NORMAL AND ABNORMAL NEGROID SEPTA PELLUCIDA

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AND

THE GENESIS OF THE CAVUM SEPTI PELLUCIDI

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TABLE OF CONTENTS

A. NORMAL AND ABNORMAL NEGROID SEPTA PELLUCIDA

1. INTRODUCTION

An unusual abnormality of the septum pellucidum discovered during the course of the dissection of a negroid (Zulu) body warranted, in the opinion of the writers, a re-examination of the anatomy and origin of this structure. It was found that the descriptions current concerning this region of the forebrain were for the most part inadequate and the conceptions concerning its arrangement and origin highly conflicting. It was, therefore, felt desirable to preface the description of the abnormal septum with a short account of the types of septum usually found in the negroid races of South Africa.

2. MATERIAL

Among the natives employed in the Witwatersrand area are to be found representatives of nearly all the negroid races which inhabit not only the

Union of South Africa but also Central and East Africa. The result is that the material for investigation is not only considerable but very varied. The septum pellucidum was examined in twelve brains obtained from individuals of the following races: Basuto 3, Zulu 2, Nyambaan 1, Morolong 1, Xosa 2, Shangaan 2, and Pondo 1.

3. THE SEPTUM PELLUCIDUM IN THE NEGROID RACES OF SOUTH AFRICA

(a) *The septum as a whole*

The septum pellucidum is the thin vertical partition which intervenes between the anterior parts of the two lateral ventricles of the forebrain in certain mammals. It is attached to the corpus callosum above and to the rostrum of the corpus callosum and the body of the fornix below. It is roughly triangular in shape; the base of the triangle is formed by the rostrum and the sides by the body of the corpus callosum above and the body of the fornix below. The two sides slope backwards to form an acute angle at the apex of the triangle. The base which presents a slight upward convexity extends from the angle at the bend of the genu in front to a point on the upper surface of the anterior commissure behind. It is fairly constant in length, measuring about 1 cm. The upper side of the triangle is formed by the curved under surface of the body of the corpus callosum and extends from the angle at the bend of the genu in front to a point where corpus callosum and fornix meet behind. The lower side of the triangle is the curved upper surface of the body of the fornix; it extends from a point on the dorsum of the anterior commissure in front to that point previously mentioned where it meets the upper side of the triangle posteriorly. In some brains this point corresponds with the point of bifurcation of the body of the fornix posteriorly, but in the majority of cases this relationship does not hold. Where a long septum exists each of its laminae secures an attachment to the crura as well as to the body of the fornix, i.e. the lower side of the triangle is formed in front by the body and behind by the crus of the fornix. This variation in relationship will be referred to again when we come to consider the cavum septi pellucidi.

The angles of the triangle may be described as anterior, posterior and inferior. The anterior angle is the angle formed by the genu and is blunt and rounded; the inferior angle rests on the anterior commissure and is approximately a right angle, while the posterior angle is acute. Obersteiner and Hill name that portion of the septum which passes down to the upper surface of the anterior commissure, i.e. the inferior angle, the pedunculus septi pellucidi. The length of the septum pellucidum as measured along the upper side of the triangle is extremely variable. In twelve negroid brains taken at random, it varied from 2·5 cm. to 4 cm., with an average length of just under 3 cm. The lower side of the triangle is shorter than the upper side and varies according to the length of the latter.

(b) *Laminae*

The septum is bilaminar, the two laminae enclosing a space called the cavum septi pellucidi (*O.T.* Vth Ventricle). The laminae are thin, triangular sheets of neuroglial tissue containing a variable amount of grey and white substance. The actual line of attachment of each lamina is from 1 to 2 mm. from the middle line. The laminae slope slightly from above downwards and inwards so that they are slightly further apart at their callosal attachments superiorly than at their fornical attachments inferiorly. The lateral or ventricular surface of each lamina forms a portion of the medial wall of the anterior horn of the lateral ventricle in front and of a variable portion of the central part of that cavity behind. It is covered by ependyma and is bathed by cerebrospinal fluid. The medial surface of the lamina is lined by a thin smooth layer of condensed neuroglial tissue and forms the lateral wall of the cavum septi pellucidi. The thickness of the laminae is very variable. In some brains they are very thin and translucent, in others almost 1 mm. thick and practically opaque. On holding laminae up to the light, we have noticed that not only are there marked differences in different brains, but the individual laminae by no means present a uniform structure throughout. Opaque areas alternate with translucent areas, and running across the lamina are translucent streaks formed by blood-vessels. While there is no absolutely constant arrangement of these areas, one finds that the less translucent areas are massed together along the upper and lower margins of the lamina, while the central strip is usually fairly clear. Further, there appears to be a greater tissue density immediately above and below the veins which show themselves as clear streaks running across the lamina.

(c) *Blood-vessels*

Very little information concerning the blood-vessels of the septum pellucidum has been obtained by a perusal of the literature at our disposal. MacAlister states that a small vein is present in each lamina and forms a conspicuous feature in it. The arteries which supply the septum are stated in Gray's *Anatomy* to be the antero-medial ganglionic branches of the anterior cerebral arteries. A number of brains have been injected, the vessels chosen being the anterior cerebral arteries and the great vein of Galen, and it is our intention, at a later date, to give a more comprehensive account of the blood-vessels of the septum. The following preliminary remarks may, however, be made now concerning the veins.

On holding up a lamina to the light, one well-marked vessel, which we may, for convenience sake, term the "inferior vein of the lamina," is clearly visible. It is a large vein which runs horizontally backwards in the lower half of the lamina and is seen more distinctly on its ventricular surface. It begins in the neighbourhood of the genu of the corpus callosum, and, after traversing the lamina, it skirts the lateral surface of the fornix to end at the upper margin of the foramen of Monro in the choroidal vein, near its junction with the terminal vein. It receives numerous tributaries which run backwards along the roof of the anterior horn of the lateral ventricle, bend downwards to descend by way of the lamina and end in the main vein at an acute angle. A few tributaries running in the floor of the anterior horn enter the lamina below and run upwards and backwards to join the main vein.

Another large but less constant vein, the "superior vein of the lamina," runs along the upper border of the lamina. It also is more apparent on the ventricular surface of the lamina. It proceeds backwards between the corpus callosum and the body of the fornix to open into the choroidal vein about an inch from its termination at the foramen of Monro. It receives tributaries from the roof of the lateral ventricle. When the superior vein is absent these last-named vessels descend to join the inferior vein. On the medial surface of the lamina only a few very small vessels are found, and these are present only in certain cases. They run downwards and forwards to enter the main vein of the lamina.

In connection with what has already been stated concerning the increased translucency of the central strips of the laminae examined, it was of interest to find a number of cases in which the areas of the central strip adjacent to the main vein was the most attenuated portion of the whole lamina. This attenuation will be discussed later in detail, as it appears to us to have a distinct bearing upon the abnormal septum to be described later. It is sufficient for our present purpose to indicate that it may point to some tensile process at work in the lamina. The thinning is most marked in these particular cases alongside the relatively fixed line afforded by the main vein.

(*d*) *Minute anatomy*

The minute structure of the lamina of the septum is described in Quain and by Piersol, Obersteiner and Hill and others. In each description there are minor differences which may be accounted for by the fact that there is considerable variation in structure in different laminae. Some are very poorly developed and the different layers indistinctly demarcated. There is, however, a general agreement that there are three main layers:

(1) medially a layer of white fibres,
(2) an intermediate layer of grey matter, and
(3) laterally a layer of white fibres covered with ependyma.

Sections have been cut through a number of laminae, the results of which will be communicated at a later date.

(*e*) *The cavum septi pellucidi*

The cavum septi pellucidi is the median cleft between the two laminae of the septum. It is completely closed in and does not communicate with the true ventricles; further, it is not lined by ependyma and does not possess a choroid plexus. Lastly, it is not formed from any part of the cavity of the embryonic cerebral vesicles. In other words, the cavum differs very markedly from the true ventricles.

In those brains in which the cavum corresponds in length to the laminae of the septum, its boundaries and relations are the same as those described for the septum. It has a roof, a floor and two sides. The roof is the curved under-surface of the body of the corpus callosum; the floor is formed in front by the upper surface of the rostrum and behind by the arched body of the fornix. Its walls are the laminae of the septum. This state of affairs is, however, exceptional in the negroid brain. In the great majority of cases examined by us *the cavum is longer than the septum* and encroaches posteriorly on the crura of the fornix and the lyra. In the twelve brains previously mentioned the cavum was on an average 1 cm. longer than the septum, the average length being just under 4 cm. In these cases the side walls of the cavum were formed not only by the lamina but also by the medial edges of the crura; and the floor was formed not only by the body of the fornix but by a narrow strip of lyra as well. In one brain, where the cavum was 6 cm. long, it extended back as far as the splenium of the corpus callosum. In this case the lyra or psalterium Davidis formed an extensive lamina stretching across from one crus to the other. It was arranged in the form of a V-shaped trough, the angle of the V resting on the tela choroidea and forming the posterior part of the floor of the cavum. The sides of the V assisted in the formation of the side walls of the cavum.

In those brains which possess a short septum and cavum, a potential space —the subcallosal space—exists between the corpus callosum and the body of the fornix. The attachment of these two structures to each other is not very intimate and the space is easily opened out by a little manipulation. In the great majority of cases the cavum extends backwards into this space, so that the body of the fornix is completely separated from the corpus callosum. In other cases where the cavum is still longer and comes into relationship with the lyra, it encroaches on another space called Verga's ventricle or the ventricle of the fornix. This is the narrow horizontal interval between the corpus callosum and the lyra. It is triangular in shape, the apex being at the point of bifurcation of the fornix, its sides the diverging crura and its base the splenium of the corpus callosum. It will be seen thus that the cavum, in opening out these spaces posteriorly, may have a very variable length. It may, as in the case quoted above, run the whole length of the corpus callosum. What determines its backward prolongation is a matter for conjecture. One may suggest either an increase in the amount of fluid in the cavum or what is perhaps more likely an excessive growth in a backward and lateral direction of the structures which bound the cavum, viz. the crura and the corpus callosum.

The width of the cavum is very variable. In some cases it appears to be merely a potential space—so much so that in opening it the laminae of the septum require to be peeled off each other. In coronal section it shows as a vertical slit. In other brains it may be as much as 4 mm. wide, forming a narrow rectangle in coronal section. Since the laminae of the septum slope towards each other inferiorly the roof of the cavum is correspondingly wider than the floor. In those cases where the cavum extends as far back as the splenium its roof widens out as the crura of the fornix diverge, so that in coronal section the cavum has a somewhat T-shaped appearance.

Although the width of the cavum is so variable, it is probable that in life the laminae are actually in close apposition with each other and that the space is merely a potential one. This is brought about by the presence on each side of the septum of a varying positive pressure of cerebrospinal fluid.

The cavum is said to contain a small quantity of fluid of the nature of lymph (Quain; Piersol), and is lined by a smooth shining layer of condensed neuroglial tissue which no doubt represents an attempt at the formation of an endothelial lining. The amount of fluid in a cavum 6 cm. long must be appreciable. We have no information, however, as to alterations in quantity or composition of fluid in the cavum in pathological states of the brain.

4. DESCRIPTION OF ABNORMAL SEPTUM PELLUCIDUM

The characters of the abnormal septum pellucidum discovered in the brain of an adult male (Zulu) are unique and bear no resemblance to anything seen in a number of other native brains subsequently examined. Nor is there any record in the literature available to us of a similar specimen.

The principal features are briefly:

(1) The unusual length of the cavum, viz. 6·5 cm. (figs. 1 and 2).

(2) A long septum pellucidum, viz. 5·5 cm. (figs. 1 and 2).

(3) A communication of the cavum septi pellucidi with the right lateral ventricle through a large aperture in the right lamina of the septum (fig. 1).

(4) Two communications of the cavum with the third ventricle (fig. 3).

(5) Abnormal posterior relations of the cavum and an abnormal fornix (fig. 5).

The cavum is an elongated cavity 6·5 cm. long and approximately 1·5 cm. deep running the whole length of the corpus callosum. It may be described as having a roof, a floor and two sides; anteriorly it is closed off by the genu of the corpus callosum and posteriorly by the splenium (see figs. 1 and 2).

The roof of the cavum is an elongated strip of the arched under surface of the body of the corpus callosum. It extends from the bend of the genu to the lower recurved end of the splenium, a distance of 6·5 cm. It is 3 mm. wide in front, 5 mm. at its middle, and 7 mm. wide behind. From it the sides slope downwards and medially to form the floor.

The floor of the cavum is uneven, being roughly concavo-convex from before backwards. It is much narrower than the roof, being formed to a great extent by the coalescence of the two side walls. From before backwards it consists of the upper surface of the rostrum, anterior commissure, body of fornix, lyra and pia mater. The latter, debouching on to the lower end of the splenium, helps to shut the cavity off posteriorly. It is actually the superior layer of the tela choroidea, which here intervenes between the cavum and the third ventricle.

The floor of the cavum is deficient anteriorly on the right side where it communicates, both in front of and behind the anterior commissure, with the third ventricle. Where in the normal brain the inferior angle of the cavum is formed by the meeting of rostum and fornix on the upper surface of the anterior commissure, in this specimen on the right side these structures fall short of each other and of the commissure—the floor being formed by pia mater and a few strands of white fibres representing the fornix commissure. The rostrum turns abruptly downwards to become continuous with the lamina terminalis. Similarly, the right column of the fornix bends down a short distance behind the commissure and then disappears into the wall of the third ventricle. In this way two narrow passages, a few millimetres wide, are formed leading from the cavum septi pellucidi to the third ventricle. On the left side the floor in this region is normal, the rostrum and left column of the fornix meeting above the anterior commissure.

The walls of the cavum extend from genu to splenium and are formed from before backwards by:

(1) lamina of the septum,
(2) crus of the fornix,
(3) lyra, and
(4) pia mater.

(1) Each lamina of the septum pellucidum is 5·5 cm. long and extend nearly the whole length of the body of the corpus callosum to the under surface of which it is attached. Their inferior attachments are, from before backwards, the upper surface of the rostrum, the bottom of the wide angle between this structure and the column of the fornix, the upper surface of the body of the fornix (which is here less than 1 cm. in length), and finally the crus of the fornix. In front the lamina is 2 cm. high, about its middle 1 cm., while posteriorly it narrows to a point as the crus approaches the under surface of the corpus callosum. As far, therefore, as the shape and attachments of the lamina are concerned, they closely resemble those of the lamina of an unusually large normal septum. There is this important difference, however, that *the right lamina of this septum* (see fig. 1) *possesses a large aperture* through which it communicates with the right lateral ventricle. The aperture is situated about the middle of the lamina, and is an elongated ovoid about 18 mm. long and 6 mm. high. Stretching across the aperture from above downwards and somewhat obliquely are two thin strands which divide it into three compartments, the middle one being the largest. Along the upper and lower margins of the aperture can also be seen two or three small projections, which presumably were points of attachments of similar strands whose central parts have since disappeared. This presumption is strengthened by the observation that the remainder of the margin of the aperture is perfectly smooth and

evenly curved. The left lamina of the septum has the same shape and attachments as the right but does not possess any aperture or other deficiency (*vide* fig. 2).

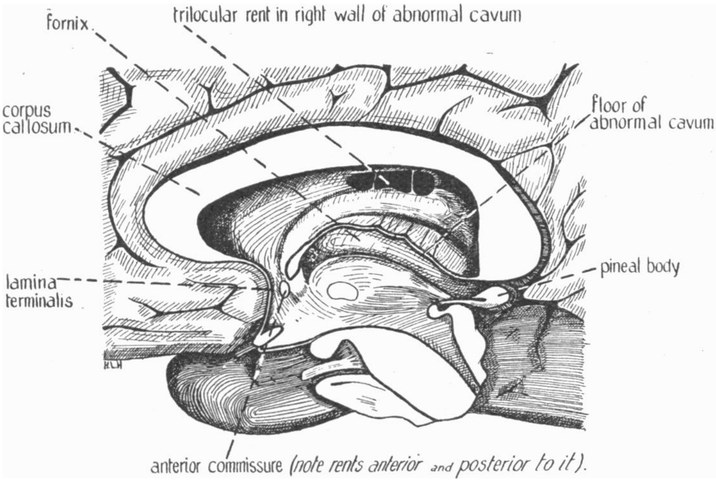

Fig. 1. To illustrate how the abnormal cavum septi pellucidi communicates with the lateral ventricle and with the third ventricle on the right side.

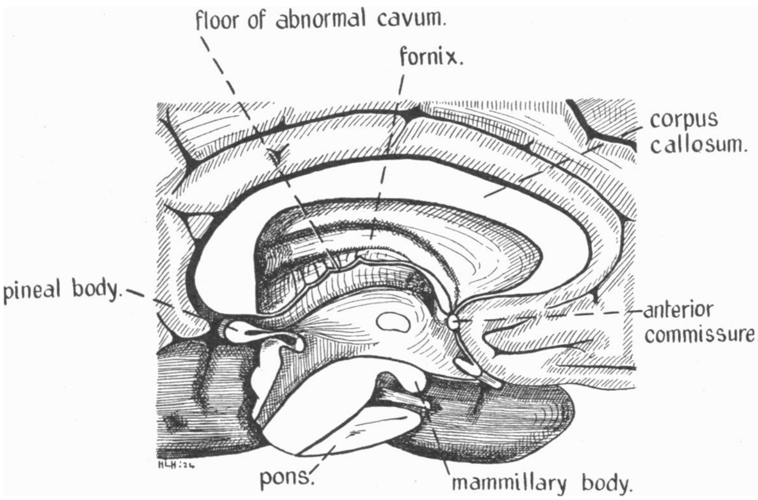

Fig. 2. To illustrate the extent and the relations of the abnormal cavum septi pellucidi on the left side.

On holding these laminae up to the light an interesting state of affairs is revealed. The attenuation which we have found to be a fairly characteristic feature of the normal lamina in the South African negro is apparent here also, but the translucent areas alternate with the thicker opaque areas in a much more regular fashion. The latter, on the left side, are massed along the upper and lower margins of the lamina and possess processes which, running from opposite sides, meet near the centre of the lamina (*vide* fig. 3). Some of the opposing opaque areas are definitely triangular; the apices of the triangles meet and thus separate the clear spaces from each other. These appearances are significant, for they also afford evidence in our estimation of the method by which the aperture in the right lamina has been formed. It is no presumption to conclude that the attenuation normally present is due to a stretching of the lamina in ontogeny, and it is justifiable to believe that we have witness in these vertically arranged triangular opaque areas, whose apices meet in the central attenuated area, that the forces causing the stretching of the lamina operate vertically to some extent.

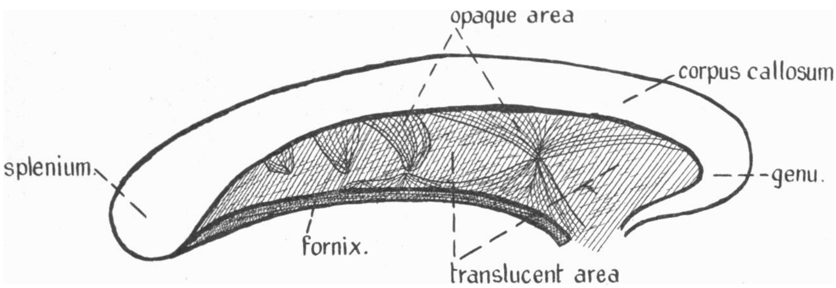

Fig. 3. Diagram of left lamina of the abnormal septum pellucidum as viewed by transmitted light.

The blood-vessels of the laminae are very similar to those in a normal specimen and are also associated with clear areas in their immediate vicinity.

The unusual conditions obtaining in this specimen, where the cavum was undoubtedly bathed in cerebrospinal fluid, provoked a histological investigation of the septal walls. The minutest examination of various portions of the laminae failed to provide any evidence of ependyma or other alteration of the lining of the cavum. It seems, therefore, clear that factors other than the mere presence of cerebrospinal fluid are essential to the production of an ependymal lining.

(2) It has been stated that the crus of the fornix helps in the formation of the wall of the cavum. The body of this structure is about 1 cm. long and is divided into two halves triangular in section connected on their medial and basal aspects by a thin narrow lamina, which helps in the formation of the floor of the cavum. The crura show marked differences from the normal. Anteriorly, instead of being flat they are triangular in cross-section (*vide* fig. 4). Along the upper edge of the crus is attached the lamina of the septum; the mesial wall of the crus forms part of the side wall of the cavum; the lateral wall helps in the formation of the mesial wall of the lateral ventricle, while the base rests on the optic thalamus and is separated from the latter by the tela choroidea. Posteriorly, beyond the septum pellucidum the crura became

semilunar in cross-section, the convex surfaces being medial and the concave lateral (*vide* fig. 5). The former share the formation of the lateral walls of the cavum, the latter in the formation of the mesial walls of the descending horns of the lateral ventricles.

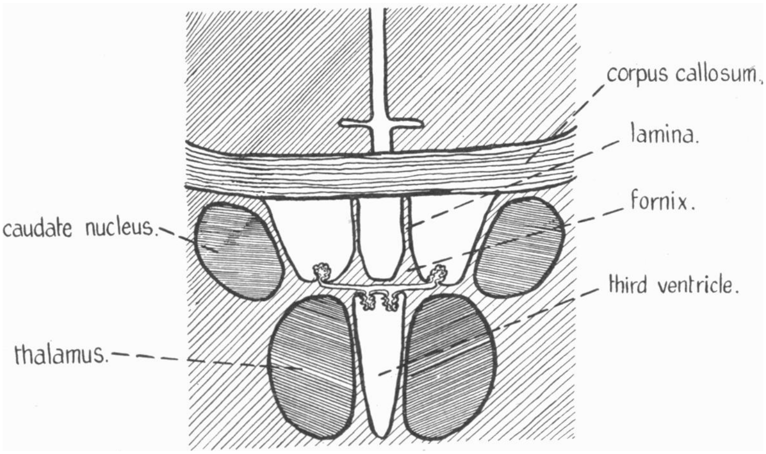

Fig. 4. Schema of a coronal section of the abnormal cavum and surrounding parts anteriorly.

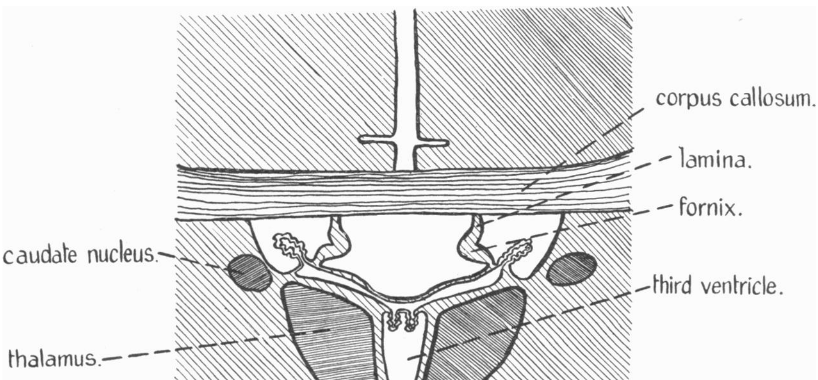

Fig. 5. Schema of a coronal section of the abnormal cavum and surrounding parts posteriorly.

(3) The lyra in this brain is very thin and incomplete. It is deficient posteriorly, the gap between its posterior curved margin and the lower end of the splenium being filled in by pia mater. Running in the lyra and connecting the crura with each other are a few minute strands of commissural fibres of the fornix (see figs. 1 and 2).

(4) The remaining portion of the side wall of the cavum is composed of pia mater which, as we have already stated, forms in the middle line a portion of the floor of the cavum. It is the superior layer of the tela choroidea. Passing forward the two layers dip underneath the lyra and proceed towards the interventricular foramina; laterally they pass upwards over the mesial surface of the optic thalamus and, insinuating themselves underneath the crus, enter the lateral ventricle. Traced backwards the pia mater can be seen to be firmly attached to the lower edge of the splenium and to be continuous with the layer which curves upwards on to the superior surface of the corpus callosum.

The boundaries and relations of the cavum septi pellucidi are best seen in coronal sections taken at different points (*vide* figs. 4 and 5).

There remain to be discussed the pathological aspects, if any, of this abnormal septum. The native, aet. 33, from whose brain the septum was obtained in the course of dissection, died of pneumonia. He had suffered from endocarditis, and vegetations were present on the aortic valves. One of these vegetations must have become separated, for a recent pulmonary infarct was present. There was nothing in the past or present history of the case to suggest a cerebral lesion; nor was there any clinical evidence to make one suspect it. It is conceivable that a minute embolus lodging in the right lamina of the septum might produce necrosis of part of the lamina and, subsequently, an aperture, but the idea is hardly tenable as the rest of the brain was perfectly healthy. Moreover, sections of the lamina in the neighbourhood of the aperture show no signs of old or recent inflammation. For these and other reasons one may also safely exclude such very improbable causes as a ventriculitis associated with ulceration, e.g. tuberculous, new growths, parasites, or an early hydrocephalus. The evidence is all against a pathological cause, and one is forced to accept the condition as either a congenital defect or an acquired developmental anomaly. One cannot but feel that the condition dated from an early age and that the aperture was formed before the fornix and its crura were fully developed. It is conceivable that the entrance into the cavum of cerebrospinal fluid under pressure (as high as 50 mm. and more) must have influenced the size and shape of the cavum and helped to prevent the crowding together of the two crura, which takes place in the normal brain.

This paper was ready to be dispatched for publication when there appeared the interesting note on "A perforated septum pellucidum," published by J. Knox Gibson (*Anatomical Record*, vol. XXVIII, No. 1). As the case described by Gibson is complicated by the presence of a cerebral trauma and insanity, and is the only case known to him and us as being set on record recently, it has still seemed worth while to record the present case.

B. THE GENESIS OF THE CAVUM SEPTI PELLUCIDI

1. INTRODUCTION

Amongst the anatomical pitfalls which embarrass the student may be reckoned the false or fifth ventricle. The very falsity of the *cavum septi pellucidi*, its lack of agreement in type or nature with other brain cavities, and the absence of any satisfactory account of its appearance or reason for its existence have at some time or other puzzled and distressed most of us.

It was, therefore, with an unusual satisfaction that I examined with Dr Beyers a forebrain which seemed to us to afford a very definite clue as to the factors concerned in the ordinary genesis of the cavum as well as in the production of the abnormality it specifically revealed.

In their *Anatomy of the Human Body*, John and Charles Bell relate that the septum pellucidum was discovered by Sylvius and that Sabbatier found it to be of triangular shape and from eighteen to twenty lines in length. They go on to remark, "It has a fluid enhaling into it like the ventricles, and is by some counted as a fifth ventricle. According to Santorini it opens into the base of the brain, opposite to the union of the optic nerves. Vieussens describes it communicating with the third ventricle. Winslow also has seen it reaching a great way backwards and conceives it to open into the third ventricle. Soemmering describes it as large in the middle, contracted backwards, and having no communication; but he asserts that it is shut in on every side. In the base of the brain we find a narrow longitudinal sulcus betwixt the pedunculi of the corpus callosum. In the bottom of this cavity there is a medullary lamina, which Vicq d'Azyr calls 'Cloison à la cavité du septum lucidum,' and the sulcus he calls 'Fosse de la base du septum lucidum.'"

The first item of interest, therefore, which emerges from the specimen here described by Dr Beyers is that it presents a condition of affairs such as was regarded as normal by Santorini, Vieussens and Winslow. It seems highly improbable that a triad of able observers such as these, all of whom enjoy an immortal refulgence at one point or other of the human frame, should have been so completely and independently misled. Perhaps an abnormality of the type they regarded as normal is not so infrequent as many of us may imagine—at any rate this specimen reveals the fact that such an abnormality certainly can and does occur.

A second and greater interest lies in the consideration of the factors concerned in the genesis of the cavum septi pellucidi itself. The specimen illustrates a cavity so enormously expanded as to extend posteriorly between the splenium of the corpus callosum above and the roof of the third ventricle below and to open by a large trilocular foramen into the cavity of the right lateral ventricle at the side and by two small foramina into the third ventricle below. Before we consider the factors concerned in the production of the abnormal cavum, which seem to us to be merely an exaggeration of those concerned in the production of the normal cavum, it will be valuable to examine the ideas already prevalent upon this subject.

2. DISCUSSION OF THE THEORY PREVALENT CONCERNING THE ORIGIN OF THE CAVUM SEPTI PELLUCIDI

There seems to have been no theory current of the method of formation of this interesting brain cavity, or of the homologies of its constituent walls, in the early part of the nineteenth century, for neither the Bells nor the Monros present any speculations upon the matter. Perhaps no speculation was to be anticipated before the evolutionary principles enunciated by Wallace and Darwin had rendered such hypothesis desirable. However, a conception grew up during the course of the century whose origin, unfortunately, our library facilities do not afford us the opportunity of tracing, but which has become the general teaching concerning the genesis of this forebrain lacuna. This doctrine is perhaps nowhere more explicitly stated than in Gray's *Anatomy* (1923 edition), where we learn that "The cavity of the septum pellucidum is generally believed to be a part of the longitudinal cerebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum, therefore, forms part of the medial wall of the hemisphere and consists of a medial layer of grey substance derived from that of the cortex, and a lateral layer of white substance continuous with that of the cerebral hemispheres."

This teaching, still current in a standard work of 1923, is to be discovered in one form or another in many of the outstanding textbooks of the Old and New Worlds. Thus Edinger and those authors responsible for the neurological section in such diverse texts as those of Rauber-Kopsch, Quain and Morris, all seem to regard the cavity as formed by the approximation and partial fusion of the cerebral hemispheres. An attempt to unravel the development of the space for the student according to this view is to be found in Morris' *Anatomy*, where the process is depicted as follows: "The corpus callosum, a development of fibres in the upper expanded portion of the lamina terminalis, thus bridges over a portion of the longitudinal fissure between the hemispheres. In the meantime, the fornix arises as two bundles of fibres, one from the hippocampus of each side. In the complex mechanics of the development of the cerebrum these two bundles approach each other under the corpus callosum, fuse for a certain distance, and together arch the cavity of the third ventricle and come to acquire their adult position. There results from these processes of growth a completely enclosed space, a portion of the longitudinal fissure, the roof of which is the corpus callosum, its floor, the body of the fornix, and its lateral walls, portions of the mesial surface of the two cerebral hemispheres."

In assessing the homologies of any structure there are surely two lines of enquiry available, one the study of the developmental facts or ontogeny, the other the study of the comparative anatomical facts which may afford clues as to phylogeny. Fortunately, in the case concerning us here both these lines of investigation have already been followed by a number of workers. The ontogenetic history of the human septum pellucidum has been investigated by Marchand (1891, 1909), by Zuckerkandl (1901) and by Goldstein (1903). As Streeter (1912) has pointed out, Zuckerkandl (1901) believed that during the formation of the commissures, "There is an approximation and fusion of a considerable area of the median walls (of the hemispheres) with resorption of the previously interposed mesodermal falx. This forms a 'massa commissuralis' through which the fibres subsequently cross." With this view, however, the other embryologists are in sharp disagreement, for Marchand failed to find any concrescence of the cerebral hemisphere walls but showed instead that until the fourth month of foetal life the septum pellucidum is a single solid homogeneous cellular mass interposed between the two lateral ventricles, but that during the fourth month a cavity appears within the previously solid mass; this cavity enlarges as the septum grows and becomes the ventricle of the septum—the septum now becoming bilaminar for the first time. Goldstein also has pointed out that, so far as the commissures (which, as it were, surround the cavum) are concerned, these are developed entirely within the lamina terminalis, and that the adjacent walls of the hemispheres play no part in the process whatever.

Other anatomists express themselves more cautiously. "The origin of the cavity," says Minot, "is uncertain; it has no connection with any of the brain cavities proper; Professor B. G. Wilder writes me that in man and the anthropoids it is wholly circumscribed by brain tissue; it is much narrower in other mammals, but the pia does not extend into it. Marchand thinks it probably arises as a cleft in the tissue."

In his article upon the nervous system in Cunningham's *Anatomy* Elliot Smith (1922) states: "There is still an element of uncertainty concerning the precise manner in which these changes (i.e. the stretching of the paraterminal body and the formation of the two leaves of the septum pellucidum) are brought about, and especially as to the precise mode of closure of the cavum septi."

The conclusions arrived at by the investigations of Marchand and Goldstein are the more trustworthy in that they entirely corroborate the comparative anatomical data. If Zuckerkandl be correct, and the septum and commissures have grown up by concrescence of the hemispheres, it is extraordinary that the whole commissural (anterior, hippocampal and callosal) system has been laid down within and is entirely surrounded by the olfactory field in all Mammalia including Man. We owe to the researches of Elliot Smith the knowledge that this commissural bed is a homogeneous mass throughout Mammalia and that the bed itself is primarily olfactory in nature. It is a portion of the paraterminal body itself. There is no evidence that the lamina terminalis is bilaminar, but the appearance of a cleft in this homogeneous tissue stratum would be no biological thaumaturgy provided the forces operating upon it were shown to be adequate.

From the standpoint of comparative anatomy this question of olfactory homogeneity is of paramount importance. By this criterion we know that the septum pellucidum of man is to be homologised with the lamina terminalis of all other vertebrates. If Zuckerkandl's description of commissural development in man were correct this homology would be untenable. It would be untenable because Zuckerkandl states in effect that the commissural system of mammals with a cavum (e.g. Anthropoids) is built up in a new tissue —formed by fusion of the cerebral hemisphere walls—which is not present in mammals (e.g. lowly Eutherial) without a cavum. There is not a tittle of evidence to show that an animal gaining a cavum septi pellucidi has acquired any such tissue for the purpose. The ontogenetic and phylogenetic lines of investigation, therefore, find a common point of meeting in the fact that the septum pellucidum in man is not formed by the concrescence of the two hemisphere walls, but was originally a solid homogeneous mass (the lamina terminalis or paraterminal body) uniting the hemispheres, which single mass later became split into two leaves by an operation of forces hitherto undescribed.

No closer parallel between the evidence of development and comparative anatomy could be found than that afforded by the history of the septum pellucidum. It has been stated that the septum or lamina terminalis is solid during the first three months of human foetal life. This is a foetal condition of affairs repeated by all Mammalia during their embryonic history, whether they possess a corpus callosum or not, but with this difference: the condition of a solid septum is found in man only during early foetal life, while it is permanent throughout life in Monotremata (Prototheria), in Marsupialia (Metatheria) and in many of the Eutheria—e.g. Edentata, Rodentia, Carnivora and Cheiroptera. Thus Piersol (1919) states that "The septum lucidum of man is the rudimentary representation of what in many of the lower (macrosmatic) animals is a much more important tract of cortical substance. In some animals, as for example, the rabbit, cat and dog, the septum is solid, a cleft never appearing in it."

So far as I know the actual range of the occurrence, amongst Eutheria, of a cleft in the septum has not been fully investigated. It appears to be present in the highest members of certain orders (e.g. Primates) and to be absent in the lower members of all orders of Eutheria. The presence or absence of a cavum septi pellucidi cannot, therefore, be of any importance from the standpoint of homologisation of the tissue in which it occurs, for even if one were to doubt the completeness of the homology throughout Mammalia one could never doubt the completeness of the homology within a single order of Mammalia, e.g. Primates. As Streeter states, "The ventricle is only present where there is a large corpus callosum." The origin of the ventricle must, therefore, be, as Marchand appears to have been the first to recognise, merely a cleft within the tissue of the septum.

In view of these facts already ascertained, there need be no question of a closure of the ventricle, since it has been enclosed from the beginning wherever it has occurred amongst Mammalia. Cases such as we have under consideration in this paper are not provoked by a failure of the cavity to close, but by an aggravation of this cleaving or clastic process (which we may term, for convenience, "clasis") to which the cavity originally owed its appearance. The "clasis" has proceeded to such an extent that the ventricle of the septum becomes continuous with the third ventricle immediately below and the lateral ventricle to the right.

That this is a correct interpretation of the ontogenetic and phylogenetic facts is corroborated by the data gleaned by Dr Beyers in his examination of negroid brains and of this particular abnormality. He has shown that in these brains an attenuation of the central strip of the lamina is a regular occurrence, that the lines of operation of vertical forces are evidenced by triangular opaque areas whose apices meet in this central strip, and that this particular anomaly demonstrates the "giving way" of the central strip at certain points while "strands" remain to show the remnants of the vertically placed opaque areas.

Nothing, therefore, can be more misleading in the present state of our knowledge than the teaching current in so many of our textbooks, which is at variance with the data of ontogeny and phylogeny and explains nothing to the inquisitive intelligence.

3. FACTORS ACTUALLY CONCERNED IN THE FORMATION OF THE CAVUM SEPTI PELLUCIDI

It remains that we should examine the factors which may possibly be concerned in this clasis of the septum during foetal and phyletic growth. It has already been suggested that the factors are tensile. Streeter (*loc. cit.*) has said of the lamina terminalis: "It is distended dorsalward and antero-lateralward through the growth of the corpus callosum, the shape of which in turn is determined by the expanding pallium. As a result of this tension there is a new arrangement of its tissue, and in the readjustment a ventricle is formed, the so-called fifth ventricle or cavum septi pellucidi. The ventricle is only present where there is a large corpus callosum."

It is an interesting and significant fact that the presence of a fifth ventricle does not synchronise with the first appearance of the corpus callosum. We have learnt that it may be absent from whole groups of Eutheria, all of whose members possess a corpus callosum. It is only when the corpus callosum becomes highly expanded that the ventricle appears. The actual appearance of the corpus callosum is, therefore, insufficient to call forth the cleft. Furthermore, it is difficult to believe that the expansion of the corpus callosum could in itself give rise to the cleft, for it expands in such a way as to exert traction upon the tissue of the septum pellucidum in a single uniform sense, i.e. in a resultant sagittal plane—upwards, forwards and backwards. Such traction is not likely to be productive of a bilaminar formation and a vertical cleft. It is a further argument against the corpus callosum as the only provocative element in this transformation that this abnormality of an excessively large cleft is found occurring in a Negro, where one would not anticipate such a preponderant aggrandisement of the callosal structures; and, as Dr Beyers has shown, an enlarged cavum is so frequently to be found in Negroid peoples in this country that one is tempted to regard the character as typical amongst them.

If we consider the physical forces to which the septum pellucidum is exposed during development and especially during the fourth month when the fibre tracts are appearing, it is evident that traction is exerted upon it in a variety of ways. There is the traction of the corpus callosum upwards, forwards and backwards in a resultant sagittal plane already mentioned. There is the traction of the anterior commissure whose resultant is in a coronal plane —whose median position of attachment to the septum signifies the lowest point in the cavum septi pellucidi. Finally, there is the traction exerted by the fornix and its commissure. It is mainly to the nature of this latter traction, in our estimation, that the appearance of a cleft and its different varieties is actually due.

This traction of the fornix or hippocampal apparatus resolves itself naturally into three separate components, two of which are in sagitto-lateral or diagonal planes (i.e. the traction exerted by the fornix itself which is attached at one end by its pillars to the side walls of the third ventricle, and at the other end by its crura to the hippocampal formations in the floors of the lateral ventricles), and the third of which is in a transverse or coronal plane (i.e. the traction of the lyra or commissura fornicis which binds the two halves of the fornix together).

In the lowlier Eutheria where the callosal commissure is small, the commissura fornicis (or hippocampal commissure) is almost of the same or even greater dimensions. With the growth of the corpus callosum, as Elliot Smith has shown, the hippocampal commissure is thrust further and further posteriorly and ventrally by the callosal expansion until ultimately it becomes a thin laminated structure. It dwindles, not only relatively, but actually, especially in microsmatic groups such as the higher Primates.

Now the traction of the fornix apparatus we have seen resolves itself into three components, two of which pull laterally and ventrally away from the upward sagittal pull of corpus callosum, while the third component tends to negative the lateral dragging of the halves of the fornix by approximating them to the middle line posteriorly. These facts may be expressed in diagrammatic form by a coronal section through the septum pellucidum posteriorly in a brain where the hippocampal commissure is well-developed (*vide* fig. 6 *a*). In such a brain the transverse linkage between the two halves of the fornix is so strong that the lateral and downward traction is only evident anteriorly and the cavity of the septum pellucidum is not prolonged far posteriorly.

But in cases where the hippocampal commissure is absent or is relatively undeveloped, the lateral and downward pull is felt at its maximum, the two halves of the fornix are torn widely apart, as in this specimen, causing the floor to open into the third ventricle anteriorly, while the side walls of the cavum septi pellucidi may be strained so greatly that it actually gives way and causes a communication to arise between the cavity and that of the lateral ventricle.

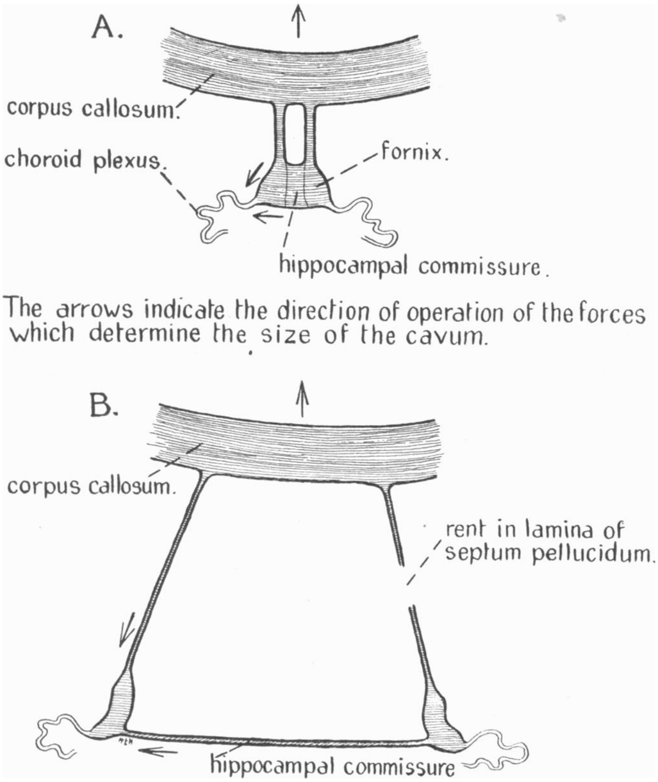

Fig. 6. Diagram to illustrate the consequences of an attenuation of the hippocampal commissure.

The contrasting results of greater attenuation of the hippocampal commissure are depicted in the same diagram (*vide* fig. 6 *b*). This illustrates how the state of affairs obtaining in our present specimen was probably arrived at. The corpus callosum is large but not unduly large, and the fornix on either side is of the usual size, *but the lyra is virtually absent.* A brief examination of the drawing (fig. 1) made from the specimen is sufficient to show that the point at which the right wall of the septum pellucidum gave way was above the apex of the fornix arch—the point at which the maximum effect of the pull was felt. Moreover, the rent was incomplete. Two fine strands of tissue remained to preserve, as it were, the lines of traction of the two opposing forces of corpus callosum and fornix. In the region of the anterior commissure the lateral divarication was not quite sufficient to separate completely the two halves of the fornix, but their junction at the body was partially severed and slits were formed (between the pillars of the fornix and the anterior commissure behind and between the anterior commissure and the lamina terminalis in front) opening to the third ventricle. Both these openings were more to the right side of the mid-line, i.e. towards the same side as that on which the lamina was broken down.

That the usual appearance of a cavum septi pellucidi is to be attributed to the attenuation of the hippocampal commissure, and the consequently increased ventro-lateral traction of the fornix in animals with a greatly expanded neopallium, seems to us to be corroborated by the fact that the cavity first appears in the fourth month of foetal life when the commissural fibres are beginning sensibly to expand the septum. This fact, coupled with the embryonic and comparative anatomical evidence, confirm the conclusion already stated that there can be no question of concrescence of the cerebral hemisphere walls and subsequent resorption. Since there is no question of concrescence and closure, it is to be anticipated that the origin of the cleft is to be sought in purely physical growth factors operating in the septum pellucidum itself. Of these factors it is evident that the fibre tracts must play a preponderantly important part. It appears equally evident that the tractions of the corpus callosum and of the anterior commissure, important as they may be in affording a basis, as it were, from which other forces might operate in producing the cavity, could not, either of them, in themselves call forth a cavum septi pellucidi. For the production of such a cleft it seems necessary that a laterally operating force is essential, and such a force is normally exerted only by the fornix apparatus and is increasingly apparent with the progressive attenuation of its commissural constituent. It may, therefore, be stated that the fifth ventricle is in the main due to a cleavage or *clasis* in the paraterminal body caused by the ventro-lateral pull of the diagonally running fornix upon the septum pellucidum.

4. CLASIS—A PHENOMENON OF NORMAL AND ABNORMAL GROWTH

In conclusion, this process of cleavage which normally calls forth the septum pellucidum in man is a particular example of a growth phenomenon widespread during development, and for this reason we have given it a specific terminology in the word *clasis*. It is a phenomenon the inverse of that to which Sir Arthur Keith has drawn valuable attention under the term "zygosis." He has shown how during embryonic life innumerable processes of union take place, which are more or less strictly comparable with the phenomenon of adhesion and union in tissues following upon wounds naturally or surgically produced. Under the heading of *clasis* we are in a position to tabulate an equally numerous series of growth phenomena which are comparable with the changes which take place clinically and surgically when by traction or other interference a partial or complete separation, or even a cavity, is produced. This term *clasis* embraces all the phenomena of cellular or tissue separation, whereas zygosis includes the contrasting phenomena of cellular or tissue union.

The factors underlying *cellular clasis* lead to the phenomena of fission, cell division, cleavage of the ovum and the like. These are gradually being recognised through the labours of many investigators as physico-chemical in nature. The factors underlying the *tissue clasis* of the embryo are less known because they have been less studied. The causes of the appearance of the exto-dermal and entodermal vesicles and the coelome in the embryonic cell-mass —are these physical or chemical or both, at base? The rifts in the tissue masses which provide the pericardial, pleural, and abdominal cavities, the blood spaces, the vacuities between the meninges, the joint cavities, the bursae—what are they? All these phenomena and many others of their type inadequately understood at the present time, present, in the same way as does the resorption of the tail of the tadpole and the laying down of bone in cartilage, examples of tissue clasis. We have in all of these clases which have been of benefit to the organism and have become heritable, inexplicable as their causation and inheritance may be for the present.

In our present abnormality we have a *clasis*, the terminal result of a process of expansion of the cavum septi pellucidi much more common, presumably from Dr Beyer's data, amongst negroid races in this country than amongst Europeans. We are in the presence here of an example of super-development, a mutation whereby at one leap the whole mechanics of the anterior ventricular system of the brain is profoundly altered, and altered in such a way as to be compatible with life and an apparently normal existence. It would be interesting to know if such a condition were actually heritable. If heritable, it is clearly recognisable that still further expansion of the human neopallium is possible, even to the extent of a complete breaking down of the septum pellucidum and the production of extensive forebrain inter-ventricular communication.

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