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ENDOCRANIAL CASTS AND BRAIN FORM: A CRITICISM OF SOME RECENT SPECULATIONS.

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EARLY in this year I published a Lecture[1] in which were described the results of an investigation made with the object of ascertaining the extent to which the inner surface of the cranial wall is moulded upon the opposed surface of the brain. In the course of this research a large number of endocranial, endodural, arachnoid, and brain casts were prepared from recent man. Duplicates of these casts have been presented to the Museums of the Royal Colleges of Surgeons of England and Edinburgh, where they are available for examination by those interested in this question.

For many years past palæontologists have made endocranial casts of the skulls of extinct animals in order to demonstrate the size and general form of the cranial cavity and also to gain an idea of the degree of cerebral development. Such casts are frequently called "brain casts," apparently on the assumption that the form of the brain is practically identical with that of the cranial cavity.

The degree of approximation of the cranial aspect of the brain to the interior of the skull differs considerably amongst the various members of the vertebrata, so that to call a cast of the cranial cavity a "brain cast" may be very incorrect, since such a cast may differ considerably both in size and form from the brain itself. The distinction between the terms "endocranial" and "brain" casts must now be specially emphasised, as several anatomists and palæontologists have within recent years used endocranial casts of dried and sometimes fragmentary skulls of man on which to base a description of the convolutionary pattern of his cerebral cortex and of other features of his brain. It is obvious that if these deductions rest upon a sound basis of observed facts this method opens up

[1] The Sir John Struthers Lecture "On the Relation of the Inner Surface of the Cranium to the Cranial Aspect of the Brain," *Edinburgh Medical Journal*, February 1915.

a very interesting line of research, by offering the prospect of important additions to our knowledge of the evolution of the brain of prehistoric man, and by yielding interesting particulars regarding the character of this organ in recent but deceased men whose brains have perished, but whose skulls are available for scientific study.

In this paper I propose to consider the evidence presented by Professors Eug. Dubois,[1] A. Froriep,[2] M. Boule and R. Anthony,[3] R. Anthony,[4] and Elliot Smith[5] in support of statements they have made regarding the brain in cases where they had the opportunity of studying endocranial casts of skulls in which the cranial wall was more or less perfectly preserved, but its contents destroyed. In my Struthers Lecture will be found a detailed account of the effect of the structures intervening between the skull and the brain in producing differences or permitting harmony between the shape of the inner surface of the skull and the outer surface of the brain. A careful comparison of a number of endocranial casts and of the corresponding brains is an essential preliminary task before attempting a reconstruction of the brain of ancient man from endocranial casts of his skull. In the course of this review I shall have occasion to consider how far the results of such work have been utilised.

Endocranial Cast of *Pithecanthropus erectus*.

At the Fourth International Congress of Zoology, held in Cambridge in August 1898, Professor E. Dubois gave a communication on "The Brain Cast of *Pithecanthropus erectus*," which was published the following year in the *Proceedings* of the Congress. At the meeting he showed an endocranial cast of the celebrated skull-cap he found during excavations in Java in 1891–92. After directing attention to certain peculiarities in the general shape of the cast, he gave the following description of the markings of the cerebral fissures and convolutions which it presented:—

"In the frontal region of the hemispheres the convolutions are most

[1] "Remarks upon the Brain Cast of *Pithecanthropus erectus*," *Proc. of the Fourth International Congress of Zoology held in Cambridge in 1898.*

[2] "Ueber den Schaedel und andere Knochenreste des Botanikers Hugo v. Mohl," *Archiv für Anthropologie*, Bd. viii., 1909.

[3] "L'Encéphale de l'homme fossile de la Chapelle-aux-Saints," *L'Anthropologie*, tome xxii., 1911.

[4] "L'Encéphale de l'homme fossile de la Quina," *Bulletin et Memoires de la Société d'Anthropologie de Paris*, 1913. (Communicated to the Society 18th July 1912).

[5] "Preliminary Report on the Cranial Cast," an appendix to a paper by C. Dawson and A. Smith Woodward "On the Discovery of a Palæolithic Human Skull and Mandible in a Flint-bearing Gravel overlying the Wealden (Hastings Bed) at Piltdown Common, Fletching, Sussex," *The Quarterly Journal of the Geological Society*, vol. lxix. pt. 1, March 1913. (Communicated to the Society 18th December 1912.)

perfectly distinct. Those on the left side are a little different from those on the right side; the latter are, further, best preserved. For first orientation the central and precentral fissures are easily identified. The intraparietal fissure is only very partially distinct, but seeming to point to a relatively large occipital lobe, an ape-like condition, undoubtedly consequent on a relatively larger development of the sensory centres of the cortex in contrast with smaller areas of association. In the neighbourhood of the median part of this sulcus the brain is very flat.

"The most conspicuous feature is the second frontal fissure, as clearly developed as in any human hemisphere, originating in the common T-shaped form from a clearly distinct inferior precentral sulcus and having the shape of a reversed ϖ. The two segments of this fissure encircle the two limbs of perfectly definite Y-shaped anterior branches of the fissura Sylvii, the stem of which is about 1 cm. long.

"The second frontal sulcus is only very partially preserved on the left side.

"On both sides a median frontal fissure is very marked.

"The first frontal fissure is interrupted in different places, a condition common in the apes as well as in man.

"The important inferior frontal convolution has attained a fair development. I found the area of its exposed superficies equal to half the average area in twelve European hemispheres, but at least double that in the brain of a large chimpanzee or an orang-utan. This seems to indicate that our fossil being possessed already a certain amount of power of speech. The pars triangularis is present in this convolution, as results from the presence of two anterior branches of the Sylvian fissure. But the pars opercularis has only a very rudimentary development" (p. 82).

Unfortunately, so far as I have been able to ascertain, no duplicates of this cast have been issued and no photographs or drawings published, although it is sixteen years since Dubois read his paper. Under these circumstances it is impossible for me to examine the evidence on which Dubois made such precise and definite statements regarding the convolutions of the anterior part of the brain of *Pithecanthropus*. I understand Dubois intends to publish a fuller report on his cast, but this long delay is greatly to be regretted, as the specimen is unique and of the greatest scientific value. An excellent ectocranial cast was made by Dubois soon after his return from Java. It has been widely distributed, and a copy of this cast was used by Professor Schwalbe in his elaborate "Studien ueber *Pithecanthropus erectus*" in the *Zeitschrift für Morphologie und Anthropologie*, Bd. 1, 1899.

Endocranial Cast of Mohl's Skull.

In 1906 Professor A. Froriep had the opportunity of examining the skeleton of Hugo v. Mohl, a former Professor of Botany in the University of Tuebingen. Mohl died in 1872, and his remains were exhumed about thirty-four years later. The vaulted portion of the skull was found intact; it included the frontal bone down to the supraorbital prominences, and the occipital to slightly below the grooves for the transverse sinuses. The sphenoid and ethmoid were decayed, and also most of the lower part of the occipital. The two temporals were preserved, except that the squamous portions were somewhat damaged. The missing parts were reconstructed and an endocranial cast made. It is evident from these facts that the part of the cast exposed in the norma verticalis is natural, but that the normæ laterales are artificial over the anterior part of the temporal lobe, the orbital surface of the frontal lobe, and the main stem of the Sylvian fissure.

So far as the number and general distribution of the digital impressions are concerned, the cast does not show any peculiarity as compared with those I have made from dissecting-room subjects and described in my Struthers Lecture.

In Froriep's article in the *Archiv für Anthropologie* he gave on plate vii. five photographic reproductions of his endocranial cast, viz. vertical, frontal, occipital, and right and left lateral views, and on plate viii. similar photographs of a model of Mohl's cerebral hemispheres. The method by which this "Gehirnmodell" was prepared from the endocranial cast and the results obtained are of interest. The endocranial cast showed the ridges due to the meningeal vessels and the elevations indicating the depressions on the bone caused by the Pacchionian bodies. These were all removed, and the plaster was also cut away along the middle line to mark the position occupied by the superior sagittal sinus and on each side for the transverse sinus. Furrows were also cut in the course of what Froriep considered to be depressions indicating the position of a number of the principal cerebral fissures. In figs. 1 to 4 are reproduced Froriep's photographs of his cast viewed from the norma verticalis and left norma lateralis before this procedure and after its conversion into a brain model. I am unable to satisfy myself either from Froriep's photographs of his endocranial cast, or, more important still, from a duplicate of this cast which I have had the opportunity of studying, of the existence of depressions of sufficient distinctness to justify the mapping out of the fissures shown in figs. 2 and 4.

In the left norma lateralis the middle and inferior temporal convolutions are as usual well marked: the superior temporal sulcus is possibly somewhat

exaggerated in making the reconstruction; part of the posterior limb of the Sylvian fissure is distinctly indicated, but its upturned posterior end, as well as the ascending anterior branch of this fissure, are in my opinion marked on the brain model without any satisfactory indication of their existence on the endocranial cast.

Even if we accepted, which I certainly cannot, Froriep's brain model as accurately defining the course of the main fissures on Mohl's brain, it is instructive to ascertain what it teaches us with regard to the degree of

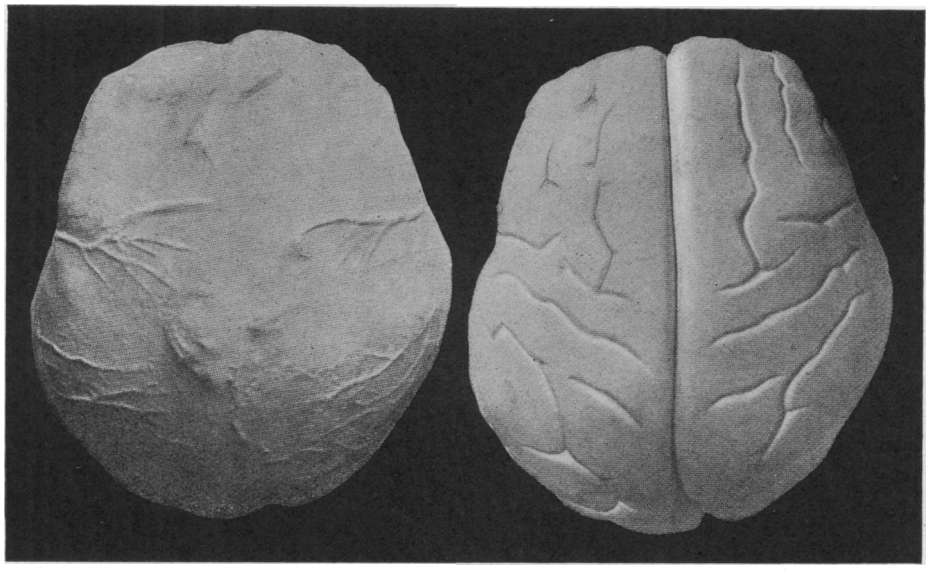

FIG. 1.—Norma verticalis of endocranial cast of von Mohl's skull (Froriep).

FIG. 2.—Norma verticalis of Gehirnmodell (Froriep).

development of his convolutions. Mohl was a distinguished botanist and one of a family of very talented brothers, and therefore we might reasonably anticipate that his cerebral cortex would exhibit at least an average degree of complexity. It is true that the results of the careful study of the brains of a number of distinguished men have not, on the whole, proved that their cerebral hemispheres possess a marked advance in the complexity of the convolutionary pattern over ordinary individuals, but in Mohl's case the various views of the model of his brain would serve admirably as a representation of the hemispheres of a seven or eight months' fœtus. The appearance of the central, precentral, superior and inferior frontal and intraparietal fissures in Mohl's "Gehirnmodell" suggest this early stage in

their development. It is evident that Froriep can only have intended to represent the course and position of the main fissures, the secondary ones not being sufficiently definite to warrant their addition. Even, however, with regard to the main fissures, his representation of their appearance must be regarded merely as a simple diagrammatic view and not an exact picture of the tortuous course they so often pursue. If from an endocranial cast only the general directions of the main fissures can be determined, and the secondary and even tertiary ones, which are essential for an estimate of the degree of cerebral development, have to be omitted, it is obvious that the evidence afforded by an endocranial cast is useless

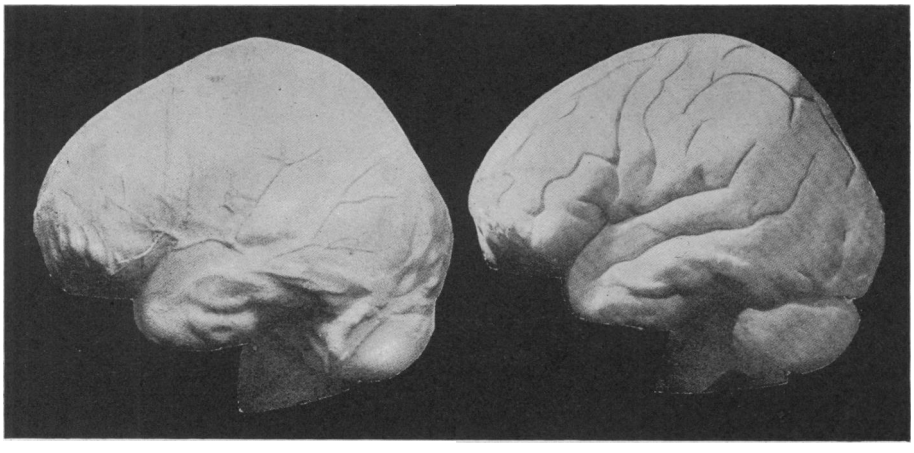

FIG. 3.—Left norma lateralis of endocranial cast of von Mohl's skull (Froriep).

FIG. 4.—Left norma lateralis of Gehirnmodell (Froriep).

in forming a reasonable estimate of whether or not the individual from whose skull it was taken possessed a simple, an average, or a complex type of convolutions. Froriep considers that Mohl had a richly convoluted brain, and he bases this conclusion upon the fact that in the profile and occipital views of the endocranial cast the main convolutions are not simple, but are composed of a large number of small prominences.

As is readily seen on figs. 1 and 3, the prominences on this endocranial cast due to the digital impressions are practically limited to the lower part of the frontal, temporal, and occipital lobes. They are even less marked than in several casts I have made from dissecting-room subjects, and I have taken a cast of the occipital end of the skull of a native Australian in which the digital impressions above the transverse sinus are quite as numerous as in Mohl's skull.

Endocranial Cast of La Chapelle Skull.

Science is indebted to Professor Boule for a series of very valuable and well-illustrated memoirs[1] on the La Chapelle skeleton and its associated remains. This fossil man belongs to the Neanderthal race; the skull is very large, and Boule estimates the cranial capacity as amounting to 1620 c.c., or distinctly above the average of modern civilised races. An endocranial cast of this skull was studied by Boule and Anthony[2] with the special object of endeavouring to form an estimate of the degree of cerebral development. For purposes of comparison they obtained similar casts of the anthropoid apes, of the Neanderthal skull-cap, and of various races of modern man. A number of these casts were those prepared by Broca in connexion with his classical researches on cranio-cerebral topography. Their paper is illustrated by photographs of the endocranial cast of the La Chapelle skull viewed from various aspects. Duplicates of this cast, with those of the outer aspect of the same skull, were made in the Museum d'Histoire Naturelle, and a limited number issued to subscribers. Through the kindness of Professor Thane I have had the opportunity of studying both the ectocranial and endocranial casts.

Boule and Anthony admit that the traces of the convolutions left on the inner surface of the cranial wall give only an approximate idea of their real appearance, and they compare such traces to the view of a statue from which one is not allowed to remove the veil. They also state that the appearance of the convolutions when *in situ* is liable to differ somewhat from that seen on a brain which has been removed from its cavity and preserved, and that such differences are liable to mislead an observer who is not cautious and has only one cast under examination. They accordingly attach special importance to the comparison of a number of endocranial casts with one another.

It is evident that they had no sets of endocranial, endodural, arachnoid, and brain casts prepared from bodies in which the brain had been properly hardened *in situ* by means of formol so as to avoid any appreciable shrinkage of the brain, nor indeed do they seem to have had suitably preserved brains to compare with endocranial casts from corresponding subjects. They write:

"Nous nous sommes surtout attaché à comparer l'objet de notre étude aux moulages endocraniens dont nous disposions" (p. 130). But surely it is much more important to compare a series of endocranial casts with the corresponding brain casts or hardened brains. The real question to be

[1] "L'homme fossile de la Chapelle-aux-Saints," *L'Anthropologie*, xx., 1909; and *Annales de Palæontologie*, 1911–13.

[2] *Op. cit.*, p. 112.

solved is, What do endocranial casts teach us regarding the brain? And the mere comparison of endocranial casts one with another can yield no direct evidence as to the degree of complexity of the convolutions of the corresponding brains, however useful they may be in forming an estimate of the general size and shape of the brain and in demonstrating variations in the markings on the inner aspect of the cranial wall.

In the "Introduction" to their paper they say:

"Notre travail nous a conduits à cette conclusion que l'encéphale de l'homme fossil de la Chapelle-aux-Saints présente un ensemble de caractères d'infériorité plus nombreux et plus marqués que l'encéphale de n'importe quel Homme actuel. S'il est humain à la fois par son volume absolu et par son volume relatif, il paraît se rapprocher de celui des Anthropoides par la plupart des détails de sa morphologie."

The large size of the endocranial cast would certainly alone justify the assumption that the brain was human, for it is nearly three times greater than that of the largest anthropoid apes. It is necessary, however, to examine some of the reasons advanced in support of their important conclusion that the brain of the La Chapelle man possessed more numerous and more important marks of inferiority than any modern race of men and that these characters indicated an approach towards the anthropoids. Boule and Anthony consider that the traces of the cerebral convolutions which are found on the endocranial cast of the La Chapelle skull are fewer, less complicated, and coarser than those on similar casts of modern man, and they assume that such endocranial markings prove that the brain of the La Chapelle man possessed a simple or low type of convolutions. I cannot assent to either of these propositions, as I have failed to discover any special peculiarities in the form and distribution of the digital impressions on the endocranial cast as compared with those in modern man. The number and depth of the digital impressions on recent skulls are well known to vary considerably, and those of the La Chapelle fall well within the normal range of variation. Further, my own observations upon a considerable number of sets of endocranial and brain casts have satisfied me that the degree of simplicity or complexity of the convolutions cannot be accurately estimated from endocranial casts.

Boule and Anthony discuss at some length the peculiarities in the position of the branches of the Sylvian fissure and of the insular opercula as compared with modern man and the apes. It would be useless to refer to their comparative results, because in my opinion the data upon which they are based are unsound. In attempting from their endocranial cast to determine the position of the anterior branches of the Sylvian fissure and the "cap" of Broca, or frontal operculum, they have made serious mistakes.

The main grounds on which such an adverse opinion is expressed will be evident from a comparison of figs. 5 and 6. Fig. 5, which is a diagram of the right lateral aspect of the La Chapelle brain, is reproduced from Boule and Anthony's paper. *Spa.* and *Spp.* indicate the position of the anterior and posterior pre-Sylvian fissures which form the anterior and posterior boundaries of the frontal operculum. In fig. 6 is seen a photograph of the right norma lateralis of the skull of a female sixty-one years old, on which has been outlined the fissures of the corresponding portion of the right hemisphere. The two anterior branches of her Sylvian fissure are

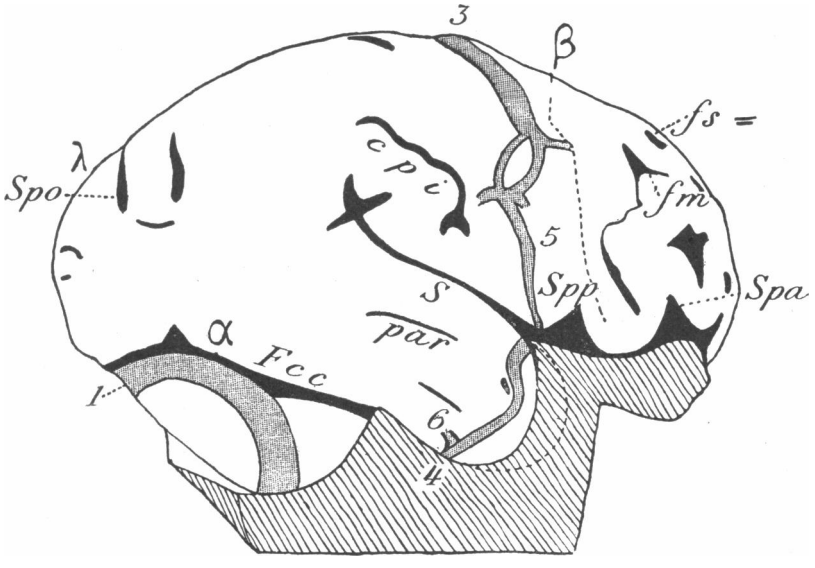

FIG. 5.—Diagram of right norma lateralis of endocranial cast of La Chapelle skull (Boule and Anthony).

seen to belong to the U-shaped type, and in this respect correspond to the arrangement represented in fig. 5. Here, however, the resemblance ceases. In the La Chapelle brain both branches appear to pass upwards from the rounded margin separating the orbital and lateral surfaces of the frontal lobe on to the lateral surface of the frontal lobe. Both fissures ascend, and the posterior one is at the level of a coronal plane passing through the anterior end of the temporal lobe. It is difficult to understand how the "cap" of Broca in such a position could form an operculum to the central lobe unless this lobe extended much further forward than is normal in the adult human brain, or the forward growth of the temporal lobe was defective. If such an arrangement of parts actually existed in the

La Chapelle brain, it would form an interesting comparison with a fœtal brain of about the seventh month (see fig. 275, *Quain's Anatomy*, 11th edition, vol. iii. pt. i.).

The brain represented in fig. 6 shows the "cap" of Broca and its associated Sylvian branches to be distinctly farther back, and this is undoubtedly the usual position.

The lateral boundary of the orbital surface of an endocranial cast is

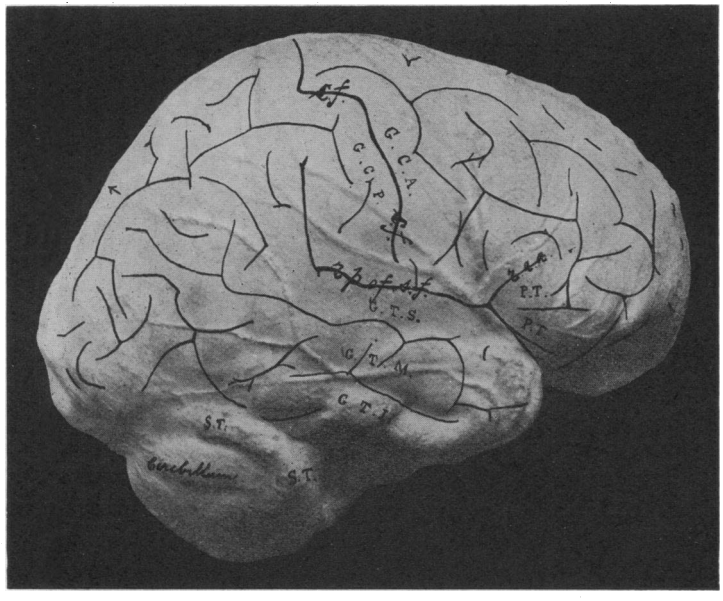

FIG. 6.—Photograph of the right norma lateralis of an endocranial cast of the skull of a female sixty-one years old. On this is outlined the fissures of the corresponding part of the brain. ½ nat. size.

c.f., central fissure; *r.p. of s.f.*, posterior branch of Sylvian fissure; *r.a.a.*, anterior ascending branch of Sylvian fissure. Inferior ascending branch not labelled; it lies below P.T., P.T. (pars triangularis).

often marked by one or more grooves which may correspond to lateral offshoots of the sulcus orbitalis on the orbital surface of the frontal lobe of the brain. Boule and Anthony were evidently making a very doubtful guess in representing these grooves as markings due to the pre-Sylvian fissures. The rashness of their attempt to localise these fissures is enhanced by the fact that in the reconstruction of the skull Boule was unable, from the pieces of the skull found, to reconstruct the roof of the right orbit and the anterior boundary of the right middle fossa of the base of the skull, so that the endocranial cast does not show the actual

form of the orbital surface of the frontal lobe or the anterior end of the temporal lobe of the brain, these having been reconstructed.

Fig. 7 is a photograph of the endocranial cast of the La Chapelle skull viewed from above. Upon this I have marked all the fissures represented by Boule and Anthony in fig. 8 of their paper in *L'Anthropologie*, tome xxii.

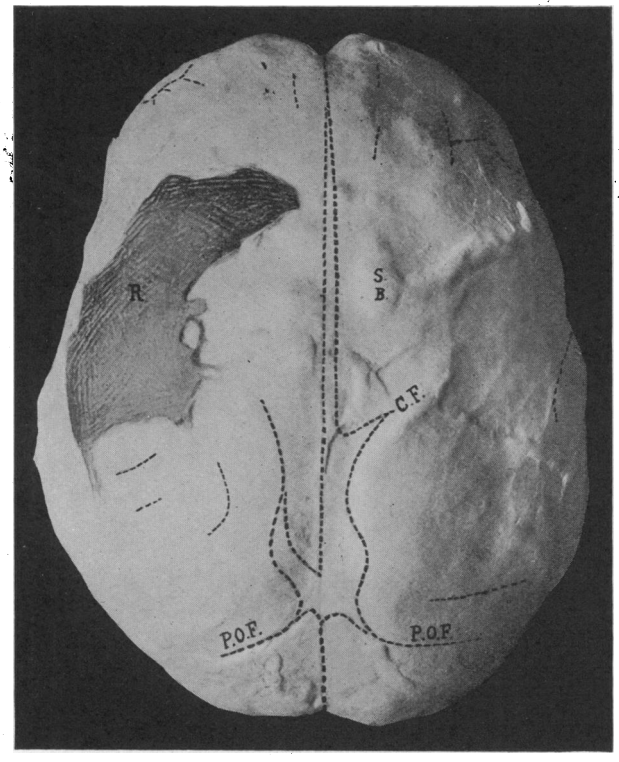

FIG. 7.—Photograph of the norma verticalis of the endocranial cast of La Chapelle skull on which is marked the position, according to Boule and Anthony, of certain cerebral fissures. ½ nat. size.

P.O.F., parieto-occipital fissure; C.F., upper part of central fissure; S.B., sinus of Breschet; R, area where cranial wall was defective.

The parieto-occipital are the only fissures whose entire course on this aspect of the brain are depicted, only traces of a few other fissures being shown, so that the convolutionary pattern on the vault is very incompletely illustrated. In the case of the fissures that are marked, Boule and Anthony appear to have assumed that any faint depression on the endocranial cast would correspond to some fissure.

If there is one point in cranio-cerebral topography that can readily be demonstrated, it is that on the vault near the median plane the superior cerebral veins, lacunæ laterales, superior sagittal sinus, Pacchionian bodies, and the cerebrospinal fluid, which tends to accumulate in this position, separate, in a number of places, the under surface of the skull from the adjacent cortex, so that the cerebral fissures and convolutions leave no markings on the endocranial cast of sufficient distinctness to enable one to determine their position and extent.

I have endocranial casts of the vault of ten skulls, each with a cast of the related part of the brain. My laboratory assistant, Miss Rea, has very carefully transferred the outlines of the cerebral fissures on to the endocranial casts. In no single instance do these fissures correspond to definite depressions indicating their position, and very frequently, in various parts of their course, they lie over eminences on the cast.

Endocranial Cast of the Piltdown Skull.

Fortunately it does not fall within the scope of this paper to give a detailed account of the somewhat acrimonious discussion which accompanied various attempts to reconstruct the Piltdown skull and to estimate the form and capacity of its cranial cavity. It is, however, necessary to mention some facts connected with that controversy which have a direct bearing on the important question of the probable size and shape of the brain of this primitive man.

In Dr Smith Woodward's account of the first reconstruction of the skull, published in March 1913, he gave the cranial capacity of the Piltdown man as 1070 c.c. (see table of comparative measurements on p. 130 of his paper in the *Quarterly Journal of the Geological Society* for March 1913), but this estimate is modified in the text as follows:—

"The capacity of the brain case cannot, of course, be exactly determined; but measurements both by millet-seed and by water show that it must have been at least 1070 c.c., while the reconstruction of the missing parts suggests that it may have been a little more" (p. 126). On a duplicate of an endocranial cast of the reconstructed skull made under Dr Smith Woodward's direction by Mr F. O. Barlow in 1912, and sold by Mr R. F. Damon, I found the water displaced was nearly 100 c.c. more than the amount given in the comparative table already mentioned. Apparently as a result of a vigorous attack by Professor A. Keith in August 1913 on the accuracy of this reconstruction, Dr Smith Woodward reconsidered the question, and finally prepared a second one, the endocranial cast of which has a capacity of almost exactly 1300 c.c., or an increase of 230 c.c. as

compared with his table of measurements, and about 130 c.c. more than the first cast. As the Piltdown cranial fragments represented less than half of the entire cranial wall, and important parts on both sides of the median plane were not found, it is obvious that it was impossible to make more than an approximately accurate reconstruction, and anatomists will, I believe, recognise the care and skill bestowed by Dr Smith Woodward, Dr Pycraft, and Mr Barlow on this difficult piece of work. It is unfortunate that in the table of comparative measurements the Piltdown skull is represented as possessing a lower cranial capacity than the Gibraltar, Neanderthal, and a typical Australian skull, whereas on the basis of the second reconstruction it is greater than any of these. It is obvious that any estimate of the Piltdown brain must vary according to the particular endocranial cast selected for examination.

Professor Elliot Smith's "Preliminary Report on the Cranial Cast" was made in December 1912, and was based upon an examination of the endocranial cast of Dr Smith Woodward's first reconstruction. His opinion does not appear, however, to have been materially modified by subsequent criticisms of this cast, for in a communication to the Geological Society of London more than two years later (in April 1914), he wrote as follows:—

"On the present occasion it is not my intention to say anything further in reference to the brain of *Eoanthropus* (because I am preparing a full report upon it for presentation to the Royal Society); but, as there has been considerable criticism of the restoration of the brain case, I should like to take this opportunity of expressing my opinion that none of the criticism has affected the accuracy of the preliminary note upon the cranial cast which I communicated to this Society in December 1912 (p. 93).

"As the correct restoration of the cranium was the necessary preliminary to any detailed study of the form of the brain, Dr Smith Woodward kindly permitted me to examine the fragments of the skull, and make an independent investigation with the view of determining what positions they originally occupied in the skull. This examination revealed a multitude of structural features which indicate precisely the true position and orientation of each of the fragments; and there is no doubt that the reconstruction of the skull which Dr Smith Woodward exhibited to the Geological Society in December 1912 was a much closer approximation to the truth than any of the various models so far exhibited in public by his critics."

The full report thus referred to was communicated to the Royal Society on the 19th December 1914, but no account of it has up to the present been published either in its *Proceedings* or *Transactions*. As Elliot Smith still adheres to the views he expressed in 1912 on the Piltdown brain, and as there

appears to be but little prospect of the early appearance of his full report on this question, I must base any criticisms I have now to make on the very brief and condensed statement contained in his "Appendix." In this he wrote:—

"At first sight the brain presents a considerable resemblance to the well-known Palæolithic brain casts, and especially to those obtained from the Gibraltar and La Quina remains, which are supposed to be women's. Like these casts, this one is relatively long, narrow, and especially flat; but it is smaller, and presents more primitive features than any known human brain or cranial cast" (p. 146).

I have already emphasised the importance of distinguishing between "endocranial" and "brain" casts, and the paragraph just quoted shows the confusion that may result from such lax terminology. It may seem unnecessary to point out that no one has hitherto been fortunate enough to obtain casts of the brain of Palæolithic man, although a number of more or less perfect endocranial casts have been made.

The question of the capacity of the Piltdown cranial cavity has already been considered, and it must surely be admitted that the assertion that it is smaller than any known human brain or cranial cast was premature and cannot now be maintained.

The further claim advanced by Elliot Smith that the Piltdown endocranial cast presents "more primitive features than any known human brain or cranial cast" necessarily requires a more detailed examination. The primitive features mentioned by Elliot Smith to which I propose to refer are the simplicity of the cerebral sulci and of the associated convolutionary pattern, and certain peculiarities in the development of the temporal and parietal lobes of the brain.

With reference to the cerebral sulci and convolutions we now give two quotations from his preliminary report:—

"In this note I do not propose to discuss the significance of the faint glimmerings which this cast affords of the pattern of the convolutions, except to remark that there are indications sufficiently definite to enable us to blot out a great part of the singularly primitive arrangement of sulci" (p. 146), and "unfortunately there are only very slight indications of the arrangements of the furrows upon the surface of the cerebral hemispheres. Nevertheless many of them can be detected, if not by sight, by passing the finger over the surface and locating the depressions by touch. These features are represented (with considerable exaggeration so far as depth is concerned) in the diagram (fig. 11) on the preceding page" (p. 146).

It is evident from these extracts that Elliot Smith found that the depressions and elevations on the endocranial cast, which apparently

corresponded to the cerebral convolutions and fissures, were very indistinctly marked, and he assumed from the "faint glimmerings" of the convolutions on the cast that the Piltdown man possessed a brain with "a singularly primitive arrangement of sulci." I have reproduced his sketch (fig. 8), which, although diagrammatic, illustrates admirably those features which he regards as of special significance. It will be noticed that none of the furrows which he has represented on the cast are named or described. More cautious than Froriep, or Boule and Anthony, he does not attempt to define the course and extent of even the main fissures, and

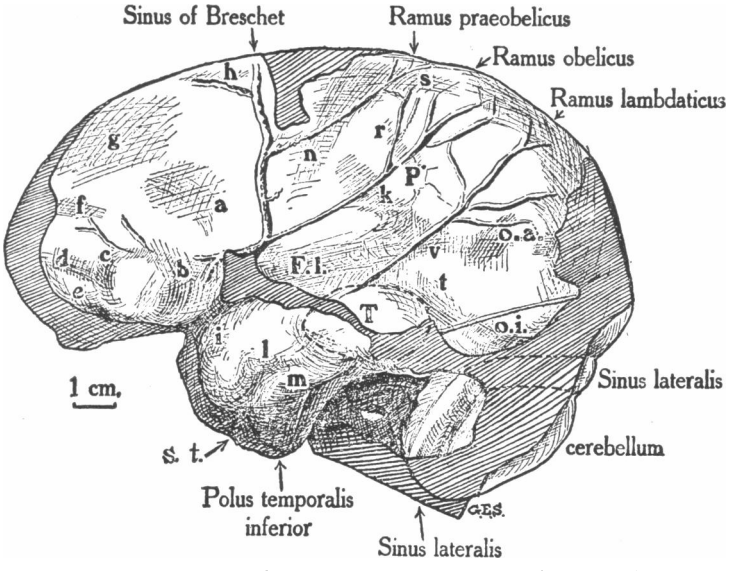

FIG. 8.—Left norma lateralis of the internal cast of the skull from Piltdown (Elliot Smith).

although letters are scattered with profusion over his diagram, not one cerebral fissure or convolution is named. The letters *s*, *n*, *k*, *v*, and *o.a.* are said to be placed on "recognisable sulci," but further details are not given, except that they circumscribe an elevated area of the parietal lobe.

I need not repeat the details of the researches recorded in my Struthers Lecture regarding the relations between endocranial and brain casts, and will content myself with saying that the evidence furnished by the markings on the cranial aspect of the Piltdown bone fragments do not justify the statement that the Piltdown man had a singularly primitive arrangement of the cerebri sulci, and this dictum can only, at the most, be regarded as a plausible hypothesis.

The next feature of the Piltdown brain to be considered is the temporal lobe. This is described by Elliot Smith as follows:—

"One of the most striking features of this brain cast is the deep excavation of the temporal area, to form the wide bay between the inferior temporal pole and the cerebellum. This is due to the marked attenuation of the temporal region; but as we have already seen in the case of the parietal region, so also here are definite signs that the expansion has begun which eventually will transform this area into the very different configuration that it presents in the modern brain. There is a very prominent elliptical swelling; the summit (at T) is raised more than a centimetre above the level of the surrounding cortex. It is 2 centimetres in vertical measurement, and almost 3 centimetres long. This peculiar configuration assumes quite a special interest when it is remembered that this obviously expanding area occupies the position where, in the modern human brain, is developed the territory which recent clinical research leads us to associate with the power of spontaneous elaboration of speech and the ability to recall names (Adolf Meyer).

"The configuration of the anterior part of the temporal area is also peculiar, though a suggestion of the same kind of form is seen in the Gibraltar brain cast. Below the point marked *l* the surface slopes inwards towards the mesial plane, so that the fulness of the temporal pole of the modern brain is wanting" (p. 147).

The deep excavation referred to above is a characteristic feature of all human endocranial casts. It is due mainly to the upward projection of the petrous portion of the temporal bone, but is completed behind by the groove for the descending portion of the transverse sinus and in front by the great wing of the sphenoid. Smith Woodward describes the left temporal bone of the Piltdown skull as "typically human in every detail," and with this statement I am in agreement. The only peculiarity of the bone, and this it shares with the other cranial fragments, is its great thickness. The thickness does not affect, except to a slight extent, the form of the cranial cavity. I have made several endocranial casts of this region on the skulls of modern man, in which the general shape and dimensions of this excavation are practically identical with those of Smith Woodward's endocranial cast of the Piltdown man. It must be remembered that no part of the sphenoid bone of the Piltdown skull was found, and therefore the exact configuration of the anterior part of the middle temporal fossa of the base of the skull cannot be ascertained.

The descent of the floor of the middle fossa of the base of the skull in the Piltdown man was supposed by Elliot Smith to be so marked that he describes a curiously pendant portion of the temporal lobe of the brain

which he names "*Polus temporalis inferior*, to distinguish it from the temporal pole of the modern man's brain." On comparing Smith Woodward's two endocranial casts I find that in the second reconstruction this descent is represented as less marked than in the first. In any case it is not based upon an actual cast of this part of the skull, but on a restoration of the sphenoid bone, as the most dependent part of the middle fossa is formed by this bone. On any ordinary endocranial cast a prominence is seen in this position which might be designated a *Polus temporalis inferior*, if one desired to increase the number of poles of the cerebral hemispheres.

The inward slope of the anterior part of the lateral aspect of the temporal lobe of the brain is not peculiar to the Piltdown man. It is a normal character of the brain of modern man (see fig. 9), and I doubt if it were more marked in the Piltdown brain.

There still remains to be noted the eminence on the lateral aspect of the temporal lobe (see dotted line surrounding letter T on fig. 8), to which Elliot Smith appears to attach special importance in connexion with the evolution of the speech centres. This eminence apparently corresponds to a digital impression situated partly on the squamous part of the temporal bone and partly on the adjacent lower portion of the parietal bone. The bevelled upper border of the squamosa has obviously been destroyed, and even on the cranial aspect the two bones do not quite meet, so that in the work of reconstruction this space had to be filled up. This elevation is therefore not entirely an actual cast of the bone fragments, but is partly dependent on the way in which the interval between the two bones is made good, and this would to some extent depend on the angle at which they are set against one another. Although Elliot Smith gives the dimension of this eminence, he does not associate it with any particular convolution, or explain how the "obviously expanding" area of this primitive brain differs from the same region in modern man.

In my Struthers Lecture I directed attention to the variations in the appearance of this region in endocranial casts and showed that prominences indicating the position of the middle and inferior temporal convolutions were of constant occurrence, while the position of the superior temporal convolution often corresponded to a smooth depression on the cast. If the Piltdown endocranial cast be compared with those of modern men in which the brains have been preserved, it will readily be seen that the eminence T corresponds to one of the digital impressions due to the middle temporal convolution. The lateral aspect of this convolution is normally broader and projects farther out than either the superior or inferior temporal convolution, and the greatest transverse diameter of an endocranial cast

is always on an elevated area corresponding to the middle temporal convolution and placed above and generally slightly in front of the external auditory meatus. I think there can be no reasonable doubt but that Smith Woodward's endocranial casts are both correct so far as the general

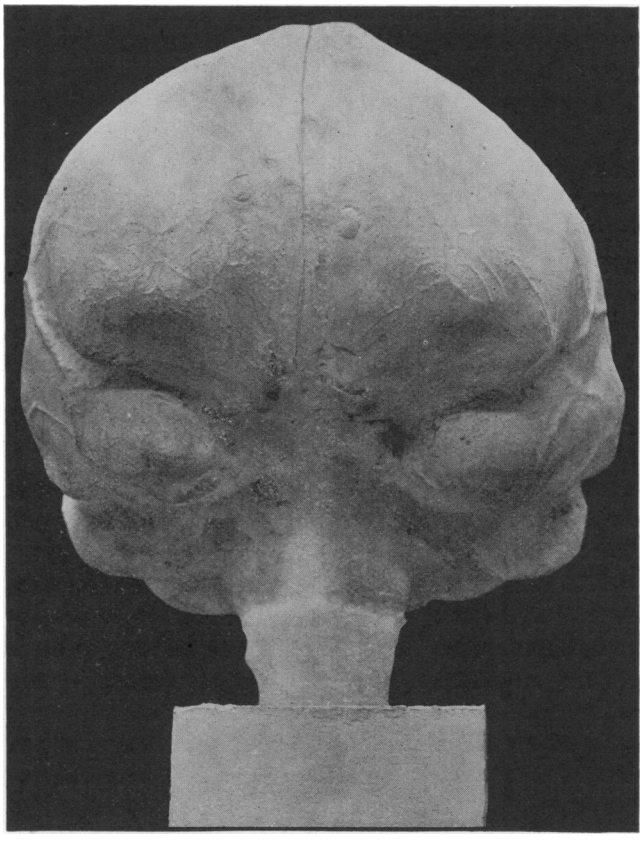

FIG. 9.—Photograph of an endocranial cast of a skull from the New Hebrides, viewed from the front. Note the prominence on the lateral aspect of the temporal lobe and the way in which the surface slopes inwards towards the temporal pole.

position of the elevation marked T in Elliot Smith's figure is concerned, but in the first reconstruction the degree to which it projects laterally as compared with the parietal area is certainly exaggerated.

After a careful study of Smith Woodward's endocranial casts of the Piltdown skull and their comparison with similar casts of modern men in whom the brain was preserved, I have come to the conclusion that the

Piltdown cranial fragments afford no satisfactory evidence in support of the view that any special part of the temporal lobe was either imperfectly or precociously developed.

Elliot Smith also describes the parietal regions and writes:—

"I have already referred to the diminution and flattening of the frontal and parietal regions. In the centre of the latter there is an area, which is well circumscribed by recognisable sulci (*s*, *n*, *k*, *v*, and *o.a.*), raised up into a low hillock, the summit of which is at point marked P. It is more pronounced on the right hemisphere. This indication of the expansion of an area, the large dimensions and fulness of which are especially characteristic of the human brain, is peculiarly significant, when taken in conjunction with a similar condition in the temporal region" (p. 146).

With reference to the diminution in the parietal region, he states that while the maximum breadth of the hemisphere, which is at T, amounts to 130 mm., "at the point P in the parietal region, corresponding to the place where anthropometrists measure the breadth of the brain case, it is only 102 mm." If I understand Elliot Smith correctly, he considers that at the area P the brain, although still imperfectly developed, showed at this low hillock the beginnings of an expansion by which this part of the brain would ultimately attain the large size characteristic of modern man.

It is unnecessary to discuss seriously the evidence in favour of the slight development of this part of the Piltdown brain, because it is based upon the first reconstruction, and Smith Woodward in his second reconstruction has considerably broadened the endocranial cast, increasing the transverse diameter at the level of P by about 15 mm. and making the general form of the upper part of the cerebral hemispheres readily comparable with many existing races.

General Summary.

It will have been noticed that Dubois, Boule and Anthony, and Elliot Smith have all endeavoured to show from endocranial casts of certain prehistoric skulls that the corresponding brains were of a "primitive" type. Thus Dubois,[1] in describing the endocranial cast of *Pithecanthropus erectus*, writes:—

"The intraparietal fissure is only very partially distinct, but seeming to point to a relatively large occipital lobe, an ape-like condition, undoubtedly consequent on a relatively larger development of the sensory centres of the cortex in contrast with smaller areas of association."

[1] *Op. cit.*, p. 112.

Boule and Anthony,[1] in the case of the La Chapelle man, assert that:

"Si le volume relativement considérable de son encéphale constitue un argument en faveur de son intelligence, l'aspect grossier de toutes les circonvolutions visible paraît au contraire, indiquer des facultés intellectuelles rudimentaires" (p. 193).

Elliot Smith,[2] more decided, writes with regard to the Piltdown brain:—

"Taking all its features into consideration, we must regard this as being the most primitive and most simian brain so far recorded" (p. 147); while Smith Woodward,[3] in a more popular account of this prehistoric man, says:—

"So far as they can be distinguished, the convolutions of the brain are simpler than those of modern man and there are certain parts which remain scarcely more developed than they are in a modern child" (p. 14).

In opposition to these views I venture to assert

1. That the simplicity or complexity of the cerebral fissures and convolutions cannot be determined with any degree of accuracy from endocranial casts, even on complete skulls, much less on reconstructions from imperfect skulls.

2. That it is not possible to estimate, even approximately, from the La Chapelle or Piltdown endocranial cast, the relative degree of development of the various sensory and association centres in the cortex.

3. That the various deductions made by Boule, Anthony, Elliot Smith, and others, with reference to the primitive and simian features of the brains of certain prehistoric men, from an examination of their endocranial casts, are highly speculative and fallacious.

[1] *Op. cit.*, p. 112.
[2] *Op. cit.*, p. 112.
[3] *A Guide to the Fossil Remains of Man in the Department of Geology and Palæontology in the British Museum*, 1915.