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BRAIN.

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Original Articles and Clinical Cases.

ON THE DEVELOPMENT OF THE LARGE COMMISSURES OF THE TELENCEPHALON IN THE HUMAN BRAIN.

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THE brains of five human embryos, ranging from the beginning of the fourth month to the end of the eighth, were at my disposal for these researches. Two of these brains, one of the beginning and the other of the middle of the fourth month, were cut into a series of frontal sections. These sections were stained by means of hæmatoxylin and eosin. Of the three other brains only a median section was made for studying the later stages of development of the corpus callosum.

The sections I made of the brain at the beginning of the fourth month were 20 μ thick and slightly deviated from the frontal plane, so that the sections meet the hemisphere, which is on the left in the photographic reproductions, in a more posterior level than the one on the right. In this brain the anterior commissure is so far histologically differentiated that it can be recognized as a strand of a fibrous structure; among the fibres are spread the nuclei of glia cells. The diameter of the commissure amounts to 0.4 mm. The commissure lies partly in the lamina terminalis, covered from behind by the ependyma of this lamella. The more anterior part of the commissure probably exceeds the limit of the lamina terminalis. This limit cannot be traced out with certainty, because in front of the lamina, and in direct continuity with it, the mesial surfaces of the pallium are united.

The corpus callosum and the fornix are also recognizable, but the tissue composing these systems is not so far differentiated as that of the

anterior commissure. Both systems are built up by a reticular tissue, the meshes of which are irregularly shaped, with a prevalence of hexagonal ones. In one direction the meshes are stretched, whilst in another direction, at right angles with the first, the diameters of the meshes are pretty nearly equal. Now the direction in which the meshes are stretched coincides with the ultimate direction of the fibres which differentiate out of this meshwork. Therefore we are able to recognize in the sections different directions, in correspondence with the final course of the nerve fibres generated by this tissue. Beyond its particular structure the reticular substance of the corpus callosum and of the fornix stains more deeply with eosin than does the surrounding tissue; moreover, it is characterized by a considerable want of nuclei; only here and there glia cells with dark stained nuclei are met with. Large capillary loops are seen in the reticular substance of the corpus callosum, penetrating from the surrounding connective tissue into the substance of the commissure.

If we compare the tissue of the commissura anterior with that of the corpus callosum, the difference is very noticeable. In the anterior commissure the transverse septa have largely disappeared and the longitudinal septa have become thicker, resulting in a more fibrous structure. Moreover, the fibres are united in bundles, which are wrapped up by glia cells.

In order to determine the place where the corpus callosum originates I reproduce two frontal sections through the lamina terminalis. The first of these sections (figs. 1 and 1A) just touches, at the left, the ependyma (E.l.) of the lamina terminalis (L.t.). At this place the lamina is continued in a tænia (T.), which goes over into the mesial wall of the pallium. What appears in the preparation as a tænia is the transverse section of an ependymal membrane. This fleece is the continuation of the lamina terminalis, which is bent in and then passes over into the mesial wall of the pallium. A little backwards this membrane is invaginated into the lateral ventricle forming the ependymal covering of the plexus choroideus of this cavity.

Now in the lamina terminalis, at a little distance from its superior margin, the corpus callosum (C.c.) is situated. At the left appears the lateral border of the commissure. This edge is convex and bordered by the ependymal cells of the lamina terminalis. Here the section is torn, so that at the place I indicate by crosses the connection between the lamina terminalis and the wall of the pallium is broken. Going to the right in the section, the continuation of the callosum into the mesial

wall of the pallium is visible. The superior border of the commissure, so far as it lies in the lamina terminalis, is concave and covered from

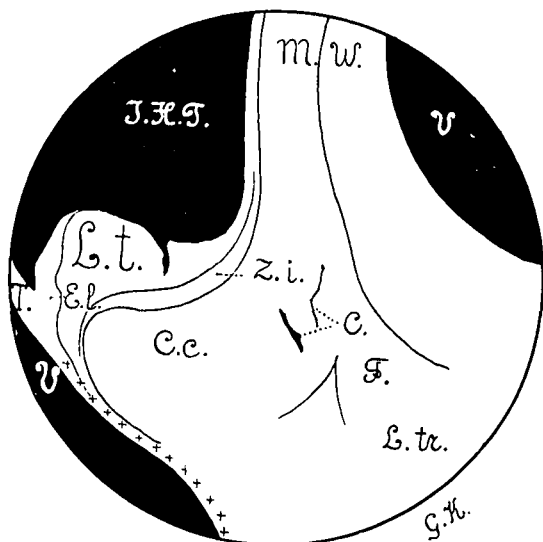


FIG. 1.

Frontal section through the lamina terminalis.

Human embryo of the beginning of the fourth month.

C., capillaries.

C.c., corpus callosum.

E.l., ependymal layer.

f., fornix.

J.H.T., interhemispherical tissue.

L.t., lamina terminalis.

L.tr., lamina trapezoidea.

M.W., mesial wall of the pallium.

T., taenia.

V., lateral ventricle.

Z.i., intermediate zone.

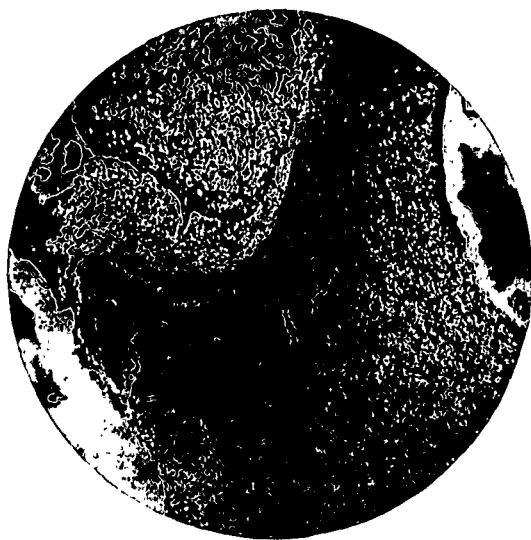


FIG. 1A.

Frontal section through the lamina terminalis.

Human embryo of the beginning of the fourth month. Photograph Zeiss obj. B.B, enl. $\frac{4}{5}$. Fig. 1 is the outline of this photograph; the crosses in that figure indicate the place where the section is torn.

above by the tissue of this membrane. The inferior border, which is the direct continuation of the lateral border, is convex

Aside from the corpus callosum, and entirely confined to the mesial wall of the pallium, lies the fornix (F). In the mesial wall the two systems cannot be distinguished. At the place where the systems diverge the difference becomes evident, the callosum forming a dense meshwork, whilst the tissue of the fornix spreads out in passing over into the lamina trapezoidea (His). Apart from the spreading out there is also the difference in the form of the meshes, those of the fornix being more stretched.

In figs. 2 and 2A I reproduce a section through the most posterior part of the callosum (C.c.) lying in the lamina terminalis. It shows this most posterior part also at a little distance from the superior border of the lamina. The tissue in which it is imbedded (Z.i.) consists of cells, the nuclei of which are more distant and stain less intensely than those of the ependyma. A narrow band of this tissue penetrates between the commissure and the ependyma, which is situated at the left and underneath the commissure. The same fact may be observed in fig. 1, where at the left a small strip of this tissue is also interposed between the callosum and the ependymal layer of the lamina terminalis. This proves that the posterior part of the callosum, though situated in the lamina terminalis, does not touch the ependyma, but is always separated from it by a thin layer of non-ependymal cells. These cells belong to the layer which in this stage of development is described by His as the intermediate layer (*Zwischenschicht*) [8 (pp. 91, *et seq.*)] of the wall of the pallium. The distance by which the most posterior part of the callosum is separated from the posterior surface of the lamina terminalis amounts to 0.1 mm.

In the more frontal region of the callosum the relations are less simple, being complicated by the union of the mesial walls of the pallium. The fronto-occipital diameter of the united part of the lamina trapezoidea attains to 0.32 mm. Both pallia meet in the zone of union at a sharp angle, in which the interhemispherical tissue (commonly called the falx cerebri) penetrates like a wedge. This formation is built up by fusiform cells with elongated nuclei; as to its structure, it is a lacunar tissue, the lacunae of which are filled up with blood-corpuscles. At a little distance from the wall of the pallium the lacunae are wide, and as such easily recognizable, but approaching the wall they become smaller, and at last are not to be distinguished from the small slits always occurring in connective tissue. In these small clefts, however, I often find one or two blood-corpuscles. For this reason I believe that at least some of these clefts have a connection with the larger lacunae. Besides

these lacunæ small blood-vessels are met with in this tissue which pass over into capillaries. Quite near the wall of the pallium the nuclei of

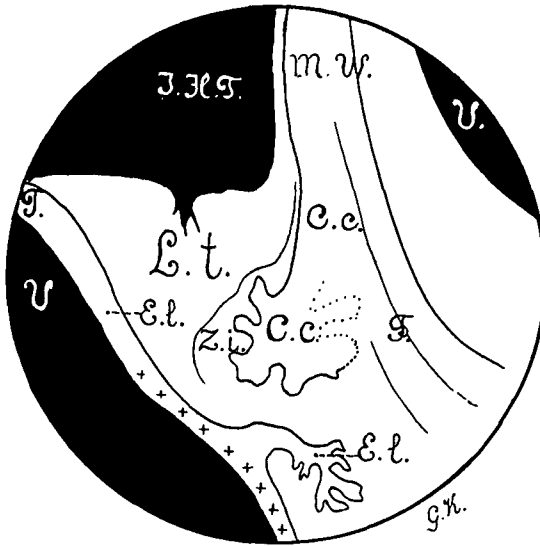


FIG. 2.

Frontal section through the lamina terminalis just touching the most posterior part of the corpus callosum.

Human embryo of the beginning of the fourth month.

C.c., corpus callosum.

E.l., ependymal layer.

F., fornix.

I.H.T., interhemispherical tissue.

L.t., lamina terminalis.

M.W., mesial wall of the pallium.

T., tænia.

V., lateral ventricle.

Z.i., intermediate zone.



FIG. 2A.

Frontal section through the lamina terminalis just touching the most posterior part of the corpus callosum.

Human embryo of the beginning of the fourth month. Photograph Zeiss obj. B.B., enl. $\frac{4}{7}$. Fig 2 is the outline of this photograph; the crosses in that figure indicate the place where the section is torn.

the connective tissue are arranged with their long axes parallel with this wall. The outer surface of the pallium itself is covered by a thin layer

of glia cells with rounded nuclei. This sheath is one cell thick. Approaching the zone of union the elongated nuclei converge towards the top of the wedge so that this top is formed by two or three of these nuclei. Now these nuclei are pressed together very flat, perhaps a little longer than the nuclei of the adjacent cells, and thereabove curved, or bent like an S. At some places one of these nuclei seems to penetrate a little into the substance of the corpus callosum and is less stained than the other nuclei. I should be inclined to interpret the process I just now described as a marginal atrophy of the interhemispherical tissue.

The substance of the corpus callosum along the lateral border of this wedge-shaped interhemispherical tissue shows stretched meshes; towards the top these meshes become shorter and more hexagonal, whilst at the same time they become smaller. The mesh-work itself at this spot stains more deeply with eosin. The whole structure gives the impression as if the tissue of the callosum sharply bends round the top of the interhemispherical tissue and is compressed. I think, therefore, that the growing commissure exerts a pressure upon the interhemispherical tissue and that this is the direct cause of the atrophy of this membrane.

Now this process of atrophy must be sharply distinguished from the ingrowth of capillaries into the commissure. In the brain under description these capillaries mainly penetrate from above through the superior border of the lamina terminalis. Not only capillaries, but also a larger blood-vessel, pierces this lamina. At the border of the commissure the vessel goes over into a capillary that penetrates into the callosum (C.c., fig. 1). It follows already from the bare topographical relations that the atrophy of the interhemispherical tissue and the ingrowth of capillaries from this tissue are two distinct processes, which may take place independently of each other. In most cases, however, especially in the more advanced stages of the development, the two processes are mixed up in such a manner as to make an analysis quite impossible. From the drawings of Zuckerkandl [30] I should be inclined to conclude that in the rat this is the case from the very first. Probably the difficulty which the analysis offers in this case induced the author to describe a *Durchwachsung* of the falx cerebri by the fibres of the callosum. In my opinion this statement is erroneous, as I never found free ending fibres nor rudiments from the connective tissue other than in direct connection with the blood-vessels that pierce the lamina terminalis and penetrate into the commissure.

The fronto-occipital diameter of the callosum amounts to 0.5 mm.; about one-third of this (0.18 mm.) is situated in the lamina terminalis,

and two-thirds (0.32 mm.) transgress the limits of the lamina and lie in the zone of union. The thickness of the lamina terminalis attains to 0.28 mm. Fig. 3 represents these relations diagrammatically.

The most posterior part of the callosum passing over from the lamina terminalis into the wall of the pallium is recurved backwards. It may be followed for some distance in an occipital direction, reminding one of the final state when there is a forceps major. In the same way the more anterior part of the callosum is continued in a frontal direction. The fornix, which lies laterally of the callosum, cannot be distinguished from it in the more occipital region. There the two structures together occupy a triangular field with its top turned upwards. The impossibility of discriminating between the two structures is caused by the fact that in this region the fornix and the callosum have about the same direction, so

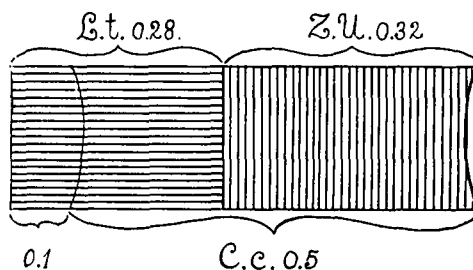


FIG. 3. Enl. $\frac{100}{1}$.
C.c., corpus callosum.
L.t., lamina terminalis.
Z.U., zone of union.

that there is no appreciable difference in the shape of the meshes. At the place where the callosum passes over into the lamina terminalis the two structures diverge, and this produces a difference in the shape of the meshes in the frontal section. The fornix spreads out and goes over into the lamina trapezoidea on its way to the hypo-thalamus. In the more frontal region the fornix is no longer present and only the callosum remains in the wall of the pallium. Callosum and fornix in the lamina terminalis, as well as in the mesial wall of the pallium, are strictly confined to the intermediate layer of this wall.

In its general features I find that the structure of the mesial wall of the pallium corresponds with the description given by His [8 (pp. 91 and 111)]. First comes an ependymal layer bordering the lateral ventricle, then a matrix (*Matrix*), next the intermediate stratum (*Zwischenschicht*); upon this follows the cortex layer (*Rindenschicht*), which is

followed by a marginal zone (*Randschicht*), covered from the outside by a thin sheath of glia cells (*membrana limitans externa*). Changes appear in this structure at the level occupied by the callosum (*cf.* figs. 9 and 9A). The matrix layer becomes thinner, those cells arranged tangentially in respect to the surface of the pallium wall disappearing first, those radially placed disappearing next. The breadth of the intermediate layer increases, and at the same time this stratum gets richer in nuclei, especially around the fibres of the commissure; these nuclei surround this structure like a cap (C.n.). The cortex layer, like the matrix, becomes thinner, bends somewhat inwards and ends in a sharp edge at a little distance from the under border of the mesial wall of the pallium. Now, in this stage of development this ending of the cortex is not so evident as it is afterwards (figs. 9 and 9A). The difference in the density of the nuclei between the intermediate layer, the cortex and the marginal zone, at the level of the edge of the cortex, is trifling, so that it is difficult here to recognize the cortex layer. That the cortex really does end may be deduced from the fact that the nuclei of this stratum show a radial arrangement, whilst this is not the case with the nuclei of the two other strata. Therefore I cannot agree with the statement of His [8 (p. 129, figs. 84 and 86)] that the cortex layer is enlarged and forms a prominence at the external surface of the pallium.

Neither have I been able to find a fissura arcuata, but at about the same level, where it is described by Goldstein [5], the inner surface of the mesial wall shows a notch. In the frontal region this indentation begins very flat, but towards the level of the lamina terminalis it grows deeper and sharper. With the indentation of the inner surface corresponds a notch at the outer surface, which lies a little lower; at the same time the wall of the pallium grows thinner, so that the place between the two notches is the most slender part of the pallium wall. In my sections there is at this place a beginning of folding in of the wall, which is doubtlessly artificial. I therefore agree in this matter with Hochstetter [9], Mall [14], Retzius [20], Goldstein [6], and others who consider the folds of the wall of the pallium in these stages of development purely artificial.

The brain of the embryo of the middle of the fourth month was not so well preserved as the first one. The embryo, when born, showed symptoms of luetic infection. In the frontal region, at the place of the arched fissure, the wall of the pallium on both sides is folded in exactly as is drawn by His [8] in fig. 86. This fold,

in the region of the callosum, goes over into a rupturing of the wall. At the place of the rupture the walls are bent in, so that these parts of the mesial walls, which are adjacent to the callosum, diverge abnormally. This divergence influences the form of the interhemispherical tissue, but not in such a degree as entirely to disturb the normal relation of this structure to the mesial wall of the pallium. It appears, from a comparison of the various dimensions, that this brain agrees in all respects with that described by Goldstein [5]. The

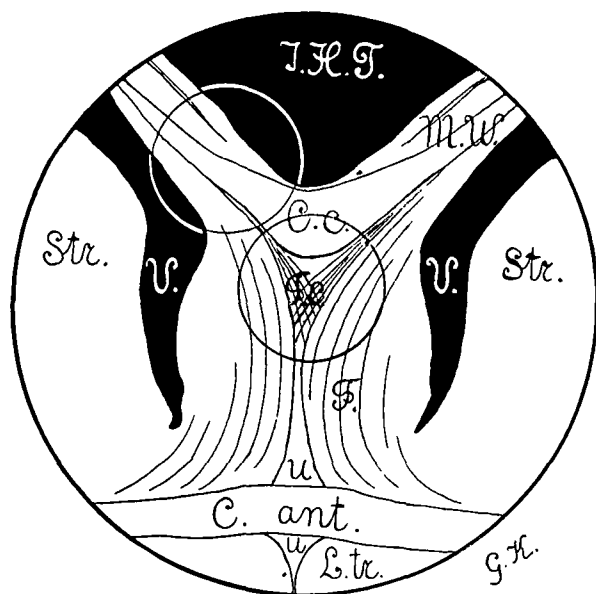


FIG. 4.

Frontal section through the zone of union at the more posterior part of the callosum.

Human embryo of the middle of the fourth month.

Outline of a photograph, enl. $\frac{1}{2}$.

C. ant., anterior commissure.

C.c., corpus callosum.

F., fornix.

F.c., fornix commissure.

I.H.T., interhemispherical tissue.

L. tr., lamina trapezoida.

M.W., mesial wall of the pallium.

Str., striatum.

U., zone of union.

V., lateral ventricle.

sections I made varied in thickness; some are $15\ \mu$, some are $20\ \mu$, according to the region of the cerebrum.

In this brain the anterior commissure has a diameter of $0.6\ \text{mm}$. The more frontal part lies in the zone of union, the more posterior part in the lamina terminalis, covered from behind by the ependyma. It protrudes into the cavity of the third ventricle, a relation which is also often met with in the adult state. Large glia cells from the zone of union are spread between the various fasciculæ of the commissure. The corpus callosum lies entirely in front of the foramen of Monro, its posterior border agreeing exactly with the frontal border

of the foramen. The tissue of the commissure is further histologically differentiated, having at this stage a more fibrous structure. This is also the case with the fornix. The fronto-occipital diameter of the callosum amounts to 2.4 mm. The most posterior part of it still lies in the lamina terminalis, but this relation is by no means so evident as it is in earlier stages of development. The lamina itself has become thicker, attaining now to a diameter of about 0.5 mm.

Fig. 4 gives the outlines of a section through the zone of union at the more posterior part of the callosum. The great commissure (C.c.) forms a closed system, which occupies the most dorsal part of this zone. On both sides the fibres of the commissure pass over into

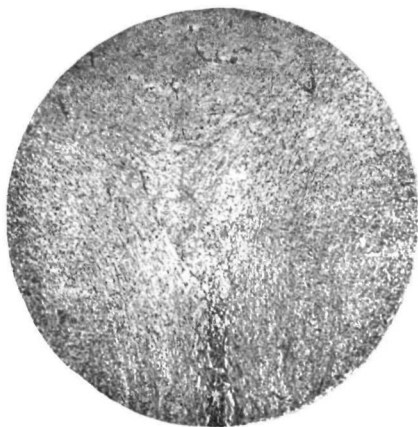


FIG. 4A.

Photograph of that part of the section which is indicated by a black circle in fig. 4.
Photograph Zeiss obj. B.B., enl. $\frac{3}{4}$.

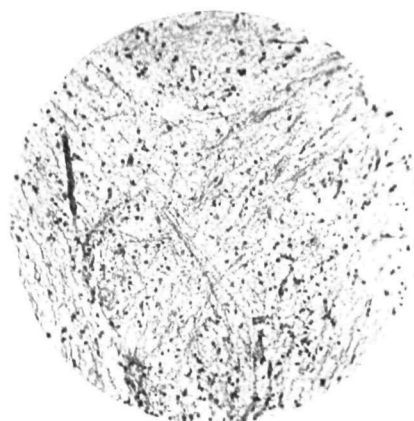


FIG. 4B.

Same section as fig. 4A; fornix commissure more strongly magnified.
Photograph Zeiss obj. D.D., enl. $\frac{7}{4}$.

the mesial wall (M.W.) of the pallium in the same way as in the foregoing stage the fornix (F.) lies laterally of the callosum. The bundles of the fornix spread out as they pass over into the lamina trapezoidea (L. tr.). They may be followed in the section as far as the anterior commissure (C. ant.), when they bend sideways in crossing this system.

At the angle where callosum and fornix meet, a bundle of fibres appears, coming from behind. This bundle spreads towards the median plane and crosses a bundle coming from the opposite direction. This crossing system belongs to the fornix, and represents the fornix commissure (F.c.). These relations may be illustrated by fig. 4A, which

is the photographic reproduction of that part of the section that is indicated by a black circle in fig. 4; and by fig. 4B, which shows the structure of the fornix commissure more strongly magnified.

The crossing of the fornix fibres lies entirely in the zone of union, as the glia nuclei can be followed dorsally of this commissure and even in the adjacent layers of the callosum. The fronto-occipital diameter of the fornix commissure is 0.24 mm. In respect to the callosum, the fornix commissure is situated in such a way that the posterior border of the callosum exceeds the posterior border of the fornix commissure by 0.6 mm. Fig. 5 represents this relation diagrammatically.

In the region in front of the fornix commissure the callosum lies in the zone of union, whilst the fornix is confined to the mesial wall of the pallium and its continuation, the lamina trapezoidea. Only the most internal fibres of the fornix leave the wall of the pallium and pass

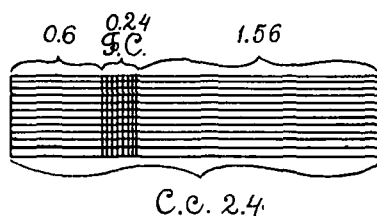


FIG. 5.

C.c., corpus callosum.
F.C., fornix commissure.

through the glia tissue of the zone of union. From the relation I described between the callosum, the fornix and the fornix commissure, I should be inclined to conclude that the more posterior part of the corpus callosum in this stage of development already agrees with the splenium, as in the adult stage only this part of the commissure shows the same relation to the fornix commissure; it follows from the topographical relation of the more anterior part of the corpus callosum to the fornix bundles that this part of the large commissure agrees with the corpus and the genu of the callosum in the adult stage. Now, this view is further supported by the course of the fibres of the callosum. The more posterior fibres passing over into the mesial wall of the pallium bend in occipital direction, exactly in the same way as do the fibres from the splenium.

The same relation exhibits the more frontal fibres in respect to the frontal region of the brain, whilst the fibres of the middle part of the

callosum have a more transverse direction. Moreover, the position of the fibres is such that in the posterior part of the callosum the fibres coming from more posterior regions lie nearer the surface than those coming from more anterior regions. Now the fibres, in proportion as they come from more occipital regions, have a more horizontal direction in the wall of the pallium, and this is the reason why in the preparations the frontal section of the callosum is triangular. The anterior part of the callosum shows a symmetrical condition in respect to the frontal region of the brain. In a schematic figure His [8] gives the same relations for a somewhat older embryo (fig. 93); only I have not been able to find the free ending fibres that His represents.

The zone of union of the pallia, in the frontal section, is triangularly shaped, with the base turned downwards (U, fig. 4). From above it is bordered by the callosum, laterally by the fornix bundles, and from below by the anterior commissure. It extends also a little below this commissure. This field is also triangular, the base resting against the commissure and the top turned towards the ependyma of the third ventricle. The tissue of which it is composed consists of glia cells. These cells are flat and mostly square or hexagonal. The nucleus is round and large and lies within a cell body that stains deeply with eosin. The cells form a meshwork with small meshes. The glia cells penetrate between the fibres of the callosum and also between the more internal bundles of the fornix. At the place where the anterior commissure passes through the zone of union they enter in large numbers into the substance of this commissure.

In the more posterior part of the zone of union, at the level of the commissure of the fornix, the structure of this tissue becomes loose in its middle portion (figs. 6 and 6A, l.p.). Here the nuclei are more distant, some of them are larger, and stain badly with hæmatoxylin; at the same time the meshes become larger. Adjacent to the fornix bundle the tissue is more dense (d.p.); the transitions between the looser and the denser parts are pretty abrupt. Now in my opinion we have here to deal with the beginning of a cleavage in the glia tissue as a rudiment of the *cavum septi lucidi*. The process extends in a fronto-occipital direction over a distance of 0.25 mm. As may be observed in the photographic reproduction (fig. 6A), the difference in the structure of the tissue does not give the impression of being artificial, because the shrinking of the tissue has only caused rents and fissures which are easily recognized. Independently of the mode of origin of the *cavum*, it is evident that the *septum lucidum* comprises more than the original

mesial wall of the pallium, for the most internal fibres of the fornix pass through the glia tissue of the zone of union. The process of

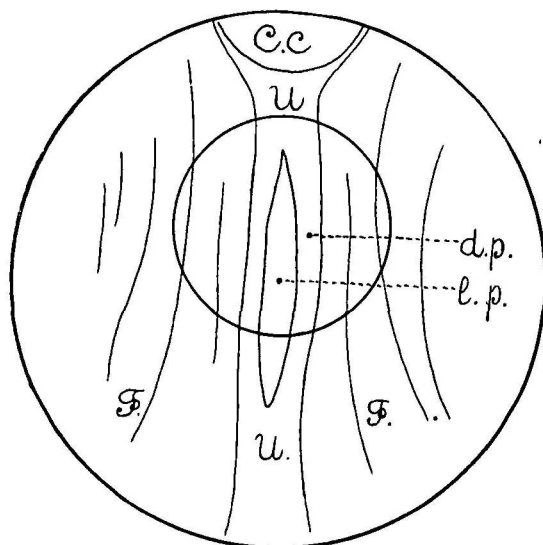


FIG. 6.

Frontal section through the more posterior part of the zone of union, at the level of the fornix commissure.

Human embryo of the middle of the fourth month. Outline of a photograph enl. $\times 7$.

C.c., corpus callosum.

d.p., dense part of the glia tissue.

F., fornix.

l.p., loose part of the glia tissue.

U., zone of union.



FIG. 6A.

Photograph of that part of the section which is indicated by a black circle in fig. 6. Zeiss obj. D.D., enl. $\times 24$.

union of the two pallia does not differ in its general features from the process I described in the younger stage. Only the atrophy of the

interhemispherical tissue and the ingrowth of capillaries coincide at several places and makes an analysis of the process illusory. At these spots at first sight a distinct line of demarcation between the interhemispherical tissue and the mesial wall seems to fail, but a close observation seldom fails to reveal some vestige of this line of demarcation. By the ingrowth of the capillaries the mesial wall gets, in the frontal section, a serrated appearance, and this causes distinct demarcation to disappear.

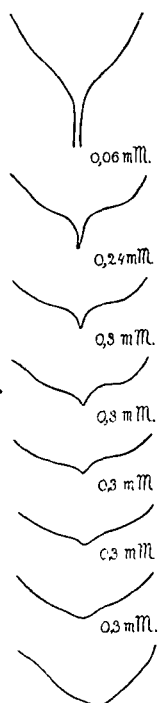


FIG. 7.

Successive profiles of the zone of union; the numbers indicate the fronto-occipital distance between the successive profiles.

Human embryo of the middle of the fourth month.

In the more frontal part of the zone of union the walls of the pallium meet at an acute angle, into which the interhemispherical tissue penetrates. The fibres of the callosum sharply bend round the top of the connective tissue. I have not seen any fibres ending free near the edge of the pallium wall in front of the zone of union. Going backward the notch between the two pallia gets more and more flattened and superficial (fig. 7). The fibres of the callosum show an equivalent relation and are still pressed against the notch.

From the combined observations I should be inclined to believe that the enlarging commissure pushes forward the interhemispherical tissue,

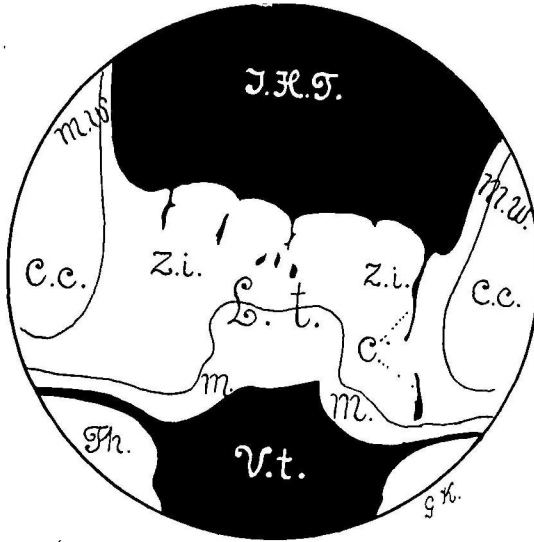


FIG. 8

Frontal section through the lamina terminalis behind the corpus callosum.

Human embryo of the middle of the fourth month. Enl. $\frac{1}{4}$.

C., capillaries.

C.c., corpus callosum.

I.H.T., interhemispherical tissue.

L.t., lamina terminalis.

M., matrix.

M.W., mesial wall of the pallium.

Th., thalamus.

V.t., third ventricle.

Z.i., intermediate zone.



FIG. 8A.

Frontal section through the lamina terminalis behind the corpus callosum.

Human embryo of the middle of the fourth month.

Photograph Zeiss obj. B.B., enl. $\frac{1}{4}$.

Fig. 8 is the outline of this photograph.

and partially brings it to atrophy. The question often put forward, whether the union of the pallia takes place in consequence of the

protrusion of the lamina terminalis or otherwise by a more direct process, is a very subtle one; my preparations are not sufficient to enter upon this question.

Behind the corpus callosum the lamina terminalis (figs. 8 and 8A) is continued over a short distance (0.6 mm.). The posterior border of the lamina is folded in and goes over into the lamina choroidea of the third ventricle. It forms the roof of the foramen of Monro, and has no direct relation to the callosum. In its structure this part of the lamina agrees with the adjacent mesial wall of the pallium. The lamina consists of an ependymal layer turned towards the foramen of Monro, then a matrix (M.) and thereupon an intermediate layer (Z.I.). A distinct cortex and marginal zone do not seem to exist. The diameter of the lamina attains 0.44 mm. From the outside a large number of capillaries (C.) penetrate into the lamina, and this produces in a frontal section the curled appearance of the border of the lamina. This curling has therefore no direct relation to the process of union, as this part of the lamina terminalis never unites with any part of the mesial walls.

The structure of the mesial wall (figs. 9 and 9A) agrees with the description I have given of the younger stage, only the different layers are more clearly differentiated. At the place of inflexion and rupturing the mesial wall is most slender; towards the inferior border the wall increases in thickness, producing a club-like appearance in the frontal section. In this thickened part of the wall the callosum and fornix (C.F.) are situated.

Concerning the relations of the different layers, I have but little to add. In the more frontal region the cortex layer, at the level of the callosum, becomes looser and is continued into the cortex layer of the lamina trapezoidea. About the fore-edge of the zone of union, instead of loosening, the cortex layer becomes discontinuous, ending with a free, sharp edge (C.I.). At a single place, however, this edge is a little swollen, but in no case have I seen the protrusion of the surface of the pallium wall by the cortex layer. In this stage of development it may clearly be seen that the nuclei of the intermediate layer penetrate into the marginal zone (Z.m.n.) round the edge of the cortex layer, and cause this zone to disappear as a distinct layer. These nuclei are continued over the dorsal surface of the callosum. Also in this stage of development the commissure is strictly confined to the intermediate layer of the pallium wall; that this is really the case is clearly demonstrated by a section passing behind the foramen of Monro; there the under border of the pallium shows very distinctly a marginal zone, and nowhere fibres of

the callosum are to be found piercing this zone and reaching the surface of the wall of the pallium.

In the same way as described for the posterior part of the lamina terminalis, the mesial wall is also curled by the ingrowth of capillaries

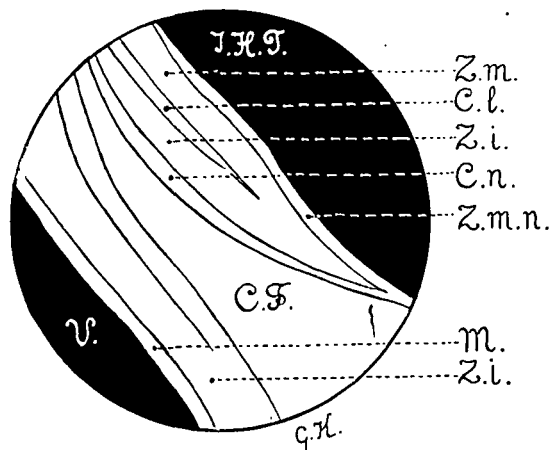


FIG. 9.

Frontal section through the mesial wall of the pallium at the place indicated by a circle (partly black, partly white) in fig. 4. The section from which the photograph is taken lies well behind the section of fig. 4. Enl. $\frac{3}{4}$.

C.F., corpus callosum and fornix.
C.l., cortex layer.
C.n., cap of nuclei surrounding the callosum fornix.
I.H.T., interhemispherical tissue.
M., matrix.
V., lateral ventricle.
Z.i., intermediate zone.
Z.m., marginal zone.
Z.m.n., nucleated part of the marginal zone.

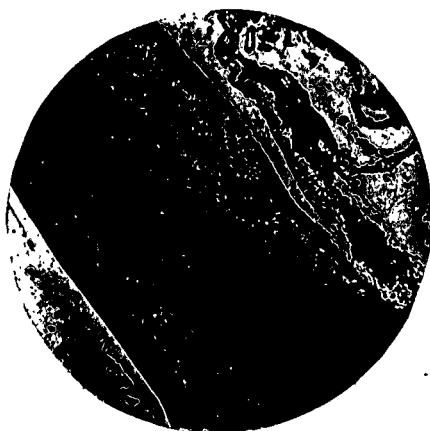


FIG. 9A.

Photograph of the mesial wall of the pallium; fig. 9 is the outline of this figure. Photograph Zeiss obj. BB, enl. $\frac{3}{4}$.

from the interhemispherical tissue. In its structure this tissue does not differ from the description given in the younger stage, and I only wish to call attention to the abundance of large blood-sinuses in the connective tissue in this stage of development.

I have no material of the stage of development when the mesial walls

begin to unite behind the foramen of Monro, so that for these later stages I can only add some superficial observations I gathered on inspection of median sections.

As a consequence of the enlargement of the corpus callosum the zone of union also increases. Dorsally of the foramen of Monro the posterior border of the callosum expands in an occipital direction and causes the mesial walls of the pallium behind the foramen to unite. At the same time with the enlargement, the callosum and the fornix bundle diverge, forming together a V lying on its side with the top turned backward. In frontal direction as well the callosum enlarges, forming the rostrum; under the influence of the expansion of the commissure in this direction the zone of union also increases. In the relative position of the systems of fibres no changes occur. The fornix bundle remains in a position lateral to the callosum in the reconstructed mesial wall of the pallium; the fornix commissure still lies ventrally of the callosum in the glia tissue of the zone of union. This latter relation is clearly seen in fig. 10, which is the reproduction of a drawing made of the median section of a brain of the end of the fifth month. Here the postero-inferior border of the callosum goes over into a beak, which is prolonged into a lamina (L.i.f.) that unites the two fornix bundles. In the beaked prolongation and adjacent to the callosum lies the fornix commissure (C.f.). If a frontal section were made at an appropriate level, this section would show the same relations as the sections reproduced in fig. 4, with the sole difference that a continuation of the cavum septi extends between the two commissures. The cavum septi, once formed, enlarges in a frontal as well as in an occipital direction, in correspondence with the enlargement of the callosum. On both sides of the median plane the posterior part of the cavum septi shows a protusion laterally of, and underneath, the callosum (R.pl.). In the same way as this recessus postero-lateralis there is a recessus antero-lateralis (R.a.l.), but this niche is by no means so well developed as the posterior one.

Now, from the fact that the fibres which compose the callosum show a regular arrangement in respect to the regions of the pallium they connect, it is obvious that the development of the pallium influences the form of the callosum. This is shown by the form of the splenium, which at the stage of development shown in the drawing is not yet rolled in. The rolling in of the splenium seems to be caused by the further differentiation of the lobus occipito-temporalis, to which the larger number of the fibres of the splenium belong. Now, the splenium follows the temporal

lobe when bending round the thalamus in frontal direction, and consequently is rolled in. By the rolling in of the splenium, callosum and fornix bundle approach each other, so that the posterior part of the cavum septi becomes smaller and the recessus postero-lateralis is reduced

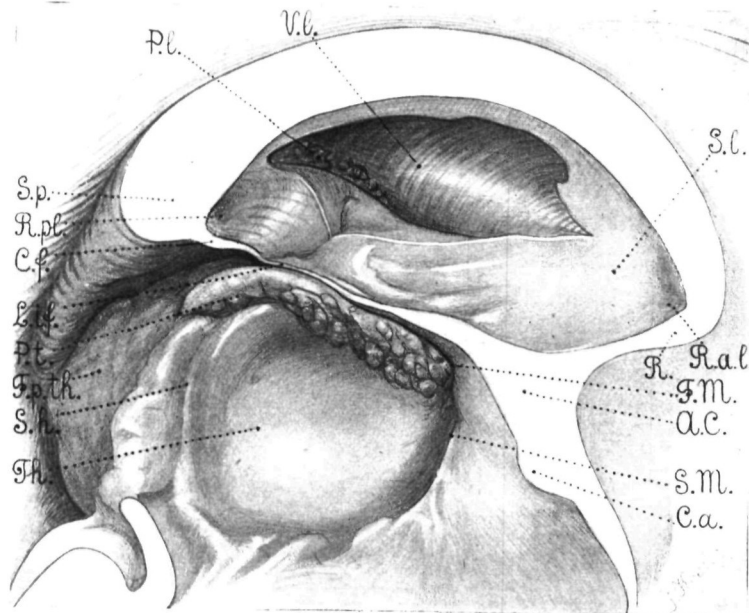


FIG. 10.

Drawing of the median section of a brain of the end of the fifth month, enl. $\frac{1}{2}$.

- A.C., anterior part of the zone of union.
- C.a., anterior commissure.
- C.f., fornix commissure.
- F.M., foramen of Monro.
- F.p.th., posterior surface of the thalamus.
- L.i.f., lamina interforncaria.
- P.l., choroid plexus of the lateral ventricle.
- P.t., choroid plexus of the third ventricle.
- R., rostrum.
- R.a.l., antero-lateral recesses.
- R.pl., postero-lateral recesses.
- S.h., sulcus habenularis.
- S.l., septum lucidum.
- S.M., sulcus of Monro.
- S.p., splenium.
- Th., thalamus, mesial surface.
- V.l., lateral ventricle.

to a transverse slit. The posterior narrowest part of the cavum—the ventriculus Vergæ—in most cases in the new-born still communicates with the anterior part of the cavum septi.

From these stages of development as reproduced in the drawing it

seems evident that the lamina that unites the two fornix bundles (L.i.f.)¹ is a remainder of the zone of union, for this lamina in frontal direction continuously goes over into the anterior part of this zone (A.C.), in which the commissura anterior (C.a.) is situated. Occipitally the lamina is continued in the prolongation in which the fornix commissure is located, and this tissue is also doubtlessly a remainder of the posterior part of the zone of union. The uniting lamina between the two fornix bundles in the adult stage shows exactly the same relation, only these parts of the zone of union into which it is continued are more reduced. Therefore this lamina, for which I should propose the name of "lamina interforin-caria," belongs neither to the corpus callosum nor to the fornix bundle, but is a remnant of the zone of union. Consequently the union of the fornix bundles in the median plane is a secondary one, and this explains, I believe, the relation that the lamina interforin-caria shows in respect to the fibres of the alveus, a connection to which Dejerine [3 (p. 278)] has given much attention.

SUMMARY.

(1) The anterior commissure precedes in its histological differentiation the corpus callosum and the fornix commissure.

(2) In a stage of development in which the diameter of the corpus callosum amounts to but 0.5 mm., about one-third of the commissure lies in the lamina terminalis and two-thirds in the zone of union.²

(3) From the relation of the corpus callosum to the fornix and to the fornix commissure it follows that the callosum at its first appearance shows all the essential features of the commissure in the adult stage.

(4) The interhemispherical tissue atrophies before the enlarging commissure.

(5) The true histological nature of the process of union of the walls of the pallium I must leave undetermined.

(6) The corpus callosum remains strictly confined to the intermediate layer of the wall of the pallium.

(7) In the region of the callosum the cortex layer of the mesial wall ends in a sharp edge.

(8) The cavum septi lucidi is probably formed by a cleavage in the glial tissue of the zone of union.

(9) The lamina interforin-caria is a derivative of the zone of union.

¹ This structure is described by Marchand [15] under the name of "Bodenlamelle des Cavum septi "; by Martin [16] as "Verlängerte Schlussplatte "; and by Dejerine [3] as the "lamina intertrigonalis."

² Unless we consider the zone of union a direct derivative of the lamina terminalis, this result is partly in contradiction with the explicit statement of Elliot Smith in "Morphology of the True Limbic Lobe." [25 (p. 198)].

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