are universal; the face is red and tumefied, the mouth is deformed, the lips projecting anteriorly. With the ice, the head is exceedingly hot; the fore-arms are strongly flexed; intellect is entirely lost. He was in the same state during the night. The 19th, in the morning, the right arm is almost without motion, the left alternately rigid and convulsed; eyes shut; he shuts his jaws when he is desired to drink, and appears to feel a little when the left arm is pinched very hard: slight heat of skin; pulse 112, full and regular. (Venæsect. ad ℥ xij, purgative enema, sinapisms, &c.) In the course of the day the patient died in the greatest agony.

"*Autops. cadav.*,—twenty-four hours after death. The arachnoid is adhering in eight or ten places in the superior surface of the brain: in removing it the cortical substance comes away with it in pieces of about the size of a franc, and about a line in thickness; the medullary substance is a little injected. The left lung is a little hard posteriorly, deprived of air, and somewhat hepatized. The right is red, and congested in about the same place. The mucous membrane of the stomach is red in its splenic portion. All the other organs are healthy[1].

"*Alteration of the general intellect from time to time, loss of mind, stupor without paralysis or convulsions; erysipelas of the face, and death.—Inflammation and softening of the grey substance, with injection of the white substance.*—Victoire, 46 years of age, was an infirm patient in the hospital Saint-Louis for the last two years. She was subject to *attacks* characterized by a sudden loss of mind, convulsive motions of the lips, and an embarrassment of the tongue analo-

[1] This case has been reported and communicated to me by Mr. Blache.

[2] *Op. cit.*, Case XVI. p. 88.

gous to the apoplectic; it was observed that sensibility was almost extinct. At the end of four or five minutes she regained her senses; but she remained as if it were not in her power to move; her looks were fixed, she stammered, and seemed as if she awoke from a lethargic sleep. She completely recovered in about an hour. For some time her courses had been irregular, eight months had elapsed since they had made their appearance. During this time the attacks just described became more frequent, when she was frequently bled from the foot. One day Victoire fell from a height of three feet, and greatly contused her left lumbar region. She merely applied pressure to the swelling. After a time, a phlegmon, which afterwards formed an abscess, made its appearance; the abscess was opened. Shortly after another swelling was formed near to the former: it was also opened; but would not cicatrize. The first wound which was closed soon reopened, and from that time a very large quantity of pus escaped from this double fistulous ulcer. She was desired to keep quiet; but she began her accustomed work, and for two years nothing particular occurred.

"The cerebral symptoms seemed to be progressive. Victoire often complained of headache, and then her face was of a dark red colour; she felt some pain in her left arm, which she said wanted strength. Her intellect daily got worse; more stupefied; when spoken to she looked like an idiot, and if asked whether she had heard, she would briskly answer *Yes*, without any other emotion. She was often giddy, and she often seized things to prevent herself from falling. She was losing strength, the circulation languished, the breath was foul, the appetite little altered. With all these inconveniences, Victoire fulfilled her services as night nurse with an ardent zeal. Being attacked with erysipelas, she was obliged to take to her bed. It was accompanied with great heat, and proceeded slowly. It was œdematous: two grains of tartar emetic produced abundant vomiting; and after this the swelling of the face abated. The secretion of the lumbar fistulæ also ceased. Little attention is paid to this phenomenon: three ounces of manna are ordered, which produce a few stools. The conjunctiva of the right eye then suppurated, for which a blister was applied at the nape of the neck. The patient complained of great pain in the hypogastrium. Manna was again ordered. Nevertheless the suffering increased, and she had no sleep the next night. The next, when I saw her, she was lying on the back, with the head inclined backwards, the face discoloured, the lips black, voice almost gone, respiration very difficult, frequent pulse, skin cold. From the dyspnœa, we suspected a latent pneumonia, and then we endeavoured to reestablish the running of the fistulæ. For this purpose a large blister was applied, but without any effect, she having died at 5 in the morning.

"*Autops. cadav.*,—twenty-four hours after death.

"1. *Cranium.* The membranes were healthy, except at the superior and middle part of the right hemisphere; there was a slight infiltration of the subarachnoid cellular tissue, and the pia mater adhered at this point. The grey substance was natural, but the white injected; in cutting it, the blood flowed from the orifices of its vessels; its consistence was not changed. The grey substance, in the space of three convolutions, corresponding to the spot where the membranes were altered, was of a red, mixed with a yellow colour; it had lost the shining appearance of the other convolutions; it was unequal, and, as it were, tubercular, and several small red points were to be seen on its surface. Its consistence was not everywhere the same: the superficial layer could easily be removed by the handle of the scalpel, and seemed as if it had been *boiled*; the deep layer was much injected, and was nearly of the same consistence as the neighbouring parts. The grey substance was thinner in the extent of the affection than elsewhere.

"2. *Abdomen.* There were evident traces of chronic peritonitis. The abdominal organs presented some peculiarities which it would be useless to relate here.

"3. *Thorax.* The pleura pulmonalis of the left side strongly adhered to the pleura costalis. The left lung was slightly congested posteriorly, and easily torn. The right lung was perfectly healthy. The heart was nearly in a normal state."

The two cases just related are very remarkable, because both the patients showed no other signs of cerebral disorder than a slight defect in the intellect. It is known that latterly MM. Foville and Pinel-Grandchamp have maintained that the grey substance presides over the intellectual phenomena, and the white over the movements. If their assertion is correct, it follows, that in both these patients there ought to have been lesion of the grey substance only: this is also what we have seen. It is true that the last patient had general convulsions; but this phenomenon evidently depended on the inflammation of the arachnoid, which showed itself in the last days, and to which she fell a victim.

"*Great grief; torpor of the left arm; a stupid and imbecile look; alteration of intellect; loss of the power of speech; death 24th day. Ramollissement of the convexity of the cerebrum, particularly of the grey substance; albuminous granulations, with an ash colour of the surrounding parts, and injection of the meninges*[1].—Mary Morlet, 23 years of age, a labouring-woman, strongly built, of a

[1] *Op. cit.*, Case XVII. p. 93.

melancholic character, has been constantly fretting for about a year, or since she left her native place. She is taciturn, and for some time has not spoken to the women working with her; for the last four months she has not been regular, which makes her fear that she is in the family way. This idea augments her troubles. Her superior extremity is now in a state of torpor, and she is taken to the Hospital Cochin the 31st December, 1821.

"The 1st of January, 1822, she is very much depressed, and complains of pain all over the body and of torpor of the right arm, symptoms which greatly disturb the patient; she appears stupid; her ideas seem fixed; her answers are not pertinent; her face is without expression; the pulse small, contracted, as if convulsive; the breath slightly fœtid; skin hot and dry, and there is pain in the epigastrium. (*Twenty leeches on the abdomen; lemonade; low diet.*)

"No change in the following week. She appeared indifferent to all that surrounded her; she seemed to be consumed by a series of dominating ideas. (*Venesect. at the arm; blister to the nape of the neck; dimulcent drink and bouillon.*)

"Jan. 9. The patient answers none of our questions, and merely says *Faut-il?* which she constantly repeats in a sad tone of voice; the right arm is paralysed, stiff, and œdematous; the features are contracted, the forehead is corrugated;

she coughs, and her respiration difficult; face red, pulse frequent and *irregular*; the pulse consists of a series of precipitated oscillations, separated by very sensible intermittences; face terreous; nose cold and pointed. (*Sinapisms to the feet, which scarcely redden the skin.*)

"The 10th. Same state. (*Blister to the nape of the neck, which does not take.*)

"The 12th. Her physiognomy appears animated; the features are more expanded; she seems to understand what is said to her, but makes no answer, and only says *Faut-il?*

"The 13th. Urinary and alvine excretions involuntary; sinking; eye fixed; concentrated pulse, soft, slower.

"The 14th. More motion of eye; expression not so sad; she smiles.

"Same state till the 17th. (*Arnica; bouillon.*)

"The 18th. Sadness returned; eyes black and blue, sunk; same state of the intellectual functions.

"The 19th, 20th, and 21st. The depression increased, vomiting. (*Another blister to the head, which does not take.*)

"The 22nd. In the evening, profound coma; little pulse, threadlike, and frequent; respiration plaintive and suspirious; eye widely open, fixed; foolish look and trismus.

"The 23rd. Eye fixed and dull; pupils dilated, immoveable; respiration noisy, rattling; plaintive sighs; convulsive agitation of the left arm. (*Venesect. in the arm.*) Death at three in the afternoon.

" *Autops. cadav.* thirty-six hours after death.

" *Encephalon.* The arachnoid covering the dura mater is healthy; the surface of the brain red and much injected, especially at the posterior convolutions of the right hemisphere; redness and injection, which appear to be owing to the presence of the pia mater, the tissue of which is much gorged with blood. Having removed this vascular network, the surface of cerebral convolutions is covered by an infinite number of clots of blood; concrete albuminous granulations are spread here and there on the convexity of the left hemisphere, and extend to that part of the right hemisphere which corresponds in the middle to the great cerebral division. These granulations are grouped, and as it were agglomerated in three principal places, which are the seat of the mischief. The most extended of these groups implicates the two hemispheres of the brain, but the left much more than the right, and it occupies the middle and internal convolutions of the superior surface of this organ: there the arachnoid which adheres to the brain is covered by granulations; it is opaque and thick: beneath it the cerebral substance is softened; its consistence is pulpy, of a grey red colour, much resembling the *enkephaloid* tissue, softened and combined with a certain quantity of blood. This softening extends about four or five lines in depth, and its longitudinal diameter is from eight to ten lines. The other smaller places present the same characters; the albuminous granulations are of the size of a grain of hemp-seed, and resemble the tubercles often found on the external surface of the intestines. These granulations are found in the seats of the disease, so that there exists at the same time softening and hardening of the cerebral substance. There is here tuberculous and enkephaloid-looking matter, evidently produced by phlegmasia. The grey substance surrounding *these parts* is of a well-marked ash colour. The lateral ventricles only contain a few drops of sanguineous serum; the cerebellum and spinal marrow are healthy; the pia mater which envelopes them is red and injected.

" *Thoracic organs.* The lungs are healthy; the pericardium distended, fluctuating; it extends as far as the right side of the chest, and contains from six to eight ounces of lemon-coloured serum. The heart, swimming in this fluid, is not at all changed; its right cavities gorged with blood are a little dilated.

" *Abdominal organs.* The stomach and small intestines are in a normal state; there are a few ulcerations in the large intestines. *The uterus is* *healthy.* The tissue of the tube and ovaries is red and as it were erectile; the fimbriated extremity of the tubes adheres to the ovaries, on which it (if I may use the term) is grafted.

"In this last case the softening had proceeded slowly; the phlegmasia had certainly been a chronic one, whilst in the preceding cases it had proceeded in a very rapid manner, and the inflammation in general had been of an acute kind: we find the same thing in the following case related by M. Avoyne:

"*Cephalalgia; furious delirium; convulsions, alternating with a state of collapse: death.—Arachnitis, with softening of the cortical substance of the cerebral hemispheres*[1].—A. Mahon, 30 years of age, of a sanguineous biliary temperament, having got drunk, fell from a first story the first of January 1816. No serious mischief arose immediately after the accident; he lost a little blood from the left ear, and cephalalgia supervened, which continued; but on the fourth day it greatly augmented: on that day, towards evening, he was seized with violent delirium and was admitted into the Hôtel Dieu, where he was tied to prevent his getting out of bed. At the end of the night he suddenly fell into a state of drowsiness. The fifth day the drowsiness was so great that nothing could rouse him; the face, a little

[1] *Op. cit.*, Case XVIII. p. 98.

pale, had a gloomy appearance; the eyelids were shut; in separating them the eyes were directed to the right side; the head was inclined to the same side, and if this position was changed it was immediately regained; the jaws were firmly shut; the pulse slow but full; the patient now and then agitated his arms, and sighed frequently. Neither the cranium nor the other parts of the body showed any trace of contusion. (*Infusion of Roman camomile with tamarinds; blister to the nape of the neck; sinapisms to the knees.*) Drowsiness diminished during the day, without the return of the intellectual faculties; in the evening furious delirium appeared at intervals. The sixth, in the morning delirium had ceased; drowsiness not so great. He now and then opened his eyes, but soon shut them again; he moved his limbs, but he constantly sighed; the eyes were still directed to the right, and the jaws shut, the face a little discoloured. (*Three leeches on each side of the neck and cupping-glasses on the wounds.*) The patient was sensible of the application of the cupping-glasses and had no delirium in the night. The seventh day in the morning, very nearly the same state; sometimes the eyes were open for a length of time, but without sight. (*Hydromel; tamarinds; ice on the head; sinapised fomentations.*) In the evening he began to sink, and continued so till the morning at six, when he died.

"*Autops. cadav.*—The cerebrum was disorganized in many places on its superior surface, and there were collections of blood between the pia mater and the arachnoid. This disorganization, which was only superficial, was rather deep in the posterior part of the posterior lobe of the left side; all the enkephalic mass was red, yellow at some parts, and very soft. The lateral ventricles, extraordinarily dilated, contained a large quantity of serum. All the other parts of the body were healthy.

"The symptoms in this case did not indicate the existence of an acute inflammation of the arachnoid; but you see that the phlegmasia is not confined to the meninges, since the cortical substance of the superior convolutions of the brain was disorganized in many places, with very considerable injection. The intellectual disorder must be attributed to the irritation of the grey substance which accompanies inflammation of the arachnoid. You are aware that MM. Parent and Martinet have shown, by a great number of facts, that delirium corresponded to inflammation of that portion of the arachnoid which covers the convexity of the brain, which tends to confirm the opinion of those who think that the intellectual faculties reside in the grey substance of the convolutions.

" *Contusion of the cranium; no remarkable cerebral symptoms the first days, then furious deli-*

rium; coma: death the 20th day.—Abscess in the grey substance of the convexity of the cerebrum; inflammation and disorganization of the arachnoid[1].—Antoine Broussart, 65 years of age, having experienced great losses in commerce, and being reduced to great misery, gave himself, on the 6th of January, in the morning, many blows on the head with a hammer; but not succeeding in killing himself, he takes a bad pair of scissors, seizes the right testicle with the left hand, and removes it with the scissors. This furious fellow is mastered, and is taken to the hospital La Charité. On the road he tried, but in vain, to strangle himself. On his arrival the surgeon who was present observed about the line of union of the parietal bones with the frontal, a considerable tumour, which he opened by a crurial incision, to allow the extravasated blood to escape, and to ascertain whether there was any fracture. The next day, the 7th, M. Roux examined the wound, and stated that there was no fracture, and had it dressed in the ordinary way, as well as that of the scrotum. (*Low diet, petit lait emetisé.*) The 8th, no accident has occurred. The following days the patient was getting better, when the wound of the head, which till then had secreted a large quantity of pus, began to get dry. The 20th he fell into a state of coma; his pulse became hard and quick, his skin exceedingly hot; an ichorous matter

[1] *Op. cit.*, Case XXII. p. 116.

flowed from the nostrils. To this, furious delirium supervenes; the patient jumps out of bed, threatens his neighbours, wishes to fight them, when he is seized by two nurses, who replace him in bed and tie him to it. He expires in a quarter of an hour.

"*Autops. cadav.*—The dura mater, which is thickened, is covered by a yellow false membrane, and on its internal surface are a few black tubercles; the pia mater is equally thickened; the arachnoid is nearly altogether disorganized, especially between the convolutions of the cerebrum, which are bathed with pus; the superficial layers of this part are softened and in a state of suppuration: there is nothing else worthy of remark[1].

"This case confirms what we have already said, viz. that a circumscribed lesion of the grey substance has no direct influence on the movements of the extremities. Effectively, the patient rises in a furious state the day of his death, threatens to maltreat his neighbours, and cannot be kept quiet until he is tied. On opening the cranium, an abscess was found, terminating in the grey substance of the brain. As to the delirium, the agitation, and the fever, they are accounted for by the phlegmasia of the arachnoid.

"*Slow answers; alteration of the intellectual faculties; a species of idiotism, without para-*

[1] This case was reported by Dr. Hennelle, then house student at the hospital of La Charité.

lysis or convulsions of the extremities: death the 37th day.—Two large abscesses, occupying the middle of the cerebral hemispheres[1].—A soldier, 26 years of age, brown, robust, and sanguineous, was in the military hospitals of Pan in November 1813. At his arrival he said he had been unwell for fifteen days; but, his ideas being confused, this statement could not be relied upon, and he could give no exact account of the phenomena of the invasion. He was tranquil, scarcely answered, the eyes wide open, with a stupid look, and he complained of nothing. He could get up to ease himself. His face was much coloured, especially the cheeks; tongue red, abdomen painful on pressure, the skin extremely hot to the touch, pulse rather slow, pretty full and developed, appetite fair.

"After ten or twelve days he appeared to be convalescent; but the stupidity and quietude remained. He seldom answered, and with much brevity; he frequently refused to get up, but frequently sat up in bed, and looked stupidly at that which was going on about him. He only spoke when he wanted something to eat, or to satisfy some other want. At the end of five or six days the heat and frequency of the pulse reappeared; diarrhœa then came on, and the febrile action subsided. The torpor increased, the wants were

[1] *Op. cit.*, Case XXVI. p. 128.

no longer known, and he died, without convulsions, the 22nd day of his arrival and the 37th of the invasion according to his account.

"*Autops. cadav.—Head.* Two large places filled with greenish pus, sticky and inodorous, each occupying the middle of one cerebral hemisphere, not communicating with the lateral ventricles, but surrounded by a white cyst, formed of a sort of concrete pus easily broken up; with this a considerable injection of all the enkephalon.

"If we take into consideration these facts," says M. Bouillaud, "which might be multiplied *ad infinitum*; if you remark, besides, that those physicians who have recently employed themselves in the study of mental alienation have remarked that it was always accompanied with a disorganization more or less deep of the cortical substance of the superior convolutions of the brain; if you reflect, lastly, that, as has been truly observed by MM. Parent and Martinet, delirium is connected with inflammation of that portion of the arachnoid which covers the convexity of the brain, you will certainly be very much disposed to agree with the opinion of MM. Foville and Pinel Grandchamp, which places the seat of intelligence in the cortical substance of the superior part of the brain."

Lesions of the Corpus Striatum.

There is no portion of the brain that *pathology* has so clearly indicated the function of as the corpus striatum, in so far as its connexion with volition and the production of voluntary motion is considered ; but I think it will appear from several facts I shall bring forward hereafter that some physiologists, as Morgagni, (who, with his usual acumen, was among the first to observe that disease or injury from extravasation into the substance of this body was followed by paralysis,) have advanced too rapidly in theory when they assigned to this body the office of conducting and producing the action of the muscles of the lower extremities, while the thalamus presides over and superintends those of the upper. Andral in referring to this subject makes the following judicious remark. "Among the cases of softening which we have detailed there are several which seem to us to form a strong objection to the opinion of those who thought they had discovered in the brain the particular parts which preside over the motions of the upper and lower extremities. Very probably these particular parts do exist, since each limb may be separately convulsed, paralysed, &c.; but it appears to us that these particular parts are yet to be found out, and we know nothing which can be so fatal to the sound doctrine of the localization of the cerebral functions as those premature localizations which some persons have been inclined to establish in latter times."

In the eleventh letter of Morgagni we find the following passage : " But whatever was the cause of this separation of the corpus striatum, I have already shown you in the third letter which I sent you, how often a hemiplegia is wont to happen from an injury in one or other of these bodies or their neighbourhood. Add to this what the sepulchretum teaches, that Willis also having sometimes examined the bodies of those who died after a long palsy, and a very grievous resolution of the nerves, had always found these bodies less firm than others in the brain, being discoloured like lees of oil, and having their striæ greatly obliterated."

In opposition to what has been said of the special function of the corpus striatum as presiding over the motions of the lower extremity, the succeeding case may be quoted, in which lesion of the part in question was accompanied with paralysis not of the *lower* but of the *upper* extremity[1]:

" *Effusion of blood into the corpus striatum of the right side ; sudden loss of consciousness ; hemiplegia on the left ; death the fifteenth day.*— A woman 48 years old, addicted to wine, fell sud-

[1] Andral, *Op. cit.*, p. 102.

denly deprived of consciousness on the 16th of March, 1823. A little time after she was bled; at the end of two hours she came to herself; she entered the hospital of La Charité the same evening. On the next morning we found the two extremities of the left side completely deprived of motion and sensation. The right commissure of the lips was drawn upwards; intellect perfect; pulse hard, vibrating, a little frequent. (She had blisters to the legs, and purgatives.) On the following day a visible amendment; sensibility restored in the paralysed side; the left lower extremity begins to perform some movements; the left upper extremity as much paralysed as on the preceding day. The 19th, she moves the leg and thigh of the left side with ease; pulse not frequent. (A blister between the shoulders.) From this period to the 1st of April symptoms of gastro-intestinal irritation manifested themselves; tongue red and dry; great thirst; tension of the abdomen; diarrhœa; delirium soon came on: the patient died in what is called the adynamic state. The paralysis of the lower extremity of the left side had been completely removed; not so that of the upper.

"*Post-mortem examination.—Cranium.* The only lesion presented by the enkephalon was in the right corpus striatum. Towards the middle part of this substance, some lines beneath its upper surface, was found a small cavity filled with blood. Around them the cerebral pulp was very soft for the space of three or four lines.

" *Thorax.*—Hypertrophy of the walls of the left ventricle of the heart, with contraction of its cavity.

" *Abdomen.*—Gastric mucous membrane very soft and red through the entire splenic portion. Intense redness, and, as it were, granular appearance of the inner surface of the ileum through a great portion of its extent.

" *Remarks.*—It is rare to find hemorrhage so exactly limited to the corpus striatum as in the above case. The commencement of the affection was similar to that of the generality of cerebral hemorrhages, whatever be their seat. The sanguineous effusion being inconsiderable, the patient soon recovered the use of her senses, and her intelligence continued quite perfect, which in this case may be referred to the seat of the hemorrhage, the effusion having taken place far from the substance of the convolutions. At first the two extremities of the side opposite to that of the sanguineous effusion were equally paralysed, which already invalidates the opinion according to which isolated lesions of the corpus striatum should modify motion only in the inferior extremity. But this is not all; one of the paralysed limbs soon recovers the power of moving, and that is the lower extremity; that is to say, the limb which, according to the opinion just now mentioned, should alone have continued deprived of motion. Thus, the more we advance the more will facts tend to destroy, or at least to stagger, assertions too hastily made. There was no appearance in this case of any curative process having been set up around the hemorrhagic cavity. The most alarming cerebral symptoms had, however, ceased, and it was under a complication of gastro-intestinal inflammation that the patient sank. She had also hypertrophy of the heart."

The following case appears to prove that the tract of neurine which conveys the dictates of the will to the lower extremities as well as that which leads it to the upper extremities, partly passes through the corpus striatum; it also teaches us that partial recovery occasionally takes place after apoplexy.

"*Traces of an old effusion of blood into the right corpus striatum; hemiplegia, preceded by loss of consciousness: death thirteen months after the attack of apoplexy*[1].—A hair-dresser, 46 years of age, entered La Charité the 27th of January, 1822. He told us that on the 21st of February, 1821, he had had an attack of apoplexy, during which he said he had entirely lost all consciousness. On coming to himself he was paralysed in the two extremities of the left side. By degrees this paralysis diminished, and when we saw him he

[1] Andral, page 103.

merely felt some debility in the left extremities. The arm of this side appeared to him not so strong as the other, and in walking he dragged the leg a little. He presented all the signs of pulmonary phthisis, of which he died the 14th day of April, 1822.

"*Post-mortem examination.*—In the posterior part of the right corpus striatum, nearer its external than its internal part, about an inch and a half below its upper surface, a cavity was found, an inch in length and an inch and a half in breadth. It was filled with a substance similar in colour and consistence to thick chocolate. No false membrane extended over the parietes of this cavity. Around it, for the extent of about half an inch, the substance of the corpus striatum was transformed into a yellowish pulp. Caverns and tubercles in the lungs; heart normal; ulceration in the intestines.

"*Remarks.*—Here again the lesion was confined to the corpus striatum, and still there was hemiplegia. Observe, however, that it was in the posterior part of the corpus striatum that the hemorrhage took place. The paralysis, though considerably diminished, existed however, in a slight degree, at the time of death. We saw what was the state of the corpus striatum after the lapse of more than a year since the hemorrhage. There was yet no organized membrane on the parietes of the cavity, and around it the cerebral substance had neither the natural consistence nor colour."

Thalamus Nervi Optici.

Morbid anatomy has not yet shed any clear light on the functions of this part, beyond the facts that volition appears to flow through it; for it is seldom injured without paralysis of some part or other being the result; and that if it is in any way connected with the phenomena of sensation, as its communication with the posterior columns would induce us to believe, it is not entirely devoted to this purpose, for there are many cases on record, in which its lesions have been accompanied with paralysis, while the sensibility of the parts paralysed has remained intact. In truth I believe with Andral [1], that though sensation is perhaps more frequently affected by cerebral hemorrhage than motion, "it has been impossible up to the present time to detect, in the nature or in the seat of the alterations of the brain, the cause which sometimes suffers sensibility to be intact, and sometimes occasions its more or less complete abolition."

In the following case [2] the lesion was so entirely confined to the thalami that it cannot but prove interesting.

"A man 60 years of age was admitted, towards

[1] Andral, p. 113. [2] Ibid., p. 103.

the commencement of November, into the Maison de Santé, with a disease of the heart of long standing. The two extremities of the left side were also paralysed; the intelligence was perfect. About three weeks before his admission, he told us that he felt his left leg fail him, and he fell, not however deprived of consciousness. A little after, he found the upper extremity of the left side also deprived of motion; the sensibility of the paralysed limbs remained. His dispnœa increased, as also his dropsy, and he died on the 25th of November, the hemiplegia continuing to the last moment.

"*Post-mortem examination.*—In the centre of the right optic thalamus there was found a cavity filled with black blood of some consistence. The cavity was capable of containing a large cherry.

"*Thorax.*—Lungs infarcted; hypertrophy of the parietes of the heart and dilatation of its cavities, which were filled with blood; cartilaginous incrustation at the base of the mitral valve; serous effusion into the left pleura; close adhesions between the heart and pericardium. Two bony concretions developed between this membrane and the proper substance of the heart.

"*Abdomen.*—Considerable injection of the intestinal mucous membrane in different parts; spleen very large, dense, and black; liver gorged with blood.

"*Remarks.*—This case differs from all the preceding, in this, that no loss of consciousness occurred when the hemorrhage came on. The two extremities of the left side were equally affected with paralysis, though the lesion existed but in one optic thalamus."

Optic Tubercles.

I am not aware that there are any cases on record in which disease of the brain has been so isolated as solely to affect these structures; but whenever they have been implicated in the diseases of surrounding parts, blindness has been the invariable result.

Pons Varolii, Crura Cerebri.

Lesions of these parts are almost invariably followed by paralysis of motion, but not always by that of sensation; a difference which appears to be connected simply with the extent of the disease. When inflammation first attacks one of the crura cerebri, it generally produces a tendency on the part of the patient to turn round; if the inflammation continue its course uninterrupted, this is soon followed by hemiplegia.

Commissures.

The confirmation from pathology of the opinions advanced in the earlier part of this work, respecting the office of the commissures, is rather of a negative than a positive kind[1].

Lesions of the commissures alone never produce paralysis either of motion or sensation, a fact from which we may legitimately infer that these parts are not in any way connected with the conveyance of volition or sensation, as those medullary fibres which are in immediate communication with the bundles of the spinal cord undoubtedly are. It is certainly difficult to refer to well-authenticated cases, where the commissures alone appeared to have suffered from disease.

Andral, I am surprised to find, decidedly says, on the subject of the longitudinal commissure: "In no one case have we seen softening of the *fornix*, whether general or partial, produce any cerebral symptoms whatever."

Lallemand[2], however, relates a case of ramollissement of the anterior pillars of the fornix in which the symptoms were chiefly connected with disturbance of the mental powers, such as unwillingness to answer questions, drowsiness, &c. But as in this instance the arachnoid was inflamed, and serum effused into the ventricles, it does not prove anything unequivocally. The same writer[3] relates another case in which there was at one time great excitement, and incoherence of the in-

[1] Nevertheless if we can prove what the office is not, we advance one step towards ascertaining what it really is.

[2] vol. i. p. 179. [3] p. 165.

tellectual powers; at another, complete prostration, plaintive cries, and agitation of the limbs. Here death supervened the 16th day after the appearance of the cerebral symptoms.—*Post-mortem appearances.* "The brain sound, with the exception of the corpus callosum and fornix, which were transformed into a species of whitish bouillie, homogeneous, and without vascularity or extravasation of blood. Arachnoid everywhere natural."

Lallemand, in his *Recherches,* points out the great resemblance between the symptoms in this case, and those of acute hydrocephalus; a circumstance, by the way, which makes it probable that the usual symptoms of hydrocephalus are occasioned by the injury or irritation which the commissures undergo from the pressure of the effused serum.

Abercrombie[1] relates two very interesting cases of the same kind as the one last quoted, in which there was softening of the longitudinal commissure without effusion; and as such cases are extremely rare, I here introduce them at full length.

"A woman, aged 30, (18th June, 1816,) was affected with violent pain in the head, which extended across from temple to temple. She was extremely restless, tossing from one side of the bed to the other, owing to the intensity of the

[1] p. 135.

pain; eyes slightly suffused, and impatient of light; pupils contracted; the pulse 60, soft and rather weak; tongue white. She was bled repeatedly, both generally and topically, and used purgatives, cold applications to the head, blistering, &c. For three days she appeared much relieved, the violent pain was removed, and she complained of pain only when she moved her head; pulse from 80 to 90. She was quite sensible, but considerably oppressed and inclined to lie without being disturbed. On the 22nd her speech was affected; she was sensible of it herself, and said that "she felt a difficulty in getting out her words"; pulse 112. 23rd and 24th: Increasing stupor, and at times incoherence, but when roused, she answered questions distinctly; double vision; made no complaint, but said her head was better: pulse from 112 to 120. 25th: Increasing stupor. 26th: Complete coma and dilated pupil; pulse 108 and of good strength. Died in the night.

"*Inspection.*—The fornix and septum lucidum were broken down into a soft white pulpy mass. There was no effusion in the ventricles, and no other disease in any part of the brain."

2nd Case. "A man aged 36, a blacksmith, had been for some months affected with pectoral complaints, which were considered as phthisical. On the 10th of November 1818, being suddenly told of the death of his daughter, who died of phthisis, he instantly complained of headache; and after another day or two a remarkable change was observed in his temper, which became uncommonly fretful and irascible. He still complained of constant headache, which was much increased by motion; his pulse varied from 70 to 110. In this state he continued for a week, without any alleviation of the headache. In the second week he began to be slightly delirious, with a tendency to stupor, the headache continuing very severe. He became gradually more and more oppressed, and at last comatose; and after perfect coma of four days' continuance, died on the 27th. His pectoral symptoms had entirely subsided after the commencement of complaints in his head. I did not see the patient during his life, but was present at the examination of the body.

"*Inspection.*—The membranes of the brain were very vascular. There was no effusion in the ventricles beyond the usual quantity. The septum lucidum was much broken down, and a large opening was formed through the centre of it. The fornix was reduced to a soft white mass, which could not be raised. There was no other morbid appearance in any part of the brain. The lungs were extensively tubercular, and in some places suppurated."

The following case, which came under my care at St. Thomas's Hospital, when dressing for Mr. Travers, also appears to prove the intimate relation which must exist between the integrity of the commissures and the due performance of the mental operations. A preparation of the morbid parts is preserved in the Museum of the Hospital.

William Menzies, aged 16, was admitted into Edward's Ward, November 30th, 1827, with fractured skull. The patient's mother states that "she considered he was never right from his birth, and supposed that his weakness of intellect was occasioned by a difficult labour; he had always a difficulty in controlling and regulating the action of his muscles so as to maintain the erect posture, and was always stumbling and rolling about; he generally appeared drowsy; he was fond of reading, and thus capable of receiving impressions, but he was unable to give a clear account of anything he had read or seen, having apparently no power of reviving impressions, or of comparing them with new ones. He sometimes talked pretty rationally, but generally," to use the mother's expression, "was *boobyfied.* Religious books were his greatest favourites; he was childish in his amusements, very good-tempered, and willing to do all that was required of him." The symptoms did not differ from those usually observed after bad fracture of the skull. He died on the seventh day after his admission.

Post-mortem appearances.—External appearances. The left side of the head appeared fuller, or more convex than the right. On removing the pericranium a fracture was apparent, extending from the external angular process of the os frontis of the right side, and across the coronal suture into the parietal bone on the left; another line of fracture extended from above the squamous suture on the right side, through the anterior inferior angle of the parietal bone into the coronal suture, and continuing in the course of that suture, met nearly at a right angle with the other fracture. The calvarium being next removed, the anterior branch of the middle artery of the dura mater was found wounded at the point where the two fractures united; a small clot of blood was situated there.

A considerable quantity of blood was effused between the pia mater and arachnoid, increasing, as it were, the brain on the right side. On the left, opposite the point where the two fractures united, as before mentioned, there was a circumscribed clot of blood in the substance of the brain; and at the inferior part of the middle lobe there was a large quantity of blood situated between the arachnoid and pia mater, the lobe at that part being softened.

On separating the hemispheres, instead of seeing the corpus callosum as usual, we observed a pale membranous bag protruding from the left side, which on being cut into was found to be a cyst, two inches in length and one in breadth, containing a serous fluid, and lined by a firm membrane. This cyst formed the roof of the lateral ventricle of the left side. On opening this ventricle, instead of seeing the edge of the body and posterior pillar of the fornix in that cavity, we discovered that they were wanting, though there was a portion of the anterior column present. On the velum interpositum there was a small hydatid, and a considerable quantity of fluid in the left and third ventricle. In the right ventricle everything was natural.

Morgagni, whose observations, founded as they are on the inspection of morbid appearances after death, connected with symptoms during life, are generally worthy of notice, even when mingled with the wild speculation which accompanies them on this occasion, broaches an extravagant hypothesis upon the function of the fornix, which I only introduce because it seems to me to prove that he had observed some relation between its injury discovered after death, and symptoms of mental disturbance occurring during life[1].

After detailing a case of epilepsy, accompanied with great drowsiness during life, in which undue accumulation of fluid in the ventricles was met with after death, he reasons upon the effect which fluid accumulated in the ventricles, either in small or large quantities, might have upon the office of the fornix, and concludes in the case before him, that the fluid, by its pressure on the fornix, was

[1] Letter IX., art. 20. *De Causis et Sedibus Morborum.*

in all likelihood the chief cause of the epileptic symptoms. He says, "As the morbid appearances in this case (the accumulation of water in particular) were joined with a propensity to sleep, and with that symptom which almost constantly follows it, a silliness or idiotism, or that kind of silliness at least which is for the most part conjoined with it, as we see in persons who are much inclined to sleep. For although a small quantity of water would press the fornix less, yet it relaxed still more that which was already lax, and by this means might render the man drowsy and heavy. You will ask, for what reason? Doubtless because, as the use of the fornix is not known, nothing forbids us to suspect its use to be of such a kind, that we are under a necessity of being sleepy when it becomes lax. Perhaps you will believe I am not serious now. However, I joke very safely; for I maintain that there is nobody who can demonstrate my suspicion to be really a false one. But let us dismiss this subject, since a propensity to sleep may, perhaps, not only be accounted for from that defect of blood which we saw there was in the vessels of the brain; but it is also sufficient here, as sleepiness has been already explained by me in another place, to show the only thing which I undertook to show at that time in the hospital also, namely, that an epilepsy might be excited either from a small or from a large quantity of water."

Cerebellum.

One of the most extraordinary cases upon record, as illustrating the functions of the cerebellum, is mentioned by Andral in his Lectures[1] on the diseases of the nervous system; it was first published by Dr. Combette in the *Revue Médicale* for April 1831. This was "a case in which the cerebellum was entirely wanting, nothing being found in its place but a quantity of serous fluid contained in the membranes: on each side a pedunculated body, not larger than a pea, was attached to the corpora restiformia; all the rest seemed replaced by a serous sac. The pons Varolii, as well as the cerebellum, was absent, and the individual in whom this remarkable lesion of the cerebro-spinal axis was observed, had attained the age of eleven years. This case shows that agenesia cerebelli, or total want of the cerebellum, does not necessarily render existence impossible, provided the other parts of the nervous centres be well conformed. The individual may even live for a considerable length of time. The child here was near twelve years of age, and we have reason for considering the disease as congenital; for had it been acquired, had this absence of the whole cerebellum depended on an actual destruction of the nervous substance

[1] 12th Lect.: Lancet, February 30, 1836.

caused by an organic lesion, it is not probable the child would have survived so long.

"What were the phenomena observed during life in this case of complete atrophy of the cerebellum and mesokephalon? What effect did it produce on the intellect? What modification in the function of motion? The intellectual faculties were obtuse, though not to a remarkable degree; the answers slow and difficult; the whole countenance expressive of stupidity: in a word, the child, though not exactly idiotic, still showed a deviation of the mental powers. The motility was also modified; the power of motion was considerably weakened in the lower limbs, which did not possess their natural force and vigour: hence the child was unable to support itself with any firmness; it fell down frequently; the legs crossed each other during walking, and the gait was irregular and unsteady. At length the child was compelled to confine itself altogether to bed, and after some time was unable to stir, even when lying in a horizontal position; thus the modification of motility consisted in a gradual abolition of motion: to this were joined epileptiform convulsions, which continued for some time, and finally carried off the patient. The sensation of the integumental covering was not modified in any way whatever. There was no increase of sensibility in the commencement, no obtuseness or diminution of feeling, even when paralysis was most complete: the senses also remained intact. The child could see, hear, and taste in a perfect manner. The functions of nutrition, of circulation, and respiration were carried on without any notable disturbance; however, the child is mentioned as being weak and delicate in constitution; a circumstance which is conformable to the opinion of older physiologists, who have attributed to the cerebellum the power of regulating nutritive life.

"In what manner were the generative functions influenced? This is a question of peculiar interest in the present case, because the cerebellum was completely absent. How, then, do we find the reproductive organs? The uterus, the Fallopian tubes, the ovaries, in a word, the whole generative system was normally conformed; and, moreover, the child, only eleven years of age, showed a precocious tendency to the passions of her sex, having been given to masturbation."

This case strongly confirms the view given above of the function of the cerebellum. It also proves that the mental faculties may exist without it.

"*Considerable softening of the right lobe of the cerebellum; with hemiplegia*[1].—A seamstress, thirty-one years old, who had hitherto enjoyed good health, about six weeks before entering the hospital of La Charité, had a fright whilst

[1] Andral's *Clinique Médicale*, sect. ii. Case I. p. 202.

menstruating: the menses were suppressed, and immediately after their disappearance she was seized with dizziness and an acute pain in the back part of the head, towards the right side. The dizziness disappeared after a bleeding, but the pain of head remained; it was unconnected with any other symptom for eight days; subsequently the patient began to experience an annoying sense of formication at the ends of the fingers of the left hand; she could use this hand but awkwardly, and was astonished at seeing what she handled with it fall continually from her grasp: she soon became unable to work with it at all; the entire arm seemed very heavy. After some time the lower extremity of the left side became weaker, and in about a month the patient had complete hemiplegia of the left side. At the same time that the patient thus lost the power of motion of one of the sides of the body, her sight, till then extremely good, became very weak, and five weeks after the invasion of the first symptoms she became completely blind.

"This was the state in which we first saw her: deprived of sight, and of the power of moving the limbs of the left side; the pain of head had then become less acute; the patient, however, still felt it, and referred it to the lower part of the occipital region of the right side.

"The paralysed limbs were flaccid, and could be moved in all directions; the skin covering them still retained its sensibility; no trace of paralysis of the face; the pupils, moderately dilated, still contracted on the sudden approach of light; the appearance of the eyes was natural; there was, however, all but complete blindness, the patient being scarcely able to distinguish day from night; the intellect was perfect, the pulse natural; the catamenia had not reappeared since they were suppressed by the fright. Leeches were first applied to the nape of the neck, then to the genital organs; aloetic pills were frequently given, and subsequently the back of the head was covered with a blister.

"No change appeared for the first three weeks of her stay in the hospital; then, without any known cause, the pain of head suddenly became more violent, and extended to the entire cranium; the extremities of the left side, which till then had remained entirely immoveable, were several times agitated with convulsive movements, which were slight in the lower extremity, but very violent and almost continual in the upper limb; acute pains accompanied these convulsions; the intelligence soon became disturbed; complete delirium set in; for twenty-four hours the patient spoke, and was agitated incessantly; she then fell into a profound coma, in which state she died.

"*Post-mortem examination.* The pia mater extending over the convexity of the cerebral hemispheres was very much injected, as was also that covering the cerebellum. The substance of the brain, properly so called, was marked with a considerable number of red points, and presented no other lesion; lateral ventricles distended with a great quantity of limpid serum; the fornix and septum lucidum natural. Externally the cerebellum appeared healthy; but we had scarcely removed some layers of the substance of its right hemisphere, proceeding from above downwards, when we found an immense cavity, where this substance, deprived of its normal consistence, was changed into a greyish *bouillie*; this softening occupied at least two thirds of the right hemisphere of the cerebellum; it partly implicated the prolongations which go from the cerebellum, either to the spinal marrow, or to the tubercula quadrigemina, or to the annular protuberance: it did not extend as far as the lower surface; in no part of its extent was there either injection or infiltration."

"*Effusion of blood into the right hemisphere of the cerebellum; hemiplegia of the left side, accompanied with loss of consciousness. Death* 50 *hours after the appearance of the first apoplectic symptoms*[1].—A female, 22 years of age, was treated at the hospital of La Charité for a chronic gastritis; she had evinced symptoms of this affection for the last two years. One evening at six o'clock, a

[1] Andral, *Op. cit.*, p. 195.

short time after having eaten, and before going to bed, she fell, suddenly deprived of consciousness and motion. After about an hour she recovered the use of her senses, but could not move the extremities of the left side. On seeing her the next morning her state was as follows: face injected equally on both sides, contraction of the pupils, vision unimpaired, air of stupor; she answers questions with correctness, no embarrassment of speech. The two extremities of the left side completely deprived of voluntary motion; they presented no trace of contraction; sensibility of the skin covering them impaired. Pulse 75, and full; heat of skin natural; respiration hurried, 30 to 34 every minute.

"This girl seemed to us to have been struck with cerebral hæmorrhage: she was bled to sixteen ounces. This produced no amendment, and the symptoms going on from bad to worse, the patient expired on the evening of the day on which she was first seen.

"*Post-mortem examination.—Cranium.* Subarachnoid cellular tissue of the convexity of the cerebral hemispheres very much injected. The latter present no appreciable alteration, except considerable sandiness of their tissue. In the central part of the right hemisphere of the cerebellum was found an effusion of blood, which formed in the nervous substance a cavity large enough to hold a pullet's egg. Around this cavity the tissue of the cerebellum was red and softened for the space of three or four lines."

A man mentioned by Serres[1], after a blow on the back and lateral part of the head, which stunned him at the time, had a certain unsteadiness in walking, which made him always anxious to take the arm of a friend; and he had a weakness of his head, which made him liable to be much affected by a small quantity of wine. This state continued about eighteen months, when he became low-spirited and irritable, and was affected with trembling of the limbs. Soon after the left leg became paralytic, and the arm of the same side felt benumbed and weakened. After the insertion of a seton in the neck, the arm recovered. Three months after this the patient died, with fever, delirium, and an affection of the bowels.

There was found disease in the right lobe of the cerebellum, with an abscess and extensive softening.

In another man, mentioned by the same writer, who died in forty days, there was palsy of the right leg, with wasting of the limb, but without loss of sensibility, the arm of the same side being little, if at all, affected.

There was found *ramollissement* of the left lobe of the cerebellum, occupying chiefly the centre of the left peduncle.

[1] *Journal de Physiologie*, 1822–23.

The cases above referred to prove that lesions of the cerebellum, like those of the cerebrum, generally produce paralysis of the side of the body opposite to the seat of injury. In some cases the sensibility was decidedly impaired, but in others this function scarcely presented any signs of implication.

One of the most interesting and extraordinary circumstances connected with injuries of the cerebellum with which I am acquainted, I give on the authority of Andral[1]. "When the hæmorrhage of the cerebellum occurs simultaneously with that of the cerebrum, or a little time after it, but so that the blood is effused on the right into the cerebellum, and on the left into the cerebrum, or *vice versâ*, there is paralysis only on the side of the body opposite to the hemisphere of the brain where the hæmorrhage has taken place; that is, on the same side as the hæmorrhage of the cerebellum. How then does it come to pass, that whereas the movements of the extremities of the right side are abolished when there is an effusion of blood into the left hemisphere of the cerebrum, the effusion which takes place simultaneously into the right hemisphere of the cerebellum, should no longer have the power of paralysing the extremities of the left side? It had this power, however, in the cases where the cerebrum re-

[1] *Op. cit.*, part i. p. 201.

mained uninjured: is not that a fact worthy of attention?" Any comment upon this circumstance in the present state of our knowledge would be premature. We would only beseech pathologists to pay particular attention to the fact, and in the first instance endeavour to ascertain whether matters invariably fall out as they are reported to have done in the cases related by the learned and very candid author above quoted.

Abercrombie[1] quotes a curious case from Morgagni, in which scirrhus of the left lobe of the cerebellum was followed by paralysis of the lower extremities, the upper being left perfectly sound.

Portal, when treating of paralysis produced by lesions of the cerebellum, says: "In some cases of injuries of the cerebellum, the paralysis and the convulsions have happened on the wounded, and not on the opposite side, as is usually the case in patients whose cerebrum has been wounded; but still this is not sufficiently proved to be received as a demonstrated point of doctrine."

Among the anomalous instances of disease of the cerebellum producing no symptoms of paralysis, I may relate one mentioned by Douglas[2]. The patient had been for three months affected with pain in the forehead, which generally obliged him to sit with his head leaning forward; he had little appetite, and his sleep was disturbed; but

[1] p. 470. [2] Quoted by Abercrombie, 129.

no other symptom of disease. He died suddenly from an attack resembling syncope, having been for a day much better, with a good appetite, and enjoying quiet sleep. An encysted abscess was found in the middle of the cerebellum, and a rupture of the left lateral sinus, which probably was the immediate cause of death.

In another part of his work Dr. Abercrombie relates two cases of abscess of the cerebellum[1], one connected with caries of the temporal bone, and the other with a spongy state of the dura mater covering it, in both of which the mind remained to the last perfectly unimpaired. The pain was excessive. No mention is made of paralysis, with the exception that in one the power of swallowing was lost, the patient having been nearly suffocated in the attempt to get something down his throat.

Bouillaud[2] sums up his observations on inflammation of the cerebellum in the following words: "It would take too long to detail all the modifications of the functions of progression and station induced by different degrees of disorganization of the cerebellum. A number of affections, designated by the vague name of *nervous diseases*, will probably before long be classed amongst the inflammatory or other lesions of the cerebellum: amongst others are those sometimes characterized

[1] pp. 37, 109. [2] *Op. cit.*, p. 279.

by the fear of falling in walking; at other times by an irresistible tendency to walk backwards, and also by a great wish to run, to jump, to turn heels over head, and various other extraordinary movements, without any reasonable motive. (I know of two extremely curious cases of this description related by the late Dr. Cassan, in the service of M. Dumeril, in the Maison de Santé.)

"Erection and emission do not appear to me essential or pathognomonic symptoms of irritation of the cerebellum, as M. Gall and Serres have advanced.

"I have never seen paralysis of sensibility or general sensation accompanied with complete disorganization of the cerebellum, a circumstance which ought to take place if the cerebellum was really the central focus of sensation.

"It is very true that the most *bizarre* agitation torments the animal whose cerebellum has been irritated; but it is an error to attribute these phenomena to an exaltation of sensibility. It constitutes, as I have said, a sort of *delirium* of the locomotive functions."

SPINAL CORD.

As I have mentioned generally the best authenticated opinions regarding the functions of the cord in the descriptive section, I shall not detain the reader further than to lay before him some interesting observations of M. Lallemand, which are not so generally known in this country as to make the insertion useless[1]. "Let us see," says M. Lallemand, "if pathology is able to furnish us, in reference to the brain, cerebellum, and medulla spinalis, with any data more applicable to man than the experiments made upon animals.

"It is now four years since I saw at the Hôtel Dieu an anenkephalous fœtus of about the full time, which survived three days. During this time it cried lustily, and sucked every time it perceived anything between its lips; but we were obliged to nourish it with milk, and sugar and water, for no nurse could be found to give it the breast.

"It executed some tolerably extensive movements of the upper and lower extremities. When we placed a foreign body in its hands it flexed the fingers to seize it, but in general all its movements had less energy than those of a fœtus of the same age.

"On examining the body of this monstrosity after its death, the cerebrum and cerebellum were found to be entirely wanting. At the base of the cranium there was nothing but the medulla oblongata and the annular protuberance, with the origin of the pneumogastric, trifacial, and optic

[1] *Observations Pathologiques propres à éclairer plusieurs Points de Physiologie*, by F. Lallemand, 2nd edition, Paris 1825, p. 85.

nerves. The whole was covered by the rudiments of the cranial bones, the meninges, and the skin.

"A case similar to the above was observed some time back at the Hospice de Perfectionnement, and many others are contained in the works of different authors, being sufficiently common in their occurrence. It is therefore unnecessary at the present day to relate numerous examples, as has been done in speaking of the more rare cases of destruction of the spinal cord. The few quoted are quite sufficient to prove that the brain is not the *only source of nervous power*, as Haller believed, nor *the only centre of the nervous system of animal life*, as Bichat thought. They prove, moreover, if it were necessary to do so in the present day, that the voluntary motions are not under the influence of the cerebellum[1].

"From all that has been said, on the contrary, it seems evident that those organs which receive their nerves from the medulla oblongata and spinal marrow draw from them the peculiar nervous power which animates them.

"But we still find a great number of observations on anenkephalous fœtuses in which respiration could not be established; and dissection proved that in these cases the *medulla oblongata* was wanting at the same time with the brain. It

[1] *Opera Omnia*, vol. i. p. 50. Boerhaave, *Instit. Medicæ*, §. 409.

is then on the medulla oblongata that the phenomena of respiration depend; it is also from this part that the pneumogastric nerves arise.

"But if the medulla oblongata and spinal cord furnish to the nerves arising from them the nervous power necessary to their functions, how is it that compression, inflammation of a portion, sometimes of very limited extent, of the cerebrum or cerebellum should produce in one case paralysis and in another convulsions of the muscles which receive their nerves from the cord? Legallois did not pretend to the ability of giving any satisfactory explanation of these contradictions. It seems to me, however, that one is easily given, if we reason here as we have done in reference to the sympathetic nerve. Let us set out from a fixed point, respiration. We have seen that deglutition, sensibility, and movement have all existed, notwithstanding the absence of cerebrum and cerebellum, so that nothing can prevent our concluding that the functions exhibited in such cases were independent of the organs which were found wanting; that, consequently, the medulla oblongata and the spinal cord neither draw from the cerebrum nor the cerebellum the nervous power which animates the parts receiving nerves from them.

"If inflammation and compression of the cerebrum and of the cerebellum produce convulsions, paralysis of the limbs, &c., we cannot compare rigorously these rapid alterations with the slow destruction of the brain (supposing it ever to have existed,) in acephalous fœtuses. I shall not revert to what has been said on the difference of the effects produced by the slow and the sudden removal of an organ ; I shall merely observe that those considerable extravasations, those enormous tumours, which compress and at the same time deform the cerebrum and cerebellum without any symptom of paralysis during life, those destructions by suppuration of entire lobes of the brain without convulsions, &c., all occurring more or less slowly, and being accompanied with different symptoms, according to their degree of *chronicity*, conduct us, as it were, by insensible steps from the acute diseases of the cerebral structures to the case of destruction of the cerebrum and cerebellum in the acephalous fœtus.

" Moreover, these apoplexies, these compressions and inflammations, are not all equally destructive of functional manifestation; and I do not hesitate to affirm that if we had observed more accurately we should have remarked some phenomena which of themselves would have led us to conjecture that the cerebrum was not the only source of nervous power. Every time that in a paralysis produced by compression, sensation and motion are not entirely annihilated, the lower extremities are less affected than the upper ; sometimes where there is affection of the sensibility, the hairs of the beard may be pulled and the skin of the arm pinched without the patient complaining: it is different, however, if you pass from the chest to the belly and legs; sensibility increases more and more in proportion as you recede from the head. If there is only partial paralysis of motion, when you pinch the arm the patient often cannot withdraw it; he raises his other hand to remove yours: but if you pinch the calf of the leg he will often retract the limb more or less slowly, flexing the leg upon the thigh. Whenever there has been complete paralysis of sensation or motion and recovery has taken place, the improvement always commences by the lower limbs. Very often, too, the lower limbs recover their functions whilst the upper remain paralysed, and nothing is more common than to meet with individuals who after an attack of apoplexy can walk more or less perfectly, though they carry the arm on the same side, perfectly useless, in a sling. There was a Swiss lately in La Charité labouring under an incomplete paralysis of the two arms; the skin had retained a little sensibility; the skin of the chest was considerably more sensible; the legs sensible and moveable as usual. The speech of this man was much deranged and his ideas confused. He died at the end of two months. Nothing but serum was found in the lateral ventricles.

"There were, about the same time, in the surgeons' wards, two patients exactly in the same condition. I do not know what the issue of the disease was in these cases.

"I have observed similar phenomena in convulsions produced by inflammation of the brain and arachnoid: the convulsive movements are constantly more violent in the arms than in the legs; they are even often confined to the arms. It then appears that these diseases have a greater influence on the spinal marrow the nearer it is to the brain, and that in milder cases they do not hinder the spinal marrow from performing its natural functions. These observations, which have not been made by any one, I have witnessed in a great number of patients; and I have not yet seen an exception. Paralysis of the lower extremities is never produced by disease of the brain.

"After wounds of the head, &c. we often find double effusions, and, after them, double paralysis of the superior and inferior extremities; nevertheless respiration continues for several days. (I have seen two children live in this state for twelve or fifteen days.) The breathing is certainly laborious; but, as it continues, the intercostals and diaphragm are not paralysed. It then appears that the spinal marrow has not so much influence on the nerves of the diaphragm and intercostal muscles as on those of other parts; it therefore influences those parts least the functions of which, in health, are most independent of the will, and which consequently are least under the control of the brain.

"But this is not all: we must also take into consideration the age when the alteration of the brain happens. Difference of age is of such importance that we can only remove the brain of mammiferous animals, without producing death, when they are very young. Legallois attributes this difference to the hæmorrhage resulting from the experiment not having so much influence on the young animal as on the adult. But we do not see why hæmorrhage should be less dangerous in early life than at any other period. We have seen that the connexion between the spinal marrow and sympathetic nerve becomes more and more intimate as the animal advances in years: why should it not be the same with the brain and spinal marrow? Whilst the fœtus is in its mother's womb the brain is inactive; but, since it is from the brain that the determinations of the will depart, there must be, after birth, a connexion more and more intimate and more and more necessary between it and the marrow; and that which proves this fact in a clear manner is that fœtuses born without brain only live for three or four days at the most. Here we cannot attribute the death to hæmorrhage. If the presence of the brain did not become more and more necessary, I do not see why, having lived for three or four days, anencephalous fœtuses should not live longer; they do not die of inanition, since deglutition is performed as usual. Besides, the movements of these anencephalous fœtuses have in general not so much energy as those of ordinary fœtuses: which proves that the influence of the brain is not confined to the mere determination of the movements subjected to the influence of the will, but that it also increases their energy. It seems to me that the slowness with which alterations of the brain are effected, the time of life at which they occur, and the weakness of the movements of anencephalous fœtuses, suffice to overthrow the objection which Legallois himself made; and that we can now conceive how it happens that in anencephalous fœtuses the medulla oblongata and spinal marrow perform their functions without a cerebrum or cerebellum, whilst the slightest abrupt alteration of the cerebrum or cerebellum annihilates or perverts the functions of the nerves which arise from the medulla oblongata and spinal marrow.

"The effects of these alterations will not hinder us from concluding: 1st, that all the nerves of animal life derive from the direct point of their origin, either in the brain or spinal marrow, the nervous power necessary for their functions; 2ndly, that the determinations of the will depart from the cerebrum: 3rdly, that the brain exercises on the spinal marrow an influence which is not confined to directing its action according to the will, but that from it results an increase of energy in the unctions of the spinal marrow; 4thly, that the influence of the brain is not the same on all parts of the spinal marrow, for example, on the parts which give off the nerves of respiration; 5thly, that this influence is so much the greater, so much the more necessary, as the fœtus advances in age."

Bouillaud[1], whose experiments on the functions of the cerebellum are referred to in another part of this work, entertains some very decided opinions regarding the localization of the cerebral functions; and, although they appear to me rather premature in the present state of knowledge, I conceive that their detail in his own words may be attended with advantage, particularly as the work from which they are quoted is not easily within the reach of the profession in general.

"*Modifications of the symptoms of Encephalitis, according to the portion of the brain affected.*"

These modifications ought to be considered with reference to the functions of the voluntary muscles, to the sensations, and to the intelligence.

1st. *Modifications of the lesions of the muscular functions according to the seat of the cerebral affection.*

"If we reconsider for a moment," says M. Bouillaud, "the symptoms observed in those patients whose cases we have related, we perceive that in

[1] *Traité Clinique et Physiologique de l'Encéphalite ou Inflammation du Cerveau et ses Suites*, by M. J. Bouillaud; 8vo, Paris, 1825, page 273.

some one limb was paralysed, that in others the paralysis affected both limbs; that in the latter the hemiplegia was complete; that in the former it was incomplete, insomuch that, for instance, the eye, the eyelids, the cheek, the tongue preserved their movements, whilst the limbs were totally deprived of their motive powers. To what may these differences, and many others which we have not described, be owing? Paralyses of different portions of the body necessarily imply a difference in the part of the brain itself which is affected. And, since the seat of the paralysis varies according to the seat of the cerebral alteration, it becomes possible to recognise the one by the other. Already have attempts been made at different times to solve this important problem. We shall cite some instances in support of this statement.

"The celebrated anatomist Willis says that observations have made it evident that limbs do not become paralytic by an effusion situated *at the anterior part* of the head or on the cerebellum.

"According to Sabourant, if we could follow the nervous fibres to their first origin in the brain, we might derive the greatest assistance from injuries of the functions of the parts where these nerves are distributed, in determining which part of the brain was the seat of the disorder. 'Each part of the body,' adds this author, 'receives without doubt constantly enough its nerves from a particular part of the cerebral mass, and an injury of this part of the brain must necessarily seriously disturb the functions of those organs where these nerves terminate, so that *clinical observations made with great care* will perhaps some day discover the origin of the nerves of each organ.'

"Sancerotte[1] has even gone further than Sabourant. From many experiments and observations, he concludes: '1st, that the extremities derive their power of motion from the opposite hemisphere of the brain; 2ndly, that the fibres destined to form the nerves of the extremities, take their origin from all parts of the hemispheres, and are collected together in the corpora striata, as well as those of the nerves of the lips, and some of those which directly or indirectly assist vision[2]; and that, besides the interlacement of the medullary fibres from one side of the head to the other, there is yet one more (remark this well) from the anterior to the posterior part, and *vice versâ*, for the motion of the limbs; so that the origin of the nerves destined to the motions of the superior extremities is in the posterior part of the brain, and reciprocally in the anterior part for the inferior extremities; 3rdly, that in cases of paralysis arising from extravasation, and more decidedly affecting one limb than another, the extravasation im-

[1] *Prix de l'Académie Royale de Chirurgie.*

[2] This last proposition is not quite correct.

mediately compresses that part of the brain which corresponds to the affected limb, and mediately the part which is in relation with the other.

Lately, MM. Pinel-Grandchamp, Foville, and Serres have promulgated an opinion which is nearly consonant to that of Saucerotte, since, according to them, the corpora striata and their anterior radiations preside over the movements of the lower, and the optic thalami and their radiations over the movements of the superior extremities[1].

"Having given the result of the principal researches which have as yet been made on the determination of the parts of the brain which govern the movements of the various muscular apparatuses of the economy, we will now proceed to relate the result of our researches and reflections.

"1. The paralysis of the organs of speech depends on lesion of the anterior lobes of the brain. I have collected such a number of facts for the support of this opinion, that I look upon it as a fact quite established. I hope that the reader will partake of my opinion in this respect, if he attentively read the observations and reasonings which I have made in another part of my work;

[1] Petit of Namur had already suspected that the limbs derived their power of motion from the superior part of the cerebral hemispheres; he had already shown, by direct experiments, that complete paralysis could only be produced by injuring the corpora striata.

the fear of falling into fatiguing repetitions does not allow me to repeat them here.

"2. Paralysis of the inferior extremities corresponds to lesion of the middle lobes, or of the corpora striata. This opinion is a slight modification of that of Saucerotte and of MM. Foville, Pinel-Grandchamp, and Serres[1]. Many observations confirming this opinion will be found in the memoir of MM. Foville, Pinel-Grandchamp, and in that of M. Lacrampe-Houstan. I have brought forward a few of them in this work; although this second proposition does not appear to me to be so satisfactorily proved as the first.

"3. Paralysis of the upper extremities is the effect of lesions of the optic thalami, or of the posterior lobes of the cerebrum. I am here only repeating the opinion of MM. Foville, Pinel-Grandchamp, Serres, and Lacrampe-Houstan. It is perhaps susceptible of some modification. I have sometimes seen an *isolated* paralysis of the arm corresponding to an affection not occupying precisely the posterior lobe of the cerebrum, but rather the point of junction of this with the middle lobe, or even a part of this last. The cases 10, 13, 19, 21, 27, 31, 32, are so many examples of paralysis of the upper extremities corresponding

[1] The difference is that these authors attributed the paralysis of which we are speaking to lesion of the anterior part of the brain, a lesion which produces paralysis of the organs of speech.

to lesion of the parts just indicated. The 24th observation, in which a ligature of some of the cords of the brachial plexus caused suppuration of the posterior lobe of the opposite cerebral hemispheres, is also a precious fact, which would seem to indicate that the nerves of the superior extremities terminate in the posterior lobe of the cerebrum.

"4. Paralysis of the muscles of the eye does not always follow that of the muscles of other parts; and consequently there must be lesion of a distinct part of the brain to produce it. Clinical observations have not yet shown the true seat of this lesion[1].

"The various partial paralyses of which we have been speaking may be combined with one another in many ways, giving rise to paralyses more or less extensive, more or less complicated. But after the preceding explanations, (supposing that they are the expression of facts,) we can always recognise the seat and the extent of the cerebral

[1] It is well known that the interesting researches of Sir Charles Bell have shown, 1st, that the sensibility of the conjunctiva belongs to the branch which the fifth pair gives off; 2ndly, that the third and sixth pair are the conductors of voluntary motion to the eye; 3rdly, that the fourth pair is the agent of the involuntary and instinctive movements of this organ, and that it establishes a sympathetic relation between the eye and the respiratory apparatus. (See Bell's Memoir, inserted in the *Arch. Général dè Méd.*, October and November 1824. See also M. Magendie's Experiments on the Motions of the Eye.)

affection by means of the knowledge we possess of the seat and of the extent of the simple paralytic affections by which the compound one is engendered.

"But if we have committed some errors in the determination of the relations between the seat of paralysis and that of cerebral injuries, it will always remain clear that there exist in the brain many centres of motion, as there exist many intellectual organs. The plurality of cerebral centres destined for motion is, in fact, proved by the existence alone of partial paralysis corresponding to a local alteration of the brain; for it is evident that if this organ was not composed of many centres of motion or conductors of muscular motion, it would be impossible to conceive how the injury of one of its points should entail a paralysis of one part of the body without causing any injury to the motions of all the other parts. I know that the preceding propositions may appear contradictory to the results of experiments made on animals. In fact it is certain that after the removal of its cerebral lobes an animal can still walk, run, move its jaws, eyes, eyelids, &c.; and it is no less certain that the alteration of a cerebral hemisphere in man produces a paralysis more or less extended of the voluntary muscles of the side opposite to the body. Can these facts be refuted by any others? Without doubt not. For facts of equal certainty do not admit of any refutation by one another. Let us content ourselves with stating them.

"A time will come when new lights will put an end to the apparent contradiction which actually exists between them; in the mean time we must not forget that the muscular system obeys several different nervous powers. Thus, for instance, the nervous power which governs the motions of the interior muscles, such as the heart, the intestinal muscles, &c.; that which regulates the respiratory motions, and all those classed under the name of *preserving* or *instinctive* motions; that which governs the voluntary motions, the reflective and intellectual powers, &c. are essentially different, and their respective seats have been absolutely determined by modern physiologists. The brain, as the organ of intelligence and centre of volition, is the nervous form which governs the intellectual motions, that is to say, what the animal executes in virtue of intellectual acts; consequently, an injury of this organ would paralyse more or less the motions of this order of functions, and might leave uninjured those of a different order. From hence the paralyses of the voluntary motions are reflected, of which we have given so many examples . . . .; and here clinical observation is not less in contradiction with physiological experiments, since, on one hand, animals in which we have removed the cerebral lobes are effectually deprived of every kind of movement reflected and directed by the intellectual combinations ; and, on the other hand, patients incapable of all voluntary and reflected movement, in consequence of a cerebral affection, execute nevertheless different movements, *automatic* and *instinctive*, as, for example, when they retract the limb on being pinched, a movement which simple volition could not have produced.

"II. *Modifications of the injuries of the sensitive functions according to the seat of the cerebral affection.*—Since each of our senses fulfills a particular function, it is evident that the injuries of sensation vary as the affection is seated in such or such of the nervous centres, which are the immediate organs in which the perception of the sensitive impression operates. Thus, the alteration of the nervous centre in which reason operates would determine an injury in the functions of the eye, blindness for instance. Thus, the alteration of the cerebral organ affecting hearing would occasion an injury in the functions of the ear, such as deafness, &c.

But there is a sensation, in some degree universal, which deserves to fix for an instant our attention ; I speak of feeling and of touch. This sensation does not appear to have a central seat so circumscribed as that of the other particular sensations, such as sight, hearing, &c.

All the nerves classed in modern times under the name of *nerves of sensation* are the organs of feeling; that is to say, there is not any of them which may not, under favourable circumstances, be sensible to the impression of external bodies. Each of these nerves plays, if we may so speak, with a feeling which belongs to it, with a function which is proper to it, and which it can preserve when the other nerves of the same kind have lost their sensitive faculty, or which may be lost when these last have preserved all their energy. This is why we observe partial paralysis of feeling, as of movement. Thus the arm may retain its normal sensibility, whilst the wrist is deprived of this faculty, and reciprocally; thus we may see the face deprived of feeling in cases in which the other parts of the body possess the sensibility which is proper to them, &c., &c. After that, each of the nerves which compose the *ensemble* of the apparatus of sensibility ought to be considered as a kind of peculiar sense, and independent of the others, and it is to the isolated alteration of the cerebral centre in which each terminates that we must refer the loss of feeling of the part to which it distributes itself. The cerebral focus which perceives the tactile impressions extends itself then over all the points where the different nerves of feeling end, just as the external organs of touch have no other limits than those of the expansions furnished by the so-called nerves of *feeling*.

" III. *Of the modifications of lesion of the intellec-*

tual functions according to the seat of the cerebral affections.—The question which we propose to examine here is connected with the doctrine of the plurality of the cerebral organs, a doctrine by which the late Doctor Gall has rendered himself so justly celebrated, and which truly deserves to be submitted to the test of pathological observation. But it is not so easy as we might at first believe, to draw from clinical observations lights capable of illustrating the functions of the brain. And why? In the first place, it does not always happen that the two hemispheres are affected at the same time; for we have seen that lesion of a single hemisphere has not interfered with the complete exercise of the intellectual faculties. In the second place, a lesion of slight extent reacts on the whole cerebral mass in such a way as to derange at once all its functions; and how, in this general functional disorder, can we recognise the phænomena peculiar to lesion of this or that part of the brain? In the third place, cerebral affections always deeply affect the speech, and in consequence the physician is not able to obtain from his patients the information which he requires in order to ascertain what are the intellectual faculties which are altered or entirely abolished.

"Thus, then, although we cannot deny that cerebral pathology may be a precious means of elucidating the mysterious functions of the brain, we cannot but at the same time allow that this method of research is surrounded with great difficulties.

"All that my observations have attained at present relative to the localization of the cerebral intellectual organs, is, that the anterior lobes of the brain are the organs for the formation and remembrance of words, or of the principal representative signs of our ideas."

He then, after referring to the cases which he cites in proof of his opinions, says: "But whilst, on the one hand, the loss of speech and of the memory of words is the inevitable consequence of disorganization of the anterior portion of the brain; and that, on the other hand, this symptom does not accompany alterations of other cerebral convolutions, are we not right in concluding that the organ of articulate language resides in the anterior part of the brain?

"Sometimes we have seen that the loss of speech may be occasioned by another cause than that of which we have treated; for instance, the paralysis of the muscles destined to the articulation of sounds. But the phænomenon most worthy of remark, I might say of wonder, is found in the fact that this paralysis itself corresponds to an alteration of the part of the brain indicated above, hat is to say, the anterior lobes."

CONCLUSION.

From all that has been said, it must still appear that our knowledge of the functions of the cerebro-spinal axis in man is extremely limited, and even indefinite. In the following summary, however, I trust I shall be able to show that it is both more extensive, and that the further prosecution of the inquiry is less beset with difficulty than is generally supposed.

1. With regard to the spinal cord, its office is plainly twofold; in the first place, it is a conductor of motion and sensation, in which respect it is analogous to the nerves distributed to the muscles, integuments, and every part of the body, the anterior columns being the organs of motion, the posterior, of sensation; in the second place, the cord is a centre from which power emanates independently of the great cerebral ganglia with which its upper extremity is connected.

2. Proceeding from the spinal cord to the medulla oblongata, we come first to the *corpora olivaria*; these might with great propriety be denominated the *pneumogastric ganglia*, their office being almost certainly to preside over the actions of the respiratory muscles, the ganglion of the sensory portion being situated external to the skull. The next portions of the medulla oblongata we encounter are the *posterior pyramidal* bodies. From the intimate connexion between

the acoustic nerves and these bodies, we should have no hesitation in speaking of them under the title of *auditory ganglia.* Their office, as well as that of the *optic ganglia,* or quadrigeminal tubercles, is obvious; and the same may be said with regard to the *olfactory ganglia,* or bulbous extremities of the olfactory nerves. There is every reason to believe that the impressions received by the extremities of the auditory nerves in the one case, and by the optic and olfactory in the other, are converted into sensations in the respective ganglia in which they terminate.

3. The *cerebellum* is unquestionably one of the centres which influence and generate power, and most probably in connexion with the functions of the voluntary muscles.

4. In intimate connexion with the cerebellum is found the *pons Varolii,* of the nature of whose office there can be very little doubt. All conspires to prove that it is the commissure or instrument for establishing a communication between the different parts of the cerebellum. From the fact of its having a quantity of cineritious neurine distributed through it, we may presume further that it is more than a mere conductor; that it is a generator of power of some kind, but of the precise nature of which we have no knowledge.

5. Whether or not individual portions of the great *hemispherical ganglia,* the last centres

of power to be considered, perform separate offices in correspondence with the different kinds of mental manifestations, as stated by the phrenologists, I candidly confess my incompetence to venture even an opinion. The whole subject of phrenology appears to me of far too much importance to be discussed without the most rigid and impartial examination of the immense body of facts adduced in support of it; and this I have not hitherto had leisure to undertake. I shall therefore only say that, so far as I am acquainted with the subject, I do not see it as otherwise than rational and perfectly consistent with all that is known of the functions of the nervous system.

6. Lastly, with regard to the office of the *commissures,* this is implied in the name by which they are known. The structure of these parts, analogy, and the few pathological facts that have been recorded, bear us out in the view taken of their office as conductors of nervous power, as the media of establishing communication between one portion of the enkephalic mass and another, and, in this way, intimately connected with the faculty, possessed by man especially, of comparing and reasoning upon the various impressions received by the different portions of the hemispheres.

THE END.

DESCRIPTION

OF

THE PLATES.

PLATE I.

In this Plate[1] the student will find his attention restricted to the nervous systems of the two first subkingdoms of nature, the Cyclo-neurose and the Diplo-neurose, or the Radiata and Articulata of Cuvier. The first, which has been selected for its simplicity, is the nervous system of the Ascaris, one of the Diplo-neurose, copied from Cloquet.

Fig. 2. has been introduced to show the close analogy between the early form of nervous system presented during the development of the Chick, and its permanent arrangement in the Articulata.

Fig. 3. illustrates the curious radiated form of the nervous system in the Star-fish, constructed in perfect accordance with the peculiar configuration of the whole animal. It is interesting also as exhibiting a perfect type of the most complicated nervous system, the centres of power, or ganglia, being placed at the commencement of each ray, with their connecting cords or commissures and the nerves distributed to the rays.

Figs. 4. and 5. represent the gradual development of the analogue of the spinal cord of the higher animals ; while the nervous system of the Lobster, as represented in figs. 7. and 8, shows a still closer resemblance in the distinct sepa-

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[1] Figs. 1* and 2* are referred to in the text erroneously as merely fig. 2.

ration of the tract of motion from that of sensation, to the vertebrated class of animals in general.

Fig. 9, representing the central ganglia in the Crab, is interesting from the illustration which it affords of the mode in which nature has arranged the analogue of the spinal cord in conformity with the general form of the animal.

The remaining figures, 1, 11, and 12, illustrating the development of the nervous system of the Caterpillar, Grub, and Moth, are instructive, in as much as they show the progressive concentration and increased size of the cerebral ganglia, in particular, as the animal advances in perfection of organization, through the agency of the increased perfection of his organs, sight, &c.

Fig. 1*. Female Ascaris seen on its abdominal surface.

a, Mouth surrounded by three tubercles.
b, The anus.
c, Contracted portion found at the union of the anterior third of the body with the two posterior thirds.
1. Abdominal nerve.
2. Vulva.

Fig. 2*. An enlarged view of a transverse section of the same worm.

A, The skin.
B, Two muscular layers.
c, Cavity of the stomach.
1. Dorsal nerve.
2. Abdominal nerve.

Fig. 2. Ovum of the Chick 24th hour. (*After Dr. Allen Thomson.*) The white line represents the rudiment of the nervous system.

Fig. 3. Nervous system of the Star-fish, drawn from a preparation in King's College Museum.

1, 2, 3. Nerves distributed to three of the rays.
4. One of the twelve ganglia.
5. One of the commissures.

Fig. 4. *From Grant's Outlines of Comparative Anatomy.*

Nervous system of the *Talitrus Locusta*, or Common Sandhopper.

All the ganglia, eleven in number, are of nearly equal size ;

the two first, which are the supra-œsophageal, scarcely exceeding in dimensions any of the others.

The œsophagus runs between the two first pairs of ganglia.

Fig. 5, *also from Grant's Outlines, &c.*, presents the nervous system of the Cymothæa. The œsophageal ring very distinct, but the supra-œsophageal ganglia scarcely developed. The two longitudinal cords with the pairs of ganglia united so as to form a uniform cord.

Fig. 7. The nervous system of the Lobster, *Astacus marinus*, Leach. *After Newport.*

1 to 14. Ganglia.

A. Cerebral ganglia.

B. Passage for the œsophagus between the crura. *C*. The subœsophageal thoracic ganglia. *D*. Post-abdominal or caudal ganglia and nerves. *E*, *E*. The origins of the nervus vagus. *a*. Optic nerves. *b*. Nerves from a distinct ganglion to the large antennæ. *c*. Nerves from another ganglion, anterior to the last, to the small antennæ. These four ganglia to the four antennæ are situated anteriorly, and a little laterally to the cords, and are connected with the sensitive columns (*d*). *e*, *e*. Origins of the vagus and of a nerve, as in insects, distributed to the sides of the mouth.

f. The continuation of the vagus along the dorsal surface of the stomach, and in connexion with the anterior distribution of the anterior aortal vessel, as in insects.

G. The glosso-pharyngeal nerve. *h*. Mandibular nerves. *i*, *i*. Nerves to the inferior lip and palpi. *l*, *l*, *l*, *l*. Nerves derived from the upper surface of the cords to the branchiæ. *m*. To the circulatory vessels. *o*. Moto-sensitive or symmetrical nerves from the ganglia. *q*. Nerves from the upper surface of the cords. *R*. The terminal pair to the rectum. *s*. Terminal nerves from the cords and ganglia. *t*, *v*, *w*. To the lamellæ of the tail.

Fig. 8. The same portion of the nervous system viewed from the upper surface, and exhibiting the two halves of the motor column passing over the ganglia.

Fig. 9. Nervous system of the Crab.

A. The supra-œsophageal ganglion, of small size in comparison with the rest of the body.

B. The neurine of the whole of the spinal ganglia united into one mass, the abdominal ganglion.

Fig. 10. Marked Fig. 1. in the Plate and in the text. Nervous system of the Larva of *Sphinx Ligustri* after it has acquired its full growth, and about two days previously to its change to the pupa state.— *AfterNewport.*

A. The supposed Brain, or anterior nodules of the cord.

1. The first ganglion situated in the head, or first segment beneath the nodules.

2, 3, 4, 5. Ganglia of the trunk supplying nerves to the legs and wings.

6, 7, 8, 9, 10, 11. Ganglia of the abdomen.

a. The anterior lateral ganglia. *b*. Nerves to the mandibles. *c*. Second pair from the second ganglion, given to the muscles of the neck. *d*. Third pair, given to the first pair of legs. *e*. The plexus of transverse or superadded nerves from the second ganglion. *f*. Nerves to the first pair of wings, originating from two roots, one from the cord, and one from the third ganglion, and connected also with the transverse plexus. *g*. Second pair of nerves from the third ganglion, given to the second pair of legs. *h*. Transverse plexus from the third ganglion. *i*. Nerves to the second pair of wings, originating, like the first, from two roots, one from the cord and one from the fourth ganglion, and connected also with branches from the transverse plexus from the third. *k*. Second pair from the fourth ganglion, given to third pair of legs. *l*. Nerves from the fifth ganglion, which, in the pupa, are those given to the posterior muscles of the trunk. *m*. Nerves from the sixth ganglion, which, in the pupa, are those of the anterior muscles of the abdomen. *n*. The last pair of nerves from the terminal ganglion, given to the rectum and organs of generation.

Fig. 11. Nervous system of the *Sphinx Ligustri* thirty days after changing to the pupa state.—*From Newport.*

This drawing exhibits the abdominal cords in their shortened state, with only five instead of seven ganglia, the fifth and sixth having passed onwards and become continuous with the fourth. The cords in the trunk and the nerves to the wings are enlarged; and those nerves, which were in the larva the first pair in the second ganglion, are also enlarged, and now originate from the cords, while the first ganglion has advanced very near to the superior lobes of the brain. The terminal ganglion exhibits a very peculiar structure.

Fig. 12. Nervous system of the perfect insect *Sphinx Ligustri*.

A. Cerebral ganglia.

B. Optic nerves. The figures refer to the number of the ganglia.
o, o, o. Respiratory nerves.

N.B. The true relative proportion in these last three figures has not been accurately maintained by the lithographer.

PLATE II.

In this Plate will be found, 1st, representations of the nervous system of two genera of the Mollusca. Fig. 1. The *Aplysia fasciata*, or Sea-Hare, and fig. 2. the *Sepia officinalis*, or Cuttle-fish. (The scattered disposition of the nervous centre in the one, and the concentration of the cerebral ganglia in the other, are better displayed in Plate III. figs. 1 & 2. than in this plate, which has been introduced more to show the relations of these ganglia to the alimentary canal, than their exact appearance). 2ndly, The cerebral ganglia of the lowest orders of the Vertebrata as regards intellectual endowment, viz. the Fish : the first forms represented, namely, figs. 3, 3*, 4, are those of the Whiting, and have been selected for their simplicity ; the two next, 6 and 7, are from the Cod, whose brain being perfectly similar to the Whiting, a view of the more internal parts has been introduced, as carrying the same point of observation a little further on. From the Cod we advance by the Eel, fig. 7, and Carp, 8 and 9, to the more concentrated form of the Skate, figs. 11 & 12.

Fig. 1. The *Aplysia fasciata*, or Sea-Hare. The digestive organs removed, excepting *A, A*, the fleshy mass of the mouth, raised, as well as the upper part of the œsophagus *B*, to show the anterior ganglion *c*, situated beneath the four pair of nerves which it gives, and the two threads which unite it to the brain *E*. *I, I*. The penis. *m, m*. The two lateral ganglia. *n, n*. Their filaments of union with the brain. *o*. Their superior filaments of union. *P*. The inferior. *q, q*. The uneven number of nerves which are the result. *r, r*. The two large nerves which they give off to form the fourth ganglion *R*. *F*. The heart. *G*. The auricle. *H*. The course of the great artery. *L*. The commencement of the artery of the stomach. *M*. Of that of the liver. *N, N*. The great artery. *P, P*. Its branch to the organs of generation. *Q*. That to the operculum. *T*. That to the parts on the left side. *U*. That to the penis. *V*. That to the straight parts of the head. *X*. That to the anterior parts. *Y*. Its termination at the mouth. Γ. The ovary.

Δ. The oviduct. Z. Its appendix. Θ. The testicle. ϑ. The epididymis. ϝ, ϝ. The common duct of generation. ξ. The bladder. Σ. The body in form of a bunch of grapes. Φ. Lateral muscular portions, principally longitudinal. (Cuvier, *Annales du Muséum d'Histoire Naturelle.*)

Fig. 2. Cuttle Fish.

a. Supra-œsophageal ganglion or brain.
b. Eye.
c. Œsophagus.
d. Mouth.

The following letters refer to the same parts in the remaining figures in this Plate.

A. Olfactory ganglia.
B. Hemispherical ganglia.
C. Optic ganglia.
D. Cerebellum.
E. Branchio-gastric ganglia, or olivary bodies.
F. Auditory ganglia, or posterior pyramidal bodies.
G. Posterior optic ganglia, or testes.
H. Tuber cinereum.
J. Spinal cord.
S. Decussation of the optic nerves.

The letter *J* has been put by mistake to the pituitary gland in fig. 12.

Fig. 3. Brain of the Whiting, the size of life, seen on its upper surface.

Fig. 3*. The same; the cerebellum being turned up, and the two olivary bodies or branchio-gastric ganglia displayed.

Fig. 4. The brain of the Whiting seen on its under-surface, exposing the decussation of the optic nerves *S*, and the tuber cinereum *H*.

Fig. 5. The Brain of the Cod, the natural size. The optic tubercles, which are hollow, are everted, and two smaller nodules, which are possibly analogous to the posterior of the quadrigeminal bodies in man, or the testes, brought into view.

Fig. 7. The brain of the Eel seen from above.

Fig. 8. Lateral view of the brain of the Carp in its natural position in the skull.

Fig. 10. Brain of the same fish removed from the skull and seen from above.

Fig. 9. From Serres's, *Anatomie Compareé du Cerveau.* The Brain of the Cod-fish, unfolded to expose the continuation of the spinal cord and its connexion with olfactory nerves.

Fig. 11. The brain of the Skate removed from the skull and seen from above.

Fig. 12. Brain of the Skate seen on its under surface.

PLATE III.

Nervous system of the Pearly Nautilus and brain of the Cuttlefish.

The drawings in this Plate have been accurately copied from the beautiful representations given by Mr. Owen in the Catalogue of the Museum of the College of Surgeons, from which work, and his memoir on the Pearly Nautilus, the description has been copied.

Fig. 1. The head and anterior muscular part of the body of the Pearly Nautilus (*Nautilus Pompilius*, Linn.), laid open from above or behind, and the nervous system displayed.

a. The cut edges of the musculo-ligamentous disc which covers the head.
B, B. The open ends of the digitations.
C. Four of the digital tentacles exposed by laying open the canals in which they are lodged.
d, d. The anterior ophthalmic tentacles similarly exposed at their origins.
e. The left external labial process. (The corresponding one on the right side has been removed.)
f. The external labial tentacles.
G. The internal labial tentacles.
h. The olfactory laminæ.
i. The internal labial tentacles of the left side similarly exposed.
k. The origin, on the left side, of the muscle which protrudes the jaws.
l. The inner concave surface of the great shell-muscles.
m. The termination of the right muscle.
n. Orifices by which the vena cava communicates with the abdominal cavity.
o. The eye laid open.
p. The pedicle.
q. The pupil, seen from within.

r. The cut-edge of the sclerotic.
s. The retina.
t. The dark pigment deposited on its anterior surface, and lining the cavity of the globe.

1. The supra-œsophageal ganglion or brain. It is in the Nautilus in the form of a simple cord or commissure, to the extremities of which are connected,
2, 2. The anterior subœsophageal ganglia.
3, 3. The optic ganglia.
4, 4. The posterior subœsophageal ganglia.
5. Buccal and pharyngeal nerves.
6, 6. The nerves which supply the digital tentacles, and in the Cuttle-fish the acetabuliferous arms.
7, 7. The nerves passing to 8, 8, the internal labial ganglions.
9, 9. The branches to the internal labial tentacles.
10, 10. The nerves supplying the olfactory laminæ.
11, 11. The nerves which supply the infundibulum.
12, 12. The nerves of the external labial tentacula.
13. The nerves of the great muscles of attachment.
14. The nerves corresponding to the par vagum.
15. The branchial nerves.
16. The ganglions communicating with the visceral or sympathetic nerves, and supplying the heart, venous follicles, and abdominal viscera.

Fig. 2. The Brain and origins of the principal nerves of a Cuttlefish (*Sepia officinalis*, Linn.).

"The bristle is placed in the situation of the œsophagus, around which the nervous masses are aggregated. The brain and optic or reniform ganglions are here developed in accordance with the more complex organ of vision, and the more extensive locomotive faculties of this higher-organized cephalopod. A small spherical body, probably analogous to the corpus geniculatum, is appended to the peduncle of the optic ganglion on either side.

"As the supra-œsophageal cerebral mass is principally in communication with, and is developed to receive the impressions transferred by the optic nerves, it must be considered as analogous to the bigeminal bodies in the brain of Vertebrata, which parts are first developed in all the higher classes, and from their constancy and magnitude in the cold-blooded Vertebrata, are evidently among the most important parts of the cerebral organ. The medulla oblongata, from which the auditory and respiratory nerves are given off, is in the Cuttlefish situated below the œsophagus: *p*, the cut surface of the cartilaginous cranium. The ganglion stellatum from which the nerves pass to the soft vascular and sensitive external covering of the *Sepia*."

1. The brain, corresponding to the central commissure of the Nautilus.
2, 2. The anterior subœsophageal mass, or *pes anserinus*, giving off (5, 5.) the nerves to the arms.
3, 3. The great reniform, or ophthalmic ganglions.
4, 4. The posterior subœsophageal mass giving off (6, 6.) the nerves to the cloak; and (8.) the nerves to the viscera.
7, 7. The *ganglion stellatum*.
9, 9. Two small spherical bodies attached to the pedicles of the ganglions.

PLATE IV.

In this Plate the student has the opportunity of observing the gradual development in the Vertebrata of the enkephalon till it approaches in the concentration and complexity of its arrangement very closely to that of man himself. The various ganglia of the senses are analogous in each species, varying but little in size and general appearance, the great diversity of configuration depending entirely on the different degrees of development of the hemispheres and cerebellum.

The letters in this Plate all refer to the same parts in each figure.

A, Olfactory ganglion.
B, Hemispherical ganglion.
C, Anterior optic ganglion.
D, Testes, or posterior optic ganglion.
E, Cerebellum.
F, Auditory ganglion.
G, Pneumogastric ganglion, or olivary body.
H, Spinal cord.
I, Tuber cinereum.
K, Posterior cerebral ganglion of the cord or thalamus nervi optici.
L, Corpus geniculatum.
m, Anterior cerebral ganglion or corpus striatum.
n, Longitudinal commissure, or fornix.
O, Pineal commissure.
P, Intercerebral commissure.

1. Side view of the brain of the Turtle.
2. Side view of the brain of a bird (the *Turkey*), with its skull.

3. The brain of the bird laid open. (*From Spurzheim.*)
4. Side view of the head and brain of a Squirrel.
5. Brain of the Rabbit: hemispheres turned back, exposing the cerebral ganglia and optic tubercles on the right side; on the left side covered by the fornix or longitudinal commissure.
6. Brain of the Squirrel: hemispheres separated, exposing the cerebral ganglia of the cord.
7. Brain of the Rabbit, under surface.
8. Brain of the Rabbit, upper surface.

PLATE V.

Fig. 1. has been introduced for the purpose of demonstrating the amazing development of the olfactory ganglia and commissure in the Horse.

Fig. 2. exhibits the disposition of medullary and cineritious neurine in the olfactory ganglia of Sheep, the two figures teaching the impropriety of describing their analogues in man as nerves with bulbous extremities.

Fig. 3, representing the brain of the Porpoise, is interesting in connexion with its rank as a mammal, though in its outward appearance and general habits the animal seems to the ordinary observer a mere fish.

Fig. 1. The anterior half of the brain of the Horse laid upon its upper surface, exposing
- 1. The olfactory ganglia.
- 1*. The divided olfactory commissures or peduncles which connect the ganglia to the anterior and middle lobes.
- 2. Optic commissure and nerves.
- 3. Third pair of nerves.
- 4. Pituitary gland.
- 5. Crura cerebri.

Fig. 2. Section of the olfactory ganglion in the Sheep close to its commissure.
- 2*. Section of the same ganglion more immediately in the ethmoidal fossa.

Fig. 3. Brain of the Porpoise laid upon its base, exposing therefore the upper surface.
- 1. Section of the hemisphere on the right side, exposing the lateral ventricle, with
- 2. The anterior cerebral ganglion or corpus striatum; the line of demarcation not being very distinct between this body and the next.

3. The posterior cerebral ganglion or optic thalamus.
4. The anterior quadrigeminal bodies, optic tubercles or nates.
5. The posterior quadrigeminal bodies, optic tubercles or testes.
6. Great transverse commissure, or corpus callosum.
7. Cerebellum.
8. Spinal cord.

PLATE VI.

In this Plate the attention of the student is directed in the first place, by the two first figures to those fibres from the anterior columns which, ascending to the cerebellum, connect the motor tract with that portion of the cerebral mass.

In the second figure he has the opportunity of observing the connexion of the sensory root of the fifth pair of nerves with the lateral portions of the spinal cord.

The remaining figures, as far as fig. 10, are peculiarly interesting, as demonstrating the relation of cineritious neurine in different portions of the cord to the size of the nerves arising from it.

Figs. 11, 12, and 13. exhibit the situation of the four ganglia imbedded in the medulla oblongata.

The two last figures exhibit the proportion between the antero-lateral and posterior columns of the cord in the cervical and lumbar regions.

Fig. 1. The medulla oblongata and pons Varolii, with a portion of the cerebellum.

1. Pons Varolii.
2. Pyramidal eminences.
3. Olivary bodies.
4. Corpus restiforme, its surface having been carefully scraped in order to show the *superficial cerebellic fibres* of the anterior columns. They are represented rather more distinct and thicker than they really appear, though their course, direction, and relation to the olivary body are faithfully given.

Fig. 2. displays a deeper view of the same fibres. The corpus olivare having been raised, those fibres which run behind that body are exposed; their relation to the sensory root of the fifth pair is likewise exposed. The figures are the same as the last, with the exception of 5, designating the sensory root of the fifth pair of nerves, and 6, which

designates the fibres from the posterior column forming part of the restiform bodies or processus è cerebello ad medullam oblongatam.

Fig. 3. Section of the spinal cord opposite the first lumbar vertebræ, exhibiting the large proportion of cineritious to the medullary neurine, the anterior portion of the cord facing upwards in each section.

Fig. 4. Section opposite the eleventh dorsal vertebræ.

Fig. 5. ——————— tenth ———————

Fig. 6. ——————— eighth ———————

Fig. 7. ——————— fifth ———————

Fig. 8. ——————— seventh cervical.

Fig. 9. ——————— fourth ———

Fig. 10. ——————— third cervical.

Fig. 11. Section of the medulla oblongata through the centre of the corpus olivare.

Fig. 1. Corpus olivare.
2. Posterior pyramidal body or auditory ganglion.

Fig. 12. Section two lines nearer to the pons Varolii.

Fig. 13. ——— close to the pons Varolii.

Figs.14. and 15. Sections to show the relative size of the antero-lateral to the posterior columns.
14. Section in the cervical region.
15. Section in the lumbar region.

PLATE VII.

This representation of the course of the anterior columns to their termination in the hemispherical ganglia has been accurately copied from Gall's large work; and to that wonderful man are we indebted for our present knowledge regarding this course of the motor tract. The appearance which is thus delineated is that which the student is directed to dissect for himself; and he will do well if he attempt the dissection in the first instance on the brain of the Sheep or the Bullock, for it is not easy to show it perfectly on the human brain the first time of dissecting it.

A. Motor tract continued from the anterior columns of the cord to the hemispherical ganglion.
B. Corpora pyramidalia.
C. Olivary bodies.
D. Pons Varolii.

F. Crus cerebri.
g. Anterior cerebral ganglion or corpus striatum.
H. Hemispherical ganglion or cineritious neurine of the hemispheres.
I. Cerebellum.
a. Olfactory nerve.
b. Optic nerve.
c. Fourth nerve.
d. Sensory root of the fifth pair.
e. Seventh and eighth nerves.
f. Anterior commissure.
h. Corpus mammillare.
i. Corpus geniculatum.

PLATE VIII.

The two figures in this Plate, also copied from Gall, exhibit a side view of the motor and sensory tracts, each passing through their respective cerebral ganglia.

Fig. 1. Letters the same as the last, with the exception of *k*, fibres from the anterior columns to the cerebellum[1].

Fig. 2. Letters the same as the last, with the exception of

P. Posterior cerebral ganglion or thalamus.
S. Tract for sensation.

PLATE IX.

This Plate has been introduced with the view of assisting the student in his study of the relations of the inferior longitudinal commissure or *fornix*, which is described as commencing in the centre of the crus cerebri from the locus niger, letter *A*, proceeding from thence to the corpus mammillare, *B*, running forward from thence towards the anterior commissure, 3, receiving fibres from the convolutions at the base of the brain, crossing and as it were kneeling upon the anterior commissure and ascending towards the great transverse commissure, receiving fibres in its course from the under and front part of the anterior lobes, and thus forming the septum lucidum, *D* : running back from thence, it spreads laterally, constituting that portion which is called the body of the fornix, *E*. passing in its course backwards over the thala-

[1] It is curious that Gall should have delineated these fibres, but without being aware of their true relations, viz. that they connect the anterior columns with the cerebellum.

mus nervi optici, 4; descending again at the back part of the brain it forms the descending or posterior pillar of the fornix *tænia hippocampi*, *F*, some of its fibres running back to be connected with the posterior lobes *I*; others crossing the projection called hippocampus major, *G*, to be connected with the middle lobe, and others again passing over the pes hippocampi, *H*, to be connected with the anterior portion of the middle lobe. Thus does this commissure connect different portions of the convoluted surface of the brain together.

Fig. 1. Great transverse commissure divided in the mesial line.
2. Commissura mollis.
3. Anterior commissure.
4. Posterior cerebral ganglion, or thalamus.
5. Section of the crus cerebri.
6. Locus niger.
7. Anterior cerebral ganglion, or corpus striatum, partially scraped away.
A. Commencing fibres of the inferior longitudinal commissure, or fornix, from the locus niger.
B. Corpus mammillare.
C. Anterior pillars of inferior longitudinal commissure, or fornix.
D. Septum lucidum.
E. Body of the fornix, or centre of the commissure.
F. Tænia hippocampi, or descending fibres of the inferior longitudinal commissure.
G. Fibres covering the hippocampus major.
H. Fibres covering the pes hippocampi.
I. Fibres covering the hippocampus minor.

PLATE X.

Superior longitudinal commissure. This Plate represents longitudinal fibres placed above the great transverse commissure corresponding with those which we have just observed below it. The relations being more simple than those of the inferior commissure, are simply designated by the letters *D*. They may be traced from the fissura Sylvii ascending forwards, and then curving backwards and winding round the great transverse commissure receives fibres from all the convolutions at the upper and sides of the hemispheres, terminating at the back part of the brain.

1. Section of the transverse commissure.
2. Soft commissure.
3. Section of the anterior.
4. Posterior cerebral ganglion, or thalamus.
5. Section of the crus cerebri.
7. Anterior cerebral ganglion, or corpus striatum.
8. Optic nerve.
9. Third pair of nerves.
10. Section of the commissure of the cerebellum, or pons Varolii.
11. Section of the medulla oblongata.
12. Section of the cerebellum.
13. Intercerebral commissure, or valve of Vieussens.
14. Optic tubercles.
15. Part of the pineal commissure.

A. Fibres running from the interior of the thalamus to the corpus mammillare.

B. Corpus mammillare.

C. Anterior pillar of the inferior longitudinal commissure divided.

D. Superior longitudinal commissure.

Note. Both these drawings are made from preparations, which I shall have much pleasure in showing to any who will favour me with a call.

PLATE XI.

In this Plate the student has the opportunity of observing several points of importance and interest connected with the origin of the nerves, which not being easily demonstrated without some little experience, it is hoped that the accompanying representations will assist him in his dissections.

The first figure represents that curious and beautiful arrangement of the fibres of the optic nerve which has been particularly dwelt upon in the body of the work; it is taken, as well as every other drawing of my own, from preparations in my possession; it will not, however, be the less valuable from its corresponding in the representation of the fibres to that of Mr. Mayo's in his folio work. The 2nd fig. represents the true origin of the third pair, and at the same time shows its connexion with the fourth pair of nerves, and this through the medium of some of the fibres of the intercerebral commissure: the origin of the motor division of the fifth pair of nerves is likewise exhibited by raising a portion of the same commissure; fig. 3. however, exhibits the motor origin of the fifth pair even more distinctly, at the same time demonstrating the origin of the fourth pair of nerves and the position of their commissure.

Fig. 1. The commissure of the optic nerves; some fibres from each retina crossing over at the commissure to join those on the opposite side; other fibres entering into the composition of the commissure, but merely running from one side of the brain to the other, are truly commissural and wholly unconnected with the retina.

Fig. 2. *A*. Crus cerebri.
B. Commissure of the cerebellum divided.
C. Optic tubercles.
D. Portion of the intercerebral commissure, divided from the cerebellum and raised so as to show the motor origin of the fifth pair of nerves, 5.
E. Cerebellum divided, showing the arbor vitæ.
F. The descending fibres of the intercerebral commissure, those by which the third pair of the nerves and the fourth pair are associated.
3. Third pair of nerves.
4. Fourth pair of nerves.
5. Motor pair, origin of the fifth.

Fig. 3. *A*. Pineal gland lying on the optic tubercles.
B. Anterior of the optic tubercles or nates.
C. Posterior of the optic tubercles or testes.
D. Motor root of the fifth pair of nerves.
H. Thalamus, or posterior cerebral ganglion.
S. Sensory root of the fifth pair of nerves.
4. Fourth pair of nerves.
5. Fifth pair of nerves.

PLATE XII.

In this Plate we have been obliged to mix two distinct subjects together, but I hope without giving rise to any confusion. The two first figures represent the origin of nerves; the remainder relate to the development of the brain, and are derived from Tiedemann's work on that subject.

The first figure exhibits the origin of the facial, not as it is usually described, but as I found it on three preparations which I dissected in succession. The origin of the auditory, as shown in the Plate, has been known for some time to some anatomists, but is not usually described so in most systematic writers.

The sensory root of the fifth may always be easily traced, as represented to have been done in this figure.

I have not introduced drawings of the origin of any other nerves, as they may be seen without any difficulty by the youngest pupil; and I have studiously avoided introducing any drawings that would enable the indolent student to learn any portion of his anatomy without dissection, the sole object of the Plates being to assist the industrious in studying nature for themselves.

Fig. 1. *A*. Commissure of the cerebellum.
B. Corpus pyramidale.
C. Corpus olivare.
D. Spinal cord.
E. Cerebellum.
5. Sensory root of the fifth pair of nerves.
7. Facial nerve.
8. Auditory nerve.

Fig. 2. A small portion of the spinal cord.
A. Anterior or motor root of the spinal nerves.
B. Posterior or sensory root of the spinal nerves.
C. Ganglion connected with the latter.

The remaining figures in this Plate represent different stages in the development of the human brain. The three first of this series exhibit the form of the fœtal brain at seven weeks, with a side and a posterior view of the cerebro-spinal axis at that early period. Viewed posteriorly it bears some resemblance in general form to that of the fish, though there is no real analogy between its parts.

The next, fig. 6., shows the amazingly rapid progress which development has taken at the ninth week, while figs. 7, 8, 9, and 10, showing the brain of a fœtus of twelve weeks, points out still more decidedly this steady advancement.

Fig. 11., showing the brain of a fœtus of fifteen weeks, teaches us how gradually this important organ advances towards perfection; and 12, exhibiting the brain of a fœtus of nearly five months, is interesting, as it demonstrates that even at this advanced period the brain is still smooth like the brain of a rodent animal.

Fig. 3. Fœtus of seven weeks.
a. Projection of the neck.

Fig. 4. Brain and spinal marrow of the same fœtus seen laterally.
a. Spinal cord.
b. Enlargement of the cord.

c. Cerebellum.
d. Optic tubercles, or quadrigeminal bodies.
e. Optic thalami.
f. Membraniform hemispheres of the brain.
g. Protuberance analogous to the corpora striatum.

Fig. 5. Posterior view of the same brain, split and open in all its length.

a, a, Spinal marrow.
b. Orifice of the canal of the spinal marrow.
c. Swelling of the spinal marrow.
d, d. The cerebellum split in the median line, and laid like a bridge over the fourth ventricle.
e. e. The quadrigeminal bodies separated from one another in the median line.

Fig. 6. Brain of an embryo of nine weeks.

a, a. The two principal columns of the spinal marrow, separated from one another by a longitudinal fissure.
b, b. Cerebellum.
c. Parts which give rise to the quadrigeminal bodies.
d. Thalami optici.
e. Membranous hemispheres, turned backwards and inwards.

Fig. 7. Brain of an embryo of twelve weeks seen in the cranium.

a, a. Fragments removed from the cranium, which has been opened.
b. Spinal marrow.
c. Swelling of the spinal marrow, which is bent inwards.
d. Cerebellum.
f. Elevation which gives rise to the quadrigeminal bodies.
g. Crus cerebri, or a cord of the spinal marrow which comes down again, and is directed forwards.
h, Membranous hemisphere of the cerebrum, broken down behind and before; it does not yet cover the eminences destined to form the quadrigeminal bodies.

Fig. 8. Brain and spinal marrow of the same fœtus seen posteriorly.

a, a. Spinal marrow, with its posterior longitudinal fissure.
b. Cerebellum, and beneath it the fourth ventricle.

c, c. Hemispheres of the cerebrum.
d. Eminences which are to become the quadrigeminal tubercles, with the fissure which they present.

Fig. 9. Inferior surface of the brain of the same fœtus.

a, a. Spinal marrow, with the anterior longitudinal fissure.
b, b. Swelling of the spinal marrow bent forward.
c, c. Peduncles of the cerebellum, which arise from the cerebellum.
d, d. Cerebellum.
e, e. Peduncles of the cerebrum.
f. Mammillary eminences.
g. Pituitary gland.
h, h. Anterior lobes of the cerebrum.
i, i. The posterior and round appendices which represent the middle and posterior lobes.

Fig. 10. View of the superior surface of the brain of the same fœtus: the membranous hemispheres are separated from one another and laid aside.

a, a. The two principal cords of the spinal marrow.
b. Posterior longitudinal fissure.
c, c. Cerebellum.
d, d. Masses which are to form the quadrigeminal bodies.
e, e. Thalami optici.
f, f, g, g, g, g. Membranous hemispheres separated from one another and laid on the sides.
h, h. The two corpora striata, which are a little wider anteriorly, and divided into two parts by a slight fissure.
i. Commissure of the two hemispheres and commencement of the corpus callosum.
k, k. Lateral ventricles, with the radiated folds of the under-surface of the hemispheres.

Fig. 11. Superior surface of the brain of a fœtus fourteen or fifteen weeks of age.

a, a. Spinal marrow.
b. Peduncles of the cerebellum separated from one another, from above downwards, which brings the fourth ventricle into view.
c. The cerebellum, which has not yet any fissures.
d, d. The right hemisphere of the cerebrum, which does not yet cover the quadrigeminal mass.
e. Sinking of the membranous hemisphere.

Fig. 12. Side view of the brain of a fœtus of twenty-seven weeks.

a. Spinal marrow.
b. Corpus restiforme.
c. Corpus pyramidale.
d. Corpus olivare.
e. Cerebellum.
f. Bending of the spinal marrow forwards.
g. Cerebellum.
h. Annular protuberance.
i. Middle lobe of the cerebrum.
k. Posterior lobe.
l. Anterior lobe.
m, m. The fissuræ Sylvii are very deep and extend to a great distance on the sides; they lodge the middle cerebral arteries, which distribute almost all their branches to the deep seated parts of the enkephalon, namely, to the corpora striata.
n. The olfactory nerve, which descends from the fissura Sylvii.
o, o, o. Depressions on the cerebral substance, which are a commencement of the convolutions.

THE END.

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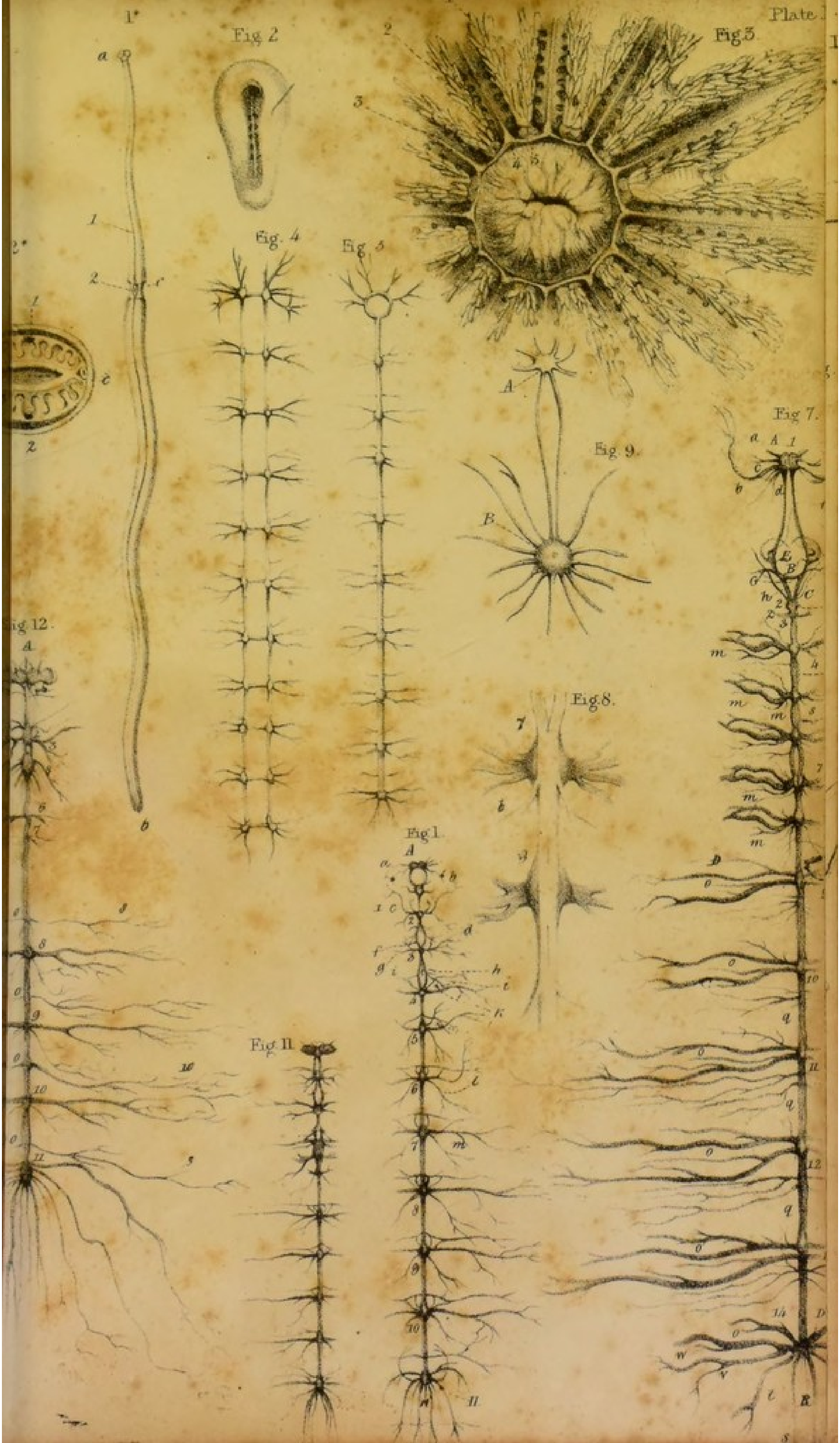
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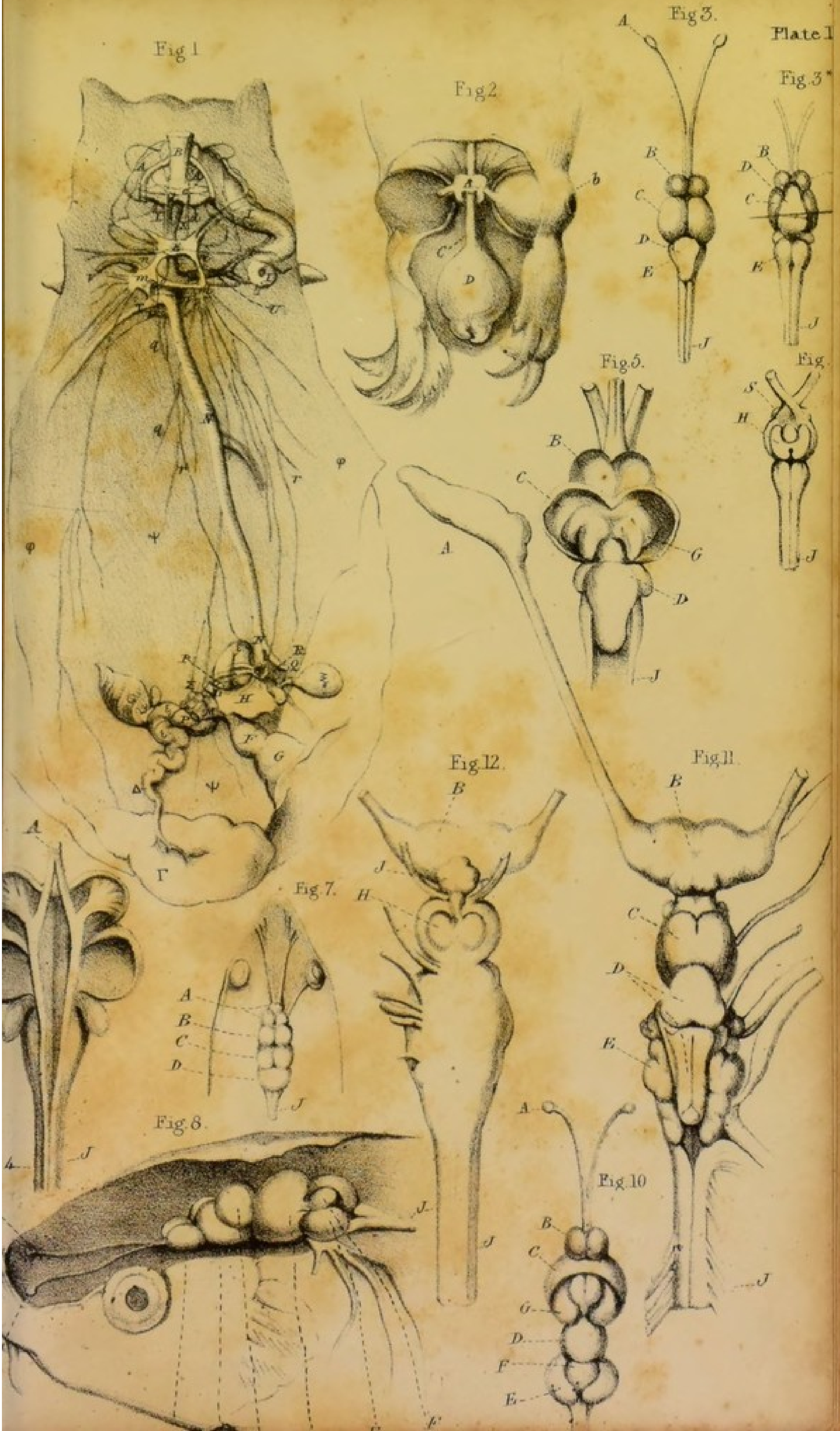
Plate I



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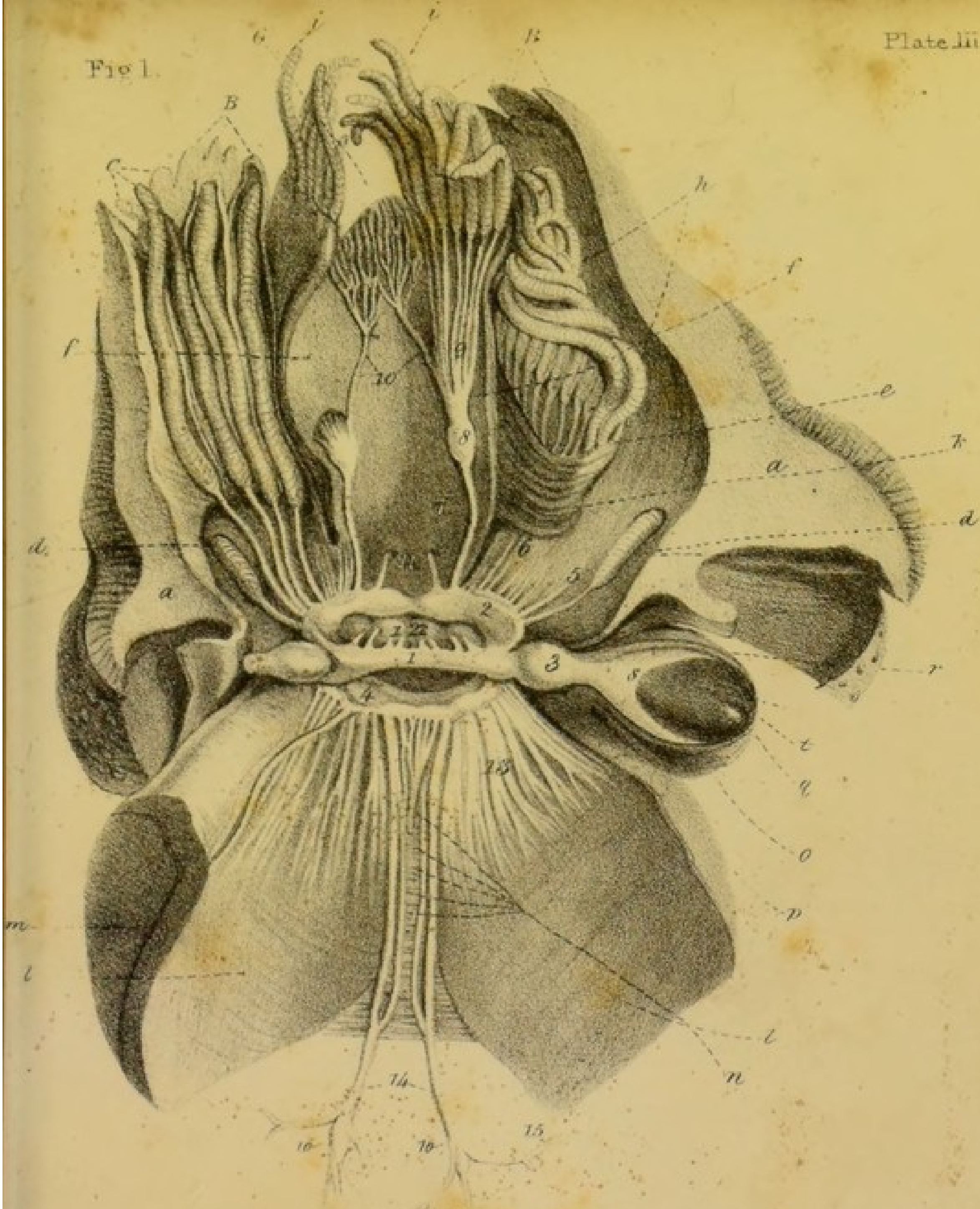

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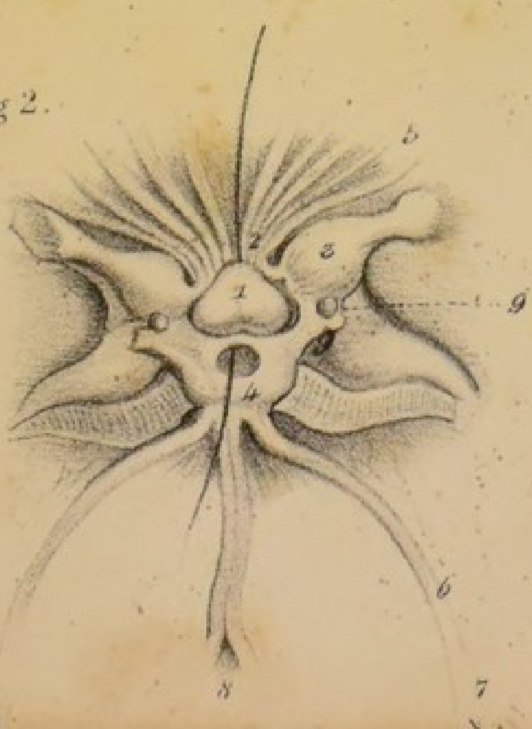

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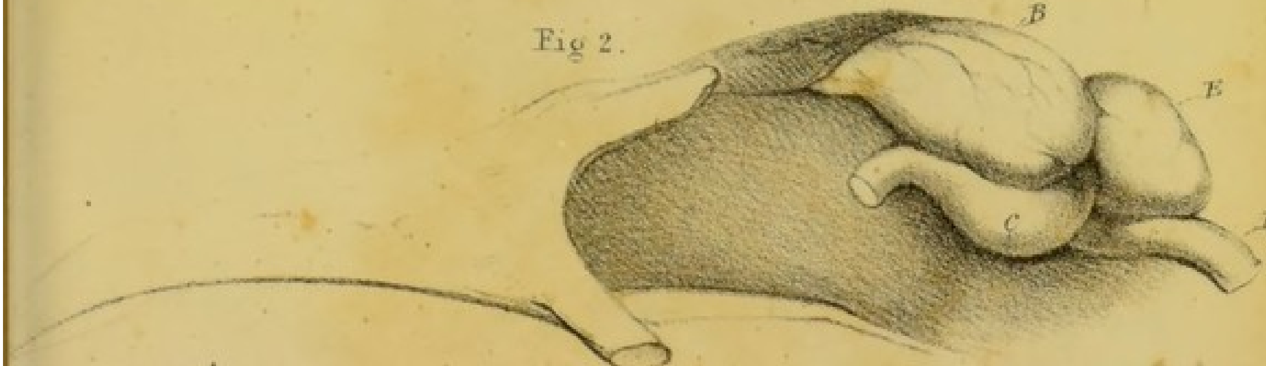

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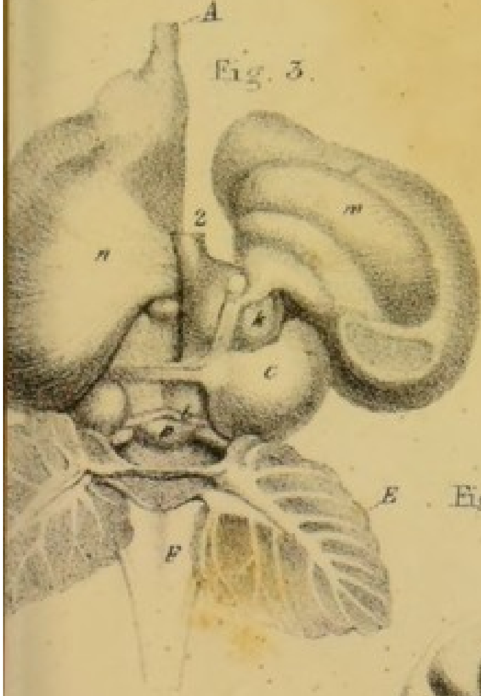

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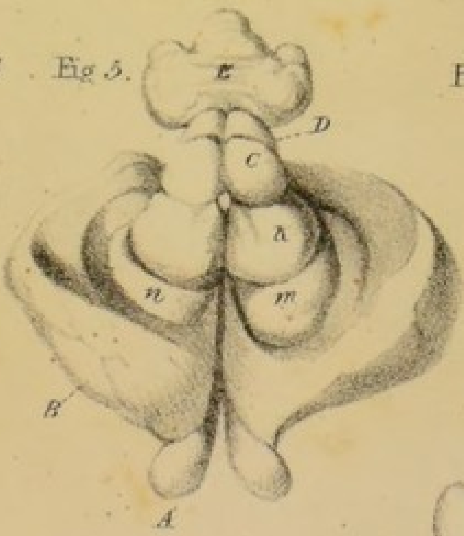

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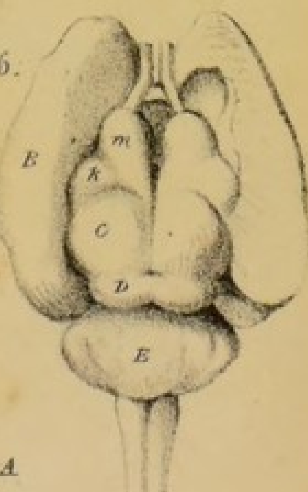

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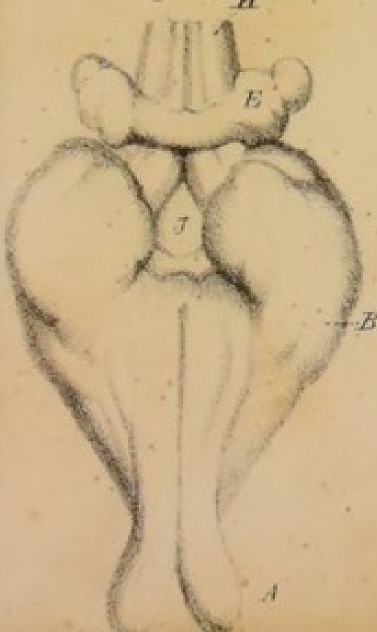

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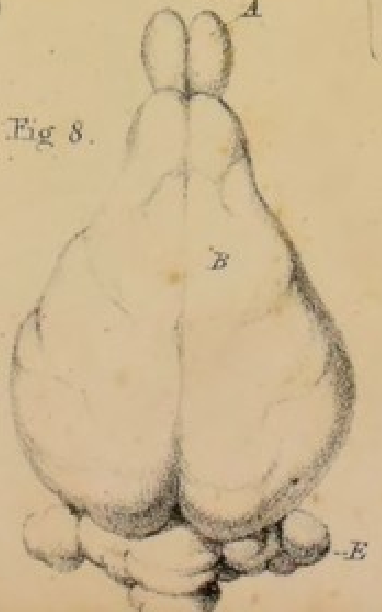

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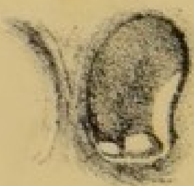

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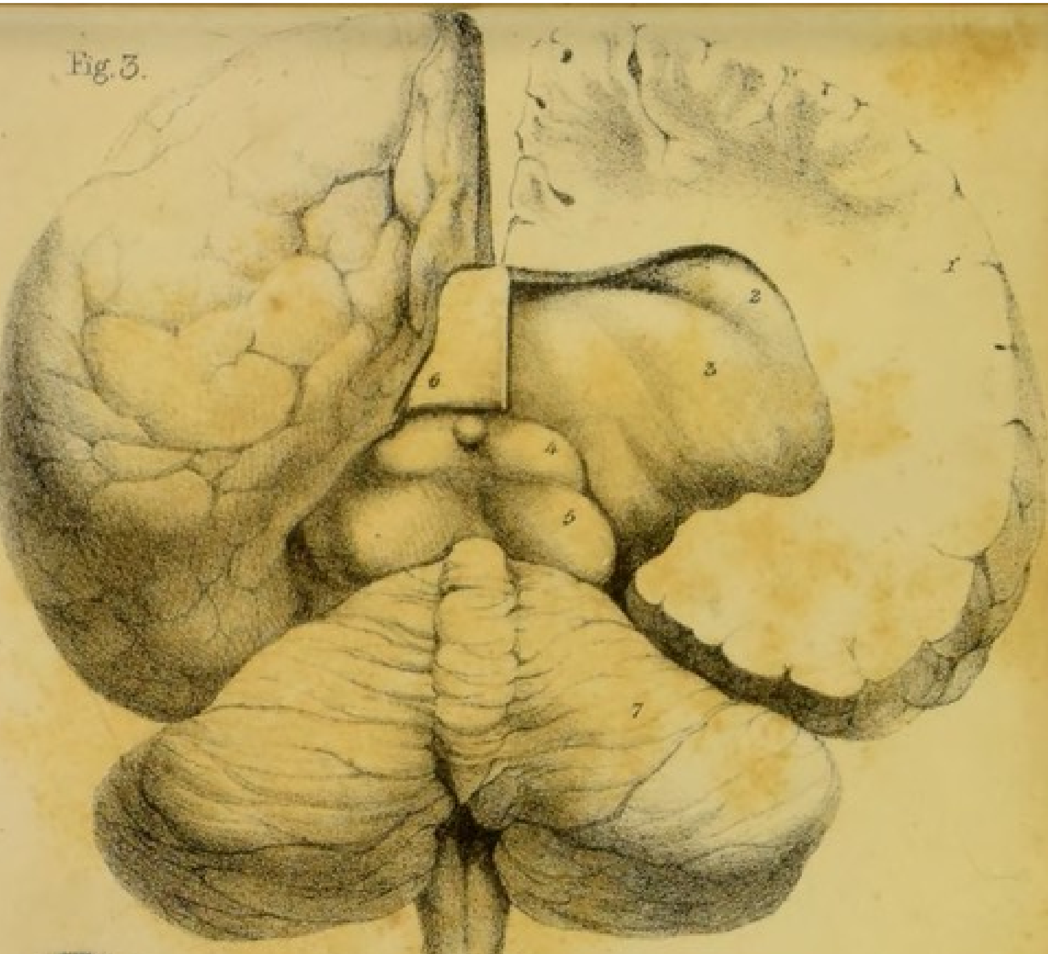

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Plate VI.

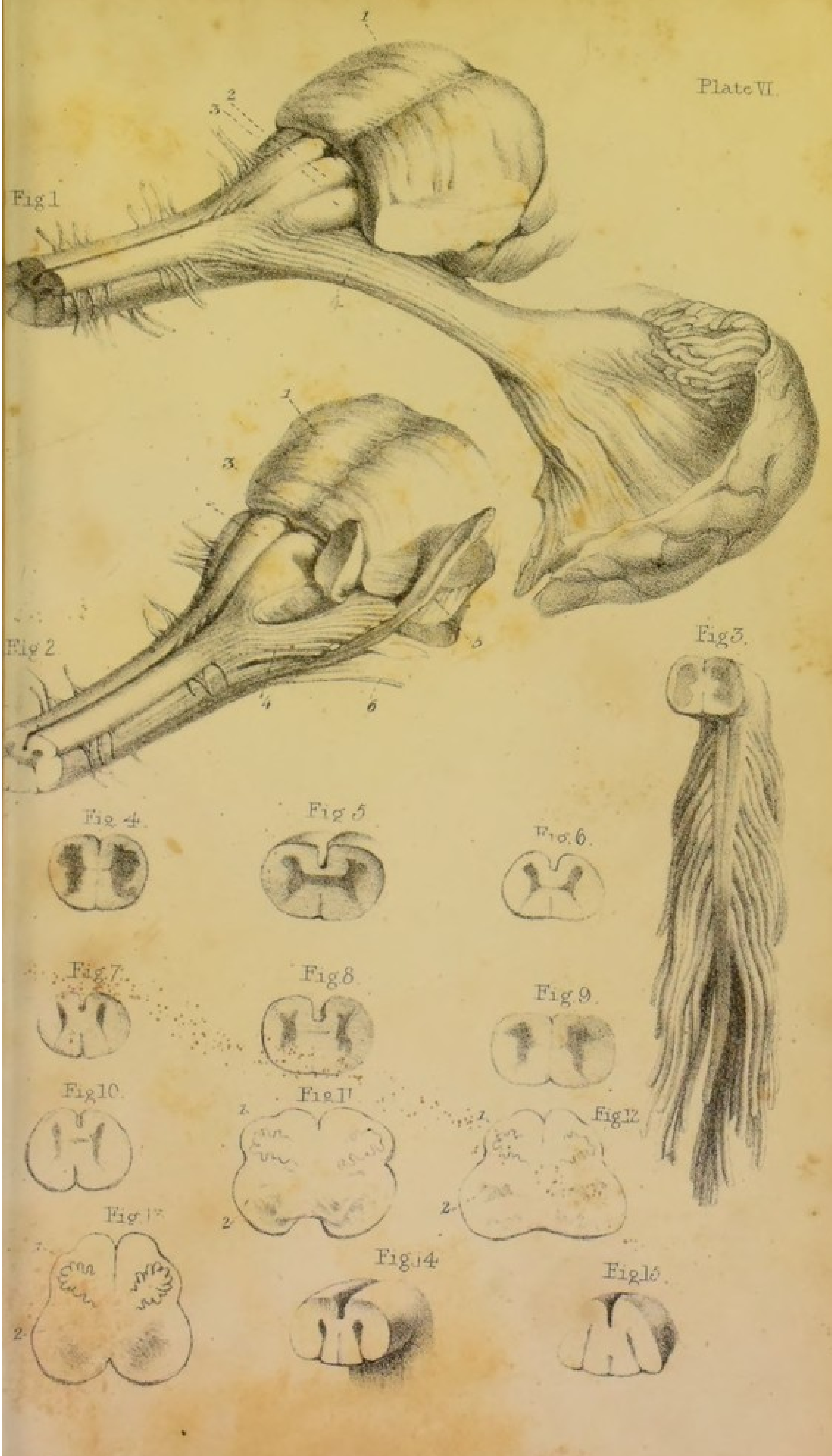
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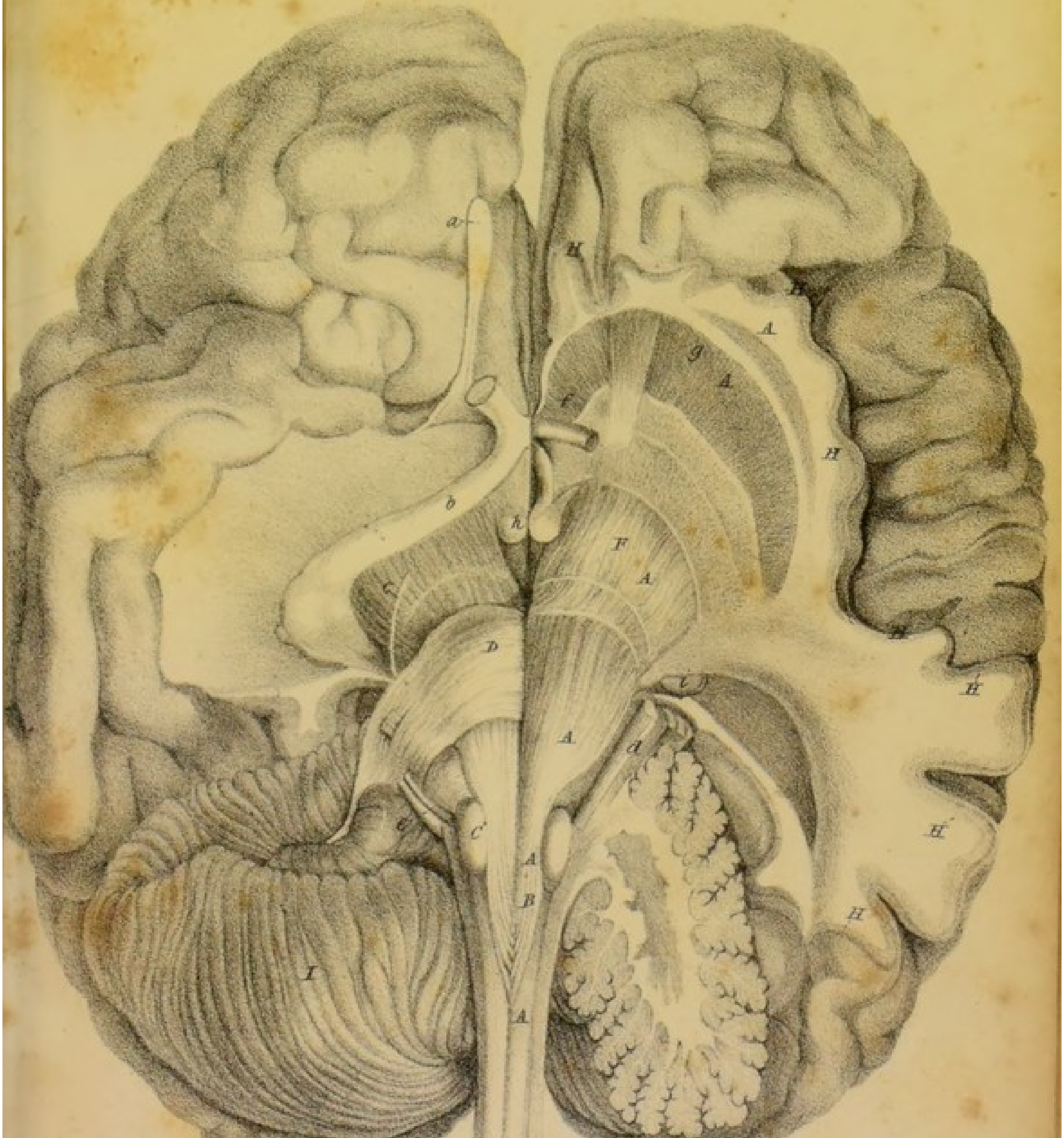
Fig 1. Plate VII



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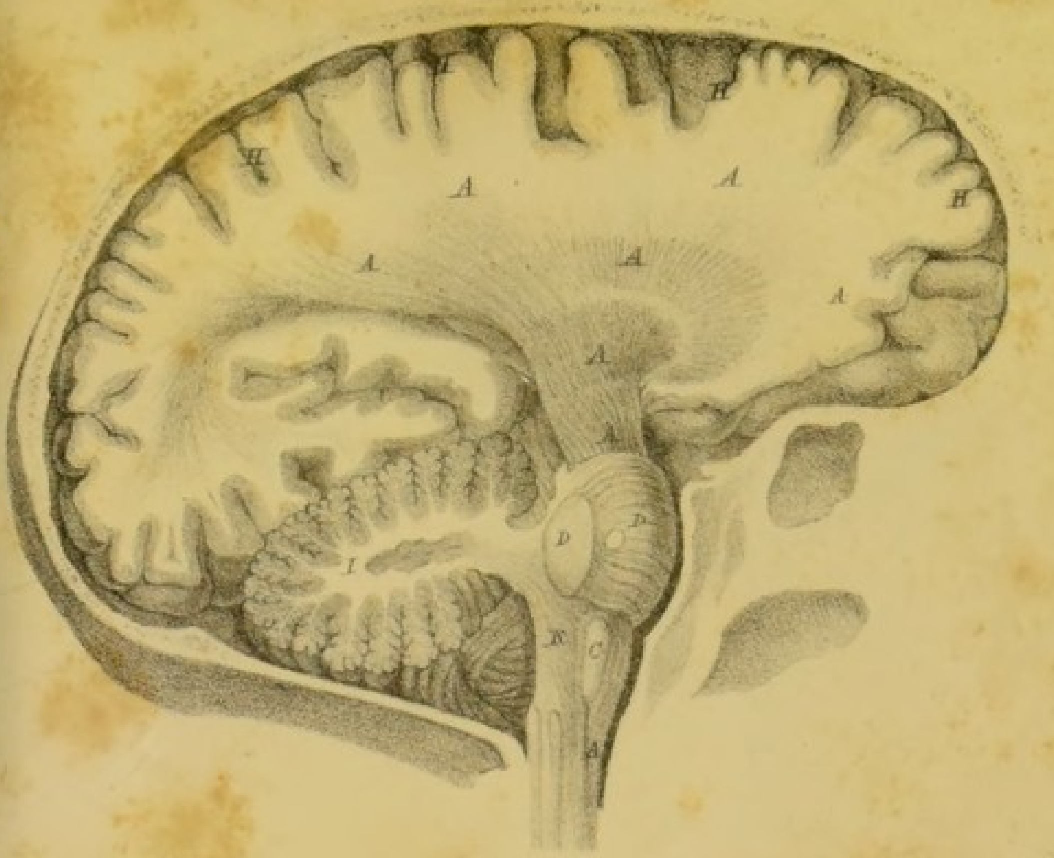

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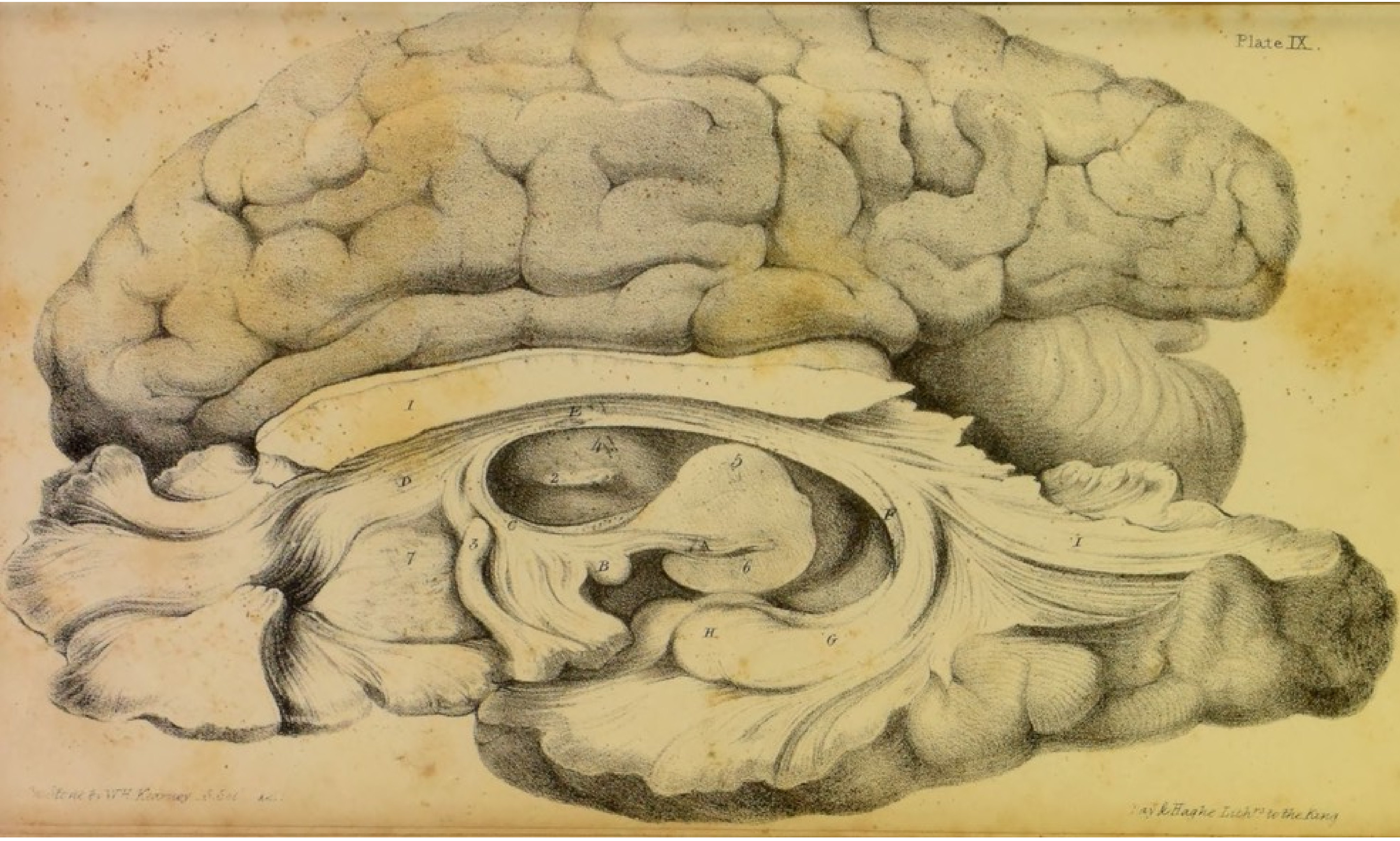

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Plate X.

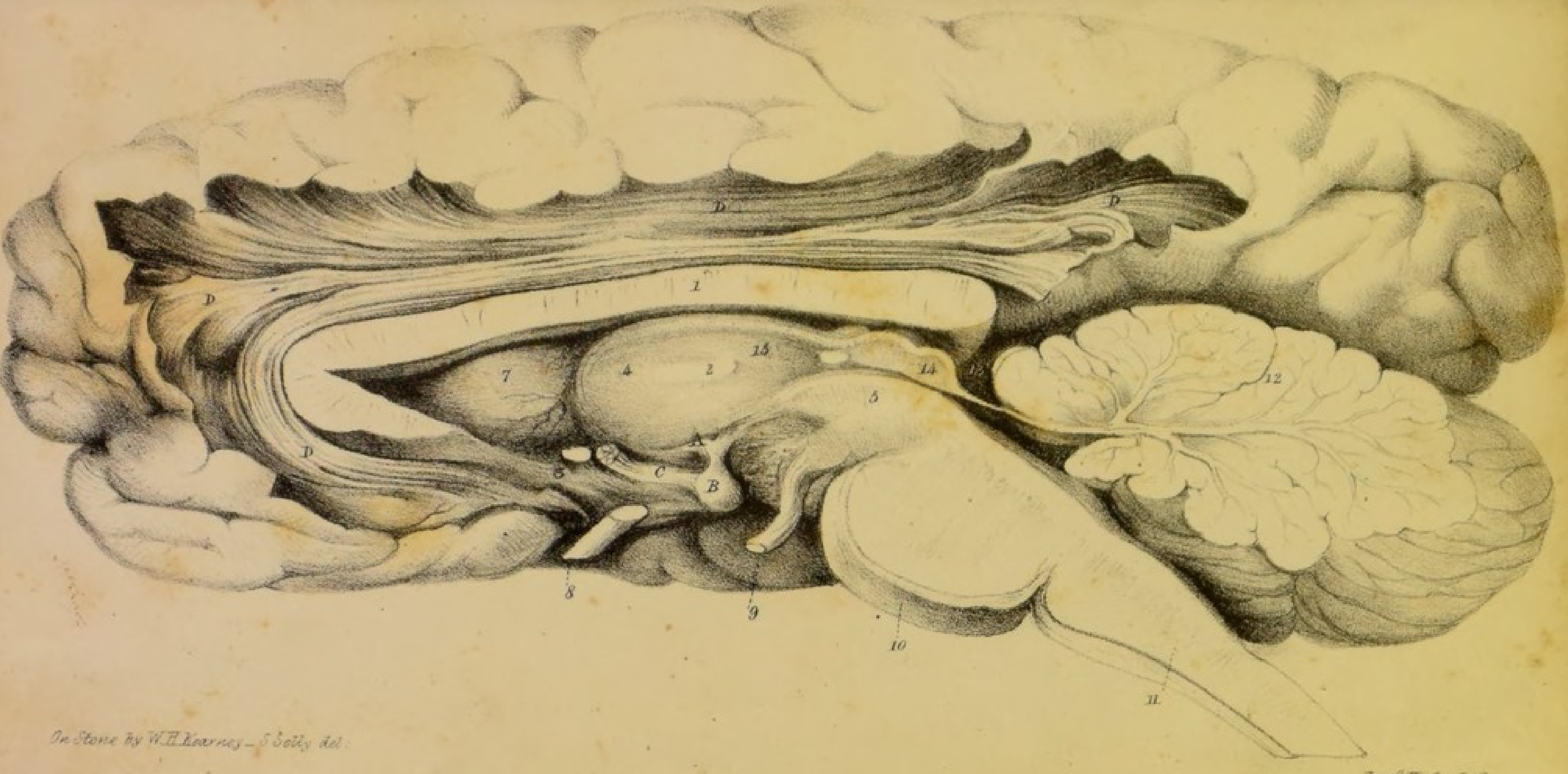

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Plate XI

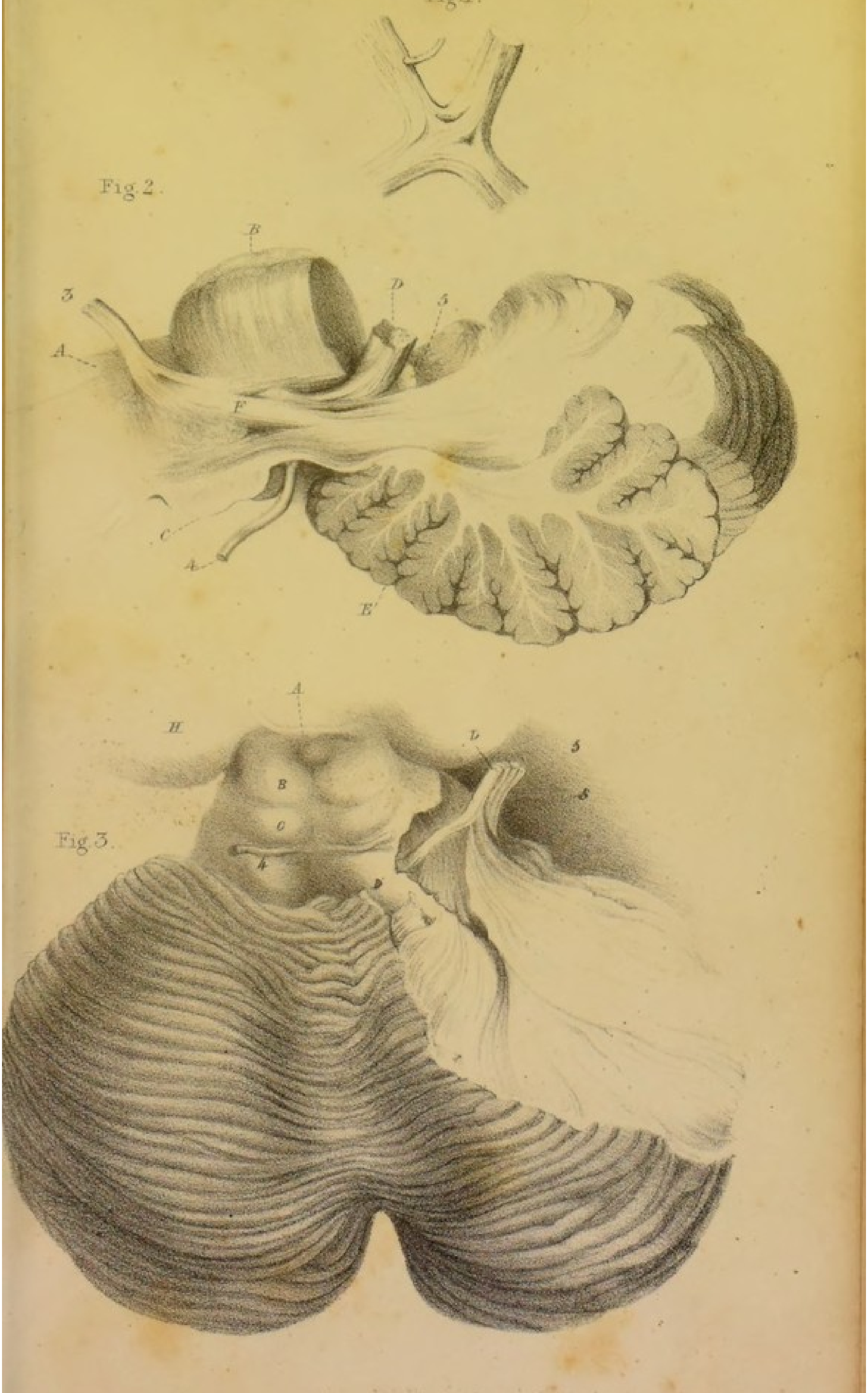

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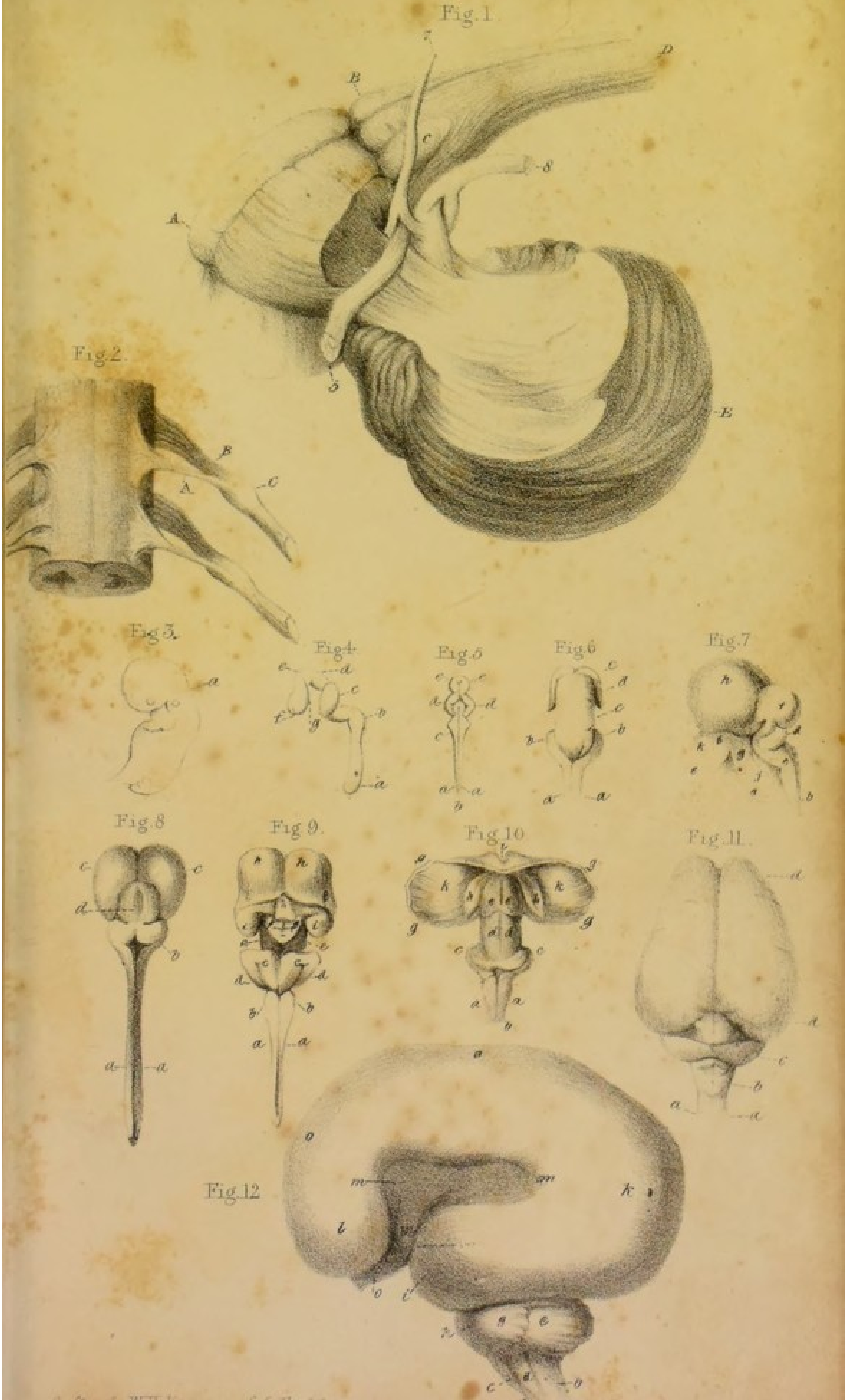
Plate XII.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