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ON THE CORPUS CALLOSUM IN THE EMBRYO.

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IN a paper which I communicated to the Royal Society on February 23, 1884, I detailed certain facts and figured certain appearances in the *adult* brain which led me to believe that the Corpus Callosum is not an interhemispherical commissure, as is generally supposed, but in reality the decussation of a great part of those fibres derived from the cortex which do not decussate at some point further down. The facts were mainly these, that when the brain is prepared in the method I employ (see 'BRAIN,' July 1883) the fibres of the corpus callosum, instead of stretching across from side to side between the hemispheres, are found to come from the cortex of one side to pass over to the opposite side, and having gained this, to turn down into the inner and outer capsules. I endeavoured to show that the bulk of the fibres which enter the inner capsule, both in its anterior and posterior segments, is composed of such crossed callosal bundles, while the motor and other fibrês which come chiefly from the cortex of the same side, which do not pass over in the corpus callosum, and which decussate further down, constitute but a small part of the entire inner capsule.

The outer capsule, I demonstrated, is composed of two layers —an external and an internal. The external derives its fibres from the operculum and edge of the Sylvian fossa behind this, while the inner is made up mainly, if not entirely, of crossed callosal fibres, which have come from the opposite side, and turned downwards.

As regards the destination of these crossed callosal fibres which have thus passed downwards into the two capsules, I pointed out that they chiefly terminate in the thalamus opticus. A few of them end in the caudate nucleus, while a considerable number, in all probability, find their way further downwards to end in the pons Varolii or other masses of grey matter below the basal ganglia. The majority, if not all the motor fibres do not pass through the corpus callosum; they belong to a different system, and, partly, at least, are continued down through the pyramids to the spinal cord as usually described.

There are therefore two main sets of fibres entering the inner capsule from the cerebral cortex; the one set comes from the opposite hemisphere, decussates in the corpus callosum, and subsequently enters the capsule: the other set, much the smaller of the two, passes into it from the cortex of the same side, and decussates somewhere lower down, chiefly in the medulla oblongata.

The facts supporting these views were mainly derived from the analysis of the nerve tracts in the *adult* human brain, and since then I have confirmed them, over and over again, in numerous observations. I find, moreover, the same appearances in all animals which I have examined, in which an undoubted corpus callosum is present. So far as I have gone, these comprise the ape, monkey, horse, sheep, dog, cat, and pig.

For the purpose of confirming or refuting the foregoing views, several methods of inquiry naturally suggest themselves, and among those which I have employed, and am at present employing, are the study of the corpus callosum in the embryo, the examination of it in destructive lesions in the human cortex, and experimental research in the lower animals. It is with the first of these—the corpus callosum in the embryo—that the present communication is chiefly concerned. The brains which I have employed in this present research, so far as it has gone, have been derived from the embryos of various animals, and from the human fœtus. The latter, as is well known, has yielded in the hands of Flechsig the most brilliant results; and although my observations in some respects lie in a different path from those of that observer, yet I have also found that the human fœtal brain is excellently well suited for such investigations. The great difficulty, however, lies in getting the materials sufficiently fresh, for it will be found by those working at the subject, that unless perfectly fresh, the embryonic brain-substance loses that consistence which is necessary to hold its parts together. The embryos of mammals are also of course extremely useful in such an investigation, and as the majority of those slaughtered for food purposes can be obtained in various stages of fœtal life, I have employed these largely in conducting the present inquiry. I have examined the fœtal human brain at almost all ages, but that age which I would specially recommend as being most suited to demonstrate the connections of the corpus callosum, is *from the end of the third to the fourth month.* It is difficult to say, of course, in the human subject what the exact age of a fœtus may be, and hence Flechsig has fallen back upon length as a surer basis to reckon by. Fœtuses, however, differ so much in length at the same period of intra-uterine existence, that even this is to a certain extent misleading, and hence perhaps the various discrepancies in Flechsig's account of the period of medullation of the various nerve-fibre tracts.

The chief advantage of studying the corpus callosum in the embryo, I have found, lies in the fact, that its fibres are developed long before those which enter the inner capsule directly from the cortex of the same side. Hence those fibres which are callosal can be clearly traced in the embryo, apart from others with which they become associated and intermingled in the adult. It is, however, only at a certain period, the above mentioned, that this can be satisfactorily accomplished. Previous to this, the fibres are too rudimentary to afford good results, and, afterwards, the direct cortical tracts and the "association system" of fibres become so highly developed that the callosal bundles are lost, or are indistinctly demarcated from them. In the adult brain I know of no appearance in the nerve centres so fallacious as that of the course of the callosal fibres after they have crossed. Looking at a perpendicular section of a fresh brain, or one hardened in spirit, it is absolutely impossible to say definitely where they go to; and hence the idea has gained almost universal credence, that they pass from the cortex of one side to that of the other, simply because the corpus callosum lies between the two hemispheres. This has never been absolutely demonstrated by any known method of inquiry. It is an absurdity to say that a single fibre can be traced in its continuity from side to side, seeing that the callosal fibres do not all lie in the same plane. Physiologically, there is literally no evidence to show that this mass of white matter is a means of uniting the functions of equivalent areas in the two cerebral hemispheres; and it is as yet unproved, even if it were a commissure, that unity of function would thereby result from duality of structure. In fact, the whole commissural theory of the corpus callosum has arisen simply from its lying between the two hemispheres, and from its fibres, in their middle course, seeming to run transversely, or nearly so, when roughly examined.

It is only when the brain is specially prepared for the purpose that the true destination of its fibres after crossing the middle line can be discovered. By this means there is brought out an appearance in Man and the lower animals which I have never seen figured in any work on the subject, and which careful observers, such as Flechsig, have either not observed or have ignored.

Were it true that the fibres are commissural, how is it that destructive lesions in one cortex do not affect the other? I have in my possession at present the brain of a woman in whom the first and second frontal convolutions have been completely destroyed, so far as the symptoms and morbid appearances indicate, from the time of birth, and yet the corresponding convolutions on the opposite side are quite intact. How is this to be accounted for on the commissural theory? I cannot conceive, if the one side is so intimately bound up with the other, that some mutual influence should not be exerted in a case such as this, where the deficiency has been caused at so early a period of life. Gudden's and

Monakow's experiments have shown that when certain regions of the cortex are excised in newly-born animals, the parts with which they are in connection are under-developed when the animal is fully grown. Why is it then that in the case of this large so-called commissure, if such it be, the same does not hold good? There seems to be a discrepancy here, which, until explained, should retard us from accepting as proven the usually recognised opinion of the connections and functions of the corpus callosum.

However great the difficulty may be of following the course of the callosal fibres in the adult, this in great part disappears when the embryonic brain is the subject of observation at the age I have before mentioned. Flechsig ('Die Leitungsbahnen im Gehirn und Rückenmark,' 1876), evidently taking it for granted that the corpus callosum is a commissure uniting different zones or areas of the cerebral cortex, has failed to notice the very remarkable appearance presented by it in from the third to the fourth month of pregnancy. He dismisses its consideration in a few words (p. 49), and says, "he will not find occasion to return to this part of the brain in the present memoir." In his succeeding publications I cannot find anything bearing on the appearances I have seen, and therefore must conclude that he has not noticed them. From this oversight I fear that his scheme of the brain, as set forth in his 'Plan des menschlichen Gehirns' (Leipzig, 1883), requires to be reconsidered. One of the chief drawbacks of his now long-famous work on the subject of the conducting paths is that he gives in his illustrations so few drawings of the brain when cut perpendicularly. I can find only one (Pl. III. Fig. 5), and in this, unfortunately, the corpus callosum seems to have been torn. The course of the callosal fibres after they have crossed is not depicted in it, chiefly, I should think, because the brain had not been specially prepared with this object in view, but also because the child from whom it had been taken was too far advanced in development (52½ cm. long, and had lived for 2½ days). It is in a much younger fœtus that the callosal fibres are to be found in their isolated state, and the reason for this is, as before referred to, that they are laid down long before those of the peduncular tract coming down from the fissure of Rolando. Thus if the brain of a fresh human fœtus about the fourth month of pregnancy be prepared by the method I employ, the corpus callosum after passing into the hemispheres can be traced with perfect accuracy throughout its entire course to its ultimate destination. Its rudimentary fibres are all deposited before the radiation of the peduncular tracts is visible, and hence it follows that if the proper age be selected, we possess in such a brain a means of studying the course and connections of the callosal fibres in their isolated state, and unc mplicated or obscured by the many other tracts that afterwards appear. The action of certain staining reagents is a great help in following out the line pursued by them.

The Corpus Callosum in a Human Embryo about Four Months old.

The embryo from which the following account is taken was said to be about the fourth month of intra-uterine existence. It looked as if this were true, and the state of the primary fissures in the cerebrum tended to confirm the opinion. It was received in good condition, and the brain after being hardened, or rather *toughened,* for four weeks in Müller's fluid and soaked in my freezing fluid, cut to perfection. I may mention that I have confirmed all the facts I am about to describe in many other embryos both of man and the lower animals.

The principle upon which Flechsig's work was based is that the various cerebro-spinal nerve tracts become medullated at different periods, the whiteness of the tracts which are medullated serving to distinguish them from those which are not. In former times "secondary degeneration," or the Wallerian method, was that chiefly relied upon; but as there are evidently some tracts that do not readily degenerate secondarily, a greater degree of certainty can be reached when the two methods are combined. The tracts in the spinal cord have thus been definitely laid down, and in the medulla oblongata the course of most of the nerve bundles is known. When we come to the brain, however, much still remains to be done, the *centrum ovale* being as yet practically a *terra incognita.*

The brain of a human fœtus about this period is comparatively smooth on the surface. There are indications of the presence of the great fissures, but, as yet, the convolutions, with the exception of the island of Reil, have not appeared. Thus there is a large wide gap representing the Sylvian fossa, with the island lying exposed in it, still uncovered by the operculum. There are also indications of the first and second frontal sulci, but the fissure of Rolando is either absent or forms the slightest depression. On cutting into the brain, it is evident that the corpus callosum has advanced much beyond other parts in development. Relatively to the volume of the brain it actually appears larger than in the adult, and not only so, but the whole callosal tract can be seen passing, as I hold it does, round the ventricles down to the inner and outer capsules. This is rendered particularly evident when the brain is frozen by my method, and polished on the surface in the microtome with the section knife. The callosal tract can then be, distinctly enough, followed from the middle line to its termination.

The whole relationship of the parts, however, is rendered much more evident when a thin section is cut and stained either in solution of perosmic acid, of acid-fuchsin, or of some nuclear staining reagent such as methyl-aniline, carmine, or logwood. I shall describe the appearances presented by each of these first, and then draw certain conclusions from them.

The Perosmic-acid Preparation.—I always stain the tissue after it has been hardened—a more delicate method than that of staining the fresh tissue. I simply lay the section in a very weak solution (1 to 800) for a night, and subsequently mount it in Farrant's medium. The preparation so obtained serves both as a naked-eye and as a microscopic object, but it is most instructive as the former.

The first glance of such a preparation shows that the fibres of the corpus callosum after crossing *do not radiate* into the cerebral medulla to reach the cortex of the opposite side. On the contrary, those issuing at the side remain as *a compact ribbon-like band,* which twists upwards, outwards, and downwards, round the ventricular cavity, and ends by entering, or rather forming, the inner and outer capsules by splitting over the lenticular nucleus. It arches much higher up in the embryo than in the adult, because the ventricle at this age is still large, and projects higher up at the sides than when the brain is fully formed. The ventricular cavity has somewhat of a Y shape, the two upper limbs corresponding to the lateral ventricles, while the lower may be taken to represent the relationship of the third. It is round the upper limbs of the Y that the callosal tract turns.

The action of the perosmic acid is to give an olive-green or light-brown tint to the whole section, but it stains the callosal tract of a dark brown, so that it becomes almost diagrammatically mapped out from all the surrounding parts. The cause of this is that *the callosal fibres are advanced in development, at this period of utero-gestation, far beyond any other nerve tract in the brain.* For while the greater part of the cerebral medulla at this time is composed simply of gelatinous tissue with embryonic cells lying in it, the callosal tract, from beginning to end, contains dense bundles of rudimentary nerve fibres.

When a small portion of the callosal tract, in a fœtus of this age, is teased out and examined with a magnifying power of 450 D., the fibres of the corpus callosum have the following appearance:—They are extremely fine, and are arranged in dense bundles. In each bundle there are to be seen usually, from five or six, up to ten or twenty individual fibres. The faintest line indicates the rudimentary axis-cylinder, while round about this is a covering of finely granular material. Sometimes it happens that the axis-cylinder becomes divested of this granular sheath, and when so, its extreme delicacy becomes apparent. The granular matter is usually so abundant and so dense, that it in great part conceals the axis-cylinder.

Glacial acetic acid, however, has the effect of rendering it more apparent, but it is best seen when accidentally the granular coating has been removed by pressure. So far as I have observed, absolute alcohol and ether do not dissolve this granular sheath, but glacial acetic acid or potash both render it much clearer even in a preparation which has been hardened. It is, therefore, in all probability not fatty as yet, and the latter reaction would seem to indicate its albuminous nature. At this stage of development I could not find any medullated fibres, and, therefore, the darkening of the tract could not be due to a fat-containing medullary sheath. The corpus callosum of an adult, when treated with perosmic acid in the same way, becomes perfectly black within 24 to 36 hours, and this is due to the large proportion of medullated fibres contained in it. The deepest stain I was able to produce in this embryo, however, was a deep brown.

The outer and inner capsules have already been referred to as being present, and it has just been stated that the callosal tract, after winding round the ventricle, forms them by splitting over the head of the lenticular nucleus. They present most of the characteristics of these structures in adult life. Thus the fibres of the inner are aggregated into bundles, which, on account of their oblique antero-posterior direction, are usually cut across in a perpendicular transverse section. Between the bundles of nerve fibres are septa of grey matter, continuous with the caudate nucleus on the one hand, and the lenticular nucleus on the other. Both capsules give a dark brown reaction with perosmic acid, the inner more than the outer.[1] There is no other part of the brain which darkens in this way, and hence my theory of the continuity of the capsular and callosal fibres gains support from this.

Not only do certain localities along the course of the tract stain deeper than others, but in the part of it which sweeps round the ventricle the perosmic acid shows, by its differential staining, that the tract consists of three layers or strata. The middle of these stains darkest, and hence I am led to suppose that it is the most highly developed. It can be traced from the middle line round to the inner capsule quite continuously. For the purpose of explanation, I shall call that part of the corpus callosum which is brought into view by separating the hemispheres, the *tectorial* part; and it can be

[1] The degree of staining depends upon the strength of the perosmic-acid solution. If a half-per-cent. solution be employed, the callosal tract and the two capsules become of a dark sepia brown and very opaque. A much more delicate reaction is obtained when the perosmic acid is more diluted.

readily noticed that the middle stratum forms the greater part of this. The other two strata become very attenuated as they approach the tectorial part, and finally cease to exist before the middle line is reached. The two parts of the preparation which are deepest stained with the perosmic acid are the middle stratum of the callosal tract in the tectorial part, and the inner capsule. The outer capsule is not so deeply tinted, nor is the part of the callosal tract which turns round the apex of the arch of the ventricular cavity. The staining is deeper, as before mentioned, in the middle stratum than in the other two, and on this account it can be readily traced from the tectorial part round the ventricle into the inner capsule. Few if any of its fibres seem to enter the outer capsule, which, as we shall afterwards see, appears to be more a continuation of the *upper* stratum.

The fibres, therefore, as they issue from the side of the corpus callosum, turn downwards, and form at this early period evidently the greater part, if not the whole, of the two capsules. They have been gathered in from the cortex of the opposite side, have passed through the *tectorial* part of the callosal tract, and have subsequently turned downwards. As regards the exact regions from which they arise, it is somewhat difficult to give precise details, so far as the embryonic brain at this period is concerned. The area being large, they are consequently less compactly aggregated than they are when they enter the *tectorial* part, or subsequently in their course downwards. At the same time they do not seem to be quite so highly developed as the fibres in these parts of the tract. They do not stain so deeply with perosmic acid, and when examined microscopically, they appear to be very rudimentary. A radiating arrangement is, however, distinctly apparent in the fibres coming from the cortex, most evident towards the vertex. In the adult brain a great mass of the callosal fibres comes from the vertex, specially from the margin of the longitudinal fissure. They sweep inwards with their concave side to the middle line, and it is also from this neighbourhood that the most of the callosal fibres in the embryo at this period seem to be derived.

The Acid-fuchsin Preparation.—The action of this substance upon nerve tissues, especially those of the brain and spinal cord, is now widely known. I am inclined to believe, that we possess in it one of the most useful of all staining reagents for the purpose of tracing the course of certain nerve bundles. Its action was originally described by Weigert ('Centralblatt f. d. med. Wissenschaft,' 1882), and since then many workers on the normal and morbid nerve centres have been able to confirm and add to what he said of it. It differs from all other staining reagents in the fact, that apparently in the presence of a chrome-potash salt, or at any rate when the tissue has been hardened in such, it stains *the nerve fibres*, and leaves the grey matter with its cells uncoloured. I was naturally led to employ it for this brain with the view of staining the callosal tract. The particular dye is known as Acid-fuchsin "S" No. 130 of the Baden Aniline manufactory, and the sample I have of it I procured from Dr. Grübler, of Leipzig.

It was questionable whether, with the rudimentary fibres of the corpus callosum, the same reaction would be given as with those which were fully developed. I found, however, that the callosal tract in the embryomic brain stains, if not so differentially as in the adult, yet so much more deeply than other portions of the cerebral medulla, that it forms to the naked eye a pink-coloured band, as clearly drawn out as if it had been done with a camel-hair pencil. The whole tract and the two capsules give this reaction, so that the continuity of the one with the other is rendered extremely evident. Microscopically it is seen to be due to the coloration of the rudimentary fibres, not to that of the nuclei which are abundantly interspersed between them.

As, however, methyl-aniline gives, if anything, a still more differential picture when the preparation is examined microscopically, I shall describe the minute appearances as seen in one stained by this latter substance.

The Methyl-aniline Preparation.—Flechsig has pointed out, that when a tract begins to become medullated, the nucleated cells within it increase greatly in number, and if such a tract be treated with a nuclear staining reagent, the coloration forms a trustworthy guide to its position, both as a naked-eye object and microscopically. The same nucleated cells are seen in abundance in the callosal tract at this age, and when stained they form an important indication of the course of its fibres. Several nuclear staining materials bring out like appearances. The one I have found best is methyl-aniline. Logwood does very well, but the former is more delicate and differential, and various degrees of staining can be obtained with it better than with logwood. I overstain the preparation, and wash out to the proper degree with dilute acetic acid and alcohol. The preparation is mounted in Farrant's solution, as previously.

The callosal tract is again seen to consist of three layers; but there is this difference in regard to their staining, that the uppermost has stained deepest, the lowest least so, and the middle presents a medium amount of coloration. The lowest layer appears to be purely cellular, the cells are all rounded, and they possess large nuclei which stain vividly with the methyl-aniline, more intensely even than those of the cortex. It measures from a quarter to a half a millimetre in thickness. Its course is to be traced from the tectorial part entirely round the ventricle, and continuously downwards to the rudimentary caudate nucleus. It is a remarkable fact, that the nearer the caudate nucleus is approached, the more intense the staining becomes, until in the caudate nucleus itself a distinct reaction is produced by this dye, the colour of the cells contained in it being a bright blue. Near the septum lucidum the coloration is much less intense, and the layer becomes so much attenuated that it is gradually lost before reaching the middle line. The same intense affinity for staining media characteristic of the cells contained in this layer is seen when logwood is employed, but to a minor extent, methyl-aniline, as just mentioned, giving a blue *reaction* with its cells. I could not distinguish any fibres within it even of a rudimentary character, nor could I find at any part fibres approaching it as if about to become incorporated with it. Its cells seemed to pass continuously into those of the still rudimentary caudate nucleus. What this layer represents I cannot definitely say. In the *adult* brain, there are always seen in this part of the corpus callosum a few bundles of fibres, turning sharply downwards and inwards to the caudate nucleus. Some of them enter it, and I think it quite possible that, later on, this layer becomes converted into these fibres, and so still retains its primary connection with the caudate nucleus. I shall not commit myself, however, to this view, until further inquiring into the matter.

The caudate nucleus at this period is entirely cellular. Fibres cannot be seen entering it from the inner capsule, and the cells are so closely packed, that when stained as described it looks like a uniform intensely blue mass. Lying outside of it, between it and the inner capsule, is a little acutely oval-shaped cellular piece of tissue, much less intensely stained, but composed of the same kind of cells. It is present in all the sections from this neighbourhood; and were it not for the sharp differentiation brought out by the staining, I should have included it simply as part of the caudate nucleus. It sends processes between the bundles of fibres of the inner capsule, and is very vascular. It stains exactly in the same manner as the lenticular nucleus, and the processes or septa which run in between the inner capsule bundles unite it directly with this nucleus.

Passing now to the middle stratum of the callosal tract, it is seen to be composed in the tectorial part of dense masses of fine fibres, with only a few nucleated cells between them. It measures from one to one and a half millimetres in thickness. Tracing it along the callosal tract, the same characteristics distinguish it until it reaches the vault of the ventricular cavity. Here, just as the tract begins to turn round, brightly stained nuclei become visible in it, and they continue until the callosal tract divides into the outer and inner capsules. In these the nucleation almost entirely ceases. The nuclei are surrounded by a little very delicate protoplasm which does not stain, and the whole cell, as a rule, is not larger than a leucocyte. They are distributed in rows between the nerve fibres, so that in a preparation such as this in which they are brightly stained, they indicate in a very demonstrative manner the course followed by the bundles of delicate nerve fibres. When more highly magnified (350 D.), they are found to exactly correspond to the inclination of the several nerve bundles.

Tracing this middle and largest stratum of the callosal tract downwards after turning round the ventricles, it is evident what becomes of it. It splits into the outer and inner capsules over the head of the lenticular nucleus. Not only does it split into these, but at this period of development *the entire inner capsule and a great part of the outer are formed by it.* After the most careful search I cannot find any other system of fibres going into the capsules—and yet they are perfectly distinct, and appear quite as advanced in development as any part of the callosal tract.

This, I hold, entirely coincides with the view announced by me in my communication to the Royal Society. I there stated, that I believed the anterior limb of the inner capsule to be composed almost entirely of crossed callosal fibres. Certainly some bundles enter it from the first frontal convolution of the same side, and probably other tracts may be derived directly from the tip of the frontal lobe, such as Meynert's anterior peduncle of the thalamus. This, I grant, may be true, but what I still uphold as entirely borne out by the examination of the embryonic brain, is that the main bulk of the fibres of the anterior limb of the inner capsule is callosal.

The most superficial of the three layers of the callosal tract is also, in the brain I am describing, the most highly nucleated. It is seen to arise in a very attenuated row of cells, which appears to be continuous with a delicate cellular layer lying on the upper surface of the tectorial part. It measures from half to one-and-a-half millimetres in thickness. Starting then with this attenuated internal extremity of the most superficial of the three layers of the callosal tract, it is seen rapidly to increase in bulk outwards, until opposite the highest point of the ventricular cavity, its maximum of breadth is obtained. It here forms a pyramid-like projection, and the particular shape thus imparted to the arch of the "crossed callosal tract" persists in some regions of the brain in adult life, more particularly in the parietal. As a rule, however, the pyramidal shape is lost when the brain is fully developed, so that the arch of the "crossed callosal tract" becomes in the adult more or less rounded. Traced further downwards, it is seen that the upper stratum becomes incorporated with the middle, and I think that most of its fibres ultimately pass into the outer capsule. It is intensely nucleated throughout, and between the rows of nuclei fibres less advanced in development than those of the middle stratum are contained.

The pyramidal projection formed by this stratum is easily accounted for when examined microscopically. The fibres and their corresponding rows of nuclei are tilted upwards at this portion of the tract, and are much more acutely arched than in any other part. It looks as if they were driven into this position by the ventricle, the pyramid-like contour of the tract corresponding in shape with the apex of the vault of the cavity.

Such being the composition of the callosal tract at this age, an interesting question comes to be whether there are any signs as yet of the peduncular tract, described and figured by Flechsig, in a viable fœtus of 52½ cm. long ('Die Leitungsbahnen,' &c., Pl. III. Fig. 5, *c.c*), and which one can see with little difficulty even in an adult brain when properly prepared. It will be noticed from the drawing he gives of it (naked-eye appearance only) that it comes down from the margin of the longitudinal fissure. He describes it thus at page 29:—"I found," he says, "in the medulla of the hemispheres a white mass which deserves minute examination, both on account of the time of its appearance, and of its special morphological properties. It was apparent in frontal sections which ran through the upper parietal region opposite the meeting-point of the two central convolutions, more especially the upper and anterior part of the posterior. It consisted of a small sharply demarcated white streak, which, leaving the external part of the capsule, that is to say, the neighbourhood of the divisions of the lenticular nucleus, ran first somewhat outwards, curved for about ½ cm. above the ventricle, was then sharply bent inwards, and finally passed upwards to end in the part of the posterior central convolution, which lies nearest the fissure of Rolando. While this band hardly reached up to the cortex in a 2½ days old child, it passed up to within ½ cm. of the same in one 9 days old."

In my communication to the Royal Society on the subject of the corpus callosum, I stated that the "corona radiata," as usually described, does not exist. The common idea is that the fibres of the inner capsule coming up from the peduncle and basal ganglia, all radiate outwards into the cortex of the same side. That is to say, the fibres simply spread from the inner capsule in all directions, and become attached to the hemisphere on the same side.

With this view I cannot agree, and the more I work at the matter, the more I become convinced that it is erroneous. Flechsig, in the passage I have already quoted, traces a thin white medullated band from the inner capsule to the upper part of the fissure of Rolando, in the neighbourhood of the paracentral lobule. This appears in the fœtus when viable, and almost at the full time of utero-gestation. As he figures it (Pl. III. Fig. 5, *c.c*), the band appears very slender—a mere twig compared with the enormous mass of the inner capsule or centrum ovale. He shows that this is directly continuous with the inner capsule, and that it comes from that region of the cortex which corresponds to the upper part of Ferrier's motor area. It further is equivalent in bulk, it will be admitted, to the tract which degenerates in an old destructive lesion in this neighbourhood, and hence there is little doubt that it consists of fibres which pass directly from the pedunculi upwards. He does not say, however, that the remainder of the so-called *corona radiata* can be traced in the same way from inner capsule to cortex. No doubt certain special tracts, such as Gratiolet's band to the occipital lobe, can, but the enormous mass of the corona radiata as described cannot be directly followed out in the same way. The band going to the motor area, as above described, forms a mere fraction of the fibres of the inner capsule, and it alone can be distinctly traced in its development from the inner capsule to the cortex of the same side.

Now in any adult brain these direct fibres can be readily seen when prepared in the method formerly described by me ('Brain,' July, 1883). They come from the margin of the longitudinal fissure, are aggregated into comparatively coarse bundles, and finally enter the inner capsule. I trace them forwards in the adult brain much further than Flechsig does in the embryo. I do not think that they are derived merely from the margins of the Rolandic fissure, or from the paracentral lobule; for I find them also coming down from the first frontal posteriorly. They are certainly, however, most abundant at the line of the Rolandic fissure, and the bundles here are coarser than elsewhere. They seem to be entirely confined to the inner capsule in their progress downwards. That some of them also enter the outer capsule I am not prepared to deny, but it has always seemed to me that the outer capsule, in its inner half at least, is composed of crossed callosal fibres derived from the "crossed callosal tract."

In the fœtus of four months, however, the inner and outer capsules are well formed and filled with developing nerve-fibres, while the band running up to the margin of the hemisphere as described by Flechsig is non-existent. The capsules, further, can be distinctly traced continuously into the corpus callosum along the callosal tract, as I have just described. Here then is a system (the callosal) well developed before any direct fibres from the cortex of the same side have made their appearance. The two capsules are of large size—relatively to the bulk of the brain of very large size, and they correspond in dimensions to the bulk of the callosal tract. If then the "corona radiata" of the inner capsule sends its fibres to the cortex of the same side, how is it that where the "corona radiata" is not present, the two capsules are yet laid down with the shape and features which characterise them in adult life? The band described by Flechsig as coming down from the motor area is one of the best marked of all the systems of the so-called "corona radiata." Here, however, in this four-months-brain there is not a trace of it, while the bundles of fibres in the two capsules are perfectly distinct. The fact, that the callosal tract can be traced macroscopically and microscopally to enter the capsules in the brain of this age, affords, I think, the explanation; and this explanation I hold lies herein, that not only in fœtal, but in adult life, the inner and outer capsules are largely composed of fibres which are callosal in their derivation. As development goes on from four months upwards, *direct* bands undoubtedly pass into them from various parts of the brain. These, however, form a small part of their bulk, compared with those of callosal origin. I think, therefore, without drawing any very detailed conclusions from the foregoing facts as seen in the four-months-brain, it may fairly be granted that these facts undoubtedly afford strong support to the views expressed by me in my communication to the Royal Society.

In summing up the main conclusions that may be inferred from the study of the four-months-embryo, I would say that they all tend to refute the idea of the corpus callosum being a commissure, and to support that of its being in reality a decussation of *certain* of the cortical fibres. These arising from the cortex on one side, pass through the tectorial part of this body to the opposite, and after circumventing the ventricular cavity, turn downwards to form the greater part of the inner capsule, at least in its anterior limb, as well as the inner half of the outer capsule.

If this then be the course of the callosal fibres in the middle part of the cerebrum, what is the disposition of those which take their origin from the frontal tips? The usual idea, as every one knows, is that the callosal fibres coming from the one frontal tip, pass through the genu of the corpus callosum, to gain a corresponding situation in the opposite tip. In this course they are supposed to run horizontally. I have long been persuaded that this idea is erroneous, but it was not till I undertook the present inquiry on the fœtal brain that I could actually demonstrate it. The course pursued by the callosal fibres in this part of the brain, is a much more difficult matter to demonstrate in the adult than might be supposed. It might be thought that the track of a large mass of fibres like this could be easily followed up. No greater error could be made. The intertwining of different systems is so complex, that I believe it is only in the fœtus, where the callosal system is alone developed, that it is to be clearly made out.

The reason for the peculiar arched course of the callosal tract, as described, is obvious. It is to allow the fibres to circumvent the lateral ventricle, and if my idea as to the course of these fibres be correct, the same obstacle has to be overcome by those fibres derived from the extreme anterior frontal region. What I have found both in the fœtus and the adult is that, instead of the callosal fibres derived from the anterior frontal region arching between the frontal tip of one side and that of the other, the fibres coming from, say, the left side, pass back horizontally to the genu corporis callosi, cross in this more or less obliquely, and, gaining the right side, turn ultimately backwards into the inner capsule. Now the anterior horn of the lateral ventricle lies considerably further forwards than the genu of the corpus callosum, and hence, in order to circumvent this obstacle to their gaining the inner capsule, they have to follow a circuitous course around it. When I found that the callosal tract was so well defined in perpendicular sections of the above-described fœtal brain, it immediately struck me that if my theory were correct, a *horizontal* section made through the tip of the frontal lobe ought to show the callosal fibres turning round the anterior horn of the ventricle, in order to enter the inner capsule. This proved to be actually the case, far beyond my expectations. A band quite as distinct as that seen in perpendicular sections is to be found in a fœtus of this age in horizontal sections, it runs from the corpus callosum forwards, outwards, and backwards, around the anterior horn of the ventricle. In the adult brain this band becomes so interwoven with other medullated fibres that it cannot be distinctly demonstrated.

As regards the future course of these fibres I cannot say anything further at present, as it would require a great wealth of illustration to make what I should like to say on the subject comprehensible. The main fact that I would wish to record in this brief communication is that which has been chiefly dwelt upon, namely, that the examination of the embryonic brain supports the conclusion I formerly arrived at of the corpus callosum being not a commissure, but in reality a decussation similar to that of the anterior pyramids.