

On the
Histology
of the
Cerebellum.

A Thesis
by
Rev. J. M. Hachan.

1869. -



Preface.

The object of the researches, the results of which are embodied in the following Thesis, ^{was} to see what light a study of the histology would throw upon the functions of the Cerebellum. Few persons, who have not made the experiment can conceive the immense difficulty of rightly preparing nerve tissue for section. My failures have been many. I have lost more than 200 brains, some of them of rare tropical animals, and which I have been unable to replace. Then, much practice is necessary before successful sections can be made. This must be my apology for some of the 240 preparations which accompany this Thesis. They have been made by a tyro in such manipulations. I may add, that I have lately improved my plan of cutting sections, and would direct attention to the sections of the Mole, Mouse and Rat as a proof of this.

I have still about 60 brains which I have not as yet had time to examine.

I do not intend to abandon my investigations into the Subject; but propose on my return to India to examine very carefully the Cerebellum of the Reptilia, (especially of the Ophidia group) a class in which there is little complexity of movement.

I have, in conclusion, to express my sincere thanks
to Professor Burnett for allowing me to make
many of my researches in the Physiological La-
boratory.

J. M. Thachan.

St Catherine's Villa,
Grange. 1869.

The Cerebellum.

It is in accordance with the universal law of mutual dependence that the animal kingdom is closely allied to the vegetable and inorganic kingdoms; the relationship being in the former case Biological, and in the latter, Chemical and Physical. Mutual interdependence of the three Kingdoms

But strange to say, the very points of relationship are the marks of distinction; for it is by those things in which there is a likeness, the unlikeness one to the other becomes manifest. Thus, an animal is like a plant in being organised, but it is a much more complex organism. In the plant, the stem, root, flower and fruit are all modifications of the leaf, whilst the animal tissues are much more varied and numerous. Again, if we compare the organic with the inorganic world, we discover the distinction marks in the points of agreement. Thus, for example, organic bodies contain no chemical elements which are not found in the inorganic world, but the com- Marks of distinction.

poor elements of the latter present a much greater variety in their atomic constitution, as well as are far more numerous than in the former.

And further, animals have both definite form and size, thus bearing a physical resemblance to some forms of inorganic substances, e.g. to crystals, but they are always bounded by curves, and do not present geometrical outlines, whilst these (speaking generally) are bounded by straight lines and have geometrical forms.

It must not be unawakened, however, that the animal ^{Essential diff.} differs from the vegetable and inorganic kingdoms ^{former.} merely in degree. It possesses that which they have not. It has a nervous system, and so is endowed with sensation, consciousness and volition. All animals (except perhaps, the Protozoa) have a nervous system; and in proportion to the degree of its development, does an animal rise in the scale of being.

Quite apart from the $\Psi\phi\gamma$ which is in man, the possession of the most highly developed nervous system is the crowning excellency in man, and gives to him an august supremacy over all other animals.

Linnaeus sentimentally says "Lapides crescunt, Vegetabilia crescunt et vivunt, animalia crescunt, vivunt et sentient." This is however, only approxi-

mately true; for as mentioned above, our sub-kingdom
 viz: the Protozoa, is, as far as we know, without any
 nervous system. It has been maintained by some
 physiologists, that nervous matter is present in
 these animals in a "diffused form"; - that is to
 say, incorporated in the tissues. But there are
 no facts in support of such a gratuitous supposi-
 tion. This opinion takes its origin in the mere desire
 for precision in classification, - for a clear and
 decisive line of demarcation between the Protozoal
 and Protophytal groups of organised beings. Reduced
 to a syllogism, the illogical character of the argument
 is at once apparent. Plants have no nervous sys-
 tem - all other animals have - Therefore the Protozoal
 being animals must have a nervous system too.

Nervous system
 not seen in the
 Protozoa.

But 1st, Analogy is opposed to such a supposition;
 for nature knows nothing of any such abrupt and
 well-marked gradations. It is by links, minute and
 almost imperceptible she binds her materials
 and forges together into our harmonious whole; and
 2nd if it be the office of the nervous system to
 bring distinct organs into mutual relation, and to
 form immediate and direct communication be-
 tween them, since in the Protozoa there is no dif-
 ferentiation of organs, there seems to be no need of

a nervous supply.

It is in the Calentmata that we first meet with nervous matter. It has been detected only in a few instances, though it may exist in others, and have escaped detection. It is found in the Families Beroe and Cydippe which belong to the class Ctenophora. These have a single or compound ganglion placed in that part of the body opposite the oral aperture. From this radiating nervous filaments pass to the soft contractile walls of the body, and to the so called auditory sac.

Nervous sys-
tem in the
Calentmata.

The nervous system in the Echinodermata is peculiar, being adapted to the radiated condition of the body.

In the Echinodermata
Loc.

In the Asteroidea (Star-fishes) a ring of nerve matter surrounds the mouth and sends three filaments to each of the rays; of these, one, according to Carpenter, traverses each entire length, whilst the two others are distributed on the caecal prolongations of the stomach.

In the Echinus (sea urchin) the arrangement of the nervous system is somewhat modified. In the absence of rays filaments diverge from the oral ring, some being distributed to the complicated dental apparatus, whilst others pass along the course of the vessels to the digestive organs. Eyespots are present in some of the Echinodermata, but the other sensory

organs are rudimentary or absent.

The body of the Annulosa is composed of numerous *In the Annulosa* segments, called Somites, arranged along a longitudinal axis. The central parts of the nervous system accordingly follow the same arrangement, being composed of numerous pairs of ganglia disposed in a longitudinal direction, and connected by inter-nuncial nervous cords. From the first pair, called supra-oesophageal or cerebral ganglia, nerve tubes pass downwards and backwards, embracing the sides of the gullet, and become continuous with the second pair, the sub-oesophageal. A pair of ganglia are found in each segment, all of which are connected by longitudinal cords.

Passing over the limited Subkingdom Molluscoidea *In the Mollusca* which comprises only the three classes - Polypoda, Tunicata and Brachiopoda, and whose central nervous system consists of a "single ganglion or of a principal pair with accessory ganglia," we come to the Mollusca proper, the highest in the scale of non-vertebrate animals. In them there are three well-marked principal pairs of nerve ganglia, named from their position or function, the Cerebral, Pedal and Pleuro-pleuronic ganglia. The Cerebral - or perhaps a better name would be Cephalic - ganglia are situ-

ated above or at the sides of the Oesophagus. They are
 joined by Commissural bands, and give off nerves
 to the labial and olfactory tentacles, to the eyes, and
 to the masticatory muscles. They are connected by
 longitudinal commissures with the Pedal and Para-
 to-splanchnic ganglia in such a way that the
 gut is for some distance completely surrounded by
 nerve matter. The Pedal ganglia, often fused
 into one mass are situated below the Oesophagus,
 and give off nerves to the foot, and also to the organs
 of breathing. The Para-to-splanchnic ganglia, situ-
 ated in the posterior part of the body supply, as indeed
 the name indicates, the parietes of the body, the
 branchial apparatus, and also the heart and
 large vessels. In the Cephalopoda there is an
 obvious approach to the arrangement which pre-
 vails in the vertebrates. The Cephalic ganglia
 are sometimes fused into one mass (e.g. in the Ar-
 gonautae) and this is more or less protected by Carti-
 laginous plates which may be regarded as homo-
 logous with the bony neural arch of vertebrate ani-
 mals.

The functions of the nervous system in these lower subkingdoms are simple or complex multifarious, according to the complexity of the organism. The

Functions of
 the nervous sys-
 tem in these
 subkingdoms.

single ganglion in the Coelenterata seems to fulfil both a sympathetic and reflex office; perhaps exercising also a sensori-motor power, but having no volitional functions. Nor have we any sign of volition in the Echinodermata; sensation here is of the feeblest character, the movements being probably excito-motor or reflex rather than instinctive. In the Annulosa the functions are more varied. We have now a well-marked sympathetic system. Some movements seem to be guided by sensation, although there are none which evince either design or intelligence. It is in the Class Insecta, that the instinctive faculties are most highly developed; and these faculties characterise in the most marked degree the orders Hymenoptera and Neuroptera, the very orders, it is worthy of remark, in which the locomotive powers so eminently prevail. In these orders of Insects, in fact in all which pass through the various stages of holometabolism, the nervous system is modified, so as to be suitable for the respective stages through which the individual organism passes. In the caterpillar there are numerous segments all of nearly equal importance; the number of ganglia is adapted to the number of segments, and the ganglia are of nearly equal size. Even the

Cephalic ganglia present no marked preponderance over the rest, the reason being that in the Caterpillar the organs of sense, and the locomotive powers are but feebly developed. In the chrysalis stage there is a modification of this arrangement. There is now an intimation of the higher functions to be performed by the mature insect. The longitudinal chain of ganglia in the thoracic region becomes concentrated to be ready for the great muscles which move the wings and lower limbs. As obliteration of some of the segments proceeds, so some of the abdominal ganglia disappear. On the other hand the ganglia of anterior segments increase, and begin to assume the preponderating size possessed by the fully formed insect. The same principle of modification which we thus observe in the progressive stages of the individual, prevails also amongst the different classes of the externally varied ^{sub}Kingdom Annulosa.†

The Cephalic ganglia of the Mollusca constitute the central sensorium, receiving all the nerves of special sense, and probably those of common sensation likewise. They may thus be regarded as analogous to the sensorial ganglia at the base of

† Marshall's Outlines of Physiology Vol. I - page 422.

the encephalon in the vertebrata. They cannot be regarded as homologous with the cerebrum, for no psychical faculties are displayed, there is an absence of intelligence, emotion and ideation; and sensation seems to be the only guiding principle.

The locomotive acts of the mollusca, are for the most part governed by the Pedal ganglia, which are probably excito-motory nerve centres. Their reflex acts are however to a certain extent under the control of the cephalic ganglia, through the longitudinal commissural bands, and so may be regarded as a foreshadowing of the spinal acts in the vertebrata. The Parieto-splanchnic ganglia preside over the movements of the heart, and also those of deglutition and respiration. These ganglia are also under the control of the cephalic ganglia. These ganglia probably serve as centres for any sympathetic nerve fibres, which these animals may possess."

The Cerebellum.

Having now cast a bird's-eye glance at the arrangement and functions of the nervous system in the lower sub-kingdoms, I pass at once to the consideration of the immediate subject of this Thesis. In addition to the locomotive and sensorial centres which the vertebrata have in common with some of the lower series (e.g. the annulosa and mollusca,) they have two other organs, the cerebrum and cerebellum to which there is nothing analogous in any of the other sub-kingdoms.

There is an interesting exception to this arrangement, ^{Nervous system of Amphioxus.} met with in the *Amphioxus* which stands at the bottom of the vertebrate series. This fish, which is met with chiefly in the Mediterranean near the Italian shores, possesses a true spinal cord which terminates anteriorly in a slight cephalic enlargement. It has neither cerebrum nor cerebellum. No sympathetic system can be traced in it. But it differs essentially from the annulosa with which, at first sight it seems natural to compare it. For the nervous matter does not embrace the oesophagus anteriorly, and further there is a true Chorda dorsalis present. This anomalous vertebrate is a good illustration of the remark made on page 3 respecting classification

The discovery by Mr Lockhart Clarke of the method of hardening nerve tissue by Chromic Acid gave an immense impetus to the investigation of its minute structure. But the researches of that diligent observer as well as the labours of others have been almost exclusively confined to the nerve tissue of man.† The intimate structure of the cerebellum in the lower animals;—how far it agrees with that which is found in man— is a field of inquiry, rich as it is in promise, which is, as yet almost uncultivated. But is it not likely that a careful examination of a large number of cerebella belonging to each species, with a comparison of the development and structure with the habits, and especially, the motions of the different animals, may afford most material aid to the right understanding of the office fulfilled by this important organ in the animal economy?

Since the Cerebellum (dim: of Cerebrum) reaches its highest development in man, I shall first of all give a minute description of its relations and structure as found in him. We shall thus be able to compare
Cerebellum in man

† Philosophical Transactions for 1851-1853-1854-1859 for the *Mordulla oblongata* & Spinal Cord. Phil^l Transactions for 1838 for the intimate structure of the Brain.

with it. the cerebella of other animals, and see how far and in what manner they differ from this typical form.

The Cerebellum fits into the inferior pair of fossae in the occipital bone, the tentorium Cerebelli separating it from the posterior lobes of the cerebrum superiorly. It consists of a central lobe called the Vermiform process, and of two lateral lobes or hemispheres. On the upper surface, the median and lateral lobes are scarcely recognisable from each other, but inferiorly there is a well marked depression, the valley, and at the bottom of this it has received the name of the Inferior Vermiform process. At the posterior margin there is a notch which well marks the division of the two hemispheres. The upper or tentorial surface and the lower or occipital surface in man correspond respectively to the anterior and posterior surfaces in mammals.

The Cerebellum is connected by means of a pair of Superior Peduncles with the Medulla oblongata, by a pair of Inferior Peduncles with the Cerebrum, and by means of transverse fibers which traverse the Pons Varolii, and which are called the middle Peduncles, the hemispheres are connected with each other. Dr Carpenter differing from all the authors

ities. I have consulted, says, "The Cerebellum has no direct connexion with the Cerebrum, and its relations are entirely with the Cranio-Spinal Axis."†

The grey and white nervous substance of which the Cerebellum is composed have a very different arrangement to that found in the Cerebrum. By far the larger portion of grey matter lies most external. This peripheral layer is deeply plicated, and is so folded up as to occupy but little space. The sulci between the laminae are analogous to those of the Cerebrum, but differ in being proportionately deeper, in running more or less parallel to each other, and therefore unconvoluted, and in some of them passing continuously over the vermiform process from one hemisphere to another. Some of the cerebellar fissures being deeper than the rest, and very constant have received special names‡ There is also a nucleus of grey matter embedded in the white medullary portion of either hemisphere, which from its corrugated appearance has received the name Corpus Dentatum. This crumpled up pouch of grey matter, open at its mouth (directed towards the peduncles) and enclosing white matter in the interior.

Corp: Dentat.

† Principles of Human Physiology. 6th Edition page 563.

‡ Quain's Anatomy. Vol. II page 523.

is almost identical in arrangement with the *Copula dentatum* of the Olivary body. The Central or medulla medullary portion, composed of white nerve tubes, projects into the various lobes, and thence into the multitudinous laminae: consequently a vertical antero-posterior section of the cerebellum presents a beautiful foliated appearance. This arrangement has received the name of *Arbor vitae*.

The intimate structure of the cortical layer is simple, extremely constant, and quite peculiar to the Cerebellum. There is a closely aggregated mass of granules, nerve cells, ^{nerve fibres} nuclei, and molecules. There are three distinct layers, an internal, external and intermediate, and the cells, granules and filaments composing these are embedded in a granular matrix.† The internal or Ferruginous layer is made up of dense masses of round granular, cellular bodies, some of which may be four nuclei, with nerve tubes passing amongst them. 2. The external or Grey layer is ~~made~~ consists of a finely molecular light yellowish substance which agrees chemically, morphologically and physically in all respects with the contents of the nerve-cell.‡ This layer is richly supplied with capillaries.

Histological structure.

† Vide Prof. Brunner's Principles of Medicine page 143.

‡ Kolliker's Human Histology. Sydenham Socy. page 432.

derived from the meninges. 3. It is between these two layers that the nerve cells proper of the cerebellum are situated. Besides a few small nerve cells, and quite different from them are the very peculiar nerve cells discovered by Purkinje. These nucleated cells vary in shape[†]; they may be round oval or pyriform. They contain colourless molecular matter, and give off long and branching processes, which are for the most part directed to the external layer. As these approach the periphery they subdivide into numerous and very slender branches. Tubular nerve fibres pass from the central white substance and traverse each of these layers. In the internal layer, according to Kölliker, they are broken up into numerous delicate fasciculi which freely interlace, and form a close net-work of nerve fibres. They are prolonged into the grey layer, but in consequence of their delicacy and the ease with which they are broken, Kölliker has found it difficult to trace their mode of termination[‡]. Valentin and Hyrtl thought they form terminal loops, an opinion which subsequent investigation has not confirmed. Professor

[†] Op. Cit. p. 433. [‡] They measure 0.016 - 0.03."

Gerlach considers the granules as small nerve cells with branching processes, which are connected with the delicate nerve fibres, that these are joined to the ramifying processes of the large nerve cells (the cells of Purkinje) and further prolonged into the external layer and then linked to the processes of the small nerve cells. He has given a diagrammatic illustration of this interesting view, which in principle is not unlike the connecting links which bind the different layers in the retina together⁺ Mr. Lockhart Clarke, although he too has not discovered such an arrangement thinks that not improbably it exists. It has not been demonstrated in the human Cerebellum; but perhaps, by tearing out a portion of a very thin section of a properly prepared Cerebellum, light might be thrown upon the question. In the section of the Cerebellum of a monkey which I have made there is important confirmatory evidence of Gerlach's view, such as I believe up to this time has not been in existence.[‡]
 (Mic. Slide No 7)

⁺ Virchow's Cellular Pathology by Chamer p. 269.
[‡] Vide Plate 1. Fig.

The central medullary portion of the Cerebellum is made up of nerve tubes which are for the most part continuous with those of the Peduncles. The middle peduncles enter the lateral parts of the Cerebellum. The inferior peduncles enter the central portion in the folia of which they are distributed. The superior peduncles are mainly connected with the folia of the inferior vermiform process, but some pass into or from the Corpus Dentatum. Tulp has, however, put forward views of a totally different character. He thinks that all the fibres of the peduncles arise from the interior of the Corpora Dentata. The fibres of the cerebellar periphery pass to, and the peduncular fibres pass from these nerve centres; and these latter decussate and terminate in such a way as to form a separate system indirectly connected with the fibres of the rest of the cerebro-spinal axis.† These views require confirmation.

Central medullary substance

†

Journ. de l'Anat. et de Physiol. (Tulp:) 1864 p. 225.

Having now entered with some care into the relations of structure and histology of the Cerebellum as it exists in man, we are prepared to adopt it as a standard of comparison. As we descend in the scale of the vertebrate series, we find the cerebella differ in the amount of development rather than in any structural change. The elementary structures, and a similar arrangement of them prevail with remarkable persistency and uniformity. There are an inner and outer layer, with the cells of Purkinje embedded between them. The Corpus Dentatum too is very constant. Its existence in oviparous vertebrates is denied by some. Professor Marshall says "they have not been seen in the oviparous vertebrates"† The fact is, that sometimes, instead of being arranged so as to look like a corrugated pouch in section, the cells of the Corpus Dentatum are scattered about in a diffused manner throughout the white central substance. This is well seen in No 87 which is a section (vertical, antero-posterior) of the Cerebellum of a Crow. No one can, I think, look through the numerous sections of different cerebella which accompany this Thesis, without being very

Histology of
all cerebella
very similar.

†

Outlines of Physiology. Vol: I p. 414.

much struck with the great uniformity; and this observation must I think form an important addition to the facts, upon which alone a sound judgment of the functions of the Cerebellum can alone be based.

Modifications of the Cerebellum in the lower animals. Modifications

1. Size and development. The Cerebellum like the cerebral hemispheres as we descend from the highest to the lowest vertebrata undergoes a gradual decrease in size, so that the sensori-motor ganglia become proportionately greater as compared with the diminished cerebral hemispheres & Cerebellum. In the higher anthropoid apes the Cerebellum is overlapped by the Cerebrum as in man; indeed, in some of the lower Quadrumana - monkeys and baboons - the extent of overlapping is greater than in man. But in passing down through the Carnivora, Cirroptera, Ruminantia, Pachydermata and Rodentia, the Cerebellum becomes gradually more and more naked, until at last it is quite visible from above. In Pisces and Reptilia it forms a distinct ganglionic mass posterior to all the other ganglia of the encephalon. The Cerebellum gradually diminishes in size as compared with the Spinal

cord, or with the weight of the body as we pass down the vertebral series. The lateral hemispheres are very largely developed in the Quadrumina, but "these parts diminish rapidly in the lower mammalia, until at last they are represented only by the small portions named the flocculi." The Cerebellum, however, is still characterised by the constant occurrence of a Pons and of a middle and lateral lobes. In Aves the central lobe is largely developed, and the lateral appendages have now all but disappeared. In Pisces the Cerebellum is a well developed organ, the central lobe now alone being present. But in the higher Cartilaginous fishes such as the shark, skate and ray, we find it consisting of a central and two lateral lobes, and sometimes even with indications of a division into laminae such as prevails in the mammalia. In the Reptilia and Amphibia it is of the most rudimentary description, though here too as in Pisces, there are important exceptions to this general statement. For whilst in the Frog and the Chelonia it consists simply of a smooth band arching over but not closing in the 4th ventricle, in Lizard it is more highly developed, and in Crocodiles approaches very closely to the Cerebellum.

of Birds, having a distinct subdivision into central and lateral lobes.

2. Lamine. These gradually diminish in num. 2. Lamine
ber, so that the arborescent appearance exhibited
in a section becomes simplified, and at last dis-
appears. The lamina themselves differ greatly
in number, form and in relative length and
breadth. Speaking generally, the number increases
in the mammalia with the lateral development of
the lateral hemispheres, whilst in the lower classes
of the vertebrata, the number depends on the a-
mount of development of the median lobe.

Mammalia.

In man

Order. Primata. A vertical antero-posterior section
shows from 18 to 20 folia. There are no secondary foli-
a. The folia are short, broad and serrated, not deep-
ly, at their edges.

Order. Quadrumana, Family Simiæ, Genus Cebidæ

In monkeys

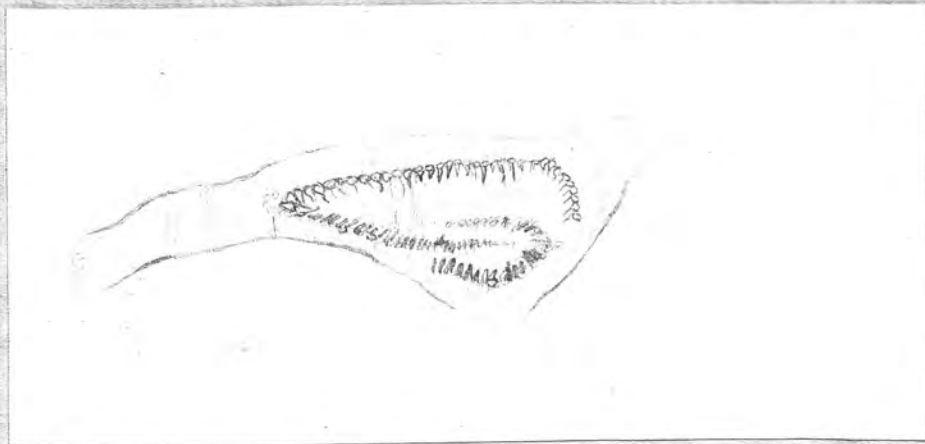
(Plate I Fig 1) From 14-16 primary folia, most having
secondary folia, some bifurcating, and others with 2
or more secondary folia springing from the side.

(No 1-7)

Order. Insectivora, Family Talpidae. (Plate I Fig 2)

In Talpidae.

The Cerebellum of the Mole, in fact the whole brain
is remarkably small. Though larger than a rat, a



Fig². A peculiar arrangement of nerve cells seen in the Brain of a Mole. It is situated near the Corp² Quadrij². The cells are arranged in a convoluted vermiform manner. They are embedded in white matter, the fibres of which run more or less at right angles to the cells. These cells are pyriform in shape, the terminal process of all looking towards the centre of the enclosed space.

rat's brain is twice as large as that of a mole. I may observe that in three brains of moles examined by me I failed to discover any trace whatever of an Optic Commissure. Cerebellum, 6-8 Primary folia, one bifurcated, all of them short and narrow.

(Mic: Slide 8-11) +

Order Digitigrada, Family Felida (Plate 1. Fig 3) In Felida

In the Cat, the Primary Folia are from 18-22. They proceed for some distance towards the periphery, and then give off two or three secondary folia which are broad and short. The cells of the outer layer are not quite as large as those in man. (Mic: Slide 12-15)

Order Digitigrada, Family Canida (Plate 7 Fig 4) In Canida.

In the dog, the primary folia are few - 8-10 - but very large and broad, the width depending not so much on the cortical layer, as on the mass of white substance perforating them. They divide into two and three terminal, and nearly all of them into several lateral, secondary folia. (Micros: Slide - 16-18)

Order Rodentia, Family Sciurida, (Plate 7 Fig 5) In Sciurida:

In the Squirrel, the primary folia are from 10-15 in number, and almost from their common center, give

+ On the opposite side there is a drawing of a peculiar arrangement of cells in the brain of the mole.

give off numerous secondary folia, they all terminate in secondary folia. (Mic: Slide 19-23)

Order Rodentia - Family Muridae (Plate I. Fig 6) In Muridae

In the Rat there are from 7-8 Primary folia, the upper and lower ones remain such, but the others have 2 or more secondary folia. In some there is a mere depression indicating, and nothing more, a disposition to divide. Such an appearance is often seen in other brains; and whenever seen it will be found that the depression is not in the outer layer alone but that the inner layer is also bent inwards, so that the relative thickness of the two layers is maintained in the bent part. (Mic: Slide 24-35: no 24 shows a vessel cut obliquely)

In the Mouse there are 6-8 Primary folia, no secondary ones, the lateral ones being large, whilst the posterior, i.e. the superior are three very short ones.

(Mic: Slides 36-42) (Some of them as also some of the Rat are very thin sections)

Order Marsupialia, Family Macropidae (Plate II Fig 1) In Macropidae

In the Cerebellum of the Kangaroo there is a remarkable development of the median lobe, whilst the lateral lobes are comparatively small. The primary folia are from 8-10 in number. They all have secondary folia connected with them, and in the some, there

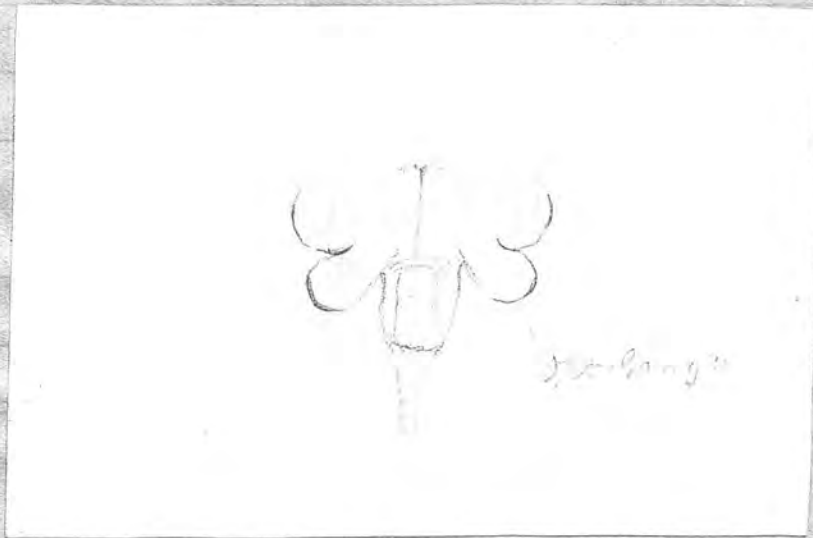


Fig ² showing the peculiar shape of the Brain of the Laughing Jack-ass. The anterior surface of the Cerebrum is vertical, and is scarcely rounded off, looking almost as if it had been cut. The brain is very short from before backwards whilst the lateral diameter is ~~far~~ disproportionately great. The upper surface is quite flat. The Optic ganglia stand out prominently (Natural size.)

have tertiary folia springing from them.

(Mic: Slides 43-46)

Class Aves. Order Raptors - Family Diurnes (Pl. II Fig²) In Falconidae

In the Sparrow-hawk, the primary folia are from 13-15 in number. They are extremely regular, being long, narrow and straight. There are no secondary folia.

(Mic: Slides 47-48)

Order Fissirostres - Family Alcedinidae (Plate II Fig³) In Alcedinidae

The Laughing Jack-ass of Australia belongs to this Family. It has received its name from the character of its cry, which some imaginative persons think has a resemblance to the bray of a laughing donkey. The primary folia are long, narrow and undivided; they are from 13-15 in number. The median folium alone shows any signs of a secondary division.⁺ (Mic: Slides 49-53.)

Order Coriostres. Family Fringillidae. (Plate II Fig⁴) In Fringillidae

The Weaverbird of Africa. The Primary folia are from ten to 12 in number, regular and generally undivided. (Mic: Slides 54-56) The yellow Bishop also from Africa belongs to this Family. The arrangement and number of folia are much the same as in the Weaverbird. (Mic: Slides 57-59).

The Cardinal of S. America belongs to the Grosbeaks

⁺ The figure represents the peculiar shape of the Brain of the Laughing Jack-ass.

It is so called from the its having a bright scarlet cap of feathers on its head, the rest of the body being clothed in a sober greyish hue. The number of the Primary folia is from 9-11. and these are generally undivided. (Mic: Slide. 60) Cardinal.

The Sparrow. The primary folia are 8-10 in number extremely regular, long-unbifurcated. The median portion is very narrow and runs up in the form of a cone. Generally in other species the peripheral border is angular. (Mic: Slides, 61-62) Sparrow

The Goldfinch. The number of Primary folia is from 8-10. They are generally undivided, but the median one is bifurcated at the extremity. Goldfinch

(Mic: Slides. (Mic: Slides 63-65)

Canary. The number of Primary folia is from 13-15. Canary.
The arrangement of the folia is very regular. They are (except the median one which is divided as in the Goldfinch) unbifurcated. (Mic: Slides 66-67. I would call attention to the fact (as bearing on the alleged function & sexual function of the Carbellum) that No 67, which is a section from the Carbellum of a male canary is identical in structure, size and arrangement with No 66, a section of a cock bird.)

Bullfinch. The number of Primary folia is from 13-15. They are generally undivided, except the Bullfinch

mediana folium. (Mic: Slides no 68-72)

Tinamou. The number of primary folia is from 12-14. Tinamou.
They are regular, long and narrow and show more disposition to divide into secondary folia. (M. Slides 73-76)

Oxyr or Great Tib. The number of primary folia Oxyr.
is from 11-12. The Cerebellum is large for so small a bird. The folia are very regular, only one of the lateral ones being bifurcated. (Mic: Slides 77-81)

Order Coraciiformes. Family Corvidae (Plate II Fig 5) Corvidae-

The magpie has a remarkably well developed Cerebellum & Cerebellum. It will be found that as a rule, the number of subdivisions in the lamina increase with the development of the Cerebellum. In the magpie the number of ^{Primary} folia is from 10 to 12. These frequently bifurcate, some are tripartite.

(Mic: Slides 82-85. There is no Corpus Dentatum visible in these sections. No 84 & 85 show vessels in outer gray layer very beautifully. These same preparations show curious molecular spots).

The Crow. The Primary folia are 11-12 in number. Crow

They bifurcate and some are tripartite. (M. Slide 86-8)

Order Icthyophaga. Family Turdidae (Plate III Fig 6) Turdidae

The Black-bird. The Primary folia are numerous, Blackbird.
being from 16-18 in number. They are long, narrow, regular, and not more than two of them bifurcate

(M. Slide 89-90)

Family Sylviidae. The Robin. The primary folia Robin
are few, 6-8. They are short, thick and generally
undivided. (M. Slide No 91)

Acridavius. The Primary folia are from 10-12 in Acridavius
number. They are short, and widen at the extremity
so as to be wedge shaped. They are generally undivid-
ed. (Mic. Slides 92-94)

Order Scansors. Family Psittacidae - (Fig. 7 Plate) Psittacidae.

The Grey Parrot of S. Africa. The Primary folia Grey Parrot.
are from 12-14 in number. They are frequently bi-
furcated and "budded". (M. Slides 95-100) +

The Green Parrot of Ceylon. The Primary folia are Green Parrot
from 13-15 in number. They are comparatively short
and thick, and frequent secondary folia appear.
(M. Slides 101-104)

The Love Bird of Australia. The Primary folia are Lovebird
from 9-11 in number. They are regular and gen-
erally undivided. (M. Slides 105-106)

+ I was much struck with the remarkable development of
the cerebrum of the Grey Parrot. Its brain was twice the
size of that of a Crow, a much larger bird, and I think
more intelligent bird, notwithstanding the imita-
tive powers of the Parrot.

Order Rasores - Family Gemitors - Genus Gourdida.

Gourdida

(Plate # Fig 8)

Ring-door. Primary folia 10-12 in number, and then are generally undivided. (M. Slides 107-109)

Ring-door.

Wood-pigeon. Primary folia are few in number short and peculiarly broad. There is but little disposition to subdivision into secondary folia (M. Sl. 110-111)

Wood-pigeon.

Family Clamators. Genus Phasianida.

The Common Fowl. The Primary folia are from 18-20 in number, with terminal divisions into secondary folia (Mic: Slides 112-113)

Chicken

The Partridge. This section is the only one not cut by myself. It was prepared by Mr. Hirling. It is also the only vertical transverse section in the collection. The Primary folia seem to be about 8 in number. The amount of secondary folia does not appear. (Mic: Slide. 114)

Partridge.

The Pheasant. The Primary folia are from 12-14 in number. They are regular, rarely divided into two, and are somewhat wedge-shaped.

Pheasant.

(Mic: Slides 115-117)

Order Gallators - Family Ardrida. (Plate # Fig 9)

Ardrida.

The Heron. The Primary folia are from 8-11 in number. Nearly every one is divided forming secondary folia. And there are indications of a ter-

Heron-

drancy to even further subdivision, as is ^{seen} ~~seen~~ at
 C. Below this, the inner
 grey layer is thicker - it
 in fact tends to push



out so as to form another cleft. [†] (M. H. 118-121)

Family Scolopacidae.

The Snipe. The Primary folia are ten to 12 in number. They are regular, some of them are club-shaped, and they show little tendency to subdivision. (M. Slides 122-125)

Snipe

Order. Natatons. Family Laridae (Plate II Fig 19)

Sea-gulls - The Primary folia are from 10-12 in number. They are undivided. (M. Slides 126-128)

Sea-gulls.

Family Anatidae -

Ducks. The Primary folia are from 10-12 in number. There are very numerous secondary folia both terminal & lateral. (Mic: Slides 129-132)

Ducks.

Widgeon. The Primary folia are from 13-15 in number. They are regular, and generally undivided. When any subdivision takes place it is in the posterior leaflets. (Mic: Slides 133-134)

Widgeon.

Tufted Pockard. The Primary folia are from 10 to 12 in number. They are long, narrow and

Pockard.

[†] No 118 shows the sheaths of the vessels (perivascular canal) very well.

and very regular. They are almost undivided.

(Mic: Slides 135-136)

The Mallard. The Primary folia are 9-11 in number. There are numerous secondary folia in some cases presenting a curious tortuous appearance. (Mic: Slides 137-139)

Class Reptilia, Order Toricatan. (Plate Fig)

Alligators. Unfortunately the brain I obtained belonged to an animal which had been dead for some days. In consequence of this, it did not harden nor are the tissues distinguishable. I merely forwarded the sections which show the non laminated appearance of the Cerebellum, and which also show the peculiar curved form it assumes.

Alligators

(Mic: Slides 141-144)

From this general survey, we see there is great variation in the number and character of the laminae, some of them being exceedingly simple while others are more complex. The general absence of secondary folia is observable in Aves, whilst they are universally present in mammalia. The general rule seeming to be the larger the Cerebellum, the more numerous are the secondary folia.

It only now remains to notice the variations seen in the cortical layer.

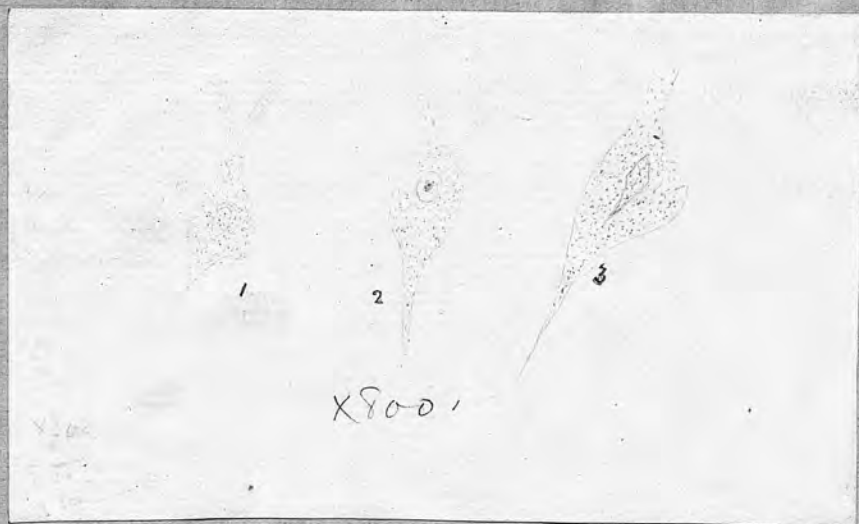


Fig 1. Isolated nerve cells lying close to the inner gray layer. 1. 2. in the Grey Parrot (Mic: Slide 65) 3. in the Ory. X 800.



Fig 2. Portion of inner gray layer of Cerebellum of Ory with nuclei in situ. Faint fibres can be seen. X 800.



Fig 3. 1-11 Isolated nuclei in the *Corbillum* of *U.*, surrounded by plasma which is prolonged into processes. 7, 10 and 11 were brilliantly coloured with Carmin, and on that account resembled the nuclei of the other bodies. In all the other bodies however, the processes were plainly connected with the perinuclear plasma. X800.

Modifications in the Cortical substance.

Modifications
in the cortical
layer.

With respect to the nerve cells proper, speaking generally, their position and shape is identical with that of man. The Figure on the opposite page represents very accurately their appearance under a high magnifying power. These cells were isolated lying close to the inner grey layer, so that their contour could be easily seen, whilst from their resemblance and closeness of position to the general mass of nerve cells, there is no doubt that they were isolated members of that mass, or at any rate identical with the bodies in the grey layer. The nucleus is surrounded by a mass of plasma, but I failed to discover any differentiation of cell walls. The plasma is prolonged into processes, the inner ones generally being single and more tapering than those proceeding in the opposite direction. Figure 2. represents a portion of the inner grey layer of the cerebellum of ox. The nuclei are in situ; they appear to be embedded in a molecular plasma in which there is an appearance of very faint fibres. These observations about the cells in the Cerebellum of the ox were made in a preparation in Dr. Bennett's collection.

The size of the nerve cells vary somewhat. Thus the size of cells.

in the Goldfinch, Cardinal, Avadavir, Blackbird, Bullfinch, Oxyr, and are about half the size. Those in the Mallard, Grey Parrot & Squirrel are about $\frac{2}{3}$ rd the size of those in man, whilst in the Weaver bird and ring-dove they are only $\frac{1}{3}$ rd. In the Mouse, Chicken, and Green Parrot they are about $\frac{2}{3}$ rd; and in the Rat, Cat, Kangaroo Sparrow hawk &c they appear to be identical with those in man.

The chief deviation from the arrangement found in man is seen in the striking diversity of proportionate thickness of the inner and outer grey layers.

Proportionate thickness of outer & inner layers.

As a general rule they border the leaflets with great regularity, the layers being narrowest near the medullary substance and gradually widening as they approach the extremity, in some cases however tapering towards the point (vide Mic. Slide 113) as seen in the chicken. This regularity is preserved in the secondary folia, but when there is only a tendency to subdivision, the relative proportions become altered, giving rise to many curious appearances. The microscopic slides of the brain when seen with a low power will illustrate what I mean. I have carefully measured the width of the inner and outer layers of several cerebella, and for the purpose of more easily comparing, give the results in a tabular form.

Table of measurement of Inner and Outer layers
of Corbillum. (Magnifying power 80 diam. linear)

No of Slide	Name	Inner layer	Outer layer
16	Colley dog	$\frac{1}{166}$	$\frac{1}{83}$
15	Cat	$\frac{1}{250}$	$\frac{1}{100}$
26	Rat	$\frac{1}{250}$	$\frac{1}{166}$
40	Mouse	$\frac{1}{400}$	$\frac{1}{166}$
19	Squirrel	$\frac{1}{250}$	$\frac{1}{100}$
46	Kangaroo	$\frac{1}{250}$	$\frac{1}{125}$
48	Sparrow hawk	$\frac{1}{166}$	$\frac{1}{100}$
57	Laughing J. Ass	$\frac{1}{150}$	$\frac{1}{80}$
54	Weaver bird	$\frac{1}{166}$	$\frac{1}{125}$
59	Bishop	$\frac{1}{166}$	$\frac{1}{200}$
60	Cardinal	$\frac{1}{400}$	$\frac{1}{112}$
61	Sparrow	$\frac{1}{500}$	$\frac{1}{250}$
65	Gold finch	$\frac{1}{500}$	$\frac{1}{200}$
66	Canary	$\frac{1}{500}$	$\frac{1}{200}$
67	Mule Canary	$\frac{1}{500}$	$\frac{1}{200}$
70	Bullfinch	$\frac{1}{166}$	$\frac{1}{125}$
74	Linnet	$\frac{1}{500}$	$\frac{1}{250}$
81	Ox-eye	$\frac{1}{400}$	$\frac{1}{140}$
84	Magpie	$\frac{1}{166}$	$\frac{1}{100}$
86	Crow	$\frac{1}{166}$	$\frac{1}{83}$
90	Black-bird	$\frac{1}{400}$	$\frac{1}{200}$
91	Robin	$\frac{1}{250}$	$\frac{1}{125}$
92	Acadamin	$\frac{1}{500}$	$\frac{1}{166}$
97	Grey Parrot	$\frac{1}{166}$	$\frac{1}{100}$
103	Green Parrot	$\frac{1}{166}$	$\frac{1}{71}$
106	Loon Bird	$\frac{1}{250}$	$\frac{1}{166}$
108	Ring dove	$\frac{1}{200}$	$\frac{1}{100}$
111	Wood pigeon	$\frac{1}{250}$	$\frac{1}{83}$
112	Chicken	$\frac{1}{166}$	$\frac{1}{83}$
115	Pheasant	$\frac{1}{250}$	$\frac{1}{166}$
121	Heron	$\frac{1}{166}$	$\frac{1}{71}$
124	Snipe	$\frac{1}{250}$	$\frac{1}{166}$
128	Sea-gull	$\frac{1}{200}$	$\frac{1}{83}$
132	Duck	$\frac{1}{250}$	$\frac{1}{100}$
134	Widgeon	$\frac{1}{200}$	$\frac{1}{125}$
135	Poekard	$\frac{1}{166}$	$\frac{1}{83}$
137	Mallard	$\frac{1}{166}$	$\frac{1}{83}$
6	Monkey	$\frac{1}{125}$	$\frac{1}{100}$

As our glance over the foregoing table without being struck with 1st the remarkable variation in the relative thickness of the Inner and Outer layers in different brains; and 2nd the fact, that though in man these two layers are of about equal thickness, in all the other cerebella examined (with the strange exception of the Bishop-bird) the outer one is the thicker of the two. It may possibly be found that the modification in the function of the organ depends to some extent on the relative thickness of the two layers.

Before concluding, we may inquire what information the Histology, gives as to the Functions of the Cerebellum.

Perhaps no subject in the whole range of Physiological ^{inquiry} has been so prolific in theories and barren in results as the office of the Cerebellum has been. Hypothesis has been piled upon hypothesis, theories after theories have been skillfully constructed upon these, the building seemed complete, and promised to be lasting, when Fact - that ruthless iconoclast - with a single wave of "Ithuriel's spear" has caused it to totter and tumble down as a house of cards.

The Cerebellum is itself insensible to irritation

(Touget). It is not concerned in the exercise of any psychological functions; nor does it appear to be directly concerned in the mental act of Volition, but if removed, the power of fulfilling the mandates of the will, especially those having reference to complicated muscular acts, is seriously interfered with - the circuit is interrupted. It does not appear to be the seat of the function of special sensation.

Foville, Pichl-Grandchamp and Duys thought it to be the seat of common sensation, because of its connection with the posterior columns of the spinal cord.

But in the case of abscision of the cerebellum, the perceptions and sensations were perfect (Combeite); and the complete removal of the entire organ, does not involve any loss of the ordinary sensorial powers.

Dr. Brown-Séquard maintains that the effects following on lesions of the cerebellum whether produced by experiment or disease, are merely the results of irritation of the cerebellum, and not of loss of function.

The able Professor of the Practice of Medicine in this University, in that learned and abstruse work "Mind and Brain" (a second edition of which was published last month) enters very fully into the subject +

+ Vide, "Mind and Brain" 2nd Editⁿ Vol: II pp. 452-460.

He considers 1st that the Cerebellum is a crucial unifying organ of organic or vegetative life. 2nd that by acting on all the motor functions of the cord, it probably through these influences all the vital activities of the body including temperature, secretion and excretion, nutrition of muscular and other tissues, and co-ordination of cardiac, vaso-motor and muscular activity; and 3rd that its functions are determined by afferent impressions derived from the periphery, the sensory nerves and the hemispheres. He holds that the Cerebellum is the immediate motor organ of the impulsive will, and has a share in the instinctive and automatic acts; and (what must at first sight appear very startling) that the "Cerebellum is virtually a great sympathetic centre and is in close functional relation with the sympathetic system." and finally, that there is a close ^{functional} connection between the Cerebellum and the genital glands. I will only add that many of the effects following on Cerebellar lesion are strongly confirmatory of some of the views just mentioned, e.g. Amaurosis, vomiting, cephalalgia, convulsive movements, epilepsy, hemiplegia, disordered movements, contraction of particular muscles, Stasis, hyperaesthesia, and noises in the ears.

Many arguments have been advanced and Experiments made to prove that the Cerebellum is the seat of the sexual function and that it coordinates muscular movements. Some thought the central lobe is connected with the genital function, and the hemispheres exercise the coordinating muscular influence. It was asserted that atrophy of the testes and loss of the sexual passion followed upon injury of the cerebellum; but in none of the recorded cases are the cause and effect distinctly defined. It does not appear whether the loss of sexual passion resulted from atrophy of the testes and whether this followed upon the injury to the cerebellum. In 138 cases, Burdach found only 10 indicating a functional relation between the cerebellum and the genital organs. The observations of M. Lasaigne proved clearly that castration does not lead to diminution in the size of the cerebellum. Some collected 7 cases in which excitement of the sexual passion was coincident with apoplexy of the median lobe, but as Pitreguin points out, in all such cases the medulla oblongata is almost sure to be implicated also. Laussana held that the muscular sense and the rotic sense are the two essential functions of the cerebellum. The arguments

Note. It is not necessary to recapitulate
the well known and interesting experiments
made by Rolando, Flournoy, Majumdar,
Kentwig, Long et. Schiff, Brown-Séquard
and Wagner.

Schiff in a recent summary concludes
that "the functions of this organ are
still unknown."

for the Sexual Function of the Cerebellum seem to me Sexual Fun
 confused, unsatisfactory and inconclusive. The conclu-
 sions arrived at from experimental and pathological ob-
 servations are by no means uniform and confirmatory
 of the opinion: ~~eg.~~ nor does histology support the view
 for I find the cerebellum of the male lizard and Can-
 any in which there is congenital impotence as fully
 developed as in lizards and canaries in which there
 is no sexual impairment. (Vide Micros. Slides)

There is much more consistent evidence that the Muscular
 Cerebellum co-ordinates and regulates voluntary mus- Co-ordinated
 cular movements. Comparative anatomy bears similar
 testimony to experimental and pathology. Fish as they are
 more active, so have they more highly developed cerebellum
 than Reptiles, and ^{more} voracious fish, e.g. Shark, whose supply
 of food depends on active and finely adjusted movements
 it reaches its maximum development in fish. So
 in reptiles, the cerebellum is small in the sluggish snake
 but more largely developed in the comparatively active
 lizards and crocodiles. In birds, it is small in galler-
 naceous birds, but much more pronounced in birds
 that feed on the wing, swooping upon their prey with
 marvellous rapidity and precision.†

† I have not seen it remarked, but I think it worthy of notice
 as bearing on this subject, that the Cerebellum is much more highly
 developed in the chick at birth which is able to stand firm at
 once, than in animals born blind as rat, cat, which cannot
 co-ordinate their movements for some days after birth.

In Mammals the exact correspondence between the size of the Cerebellum and Complexity of movement is more marked. In the Anthropoid apes which some times walk erect it approaches nearest to that in man. It is in the act of walking erect that the greatest variety of muscles are brought into play. Man is formed for this kind of progression and in man we find the Cerebellum a more perfect organ than in any of the lower animals.

Before finishing this Thesis it will be well to gather together the facts demonstrated in these researches, and dismissing all mere hypothesis, to see what conclusions may be drawn from them.

Conclusions.

1. The Elementary Structures and arrangement, unlike those of the Cerebrum are uniform in all the Cerebella examined by me.
2. The bodies so thickly imbedded in the inner layer are not free nuclei, but each one is surrounded by a differentiated mass of plasma, so that it may be defined as - a nucleated mass of plasma -.
3. Golgi's views as to the connexion of the bodies in the inner layer by means of nerve filaments passing between and into them, are so far confirmed

as that it is shown that nerve filaments are continuous with the processes of these nucleated masses of plasma.

4. There is great difference in the relative thickness of the Inner and Outer layer in various Cerebella.
5. The cerebellum of the male Linnet and Canary is identical in structure with that of the Linnet and Canary in which there is no congenital sexual impotence: therefore Histology thus far, gives no evidence as to the alleged sexual function of the Cerebellum.
6. The number, size and complexity of folia are in direct proportion to the variety and complexity of motion.

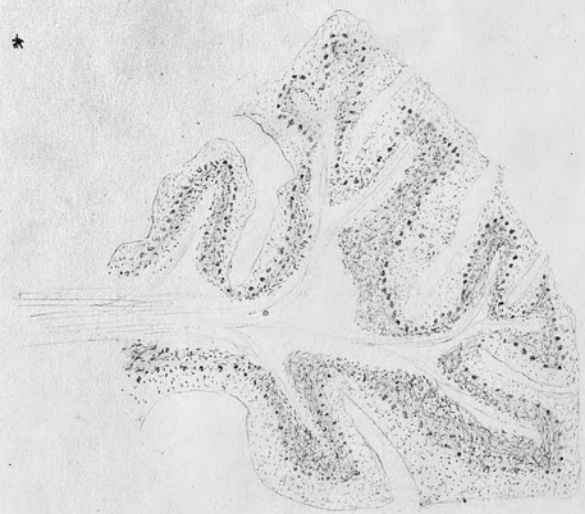


Fig. 1.



Fig. 2.



Fig. 3.

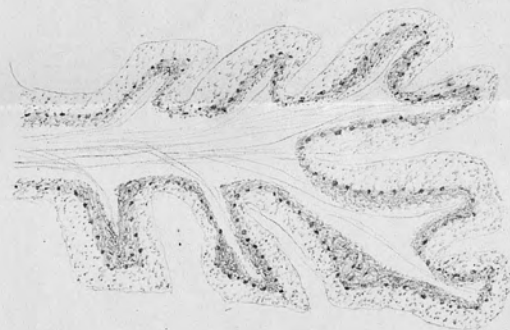


Fig. 4.



Fig. 5.

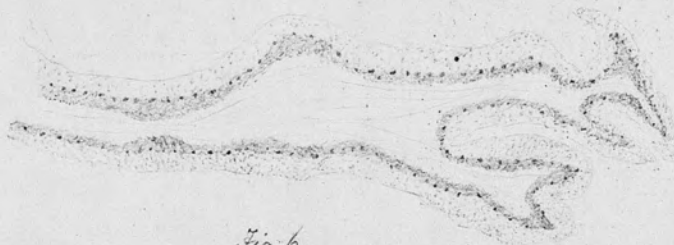


Fig. 6.

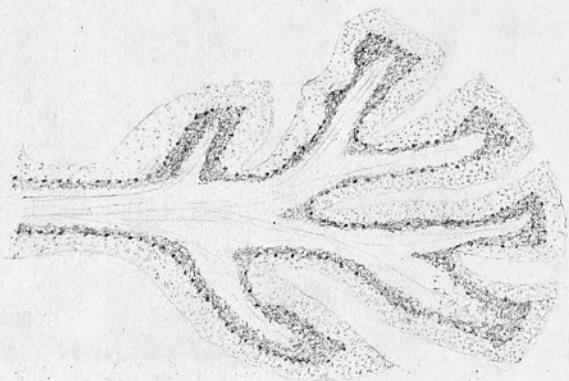


Fig. 1



Fig. 2.

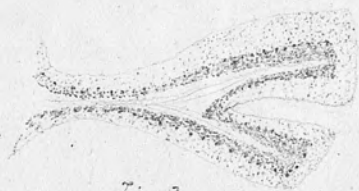


Fig. 3.



Fig. 4.

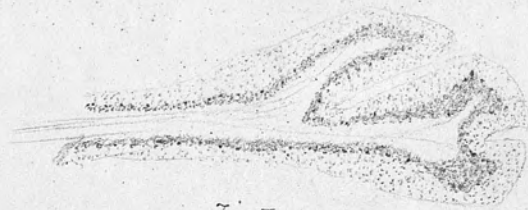


Fig. 5

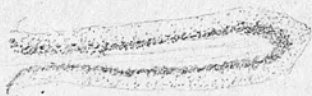


Fig. 6.



Fig. 7.



Fig. 8.



Fig. 9.

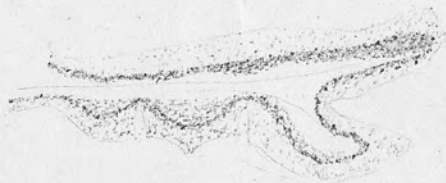


Fig. 10.



Fig. 11.