REPORT ON THE LESIONS, PRIMARY AND SECONDARY, IN THE BRAIN AND SPINAL CORD OF THE MACACQUE MONKEY EXHIBITED BY PROFESSORS FERRIER AND YEO.

BY E. A. SCHÄFER, F.R.S. *Jodrell Professor of Physiology in University College, London.* Plate XII.

A. The lesion in the cerebral cortex.

1. Description of the part of the brain involved in the lesion of the cortex.

The boundaries of the lobes on the external surface of the macacque's brain are very evident, much more so indeed than in the human subject (Figs. 1 and 2). The furrow of Rolando (R) stretches from the middle of the mesial edge of that surface downwards, outwards and somewhat forwards to within a very short distance of the middle of the Sylvian fissure and cuts off the frontal from the parietal lobe and from the rest of the brain. The frontal lobe thus marked off is about as large in proportion to the rest of the brain as in man, but is relatively much less furrowed. The parietal lobe on the other hand although containing the same chief furrows as the parietal lobe in man is relatively much smaller. This reduction in size of the parietal lobe is compensated for by the much greater superficial development of the nearly smooth occipital lobe, from which it is completely separated on the surface by the upper part of the strongly developed external parieto-occipital fissure. This fissure in its lower half divides the temporo-sphenoidal and occipital lobes.

The temporo-sphenoidal and parietal lobes are also in the macacque usually very sharply marked off from one another owing partly to the fact of the Sylvian fissure running superiorly into the parallel fissure, partly to the angular gyrus being narrowed at its junction with the middle temporo-sphenoidal convolution.

The superficial lesion involves portions of the frontal and parietal lobes of the left side of the brain. Neither the occipital nor temporo-sphenoidal lobes have been in any way injured, nor does the lesion extend to the mesial surface of the hemisphere.

It will therefore only be necessary for our present purposes to describe the furrows and convolutions of the fronto-parietal region.

The *frontal lobe*, the part of that region in front of the sulcus of Rolando exhibits only two distinct furrows. One of these is antero-

posterior in direction (*ant.*) and stretches from the apex of the lobe backwards through more than half its length, running a short distance above the sharply curved border which separates the external from the orbital surface of the lobe. The second furrow (*tr. fr.*) is mainly vertical and behind the first one. Starting from a point a little above the angle enclosed between the Sylvian fissure and the orbito-frontal border, this furrow extends upwards on the lobe rather more than half way over the external surface. It then bends forwards over the antero-posterior or apical furrow for a variable distance. We may provisionally distinguish these two furrows of the frontal lobe according to their general direction as the antero-posterior and the vertical. They here and there have small lateral furrows connected with them, and on the parts which they separate from one another there are indications of the commencement of other furrows, but these appear for the most part to be inconstant in size and position, and scarcely worthy of special mention. An exception must however be made for the small antero-posterior furrow marked *x* in the woodcuts, for this appears to be tolerably constant in position, being always placed parallel with, and a short distance from, the inner border of the external surface, and a section shows it to be something more than a mere superficial grooving (Fig. 4, *x*).

The two furrows above-mentioned cut off from the antero-external portion of the lobe a triangular surface which is bounded on the third side by the orbito-frontal border. This surface corresponds according to Gratiolet[1] to the third frontal convolution in man, the first and second convolutions being represented by the part of the lobe above the antero-posterior furrow, the two being only imperfectly separated by the anteflexed portion of the vertical furrow. This would make the antero-posterior furrow to represent the inferior frontal of human anatomy and the anteflexed part of the vertical furrow to represent the superior frontal furrow; and this is the view which has usually been adopted[2]. Bischoff[3] on the other hand has contended that the antero-posterior furrow is the superior frontal of the human brain, all above it being superior frontal convolution, all below it middle frontal, the inferior frontal convolution being either altogether absent or quite rudimentary and blended with the middle one. The point is the more difficult to decide since the anterior limb of the Sylvian fissure is absent in the

[1] *Mémoire sur les plis cérébraux de l'homme et des primatès.* Paris, 1854.

[2] See Ferrier, *Functions of the Brain*, pp. 138, 139.

[3] *Ueber das Gehirn eines Gorilla und die untere oder dritte Stirnwindung der Affen. Sitzungsb. d. Münchener Akademie*, 1877.

macacque and it is around this that the third frontal convolution curves in the human brain. There is a further difficulty to the more generally received view arising from the fact that this third frontal convolution in man is connected with the faculty of speech, and it may be argued that it could therefore scarcely be expected to be more largely developed in proportion in the monkey than in man, as would be the case if Gratiolet's view were accepted. Since therefore the homologies are not clear it will be better to speak of this furrow merely as the *antero-posterior* or *apical furrow*. As for the vertical furrow this it seems clear must be regarded as the homologue of the *precentral or transverse frontal sulcus* of human anatomy (at least its lower end), and it may accordingly be so designated.

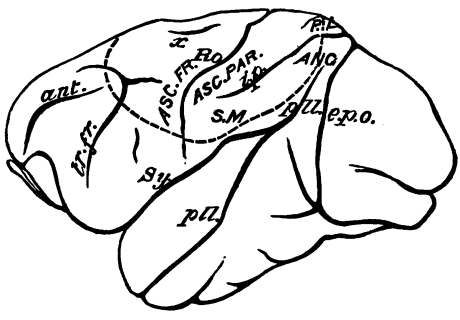


FIG. 1.

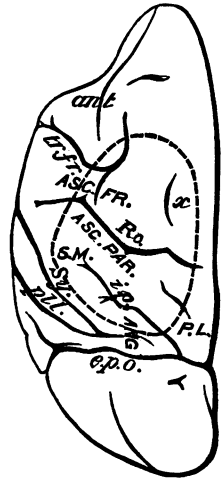


FIG. 2.

FIG. 1. Brain of a macacque monkey: profile view from the left side (for description see text).

FIG. 2. Brain of a macacque monkey, viewed from above (see description in text).

These two furrows may be looked upon as dividing the frontal lobe into three unequal and irregular parts. Of these the part between the transverse frontal sulcus (which we may continue upwards by an imaginary line towards the great longitudinal fissure) and the furrow of Rolando represents the *ascending frontal convolution* of human anatomy. As regards the rest of the lobe we have just seen that there is a very considerable difference of opinion amongst authorities on the subject of the homology of its parts, and since this is a question which can only be decided by the study of a large series of brains of Primates it has not been hitherto possible to obtain either the material or the

leisure which alone would enable the decision to be attempted. I shall content myself therefore with speaking of the whole portion of the lobe in front of the transverse frontal sulcus as the *anterior portion* and shall speak of the *upper* and *lower divisions* of this according to their position with reference to the apical or antero-posterior furrow[1].

The parietal part of the fronto-parietal region (*parietal lobe*) is proportionately much more convoluted than the frontal part and the identification of its convolutions is far more easy. The furrows of this lobe are the *intra-parietal sulcus* (*i. p.*) which passes obliquely upwards and backwards (being nearer the furrow of Rolando below, and gradually becoming further from it above) to end near the inner margin of the hemisphere in the parieto-occipital fissure (it does not pass across this into the occipital lobe as in man), and the upper end of the *parallel sulcus* (*pll.*) which having received the Sylvian fissure is continued upwards and backwards into the angle which the intra-parietal sulcus forms with the parieto-occipital. The convolutions of the parietal lobe may be described as being four in number as in man, but the divisions are, it must be confessed, somewhat artificial, for the *parietal lobule* (P. L.) is freely continuous with the *ascending parietal* (ASC. PAR.) being merely an expansion of its upper end, and the *supra-marginal* (S. M.) is nothing more than the short and thick bridge of junction between the lower end of the ascending parietal and the ascending limb of the *angular convolution.*

2. Extent of the lesion in the cerebral cortex.

The brain as it came into my hands, i.e. hardened in bichromate of ammonia, presented on the left side a smooth depressed surface of an irregularly triangular shape, with the angles much rounded, not unlike the bowl of an egg-spoon. This space occupied the whole of the centre of the fronto-parietal region. It was covered by a firmly adherent membrane which at the time I did not know to be part of the dura mater. I supposed the latter to have been removed, as it was from every other part, in taking out the brain, and I could only refer the presence of a dense membrane here to the supposition that it owed its origin to inflammatory action[2], but subsequent more careful examination

[1] In the preliminary abstract report which was published in the *Transactions of the International Medical Congress* the nomenclature of these parts was borrowed from Ferrier's *Functions of the Brain.* It seems desirable however since there is some doubt about the matter rather to employ terms which have not acquired special significance in human anatomy.

[2] See the preliminary report in the *Trans. Int. Med. Congr.*

showed its true nature. Unfortunately I had not had an opportunity of seeing the brain before it was placed in the hardening solution or it would have been less easy to have fallen into the error in question.

The dura mater was not only inseparably adherent to the depressed surface above-mentioned but also adhered, although much less firmly, to the surrounding surface of the brain for a space of four or five millimetres: on separating it here, the subjacent surface was found uninjured, the loss of brain cortex being strictly limited to the depressed surface. The limits of this therefore indicate the extent of superficial lesion (see the dotted line in Figs. 1 and 2):—

Mesially it is bounded by a line running parallel with and about four or five millimetres from the inner border of the hemisphere in its middle third. Posteriorly by a line which crosses the intraparietal furrow and runs close in front of and parallel with the upper end of the parallel sulcus and the upper third of the Sylvian fissure to a point nearly on a level with the lower end of the furrow of Rolando. And anteriorly by a line passing from this point obliquely forwards to join the anterior end of the first line about the middle of the frontal lobe.

But the triangular area thus enclosed has, as before said, its angles very widely rounded off.

The area comprises the following parts:—

In the frontal lobe. The ascending frontal convolution except a very small portion of the upper end next the great longitudinal fissure and except also its lower end; about one centimeter in length or nearly one-third of the whole length of the convolution here remaining intact. The posterior third of the upper division of the anterior portion of the lobe, the lower division remaining untouched.

In the parietal lobe. The greater part of the ascending parietal convolution, only about 5 mm. at the upper end and 6 mm. at the lower end remaining. A small piece of the parietal lobule. Rather more than the half (longitudinally) of the ascending limb of the angular gyrus and of the supra marginal convolution.

The other lobes are not encroached on by the injury nor is the internal surface of the hemisphere, although as will be explained presently it is probable that by an undermining process of secondary nature a portion of the marginal convolution may have been cut off from continuity with the central parts of the cerebrum.

B. Secondary lesion in the medullary centre.

Sections through the injured part of the cerebral cortex which were

made with the view of determining the depth to which any secondary inflammatory process may have extended into the medullary centre, unexpectedly revealed the existence of a large cavity occupying nearly the whole of that part of the medullary centre which lay immediately below the seat of injury. This cavity, which is seen in transverse vertical section in Fig. 3, is covered in by a comparatively thin layer of brain substance. The nervous character of this is however only apparent near its margins where it passes insensibly into the normal tissue of the medullary centre; elsewhere it is infiltrated with small nucleated cells, and with fibres of connective tissue nature and appears to have lost all nervous structure. Superficial to this layer and intimately connected with it is the piece of dura mater already mentioned in describing the superficial lesion.

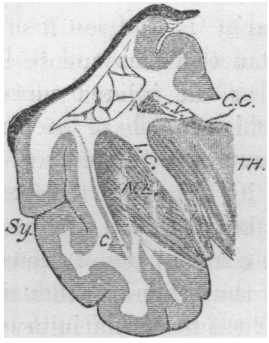


FIG. 3.

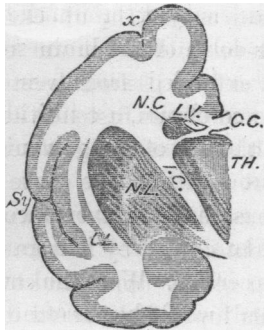


FIG. 4.

FIG. 3. Section across the left central hemisphere of the brain of the macacque monkey described in the text, showing the position of the secondary lesion in the medullary centre.

Sy., Sylvian fissure; C. C., corpus callosum; L. V., lateral ventricle; N. C., nucleus caudatus; N. L., nucleus lenticularis; TH. thalamus opticus; I. C., internal capsule; CL. claustrum.

FIG. 4. Section across the left hemisphere of the brain of a normal macacque monkey made at about the same situation as the section shown in Fig. 3.

The cavity does not extend so far into the medullary centre of the cerebrum as to reach the corpus striatum, nor does it communicate with the lateral ventricle. The latter is however much enlarged, but as regards its epithelium and otherwise, it appears normal. The floor and walls of the cavity, like its roof, are pervaded by fibres and infiltrated with nuclei belonging to small cells, but not to anything like the same extent as the roof. Indeed a short distance from the cavity the medullary substance surrounding it presents a completely normal

appearance, so far as could be determined in the vertical sections which were made of it. There is no epithelial lining to the cavity although its boundary is quite sharply defined. It is traversed here and there by ragged-looking irregularly branching fibrous strands some containing vessels, but it otherwise seems, so far as the hardened preparation can show, to be occupied only by albuminous fluid without corpuscular elements—although there is some possibility that these may have been present, and have become lost in preparing the sections.

I have some hesitation in pronouncing on the nature of this cavity. That it is of secondary formation and not a part of the primary lesion would appear certain from the fact that it is covered over by what is undoubtedly, although much altered, a layer of brain substance. I am inclined to adopt an opinion which has found favour with more than one pathologist with whom I have had the opportunity of discussing the subject, that the cavity is the result of a softening and breaking down of the brain substance in consequence of thromboses which have extended from vessels at the injured surface to others deeper in the cerebrum, a condition which may have been more readily produced by the use of the galvanic cautery in the removal of the cortex cerebri[1]. But whatever the cause of its formation, the fact of its being there is of considerable importance as bearing upon the extent of surface which would be cut off by it from the central parts of the cerebrum and from the crus cerebri. Were the cavity more extensive than the superficial injury the result would be the same as if the superficial injury were greater, since the cutting off of other than the directly injured parts from the internal capsule would have the same effect as their actual removal. But in such a case as this where the cavity is coextensive or nearly so with the injury and does not reach the corpus striatum the result of the experiment as deduced from the superficial lesion is not vitiated; since we can suppose that only the fibres connecting the removed part of the cortex and the internal capsule are involved in the secondary breaking down, and these were by the superficial lesion alone deprived of their function.

Although however it would in the present instance be for the most part only these fibres which are involved in the secondary lesion it is possible that it may have involved some others. For if we look at the section which is shown in Fig. 3, we observe that the most direct path of fibres between the otherwise intact grey matter of the convolution on

[1] I am given to understand however by Dr Ferrier that the existence of such a secondary lesion as this cavity is quite exceptional.

the inner or mesial side of the removed cortex, and the internal capsule is cut off by the cavity, so that unless some of these fibres pass round the inner corner of the cavity to reach the internal capsule, and this is a point which it is difficult to determine, this portion of grey matter will also have been to all intents and purposes cut off and rendered functionless. It is on this account as I have already stated (p. 320) that it may be right to include a part of the marginal convolution of the inner surface of the hemisphere (to which the grey matter in question belongs) amongst the parts cut off by the operation.

C. Secondary degenerative changes in the pyramidal tract (see Plate XII.).

1. In the internal capsule (Fig. 1, Plate XII.).

Sections of the internal capsule of the left side made across the course of its fibres show in its central part a number of bundles most of the fibres of which have lost their medullary sheath and have undergone the Wallerian degeneration[1]. The degenerated bundles are not all closely packed together but are somewhat scattered, being here and there separated by others which present a normal appearance. It is noticeable under higher powers that in many of the flattened bundles in which degeneration has taken place there is a thin layer forming a sort of cortical stratum, in which the fibres appear normal.

2. In the crus cerebri (Fig. 2 and 3, Plate XII.).

In the crus cerebri of the same side there is a well localized patch of degeneration. It is situated in the central part of the crusta near its ventral border, occupying an oval area which tapers slightly in the mesial direction, and although as just stated sufficiently well localized is not sharply marked off from the surrounding normal white substance.

3. In the pons Varolii, and in the medulla oblongata above the decussation of the pyramids (Figs. 4 and 5, Plate XII.).

The degeneration is now both well localized and sharply defined. It comprises in fact the principal bundles of the left anterior pyramid; and the degeneration of the fibres is so complete as to give in stained sections an exceedingly sharp contrast with the neighbouring undegenerated white matter.

4. In the region of the pyramidal decussation (Figs. 6 and 7, Plate XII.).

At the decussation the degenerated tract passes obliquely across the

[1] This term is applied to the changes which are undergone by nerve-fibres as the result of separation from the nerve-cells which act as their nutritive centre.

anterior median fissure to the opposite or right side of the medulla. Here it runs down for a short distance in the formatio reticularis. A portion of the tract remains however at first in the anterior column, and this portion, at least a considerable part of it, at a little lower level appears to be passing towards the formatio reticularis of the same or left side of the medulla. But in sections still lower down in which the degeneration is very well marked in the formatio reticularis of the lateral column of the right side I have been unable to detect any sign of it on the left side, although as will immediately be stated a patch of degeneration occurs in the cervical cord in the lateral column of both sides.

5. In the cervical part of the spinal cord (Fig. 8, Plate XII.).

In the cervical cord there is a well-marked patch of degeneration in the right lateral column occupying an irregular triangular area in the posterior part of that column. The patch is not very sharply defined, especially externally where it merges somewhat gradually into the normal white substance, nor have all the fibres in it undergone degeneration.

It occupies the situation of the crossed pyramidal tract and is what was to be expected to be found accompanying degeneration of the anterior pyramid on the right side of the medulla. But what was not to have been expected is the presence of another patch of degeneration upon the *left* side of the cord (i.e. on the side of the injury), occupying almost exactly the same position and of the same extent as the degeneration on the right side, but less accentuated by the process of staining employed, and therefore probably containing fewer degenerated fibres. The degeneration in the cervical cord is therefore bilateral. The fact is obvious in all the sections which I have prepared from it.

I am not aware that a bilateral degeneration in any part of the cord following unilateral lesion of the motor tract higher up has as yet been observed. And it is the more perplexing because no symptoms were recorded in the monkey during life which indicated any loss of voluntary power on the left side of the body, and also because neither in the lower end of the medulla oblongata nor in the dorsal or lumbar regions of the spinal cord can a bilateral degeneration be made out. The only gleam of elucidation as to the source of the degenerated fibres in the left lateral column in this region which it has been possible to obtain is to be found in the observation above recorded of the apparent passage of a small part of the degenerated left anterior pyramid *towards* the left lateral column whilst the larger part took the more usual course towards the opposite lateral column. I have searched in vain for any sign of

degeneration along the pyramidal tract of the right side of the medulla, pons and crus cerebri, and of the right internal capsule.

6. In the dorsal and lumbar regions of the cord.

The dorsal and lumbar parts of the spinal cord were not placed in my hands but I have had the opportunity of examining a carmine-stained section of each, these having been placed at my disposal by Dr Ferrier by whom they were prepared. The situation of the descending degeneration in these regions is shown in Figs. 10 and 11, Plate XII. It is strictly unilateral, being confined to the right lateral column, and it there occupies the well-known position of the crossed pyramidal tract, tending gradually to approach the surface of the lateral column. Beyond its gradual diminution in size as compared with the same patch in the cervical region there is nothing special to be remarked about it.

To sum up:—There has been removed in the monkey the greater part of the two central convolutions, and the adjoining parts of the frontal and parietal lobes on the left side of the brain.

Underneath the lesion thus produced there has become formed by secondary processes in the medullary centre an excavation nearly conterminous with the superficial lesion and not involving the basal ganglia.

The pyramidal tract connected with the left side of the brain has undergone the Wallerian degeneration throughout its whole extent.

There exists an unexplained tract of degeneration in the left lateral column of the cervical cord.

DESCRIPTION OF PLATE XII[1].

The figures represent outlines of sections magnified about 3 diameters, through various parts of the brain and spinal cord of the monkey. The degeneration-tract in each one is indicated by dark shading.

Fig. 1. Oblique section through the internal capsule, corpus striatum, thalamus, &c.

cc. Corpus callosum.
l. v. Lateral ventricle.
n. c. Nucleus caudatus.
n. l. Nucleus lenticularis.
th. Thalamus opticus.
i. c. Internal capsule with degenerated bundles.

[1] The figures in this plate were kindly drawn for me by Mr H. H. Brown.

Fig. 2. Transverse section through the superior corpora quadrigemina

a. s. Aqueduct of Sylvius.

III. Third nerves.

t. Tegmentum.

s. n. Substantia nigra.

cr. Crusta with degenerated tract.

Fig. 3. Section across inferior corpora quadrigemina.

P. Fibres of pons. The other letters as in Fig. 2.

Fig. 4. Section across the pons Varolii.

IV. v. Fourth ventricle.

VIII. Auditory nerve.

VI. Sixth nerve.

Fig. 5. Section across the upper part of the medulla oblongata.

o. Olivary nucleus.

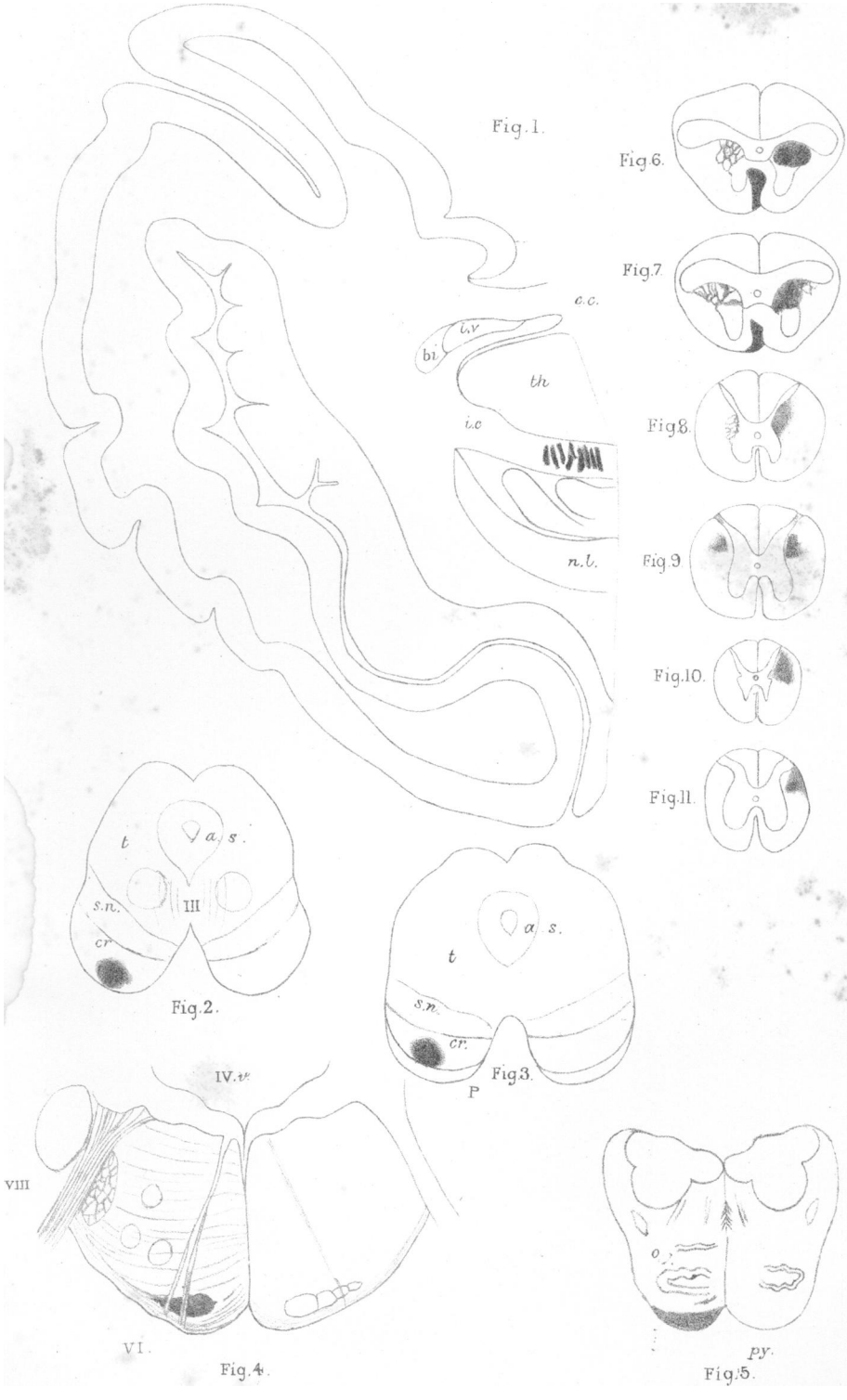
Figs. 6 and 7. At the decussation of the pyramids.

Fig. 8. Immediately below the decussation.

Fig. 9. At the cervical enlargement of the spinal cord.

Fig. 10. From the middle of the dorsal region.

Fig. 11. From the lumbar region of the cord.



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