Palæontology. — *The Shape and the Size of the Brain in* Sinanthropus *and in* Pithecanthropus. By EUG. DUBOIS.

(Communicated at the meeting of April 29, 1933).

[PLATES I—IV]

The most impressive if not the most significant of the numerous important human fossils unearthened in this still young century, was certainly the skull of *Sinanthropus pekinensis*, discovered on December 2, 1929 in the "Lower Cave" at Choukoutien, 40 km south-west of Peking, by the Chinese geologist W. C. PEI.

This nearly complete brain-case, only the base being deficient, and a second, much less complete one, discovered by PEI in the same cave, were prepared, studied and described by the author of the species name, DAVIDSON BLACK, Professor of Anatomy in the Peking Union Medical College. He published the results of his thorough investigation in two preliminary reports on the first and a notice on the second skull, in 1930, and finally in a splendid detailed craniometric and craniographic description of the external skull morphology of the two *Sinanthropus* specimens, including comparisons between these crania and those of other hominids and anthropoids, in 1931 [1]). He now concludes, as to the probable ontogenetic age and the sex of the two skull specimens, that the nearly complete brain-case, the Locus E skull, is that of an early adolescent. This conclusion is founded on the evidence of vigorous suture growth along the major vault sutures in this exceptionally thick-boned skull, not normally encountered in modern skulls of later adolescent age. The male sex is betrayed by the massively developed torus supraorbitalis and other male features, such as the strong contours of the zygomatic and supramastoid crests and the postero-inferior parietal thickenings in their relation to the torus occipitalis. The second, much less complete, the Locus D skull is considered to be that of a young adult, on account of the partial obliteration of the coronal suture. As a result of comparative study with other skulls the considered opinion is offered that, with a high degree of probability, the evident differences in form between the two skulls are due solely to differences in age and sex, the Locus D skull representing a female individual.

Judging from the preliminary reports, notice and photographs, which, in

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1) DAVIDSON BLACK, On an Adolescent Skull of *Sinanthropus pekinensis* in comparison with an Adult Skull of the same Species and with other Hominid Skulls recent and fossil, Geological Survey of China. Palæontologia Sinica. Series D. Volume VII, Fascicle 2. Pp 1—144. With Plates I to XVI and Text figures 1 to 37. Peiping 1931.

1930, Professor DAVIDSON BLACK most kindly distributed to experts in the matter, both skulls appeared to be clearly neandertaloid, like the lower jaws and teeth of his first reports on the species. However, they also exhibited certain unique morphological features, which he regarded as evidences of archaic generalization. At the same time the first skull exhibited resemblances with *Pithecanthropus,* of which, still in his final report, he says: "it is clearly evident that the crania of *Sinanthropus* and *Pithecanthropus* resemble one another much more closely than they do any other known hominid type". Some other very able anatomists, WEIDENREICH, WEINERT, judging from those photographs, even found a striking similarity, which induced them unhesitatingly to include the fossil Peking Man in the genus *Pithecanthropus,* and to emphasize at the same time the close relation which, in their opinion, exists between the latter and Neandertal Man.

As to the probable taxonomic and phylogenetic status of *Sinanthropus,* DAVIDSON BLACK resumes his opinion as follows: — "Its cranial and dental characters are such as to imply that *Sinanthropus* could not have been far removed from the type of hominid from which evolved both the extinct Neanderthaloid and Rhodesian forms and the modern *Homo sapiens*". As I understand it, this is regarding *Sinanthropus* as the common ancestor of the two great hominid groups (species): *Homo neandertalensis* and *Homo sapiens.* His further study of certain of the major craniometric and craniographic characters which, to his mind, serve sharply to distinguish *Sinanthropus I* from other hominid types ancient or modern, and of the unique morphology of the tympanic portion of the temporal bone, which made it evident that the meatus and the middle ear in this adolescent *Sinanthropus* must have presented relations similar to those which in modern man are typically developed only in infants and very young children [1]), would seem amply to sustain this opinion.

Although acknowledging the resemblances exhibited by the crania of *Sinanthropus* and *Pithecanthropus,* it is equally apparent to DAVIDSON BLACK that they differ from one another in points of proportions and detail to a degree amply sufficient to proclaim their generic distinction. The strikingly higher and fuller frontal and parietal vault curve of the midsagittal contour of *Sinanthropus* constitutes a character serving sharply to distinguish this form from *Pithecanthropus.* Another important feature, in which these two crania, in norma basalis view, significantly differ is that the vertical planes in which fall the least frontal diameter and the greatest vault breadth, both occupy relatively and absolutely a position much further back upon the *Pithecanthropus* calvaria than on *Sinanthropus.* This is connected with a very striking and most significant difference to be observed in the outlines of the two mid-horizontal contours in glabella-opisthion orientation — norma basalis view. That of *Sinanthropus* is a long oval

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[1]) Further, the mammilary portion of the mastoid process is even more slightly developed than in Neandertal Man (of Krapina), recalling as it does the condition found in infants.

with full frontal and occipital arcs, not greatly dissimilar to that of Neandertal, and indeed many modern human skulls. The contour of *Pithecanthropus* on the other hand is significantly pyriform in outline with narrowed frontal and broad occipital arcs ; the latter being quite markedly flattened posteriorly. The same conditions as in *Pithecanthropus* are found to obtain in no less marked degree in the juvenile crania of the great anthropoids — and, I may add, the adult crania of the gibbons.

To those differences between *Sinanthropus* and *Pithecanthropus*, so excellently described by DAVIDSON BLACK, as I could verify by comparing the calvaria of the latter with the now available beautiful cast made by Mr. F. O. BARLOW of the completely prepared *Sinanthropus* brain-case, there is no need to add any others, as they have no direct relation to differences in the shape of the brain, the proper subject of this report [1]).

The apparently archaic character of *Sinanthropus* appears to be in accordance with the geological age of the Choukoutien cave deposits, which, as judged from the mammalian fauna, is regarded as probably Lower Pleistocene (TEILHARD DE CHARDIN and YOUNG, PEI). However, there are in such estimations always elements of uncertainty. Possibly this age attributed to the fossil cave fauna may be subject to revision, since we now have conclusive, though indirect evidence of distinct humanity of *Sinanthropus*, in the established facts that he knew the use of fire and the manufacture of stone implements (PEY 1931), reminding of the Mousterian fashion according to Prof. BREUIL (1931), though representing a more crude lithic culture according to TEILHARD DE CHARDIN and PEI (1932).

Conclusive direct evidence as to complete humanity of *Sinanthropus* and his generic distinctness from *Pithecanthropus*, which was anticipated by the comparison of the crania, I expected from a comparison of the endocranial casts conveying the general shape and dimensions of the brain which filled the crania. Particularly interesting in this respect it would be to verify the significance of the strikingly higher parietal vault curve in the side view contour of *Sinanthropus* "constituting a character serving sharply to distinguish this form from *Pithecanthropus*", for indeed the parietal vertex of the brain is an elementary distinctive human character.

Many years ago, when I had entered upon studies on the cephalization of *Pithecanthropus*, I compared an endocranial cast of the latter with endocranial casts of Man on the one side, and Anthropoid Apes (Chimpanzee, Orangoutan, Gibbon) and some Monkeys (*Cebus*, *Midas*) having the highest "relative brain volumes", on the other hand, in order to find out a possible connection between relative volume and shape of the brain.

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[1]) One of these differences may, however, be noted here, as it sharply serves to distinguish *Sinanthropus* (and the Chimpanzee) from *Pithecanthropus* (and the Gibbons). This is the complete absence, on the nuchal part of the occipital bone, of the fossae for the attachment of the two rectus capitis posticus minor muscles, whose presence was so striking a feature in *Pithecanthropus*.

Comparison of the mid-sagittal outlines of telephotographic side views of those endocranial casts, in subcerebral (orbital—suboccipital) plane orientation, as represented in the two Figures of Plate IV (to be compared with the lower Figure of Plate III), did not prove the existence of such a connection. The outlines of *Pithecanthropus, Hylobates agilis* and Chimpanzee nearly agree, and in the parietal region, even those of the hypsicephalic orangoutan and also the Platyrrhine monkeys. Man, however, is distinguished from all of them by the possession of a high p a r i e t a l v e r t e x. At the same time his lobus temporalis, in distinction from all of them, appears as much more inclining to the front.

Doubtless this striking feature of the human brain-shape is to be considered as a consequence of this that in Man the head is poised upon the vertebral column, in distinction from the Apes, whose forward bent head is kept in position by the muscles attached at the nuchal part of the occipital bone. Apparently, in this respect *Pithecanthropus* was not humanlike.

Lately Prof. DAVIDSON BLACK supplied the fervently anticipated direct evidence of the perfectly human nature of *Sinanthropus*. In January his report on the endocranial cast of the Locus E skull, which cast he had made in 1930, was published [1]), and in the same month very exact copies of the original by Mr. F. O. BARLOW were made available, who most kindly sent the first finished one to the Teyler Museum, where it came at my disposal on February 8. From this date I have closely studied this extraordinarily interesting specimen, also by means of telephotographs (made with a lens of 150 cm focal length, set up at a distance of 3 meters from the object).

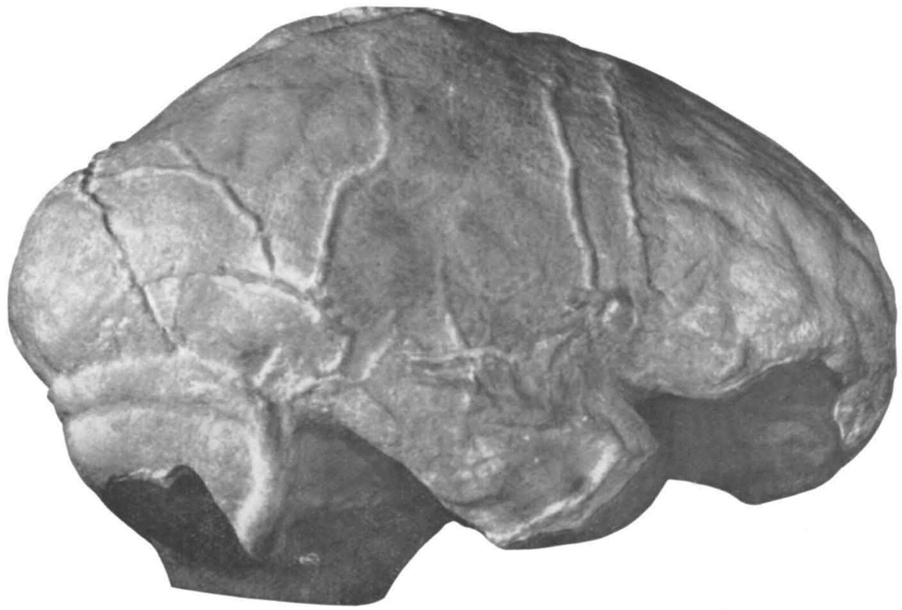
Plates I and II in this paper give reproductions of those telephotographs representing the norma verticalis and norma lateralis dextra views of this *Sinanthropus* endocranion, in $^3/_4$ natural size, beside the corresponding views, in the same reduced scale, of *Pithecanthropus*. The accurate comparative diagrammatic drawings of Plate III were made by the same and an analogous exact method.

My expectation of the significance of this endocranial cast had not been pitched too high. It really settled the question on the complete humanity of *Sinanthropus*.

It, moreover, gave evidence of an important peculiarity of this individual man. In his Report DAVIDSON BLACK says, that at first it had been intended to describe the endocranial cast of both this specimen and that of the adult skull, from Locus D, together, but as circumstances had retarded the work of restoration on the latter specimen, the report on the Locus E specimen would no longer be delayed. This means the joyful expectation of a fuller restoration of the other skull and the future availableness of another

[1]) DAVIDSON BLACK, On the Endocranial Cast of the Adolescent *Sinanthropus* Skull. Proceedings of the Royal Society. Series B. Vol. 112. Biological Sciences. Pp. 263—276. With six Plates. London, January 2, 1933.

Upper Figure: Endocranial cast of adolescent *Sinanthropus*.
Lower Figure: Endocranial cast of *Pithecanthropus erectus*.
Both telephotographs of norma verticalis view. × $^3/_4$.



Upper Figure: Endocranial cast of adolescent *Sinanthropus*.
Lower Figure: Endocranial cast of *Pithecanthropus erectus*.
Both telephotographs of right norma lateralis view in subfrontal (orbital)-suboccipital cerebral plane orientation. × $^3/_4$.

endocranial cast of the species, enabling us to verify the signification of that peculiarity of the locus E *Sinanthropus.*

In a most able manner DAVIDSON BLACK has restored the relatively small missing part of the first endocranial cast, apparently thus nearly approaching reality. This part having been painted an ochre colour is indicated in dark tone in the photographs.

Apparently the cast represented in the Plates of his report is the natural one, as appears from the irregularly interrupted vascular markings, the numerous diminutive pits, eminences and other small unevenesses on the surface of the preserved parts. These otherwise insignificant defects were obviously mended in the cast from which our copy was taken.

From comparative measurements of mean lengths in DAVIDSON BLACK's norma verticalis, frontalis and lateralis views, in photographs and diagrams of the endocranion report, our copy appears to be admirably exact in breadth and height, only slightly expanded in length, in proportion of 157 to 159 mm. Equal lengthening was found by comparing with the "inner skull length" in the skull report.

Having in this way, as much as possible, made sure of the exactness of the copy endocranial cast, I may now again draw the attention to the Plates I and II of this report, and proceed to compare *Sinanthropus* with *Pithecanthropus.*

There is obviously little difference in size between the two brains, in **shape**, however, they are surprisingly unlike.

As we could expect from the comparison of the skulls in the norma verticalis view, the brain form of *Sinanthropus,* in this view, is oblong and narrow against the more rounded, broad form of *Pithecanthropus* (Plate I).

Most strikingly different are the two brains in the norma lateralis view (Plate II). The frontal part in *Sinanthropus* is much fuller and rounder, as was anticipated from the shape of the brain-case. Likewise the dissimilarity in the shape of the parietal contour of the brain-case is repeated, but much more strikingly and significantly, on the brain itself. The contour line between the bregma and the lambda (in a straight distance of about 90 mm in both specimens), which is nearly flat in *Pithecanthropus,* is strongly elevated in *Sinanthropus* to a real and distinctly human parietal vertex. At the same time we find, herewith again in correlation, the temporal lobe humanly declined to the front.

These features are clearly demonstrated in Plate III, showing diagrammatic drawings of the norma lateralis view contour of the *Sinanthropus* endocranial cast in comparison with endocranial casts from a normal mesocephalic human (Dutch) skull and (in the inset) a microcephalic skull of 375 c.c. capacity [1]). Microcephaly, although greatly altering the brain shape in other respects, does not at all take away the parietal

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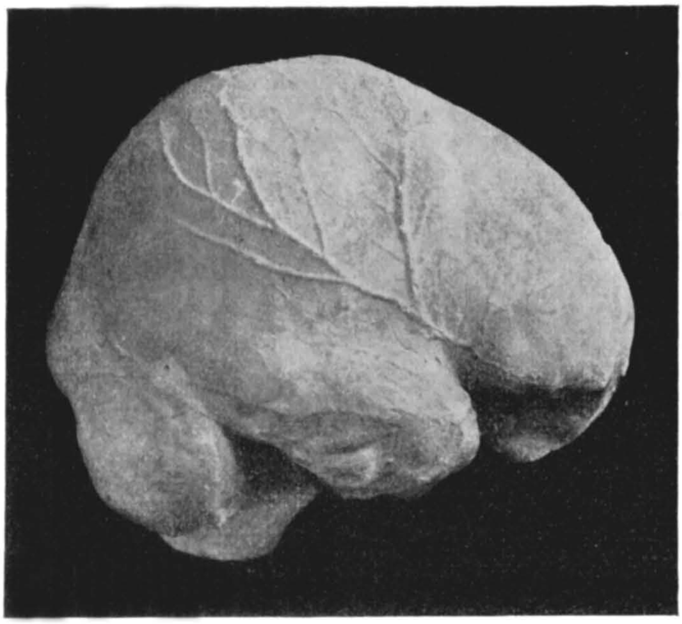
[1]) This is the skull in the Leiden Institute of Anatomy, described by SANDIFORT (1835).

vertex, that essential human character, which *Pithecanthropus* as well as the Apes does not possess (Plate III, lower Figure).

From this and other comparisons it appears to be a consequence of the oblong, dolichocephalic (cranial index 71) brain form of *Sinanthropus*, that its parietal elevation does not rise to quite such a height as in that mesocephalic brain, and that it is surpassed still more by the brachycephalic Javanese brain, as shown in the Text Figure on this page. Telephotograph of endocranial cast of Javanese skull, norma lateralis view in subcerebral (orbital-suboccipital) plane orientation. × ½.



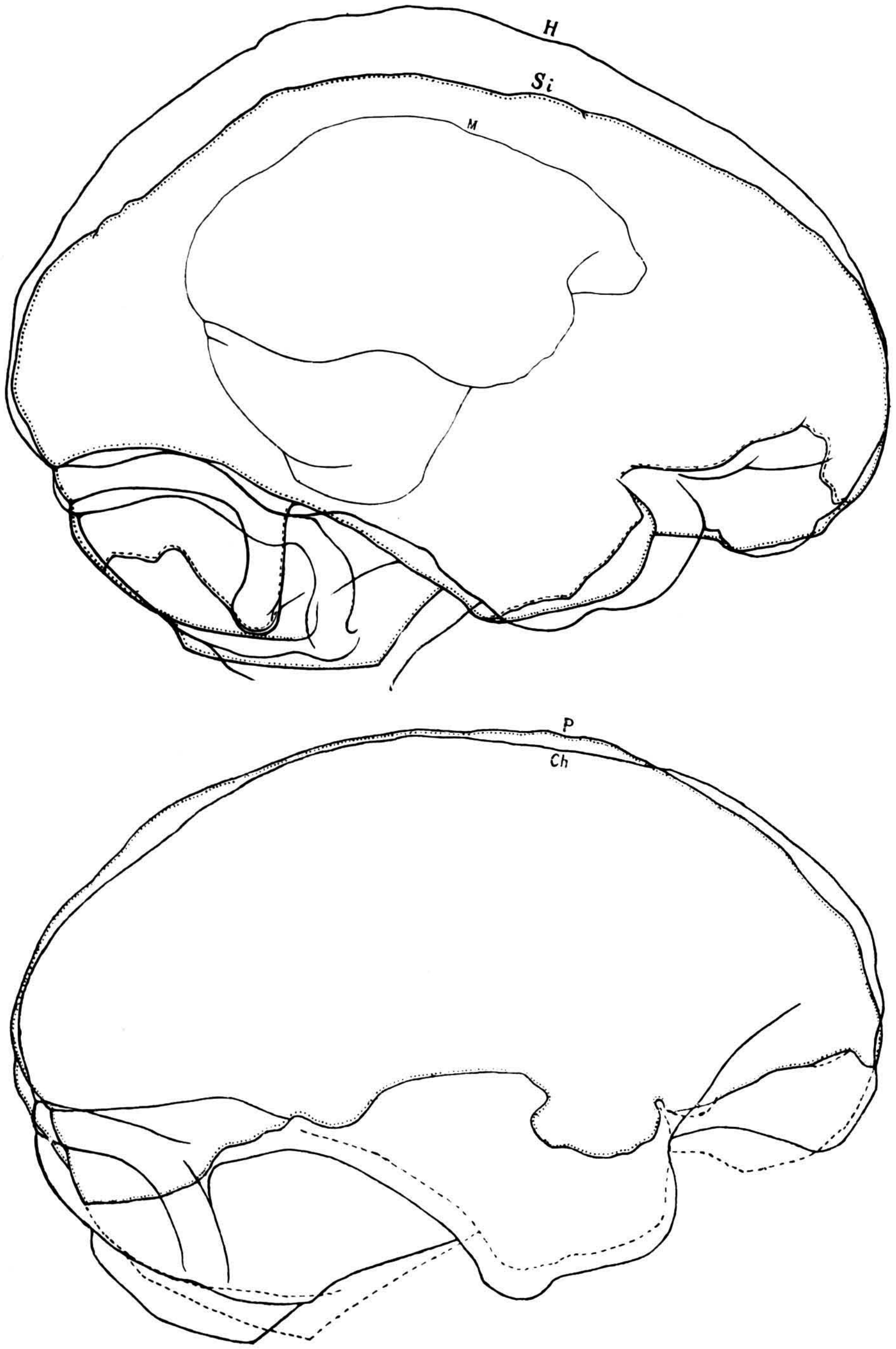
On the other hand, in the lower Figure of Plate III, the outlines of braincasts, in norma lateralis views, of *Pithecanthropus* and Chimpanzee [1]), which nearly coincide, lack a parietal vertex. The conclusion is obvious, that in *Pithecanthropus*, in distinction to *Sinanthropus*, the head was not poised on the vertebral column.

Another important character of this *Sinanthropus*, of which the endocranial cast, corresponding in shape and volume with the cranial cavity, may also give evidence, is the size of the brain.

Before knowing DAVIDSON BLACK's report on the endocranial cast, wherein he published the results of his accurate volumetric determinations, I had measured the volume of the copy of that cast, by means of a very exact hydrostatic balance, as to be 930 c.c. Apparently, however, this result of the most exact volumetric method, needed a correction, a slight

[1]) Endocranial cast of a very fine adult female skull, capacity 385, from the Amsterdam Institute of Anatomy.

PLATE III.



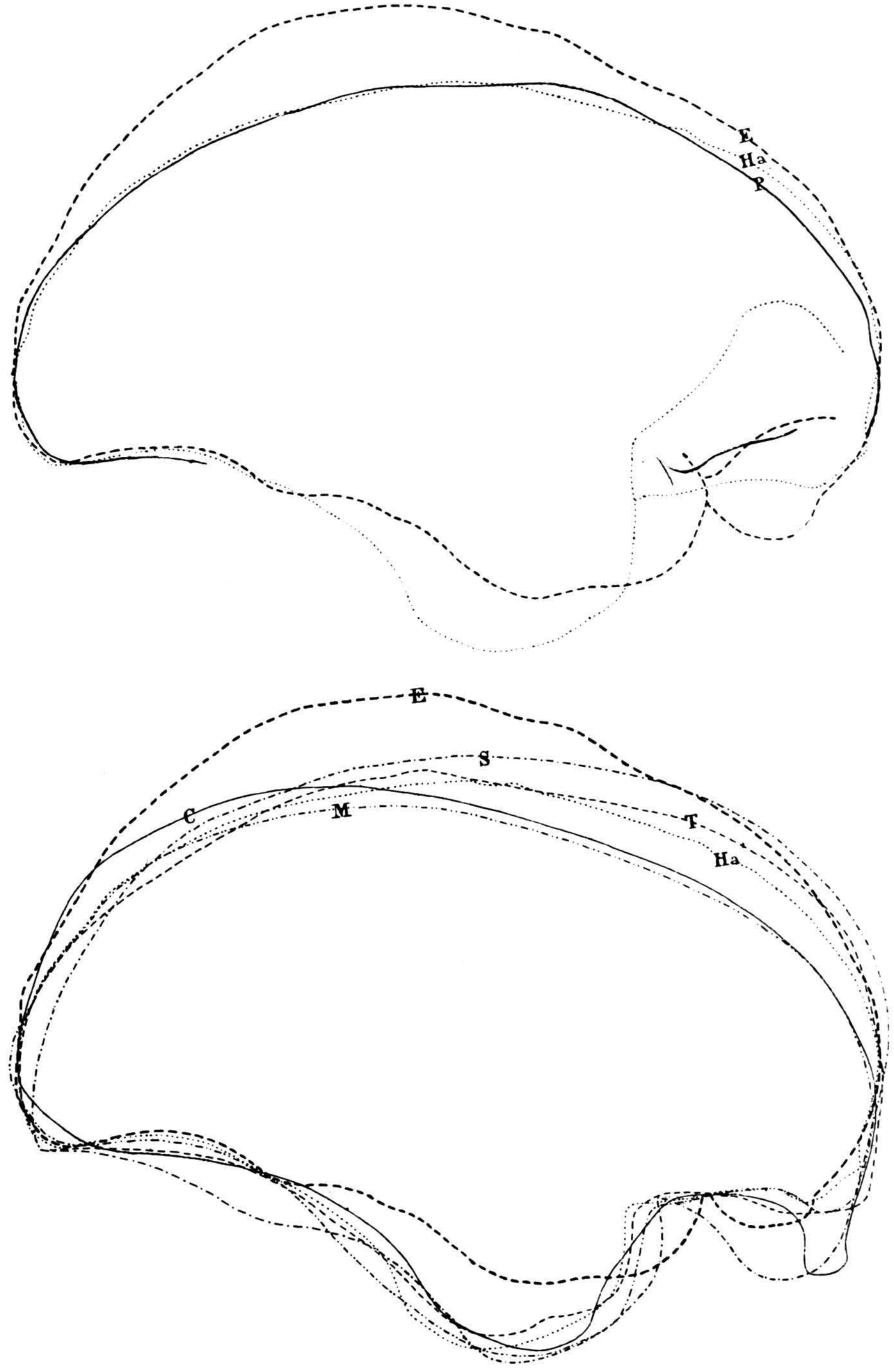
Upper Figure: Endocranial casts of adolescent *Sinanthropus* (*Si*). × 3/4, mesocephalic normal man, Dutch (*H*). Made to equal length. Inset: Microcephalic man (*M*). × 5/9.

Lower Figure: Endocranial cast of *Pithecanthropus erectus* (*P*). × 3/4, and Chimpanzee (*Ch*). Made to equal length.

Both Figures diagrammatic drawings (telephotographic outlines) of right norma lateralis views. Same orientation as in Plate II.

EUG. DUBOIS: THE SHAPE AND THE SIZE OF THE BRAIN
IN SINANTHROPUS AND IN PITHECANTHROPUS.

PLATE IV.



Upper Figure: Endocranial casts of *Pithecanthropus erectus* (*P*). × 3/4, mesocephalic Man (*E*), and *Hylobates agilis* (*Ha*). Made to equal length.

Lower Figure: Endocranial casts of mesocephalic, Dutch, Man (*E*), Chimpanzee (*T*), Orangoutan (*S*), *Hylobates agilis* (*Ha*), *Cebus* (*C*), and *Midas* (*M*). Made to equal length with *P* of the upper Figure.

Both Figures diagrammatic drawings (telephotographic outlines) of right norma lateralis views. Same orientation as in Plate II.

Proceedings Royal Acad. Amsterdam, Vol. XXXVI, 1933.

reduction, on account of the difference between the length of this cast and the length of the cranial cavity as measured directly by DAVIDSON BLACK. Then having verified the exactness of our copy by comparing its length, breadth and height with the corresponding measurements on the photographs and diagrams in the endocranion report, as indicated above, I calculated for the probable real volume of the original endocranion, corresponding with the cranial capacity and the volume of the brain with its envelopes, **918** c.c., by which t h i s *Sinanthropus* nearly approaches, but not really surpasses *Pithecanthropus*.

This volume approaches the lower result of the two methods of volumetric determinations applied by DAVIDSON BLACK, the one which he held for less reliable, yielding approximately 900 c.c., whereas by the other, which he considered to yield the most accurate volumetric results, he found 964 c.c.

The difference between these results being very great, and as in the present instance it indeed seemed desirable to obtain the most reliable figure, I have endeavoured to ascertain the degree of exactness of the two methods applied by the distinguished anatomist.

According to his own words (p. 264 of the report), DAVIDSON BLACK proceeded as follows:

"A number of trial restorations of the base of the endocranial cast were made and cast in plaster before the one which probably approximates most nearly to the correct form was selected. These various plaster casts were dried and waterproofed by impregnation with shellac under negative pressure. Their respective volumes were then determined in water by the displacement method in a cylindrical vessel just accommodating the specimens. As a result of repeated trials by two independent and qualified observers the volume in each approached 900 c.c., it being impossible to obtain a more accurate reading of volume displacement in a vessel of the size necessary to accomodate one cast."

"To overcome this difficulty a Negocoll cast was made of the restored endocranial cast which had been finally selected for description. This Negocoll was then melted and poured in cylindrical moulds which when set were of a size readily to be accomodated within graduated measuring cylinders. Twenty-five consecutive determinations of the volume of these Negocoll cylinders were then made in order to permit the calculation of the probable error."

In a number of trials I now found it easily possible to obtain accurate readings of volume displacement in a cylindrical vessel of 14.5 cm width, spaciously accomodating the endocranial cast, to 0.5 mm shifting of water-level, corresponding to about 8 c.c. of volume displacement, if using the right illumination and slips of white paper as indicators.

As in such vessel 64 c.c. (the difference of the results obtained by the two methods) of volume displacement correspond to about 4 mm shifting of water-level, this difference must not chiefly be imputed to the inaccuracy of this direct displacement method, as an error of observation, but obviously for the greater part to the indirect method, that using a Negocoll endocranial cast.

Further experiments taught me that Negocoll, in the conditions of the volumetric method described by DAVIDSON BLACK, unavoidably expands by absorbing a certain quantity of water, the volume thus increasing about 5 per cent. in a short time. After this the Negocoll retains very nearly the same thus obtained volume during a much longer time than is required for twenty-five consecutive determinations of the volume.

In this way I convinced myself that the great difference between the results of the two methods was chiefly owing to the unsuitability of Negocoll for such volumetric measurements. Moreover a confirmation was thus found of the result of my own determination, as $964 \times \frac{100}{105} = 918.1$.

Such a volume of the endocranial cast or cranial capacity of 918 c.c., about equal to that of *Pithecanthropus*, is certainly a very low one for a human skull, as this *Sinanthropus* undoubtedly is. For at the age of this early adolescent human individual the volume of the brain is almost equal to that of the adult. Such a boy of 15 or 16 years of age was also the Neandertal individual of Le Moustier, whose cranial capacity is estimated to be more than 1500 c.c., but how youthful are the morphological features of his skull! The shape and the major features of this *Sinanthropus* skull, on the contrary, are those of a full grown male Neandertaler. They are undoubtedly very different from the typical skull shape and features of a child, and of a female of his race, and also from those of a pygmean race or a normal small individual of his own race. We meet here with a contradiction of cranial form and cranial capacity, a contradiction emphasized by the other *Sinanthropus* skull, attributed by DAVIDSON BLACK to an adult woman. In contradistinction with the adolescent skull it, indeed, exhibits true female features. It is difficult to estimate the capacity of this very incomplete cranium, however 1150 c.c. will probably not be too high an estimate. In proportion to such a female capacity a normal adult male of the same race should have about 1300 c.c. capacity. However the adolescent *Sinanthropus* exhibits adult morphology in combination with a brain volume very much smaller than the normal one of his age.

This is a contrast which is perfectly unconceivable if we consider this *Sinanthropus* youth as a normal individual. The conclusion appears unavoidable that the brain in this individual was not full-grown. In accordance with this the brain exhibits a feature frequently found in microcephalic brains. Clearly the Sylvian fissure had not yet attained the development of the full-grown human brain but, most conspicuously on the left hemisphere, in its inferior part still remained in the infantile condition of a fossa, the inferior frontal gyrus and the temporal lobe there being widely separated from one another, and thus the insular region left incovered by its operculae. This particular feature of this *Sinanthropus* brain is well described by DAVIDSON BLACK.

In conclusion I may express my opinion that the adolescent *Sinanthropus* is a human male, belonging to the Neandertal group of mankind, the species *Homo neandertalensis*, maybe an interesting new race, with individually imperfectly developed and hence abnormally small brain.

Further skulls will instruct us how far the striking external particularities of the Locus E skull are characteristic of a distinct race or only individual features due to unfinished ontogenesis.

Embryology. — *Über den Glykogenstoffwechsel tierischer „Organisatoren"*. Von M. W. WOERDEMAN.

(Communicated at the meeting of April 29, 1933).

In einer vorigen Mitteilung [1]) habe ich berichtet über den Glykogenstoffwechsel des Organisationszentrums in der Amphibiengastrula.

Ich fand, dasz die bei der Gastrulation invaginierten Zellen in kurzer Zeit nach der Einrollung den grössten Teil ihres Glykogens verlieren und dasz also offenbar in der Urmundlippe sehr besondere Stoffwechselverhältnisse herrschen. Ich habe die Vermutung ausgesprochen, dasz in irgend einer Weise diese Stoffwechselverhältnisse zusammenhängen könnten mit den merkwürdigen Wirkungen, die von den Urmundlippen ausgehen und welche SPEMANN veranlasst haben von einem „Organisationszentrum" in den Urmundlippen zu sprechen.

Nun giebt es verschiedene Wege um zu untersuchen, ob wirklich zwischen der Glykolyse und den Organisationswirkungen eine Beziehung besteht.

Wir haben in letzter Zeit in meinem Institute versucht die Hypothese zu prüfen, ob Organisation (Induktionswirkung) und Glykolyse in den Zellen des Organisators (Induktors) mit einander etwas zu tun haben, wobei wir tatsächlich verschiedene Wege eingeschlagen haben.

In der vorliegenden Mitteilung werde ich nur über einen dieser Wege berichten, nämlich über den histiochemischen Glykogennachweis in Zellgruppen, die als Organisatoren betrachtet werden können.

Bekanntlich hat SPEMANN die Augenblase einen sekundären Organisator genannt.

Sie soll die Linsenanlage im Ektoderm des Kopfes induzieren. Obwohl die Frage, in welcher Weise die Linseninduktion stattfindet, noch nicht vollständig geklärt ist, kann man wohl als gesichert annehmen, dasz bei den Amphibien die Augenblase auf das überlagernde Kopfektoderm eine Induktionswirkung ausübt.

Es lag nun nahe zu untersuchen, ob auch in diesem „Linsenorganisator" der Glykogenstoffwechsel besondere Verhältnisse zeigt. Ich habe deshalb mit der in der vorigen Mitteilung beschriebenen Technik (Jodreaktion nach

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[1]) Cf. diese Proceedings Vol. XXXVI, N°. 2, 1933.