PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

A Comparative Study of the Endocranial Cast of Sinanthropus

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X. *A Comparative Study of the Endocranial Cast of* Sinanthropus.

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[Plates 53–55.]

We have made this attempt to describe and interpret the endocranial cast of *Sinanthropus* in deference to the wishes of Professor Davidson Black.* When he submitted to the Royal Society his preliminary report (Black, 1933, *a*), he explained to us that he did not regard it as a disadvantage that his paper was incomplete, because it opened the way for those who had opportunities for comparing the cast with those of other human fossils and actual brains of primitive men and apes, to undertake the necessary work of comparison and interpretation, and we willingly undertake this duty. Each of us has independently studied the actual fossil skull in the Union Medical College at Peiping and examined the beautiful cast made by Professor Davidson Black from the actual fossils, and we should like to express our gratitude to him for these opportunities and many other kindnesses which he showed us.

In studying the endocranial cast obtained from the Piltdown skull one of us (G. E. S.), years ago, was impressed by the extraordinary resemblance presented by the form of the brain in this extinct member of the human family to that of the primitive brain of a modern human being, a Sudanese negress (Elliot Smith, 1927, figs. 40 and 41). The other (J. L. S.) was impressed by the remarkable likeness to the endocranial cast of *Sinanthropus* of the brain of the Bushwoman, described in 1865 by Professor John Marshall. The recognition of these facts adds particular importance to the consideration that both the authors of this communication have served an apprenticeship to the task by examining large series of primitive brains, aboriginal Australians (J. L. S.) and Sudanese negroes (G. E. S.), and have devoted some attention to the comparison of the brains of the anthropoid apes and primitive men. In attempting to interpret the significance of the endocranial cast of *Sinanthropus* special attention must obviously be paid to comparison with the casts of *Pithecanthropus* and *Eoanthropus*. The comparison with the brains of the larger apes is also important, throwing light as it does upon the characters one ought to expect to find in extremely primitive human brains.

In attempting to convey some real conception of the nature of the form of the brain we have resorted to the use of series of contours, figs. 10–14, so that the reader at a glance can obtain a graphic expression of the distinctive peculiarities of form.

* The misfortune of his premature death deprives us of the pleasure of presenting this memoir to him.

The Occipital Region.

The region of the occipital poles is so clearly modelled that its features can be identified without any uncertainty. The interpretation is further facilitated by the fact that this part of the brain conforms to a pattern which is well known in the Orang-utan, fig. 1, Plate 53. The sulcus lunatus (18) coincides with the lambdoidal suture, fig. 2, and its prominent posterior lip clearly defines the limit of the great occipital operculum which marks the boundary of the area striata.

The occipital or lunate operculum, fig. 3, Plate 53, forms a triangular elevation on the posterior aspect of the cast. The projection is so prominent that the operculum is defined almost as clearly as it would be on the brain itself; moreover, the cast shows that the texture of the surface of the occipital operculum is different from that of the area lying anterior to it, as it is in the apes and monkeys. The base of the triangle lies at the middle line and extends anteriorly to within 2 mm. of the lambdoidal suture. The antero-medial angle forms a prominent rounded swelling which might be termed the *superior polar eminence* (S.P). In such types the medial part of the lunate sulcus (18) constitutes the superior polar sulcus of Shaw Bolton. This sulcus is probably represented in *Sinanthropus* by the depression which exists between the superior polar eminence (S.P) and the lambdoidal sutural marking (λ). The postero-medial angle likewise forms a prominent projection which might be termed the *inferior polar eminence* (I.P). On the left side there is a depression on the inferior margin of the hemisphere about 2 cm. from the middle line that represents the inferior polar sulcus. The lateral angle of the operculum lies well forward in the angle formed by the lambdoidal suture and the lateral sinus (L.S). The anterior boundary of the operculum forms a gentle curve with its convexity directed forwards. There are slight depressions in the area striata which comparison with primitive human and simian brains enables us to interpret with some confidence as the posterior extremity of the sulcus retro-calcarinus (20) and the Y-shaped sulcus calcarinus externus (19). When viewed from above the occipital operculum projects behind the lambdoidal suture (λ) to a greater extent than it appears to do in the casts of Bushman and other primitive human races. There is no asymmetry in the occipital poles such as one is accustomed to find in most human brains.

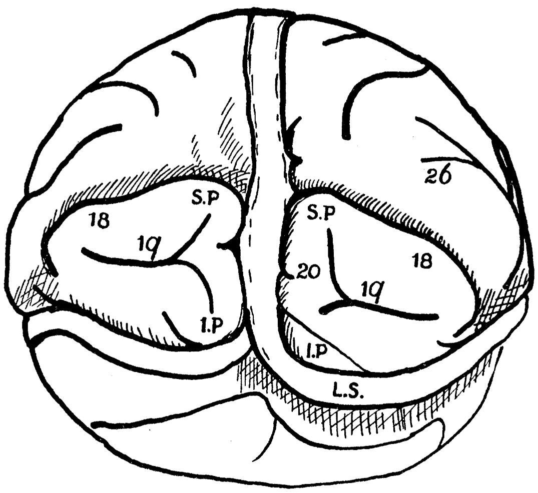


Fig. 2.—The sulcal interpretation of the posterior aspect of the cast of *Sinanthropus*, as shown in fig. 3, Plate 53.

Parietal Region.

In the description of the endocranial cast of the Rhodesian Skull one of us (G. E. S.) emphasized the importance of the expansion of the parietal region immediately behind the posterior end of the fissure of Sylvius, which expresses itself in the form of a rounded elevation of the surface—this is marked (P) in the figures of the report (ELLIOT SMITH, 1928). The corresponding expansion (P) in the cast of *Sinanthropus* forms a prominent feature and is related to the parallel sulcus where it turns upwards to pass round the posterior end of the fissure of Sylvius, fig. 4.

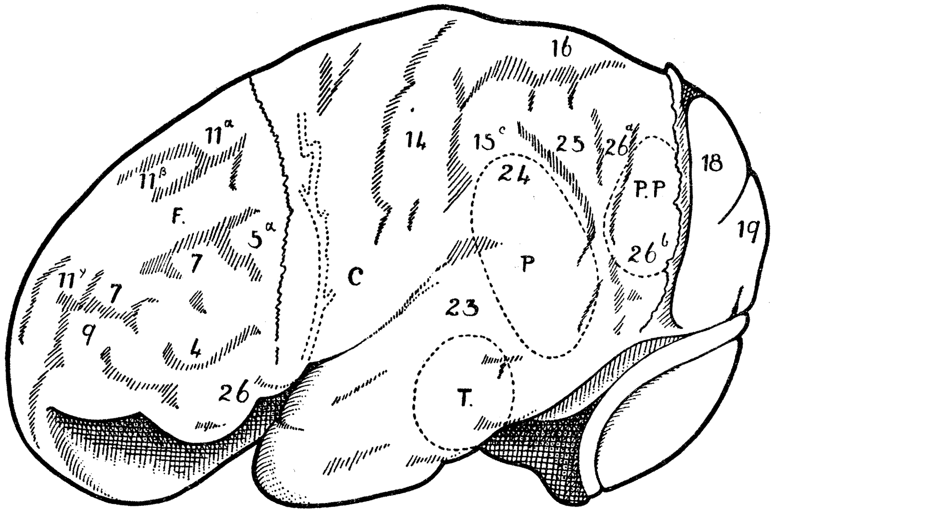
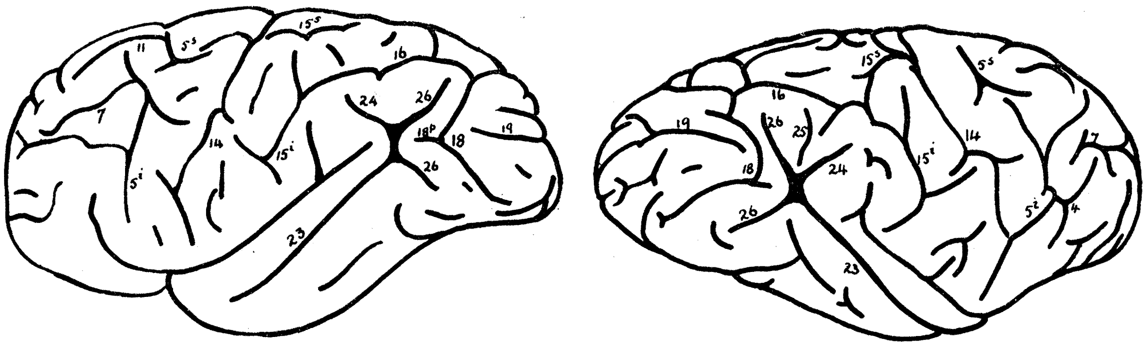


FIG. 4.—The sulcal interpretation of the left lateral aspect of the cast of *Sinanthropus*, as shown in fig. 5, Plate 53.

A comparative study of the parallel sulcus and its branching provides the interpretation of the parietal region in the cast of *Sinanthropus*. In the Gorilla, figs. 6 and 7, the parallel sulcus (23) turns around the posterior end of the fissure of Sylvius and its anterior end (24) is directed towards the concavity of the sulcus postcentralis inferior. At the most posterior part of the bend superior (26*a*) and inferior (26*b*) diverging branches are given off posteriorly in such a way that the posterior end of the parallel system has the form of a letter X, fig. 6. This cruciate sulcal pattern is an expression



FIGS. 6 and 7.—The right and left hemispheres of the brain of a Gorilla, showing the arrangement of the parallel sulcus and its associated posterior branches.

of the localized expansion of the inferior parietal region and its centre may well be regarded as a dynamic point. It is one of the most significant areas of the brain when simian and human brains are compared, for the precocious expansion of this cortical area is a distinctive feature of the human brain. Immediately in front of the inferior parietal expansion is the localized projection of the posterior end of the second temporal convolution which was described in the report on the endocranial cast of Rhodesian Man as the temporal boss (T). This feature is of special interest because it corresponds to a region in a modern human brain, injury to which is associated with inability to understand spoken language. Its precocious appearance in the endocranial casts of *Sinanthropus* and other early human types, such as *Eoanthropus* and *Pithecanthropus*, raises the possibility that the earliest men may already have acquired the power of speech.

It is fortunate that in the endocranial cast of *Sinanthropus* we can associate the sulcal pattern with these areas of expansion and compare this pattern with simian types.

The Parallel Sulcus.

The temporal part of the parallel sulcus is difficult to distinguish on the cast because of the prominent ridges corresponding to the impressions of the posterior branches of the meningeal vessels. There are, however, particularly on the right side, fig. 8, disconnected depressions which represent this part of the sulcus (23). This part of the

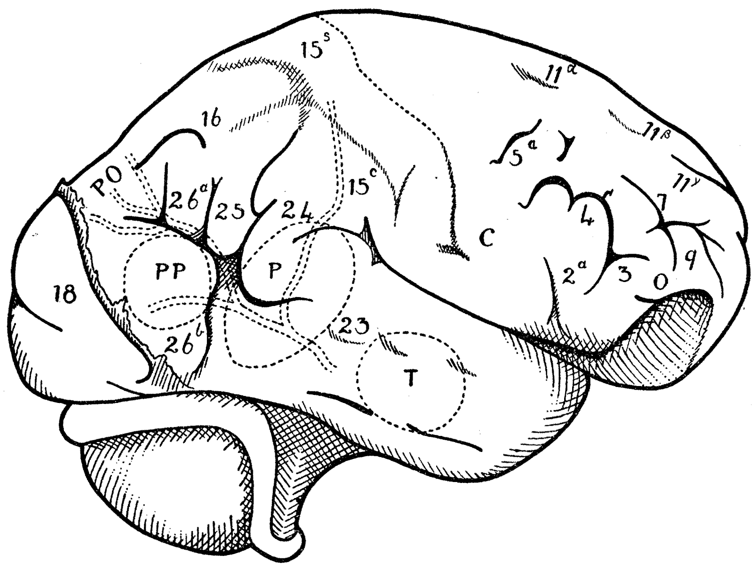


Fig. 8.—The sulcal interpretation of the right lateral aspect of the cast of *Sinanthropus*, as shown in fig. 9. Plate 54.

parallel sulcus separates Brodmann's areas 21 and 22 in the human brain. The remainder of the parallel sulcus is clearly visible on the right side, fig. 8. About 2 cm. posterior to the depression caused by the posterior end of the fissure of Sylvius a well-marked depression is seen (just behind P in fig. 8), across which passes one of the meningeal vessels. This depression marks the bend of the parallel sulcus as it turns round

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

the posterior end of the fissure of Sylvius. From this depression, which agrees with the central part of the X already referred to in the Gorilla, four linear depressions radiate. Antero-superiorly a long depression extends upwards and forwards towards the region of the upper part of the sulcus postcentralis inferior, fig. 8. This is the superior parallel sulcus (24)—the ascending I of Kappers. It forms the upper and posterior boundary of the parietal elevation (P) in *Sinanthropus*. Postero-superiorly a linear depression follows one of the meningeal vessels in the direction pointing towards the superior polar eminence of the occipital operculum. From this depression two branches pass upwards and slightly forwards into the parietal region. The anterior of these is the sulcus angularis (25)—the ascending II of Kappers—and the posterior is the upper element of the sulcus occipitalis anterior (26*a*)—the ascending III of Kappers. Postero-inferiorly a linear depression passes downwards and backwards towards the tentorial margin of the hemisphere (26*b*) and represents the lower element of the sulcus occipitalis anterior—the ramus descendens of the parallel sulcus in the Apes. The upper and lower elements of the sulcus occipitalis anterior are brought into relief by the rounded elevation of the preoccipital cortex, here named the postparietal eminence (PP) which lies between the arcade formed by them and the occipital opercular (lunate) sulcus (18). The antero-inferior arm, the main stem of the parallel sulcus, is indicated by a linear depression on the surface of the parietal eminence (P).

The sulcus intraparietalis (16) is represented on the right side by a curved depression surmounting the upper ends of the sulci occipitalis anterior and angularis and a flattened area into which the upper end of the superior parallel sulcus appears to run.

The sulcal pattern and the position and shape of the rounded elevations on the cast clearly reveal that, compared with the simian brain, marked expansions of the cortex have taken place in the area surrounding the posterior end of the fissure of Sylvius (P), in the posterior temporal region (T) and in the preoccipital region (PP).

Although the sulcal pattern of the parallel system is not so clearly shown on the left side, fig. 4, as it is on the right, a reasonable interpretation is possible because the raised area (T), (P) and (PP) are almost identical in form and position on the two sides and at critical points there are depressed markings of the sulci related to these raised areas, figs. 5 and 9, Plates 53 and 54. The dynamic point of the parietal lobe is the central depression at the junction of the parallel system of sulci at the posterior edge of the inferior parietal eminence about 2 cm. posterior to the depression for the posterior end of the fissure of Sylvius. This depressed centre lies just above the point where the posterior branch of the meningeal vessel breaks into branches to spread over the upper part of the parietal lobe. The superior parallel sulcus (24) forms the postero-superior boundary of the inferior parietal eminence and its position is marked by a vessel. This sulcus is directed upwards and forwards and appears to run into a depression which is interpreted as the upper end of the sulcus postcentralis inferior (15*i*) where it joins the pars horizontalis sulci intraparietalis. The sulcus angularis (25) is related to another vessel and is closely associated superiorly with a curved depression formed by the sulcus intraparietalis. The upper element of the sulcus occipitalis anterior (26*a*) is faintly indicated in the same position as on the right side. The lower element (26*b*) is probably represented by a wide hollow which passes into the pre-occipital notch.

The Postcentral and Central Sulci.

Whilst there are only very faint indications of the sulcus centralis on each side the position of the posterior end of the fissure of Sylvius, the general topographical relations of the coronal suture and anterior meningeal markings, and the position of the inferior frontal sulcus permit of a very close localization of this sulcus. But apart from these aids there is a depressed marking on the right side 2 cm. anterior to the posterior end of the fissure of Sylvius which is taken to represent the lower end of the sulcus centralis; and on the left side there is a faint curved depression lying 4 cm. above the fissure of Sylvius and about $1\frac{1}{2}$ cm. behind the anterior meningeal markings which corresponds approximately with the position of the inferior genu of the sulcus centralis. Figs. 4 and 8 show the hypothetical reconstruction of the sulcus centralis on the two sides.

Behind the markings for the sulcus centralis there are faint depressions corresponding with the postcentral sulci also shown in the above figures.

The Precentral Sulci.

As in the majority of primitive endocranial casts so far examined there is a very distinct ridge or elevation passing across the hemisphere immediately behind the very definite frontal depression (F). This ridge (C) has on it the markings for the coronal suture and the anterior branches of the middle meningeal vessels. Except for well-marked depressions close to the medial border and lying 2 cm. behind the upper end of the coronal suture which represent the superior precentral sulci, there are no markings for the inferior precentral sulci. From the general position of the sulci on the lateral surface of the frontal lobe it is probable that the position of the sulcus præcentralis inferior is immediately posterior to the coronal suture inferiorly. It would appear from the general topography that this sulcus does not lie so far posteriorly as it does in higher races of man. It is therefore of interest to recall the observations of CUNNINGHAM that in the early ontogenetic stages the sulcus lies anterior to the coronal suture, at eight to nine months it is coincident with it, and after birth it lies behind it.

The Sulci of the Frontal Lobe.

The Anterior Part of the Fissure of Sylvius.—The anterior part of the fossa Sylvii is widely open. Not only is the upper border of the temporal pole separated from the under surface of the frontal cap anteriorly, but also this gap is accentuated by the manner in which the lower border of the frontal lobe and the upper border of the temporal pole are bevelled. This question of the form will be dealt with later It is not possible to distinguish the anterior limbs of the fissure of Sylvius with any degree of certainty. On the right side there is a depression immediately in front of, and partly including, the lower end of the coronal suture which might be regarded as a single ascending limb. On this side the under surface of the frontal cap is smooth and there is no indication of a horizontal limb. On the other hand, there is on the left side a distinct horizontal depression on the under surface of the posterior part of the frontal cap which could well be a horizontal limb, but on this side there is no depression caused by an ascending limb.

The Superior Frontal Sulcus (11).—In the higher apes the superior frontal sulcus is generally constituted by a series of disconnected sulci which, in the human brain, tend to fuse together. The most posterior element is generally fused with the sulcus præcentralis superior to form a triradiate sulcus. In *Sinanthropus* the position of this sulcus would probably lie about 2 cm. posterior to the upper end of the coronal suture. Whilst there are depressions in this region in the cast they are not sufficiently clear to warrant any assumptions. Anterior to the coronal suture there are disconnected sulci, three on the right side and two on the left, lying parallel with the medial border and having a slight obliquity towards it which clearly represent the elements of the sulcus frontalis superior (11, α, β and λ). The form and position of these sulci suggest that there is in this region very little, if any, advance on the condition found in the apes.

Lying from 1 to 2 cm. lateral to the sulcus 11α, and immediately in front of the coronal eminence, there is a depression with a forward and inward inclination which corresponds with the anterior horizontal arm of the sulcus præcentralis inferior of CUNNINGHAM (5*a*). This is the sulcus which one of us (J. L. S.) has identified as the homologue of the upper end of the sulcus arcuatus. The sulcus frontalis medius (7) is plainly shown lying anterior and slightly lateral to 5*a*. It is continued forward on both sides into the axial sulcus of the frontal keel—the sulcus fronto-marginalis of WERNICKE (9).

The Sulcus Frontalis Inferior (4).—This sulcus is plainly visible on both sides. On the right side it forms an arcuate sulcus which is the upper boundary of the frontal cap. Anteriorly it ends in a transverse sulcus radiatus (3). On the left side the form of the sulcus frontalis inferior is slightly different from that on the right side, but it is still plainly visible.

We would suggest that this sulcus was brought into being as a new compensatory sulcus in response to the expansion which is here obviously taking place immediately anterior to the lower end of the precentral region.

The Form of the Endocranial Cast of Sinanthropus.

In dealing first with the description of the sulcal pattern as a general introduction to the cerebral morphology of *Sinanthropus* we are alive to the lesser importance of this in comparison with that revealed in the study of the form and proportions. There are areas of localized elevation and areas of depression which are significant in interpreting the evolutionary changes which are responsible for determining the higher types.

The essential features of form manifesting critical areas in the rise from the simian type were first clearly portrayed by MARSHALL in 1864 in his masterly survey of the brain of a Bushwoman. It is remarkable that he should have selected areas from comparative studies alone without the aid of the new knowledge acquired in the histological and pathological fields by BOLTON, FLECHSIG, CAMPBELL, BRODMANN, HEAD and many others. Using these methods in conjunction with a critical survey of the morphological interpretation of diverse sulcal pattern, one of us (G. E. S.) has shown in the endocranial casts of fossil man the evolutionary importance of areas of elevation or depression and has suggested the lines of development that led to the attainment of the form of the brain in modern man.

The full significance of these studies is realized in the endocranial cast of *Sinanthropus*. They receive confirmation, and the evidence is convincing, that the endocranial cast of Peking man reveals a type of brain which fulfills all the requirements which make it the ideal generalized type from which the brains of all the known varieties of fossil and modern man can have been derived. It is to those features of form that, having established the general topography from the sulcal pattern, we wish to draw attention.

The cast of the brain case of *Sinanthropus* is the most perfect specimen of the form of the brain in a human fossil. Many features are visible which it would hardly have seemed possible could be retained. This is due not only to the condition of the fragments themselves, but also and more so to the superb artistry and technical skill with which the Peking material has been prepared by Professor DAVIDSON BLACK. We who have been privileged to visit the site from which *Sinanthropus* was obtained and to visit the Cænozoic laboratory in Peking alone can realize the labour involved in the preparation of this cast. But it is not only to Professor DAVIDSON BLACK that we would pay our tribute, but also to Drs. WONG, TING, PEI and the many other Chinese collaborators in the Geological Survey of China.

Viewed from above, the cast of *Sinanthropus* presents a long and narrow ovoid form. It is widest at the level of the parietal eminences which are situated one-third of the way from the occipital to the frontal poles. From the parietal eminence the brain slopes away in all directions; posteriorly it slopes sharply backwards to the occipital operculum, superiorly it slopes fairly sharply at first and then more gradually towards the vertex. The steepness in this superior slope which is so characteristic of higher types of brain is lacking. Hence this cast has a distinctive slope, in common with *Eoanthropus*, when viewed from the posterior aspect. Anteriorly the surface slopes forward to the coronal eminence, where the contour is again rounded by a definite precentral eminence in front of which the frontal areas become constricted. The general contour of the brain when seen from above is almost exactly similar to that of *Pithecanthropus*. In describing MARSHALL's brain of the Bushwoman, one of us (J. L. S.) has drawn attention to the similarity between it and *Pithecanthropus* in this respect.

Viewed from the side, figs. 5 and 9, Plates 53 and 54, the parietal region is prominent; the vertex forms a gentle curve and is more raised than it is in *Pithecanthropus*. Its highest point is above the parietal eminence. The frontal region is flattened and ill-filled. The frontal cap forms a salient landmark in front of the most anterior point of the temporal pole. In front of the frontal cap the orbital margin (O) is full and passes forwards to end in a well-marked and prominent frontal keel. The temporal region is narrow and the temporal pole is long and slender. The temporal pole passes forwards and markedly inwards under the precentral region. The bevelling of the edges of the temporal pole accentuates the open condition of the fissure of Sylvius.

Viewed anteriorly, fig. 16, Plate 54, the frontal keel, the prominent external angle formed by the frontal cap, and the depression of the surface of the frontal region constitute some of the most striking features of the cast.

The Rhodesian cast shows striking inequalities in the fullness of the cortical areas brought into prominence by the process of expansion which affects certain other areas and on this subject one of us (G. E. S.) wrote: "Hence there is revealed in the Rhodesian cast a much more striking demonstration of the development of the cerebral hemisphere that is going on within the human family than in any other cast." This is now no longer the case, for the cast of *Sinanthropus* shows the earlier stage even more clearly than does the cast of *H. rhodesiensis*.

Perhaps the most significant feature of this cast of *Sinanthropus* is the exceptional degree of symmetry of the two hemispheres. This is quite unusual in the human brain. It is shown not only by visual examination of the whole cast, but also by the contours. The two hemispheres are almost exact mirrored replicas of one another. Posteriorly the two lunate sulci and occipital opercula are symmetrical, and are equal in size, have the same form and present precisely similar relations to the lambdoid suture. The symmetrical arrangement of the lunate sulci is found more often in primitive members of the human family than in the higher races. In MARSHALL's brain of the Bushwoman they are equally large on the two sides; the condition is also occasionally seen in Australians, Negroes and Chinese. Apart, however, from the occipital operculum the striking elevations of the surface where development is commencing, the parietal eminence related to the posterior end of the fissure of Sylvius, the temporal eminence at the posterior end of the second temporal convolution, the post-parietal eminence and the raised elevation related to the coronal suture and the anterior branches of the middle meningeal vessels all display complete correspondence on the two sides. So also are the areas of lack of development as expressed in depressed areas of the surface. The frontal region in front of the coronal eminence is flattened and ill-filled and although it is smaller in *Sinanthropus* the general form of the region bears a close similarity to the condition found in Rhodesian man. Immediately in front of the medial part of the occipital operculum the parieto-occipital region is markedly depressed (P.O). One of us has found that this area is backward in its development in the brain of the Australian aboriginal.

The two occipital opercula (areæ striatæ) stand out as prominent bosses. Viewed from above they are visible, projecting behind the lambdoidal suture. If the contours of *Sinanthropus* are compared with those of the Bushman, figs. 10 and 12, it will be observed that the lambdoidal suture is placed relatively further back in the Bushman.

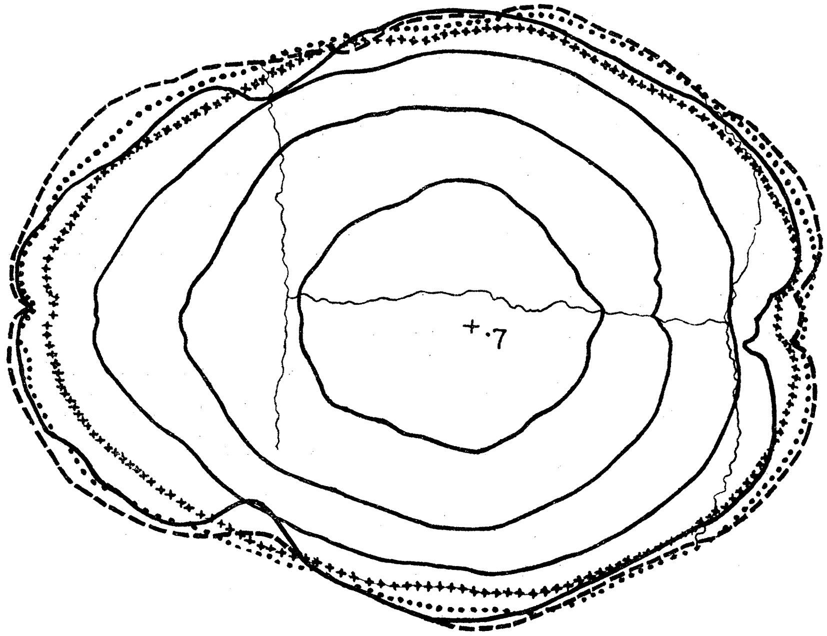


FIG. 10.—Horizontal contours of the cast of *Sinanthropus* taken 1 cm. apart with reference to a base plane extending from the lowest point of the groove between the lateral sinus and the occipital lobe to a point 5 mm. above the lowest point of the frontal cap.

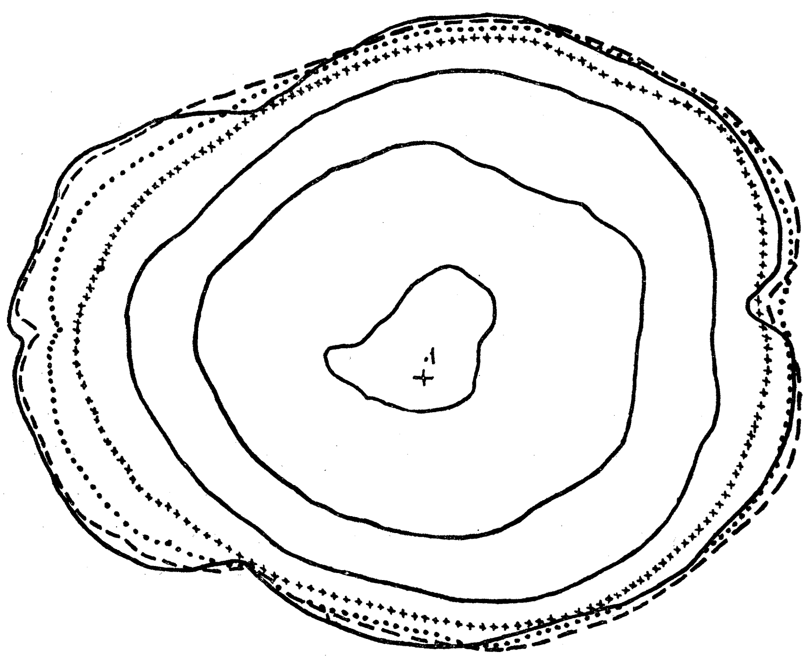


FIG. 11.—Horizontal contours of the cast of *Pithecanthropus*.

In *Sinanthropus* the opercular surface looks slightly upwards as well as backwards; in the Bushman the expansion of the parietal region, having progressed further, has caused a rotation of the occipital region downwards and backwards, and in higher types this downward rotation progresses still further, so that very little of the area striata is visible from above. In the Australian aboriginal FLASHMAN referred to the peculiar drawn-out appearance of the occipital region which is characteristic of the brain of this race. The same appearance is present in the cast of *Sinanthropus*. The præ-occipital cortex immediately in front of the sulcus lunatus is slightly depressed owing to under-development. This accentuates the form of the occipital operculum. It gives the occipital operculum the appearance of a cap applied to the posterior aspect of the brain and intensifies the peculiar drawn-out form of the occipital region which attracted FLASHMAN'S attention.

The most salient feature in the inferior parietal region is the parietal eminence,

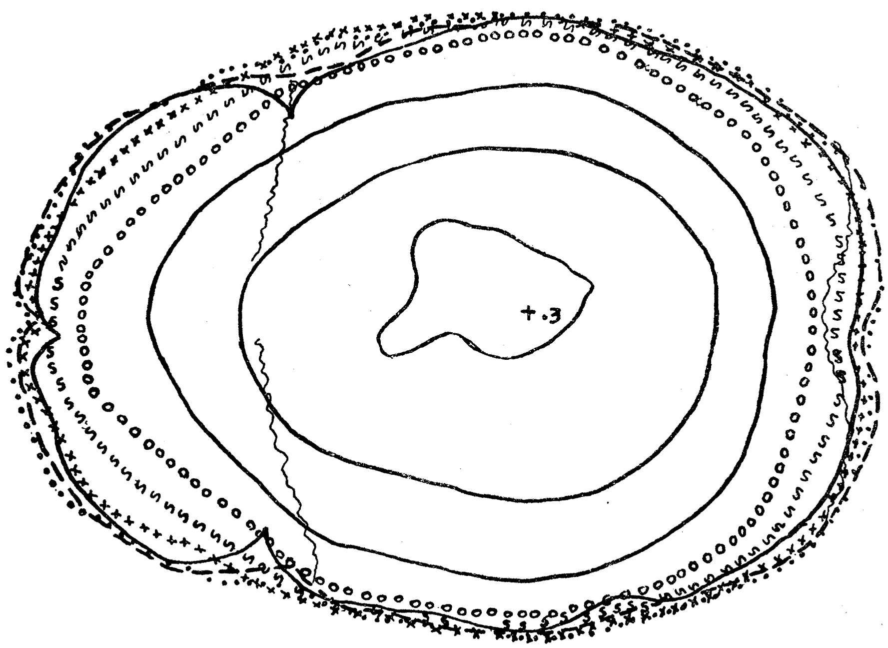


FIG. 12.—Horizontal contours of the cast of a *Bushman*, No. D. 708 of the collection of the Royal College of Surgeons.

figs. 5 and 9. It is a crescentic-shaped bulging of the cortex which lies posterior to and partly surrounds the caudal end of the fissure of Sylvius. Superiorly it extends upwards and slightly forwards into the angle formed by the sulcus postcentralis inferior and the pars horizontalis sulci intraparietalis. This part of it might be termed the supra-marginal boss. Posteriorly the parietal eminence is limited by the hook of the parallel sulcus. Immediately behind it there is a small depression at the point of branching of the parallel sulcus. On the left side the posterior limit of the eminence is marked by a vessel. Inferiorly the parietal eminence turns downwards and slightly forwards into the posterior part of the temporal lobe, where it becomes more or less confluent with the temporal eminence. The horizontal contours, fig. 10, show the lower part of the parietal eminence as the most lateral feature of the cast. The vertical contour, fig. 13, shows the parietal and temporal eminences slightly separated from one another. Behind the parietal eminences the surface of the cast slopes away to the occipital operculum and shows on either side a localized elevation of the præoccipital region already referred to as the postparietal eminence, figs. 5 and 9.

The region of the parietal area which lies above the parietal eminence is somewhat depressed and shows the markings for the sulcus intraparietalis.

The cast of *Sinanthropus* reveals, therefore, that the first expansion of the parietal lobe takes place in the supramarginal lobule and in the region immediately below this. The somewhat fuller unfolding of the parallel sulcus in *Sinanthropus* when compared with the higher apes and the position of the parietal eminence suggest that it is along the line of the visuo-auditory band that the changes occur which finally bring about the

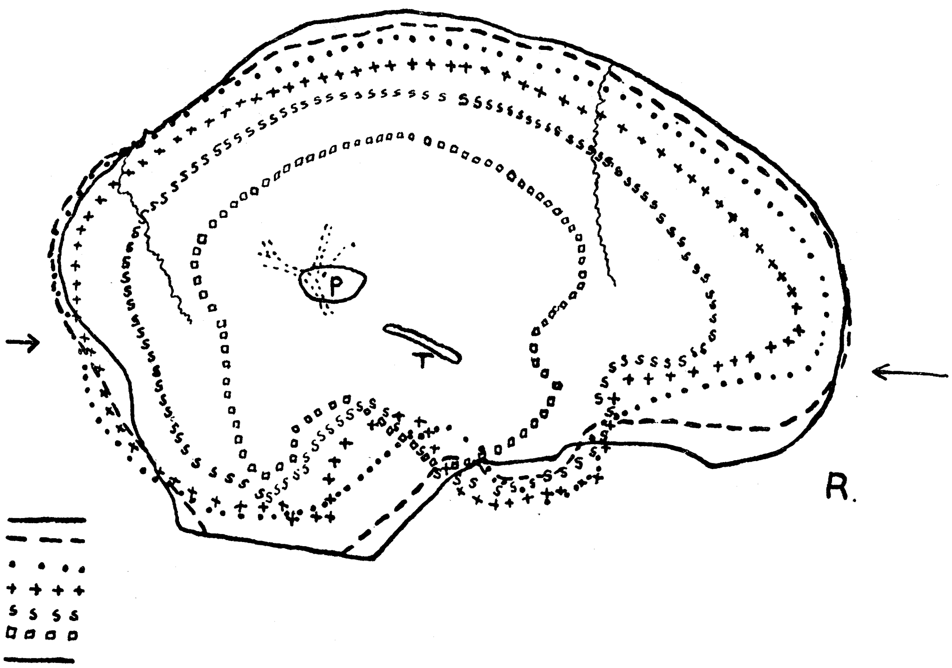


FIG. 13.—Vertical sagittal contours of the right hemisphere of *Sinanthropus*. The base contour is the mid-line.

general and uniform expansion of the parietal region in higher races. This receives striking confirmation in the endocranial cast of the Bushman. The contour, fig. 12, reveals the essential features of the order of these evolutionary changes. If one superimposes the contour map of *Sinanthropus* on that of the Bushman it is seen that, although the frontal areas of the latter are perceptibly larger, they almost coincide. On the other hand, the areas of the parietal bones are entirely different; the parietal bones of the Bushman are longer than those of *Sinanthropus* and, as we have already seen, the occipital region has been rotated backwards and downwards so that very little of the dorsal surface of the occipital region is visible. Turning now to the region of the parietal eminence in the casts, it is at once apparent that the parietal eminence as we have defined it in *Sinanthropus* is in the Bushman relatively far forward, and that behind it the whole parietal region has filled out. There is no longer a slender posterior part of the parietal area on which the occipital operculum appears to be capped.

The temporal region presents a very primitive appearance. Posteriorly it is slightly expanded to form the temporal eminence. Looked at from above the sides of the parietal region slope outwards to these eminences. It is this peculiar sloping which gives the very unusual form of the skull in which the temporal bones are splayed somewhat outwards. The under surface of the temporal lobe is hollowed out, producing a relatively wide deficiency between the cerebellum and the temporal lobe. But it is at the temporal poles that the most significant features are found. In describing the brain of MARSHALL'S Bushwoman one of us (J. L. S.) drew attention to many features which were regarded as primitive in this region. The whole question of the relationship of the temporal pole to the open condition of the Sylvian fissure and of its relationship to the so-called frontal cap was discussed. Every feature there described finds its counterpart in the endocranial cast of *Sinanthropus*. The temporal poles are small and slender. The temporal lobes fall away markedly in size in front of the temporal eminences and their edges have the appearance of having been bevelled. Viewed from below, the temporal poles are pointed, and they are widely separated from the under surfaces of the frontal lobes. This separation accentuates the open condition of the anterior end of the fissure of Sylvius. The anterior limits of the poles do not reach as far forward as the tips of the frontal caps; almost the whole of the under surface of the frontal lobe is visible; the temporal pole fails in any way to hide the orbital sulci which are clearly marked on the left side, and thus it is probable that the anterior perforated space was considerably exposed. The fact that the anterior limit of the poles does not reach as far forward as the tip of the frontal cap disposes of the question whether the frontal cap in the higher apes is in any way homologous with the frontal cap in man—the so-called frontal cap of BROCA.

The examination of a series of anthropoid brains using BRODMANN'S cortical areas as criteria for homology shows that the tip of the temporal pole lies in the same transverse plane as the frontal cap or in some cases actually anterior to it. BRODMANN'S charts show that this level is the place where his areas 4 and 6 occupy the cap. The lower ends of the sulci centralis and precentralis are within the cap. The temporal poles in *Sinanthropus* are well anterior to the place where areas 4 and 6 should lie. It is clearly shown in the cast of *Sinanthropus* that the lower part of the coronal eminence is a localized expansion of the precentral cortex.

Looked at from above the general contour of the brain, fig. 13, becomes markedly narrower immediately in front of this inferior precentral expansion.* In addition to this expansion the protuberance which is identified as the frontal cap is part of a general expansion (O) which involves the orbital margin of the frontal lobe, figs. 5 and 9. Com-

* The exceptionally small brains which one finds at times in all races—I have seen one of 870 cc. in an Egyptian Fellah-woman and one of similar size in an Englishwoman in the Dissecting room at University College, London—tend to assume this form.—G. E. S.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

parative study shows that not only is there a general enlargement of the precentral region in its lower part, but also that the inferior frontal region has expanded far ahead of the condition in the apes. So that this new frontal cap might almost be regarded as the cap of BROCA. It will further be shown that this region is in all probability the place where the first expansions of the frontal territory occur in response to the expansions which we have already described in the parietal lobe. The superficial resemblance then between the frontal cap in the apes—the so-called frontal cap of ANTHONY—and the frontal cap in man is correlated with the fact that corresponding bony areas of the skull in the apes do not in man cover homologous areas of brain.

The Cast of Sinanthropus *Compared with that of* Pithecanthropus.

Looked at as a whole the essential similarity of these two casts is at once apparent. The contours of the two casts are placed horizontally 1 cm. apart; the basal contour is drawn on the level of a line which cuts the cast posteriorly at the lowest point of the groove between the occipital territory and the lateral sinus and anteriorly at a point 5 mm. above the lowest point of the frontal cap. Figs. 10 and 11 are very similar to one another, the main difference being seen in the greater height of the cast of *Sinanthropus*. The vertex in *Pithecanthropus* is flatter. This gives the cast a more squat appearance. Although the vertex in *Sinanthropus* is higher the difference in the two casts in this respect is not so much a matter of contrast in cortical structure, but is due in great measure to the fact that the great longitudinal sinus in *Sinanthropus* has grooved the bony parietes more deeply so that the cast of it forms a prominent feature on the vertex. These facts are very clearly demonstrated in the examination of the vertical sagittal contours of the lateral aspects of the right hemispheres, figs. 13 and 14.

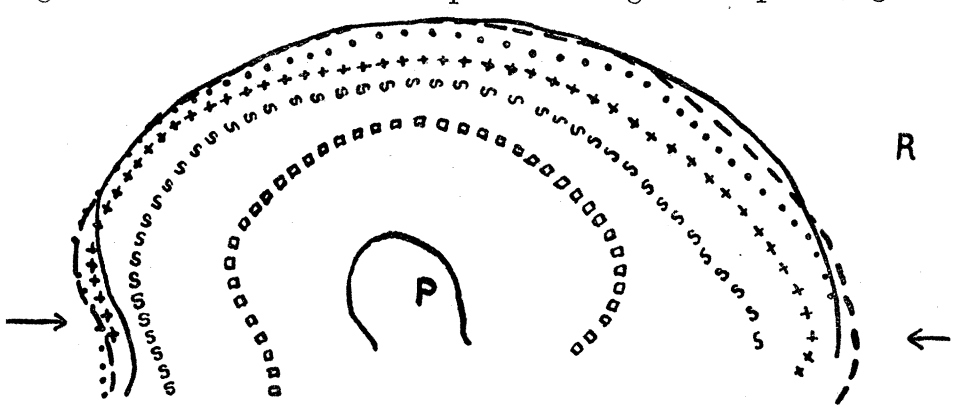


FIG. 14.—Vertical sagittal contours of the right hemisphere of *Pithecanthropus*.

In these figures the basal contour is taken at the middle line. The two figures are almost exactly identical contour by contour except the midline contours. In *Pithecanthropus* the first and second contours are coincident at the vertex, whereas in *Sinanthropus* the midline contour is separated from the second. The contours show that the general form of the two casts is similar to a marked degree.

There are, however, certain differences ascertainable by naked eye examination. On the whole the cast of *Pithecanthropus* is not so finely modelled as that of *Sinanthropus*; the minor features are not clearly portrayed, and much of the sulcal interpretation cannot be other than problematical. In *Pithecanthropus* the region posterior to the parietal eminence is somewhat fuller; the parietal contour is merged into the occipital contour without any clear-cut delimitation of the occipital operculum. Nevertheless, particularly on the right side, there are impressions which indicate the presence of the sulcus lunatus. In *Sinanthropus* the impressions for the lateral sinuses are more nearly symmetrical and consequently the lower borders of the occipital lobes when looked at from behind are approximately on the same level; in *Pithecanthropus* the lower border of the left occipital lobe is considerably lower than that of the right side where alone the lateral sinus is visible.

In the parietal region, except for the vertex, which has been considered, the elevations and depressions of the surface correspond very closely in the two casts.

In the frontal region the differences between the two casts appear at first sight to be small, and yet these differences are significant in revealing the early stages in the evolution of the frontal lobe. Looked at from the front the cast of *Sinanthropus* presents a somewhat pointed appearance. The orbital margins are gently curved and run forwards into a well-marked frontal keel. Compared with the higher apes the anterior contour of the frontal lobes is somewhat blunter and the orbital margin appears fuller; nevertheless from this aspect the cast of *Sinanthropus* is distinctly simian. Unfortunately the edge of the orbital margin is missing in *Pithecanthropus* except for a small part on the right side. It is probable, in virtue of the fact that the lateral contours are so similar, that there was a frontal keel as pronounced as in *Sinanthropus*. The anterior view of the cast of *Pithecanthropus* is definitely blunter in appearance than that of *Sinanthropus*. There is an antero-external angle placed only very little behind the level of the most anterior point of the cast; this angle is only very faintly indicated in the cast of *Sinanthropus* where the superciliary margin passes uninterruptedly into the orbital margin. The presence of the antero-external angle in *Pithecanthropus* which appears to belong to the same general mass as the postero-external angle formed by the frontal cap gives the inferior frontal region a bolder and fuller appearance than it has in *Sinanthropus*. It is as though the cortex of the frontal lobe had flowed down over the lateral surface and become banked up along the orbital margin. The lower end of the precentral region in *Pithecanthropus* is somewhat fuller and therefore it is apparent that the changes leading to the expansion of the frontal lobe were in a slightly more advanced stage in *Pithecanthropus* than in *Sinanthropus*. We have already referred to the fact that the region behind the parietal eminence is also slightly fuller in *Pithecanthropus*. The frontal expansions are probably the expression of the higher motor responses to the development of the sensory areas in the parietal and post-temporal regions. We should therefore find corresponding differences in the temporal region. On the left side of the cast of *Pithecanthropus* the temporal region is practically all missing; but on the right side enough is preserved to allow definite conclusions to be drawn. The anterior part of the temporal lobe below the level of the precentral area is fuller in *Pithecanthropus*; its upper border is not bevelled off and finally it is in contact with the frontal cap at the most anterior point at which it is preserved. This is in striking contrast with *Sinanthropus*, where the temporal pole falls away so sharply and comes to lie posterior to the tip of the frontal cap.

We are therefore of the opinion that the endocranial cast of the brain of *Sinanthropus* is more primitive and in an earlier stage of evolution than that of *Pithecanthropus*; that the conditions found in *Pithecanthropus* are all in harmony with the suggestion that *Pithecanthropus* must have been derived from a generalized type. Further, their essential similarity is so marked and they are so closely related that this type was probably *Sinanthropus*. We are also of the opinion that the period of time necessary for the greater development in *Pithecanthropus* could not have been very long.

The Endocranial Cast of Sinanthropus *Compared with that of Rhodesian Man.*

One of us (G. E. S.) has previously described the salient features of the endocranial cast of Rhodesian man. The features of the cast of *Sinanthropus* confirm in detail the opinions expressed in that report, and we feel that a reference to that description would be a more telling method of contrasting the two types than any discussion here.

The Endocranial Cast of Sinanthropus *Compared with that of a Bushman.*

We have selected the endocranial cast of a Bushman for comparison because it appears to us that, from the known brains of Bushmen, this race shows a greater assemblage of primitive features than is to be found in other races. The particular cast which is used here is to be found in the Museum of the Royal College of Surgeons in London (No. D. 708). We wish to express our thanks to Mr. Burne for putting a copy of this cast at our disposal.

Compared with that of *Sinanthropus* the Bushman cast is seen to be uniformly enlarged. There have been significant expansions of new areas, but there is also apparent a general increase of the areas already present in *Sinanthropus*.

The contours, figs. 10 and 12, give a quantitative picture of the growth changes. In the occipital region the lambdoidal suture is placed relatively further back. The elevation of the occipital opercular region (area striata), although apparent in the cast, is hardly visible from the dorsal aspect. In the parietal region the first four contours are almost coincident for a considerable length. The walls of the inferior parietal region have grown vertically upwards. On the map the parietal eminences are relatively further forward than in *Sinanthropus*; and posterior to them there is a general and uniform enlargement of the cortex which would correspond with the new development of those cortical areas which have been shown by the researches of

Flechsig, Brodmann and others (in Elliot Smith's "Evolution of Man," p. 163) to be the last to be formed in the higher races.

On the cast itself the parietal eminences occupy a position corresponding to the posterior end of the fissure of Sylvius. Above the eminences the surface of the brain as it passes to the vertex is filled out and there are no impressions which could be interpreted as sulci. Posteriorly the preoccipital region is uniformly filled out and there is no longer a parieto-occipital depression, which forms such a distinctive feature in the casts of *Sinanthropus* and Rhodesian man. Below the parietal eminence the temporal eminence is still present at the posterior end of the second temporal convolution, but very significant changes have taken place in the temporal area. It has filled out below, and the angle between it and the cerebellum has become much more acute. Anteriorly the temporal pole is bolder, its edges are filled out, and its surface is only very slightly depressed below the level of the parietal and frontal contour. The tip of the temporal pole still lies slightly posterior to the tip of the frontal cap. Relative to the coronal suture there is a fuller development of the region of the frontal cap. Although the length of the temporal area has increased, it still fails to reach the tip of the frontal cap; this suggests that the cortex of the inferior frontal region has been pushed forward in the general expansion.

In the frontal region there is a keel which is relatively large, but looks less simian than does that of *Sinanthropus*. This is due to a general thickening of the orbital margin. The cast of the Bushman is remarkable in that, as compared with the casts of higher races, the frontal region is markedly depressed. It is depressed almost to the extent revealed in Rhodesian man. This depression is accentuated by the prominence of the coronal eminence and by the thickening of the inferior frontal region extending from the precentral region almost to the frontal pole. The contours show all these features in the frontal region.

Whilst the endocranial cast of the Bushman thus reveals a much higher type of brain there are nevertheless significant differences between it and the casts of European brains. Into these differences we do not propose to enter here. It may, however, not be out of place to state that this cast of the Bushman shows a somewhat more highly developed brain than that of Marshall's Bushwoman which has been discussed by one of us (J. L. S.) elsewhere. The result of the examination of the cast of the Bushman is of importance, for it leaves no doubt that it was derived from some such generalized type as *Sinanthropus*. In other words, the evidence shows that the cast of *Sinanthropus* is unspecialized; that it fulfils all conditions which permit us to state that it could give rise to all known types of human brain; and finally that there is no evidence to show that it was in any way abnormal. The features which we have emphasized have no relation to such pathological states as microcephaly, but are all sufficiently developed to indicate the highest type of anthropoid brain so far discovered in the early pleistocene period.

The development of the parietal, temporal and frontal regions has progressed far

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

enough to warrant the conclusions arrived at by Davidson Black and his confrères that *Sinanthropus* was capable of that degree of skill and intellectual capacity indicated by the ability to fashion implements and to make fire.

We have omitted any comparison with the endocranial cast of *Eoanthropus* deliberately because we feel that while any doubt exists as to the accuracy of the reconstructions of this interesting relic it would detract from the value of these observations, which have been made on approved and accepted material.

We have to express our gratitude to Miss Lilian Pocock for the exceptional care and skill with which she has so faithfully and artistically rendered the appearance of the cast of *Sinanthropus* in figs. 3, 5, 9, 15, 16 and 17.

Summary.

The endocranial cast obtained by Professor Davidson Black from the Peking Skull reveals so clearly the form of the brain that once occupied it as to enable the observer to compare it with the actual brains of modern men and appreciate the amazing identities displayed by primitive members of the Human Family, whether they lived in extremely remote geological times or recently. The common primitive type that such comparisons reveal is very close to that displayed in the Gorilla, Chimpanzee and Orang-utan. Hence it becomes possible to recognize the features of the brain that are distinctive of human rank.

The occipital region of the primitive human brain is identical with that of the apes. In other regions of the cerebral cortex the attainment of human rank is associated with a precocious expansion of the posterior end of the second temporal convolution and the orbital margin of the frontal territory—probably both expressions of the acquisition of speech. The precocious expansion of the lower parietal area—supramarginal convolution—and the pushing forward of the pole of the temporal region and subsequently the expansion of the mid-temporal area are probably expressions of the provision for the attainment of greater skill in movement and particularly in locomotion. An unexpected peculiarity of the primitive human brain is a degree of symmetry between the two cerebral hemispheres which is quite exceptional in the human brain.

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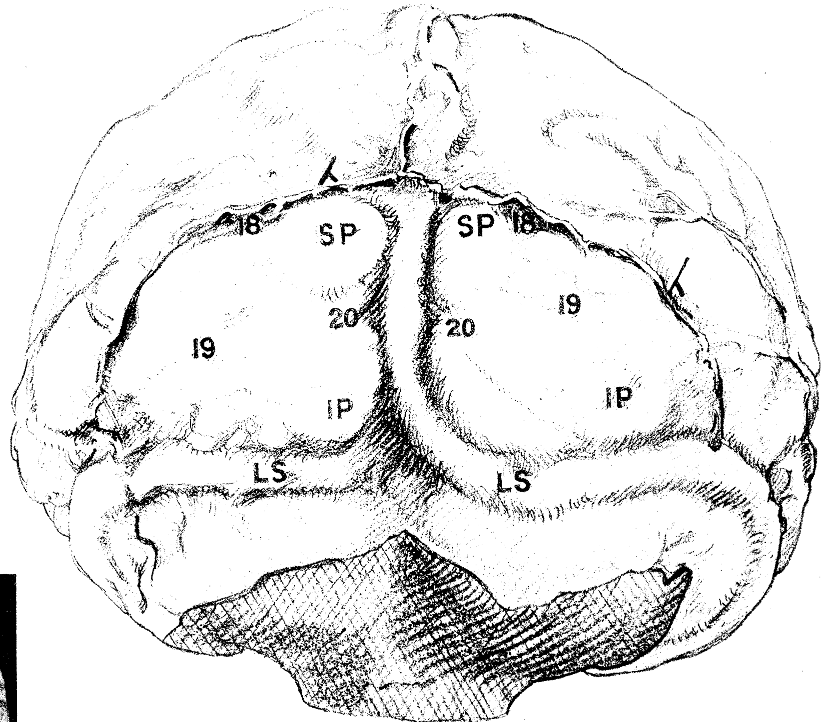

Fig. 3

Fig. 1

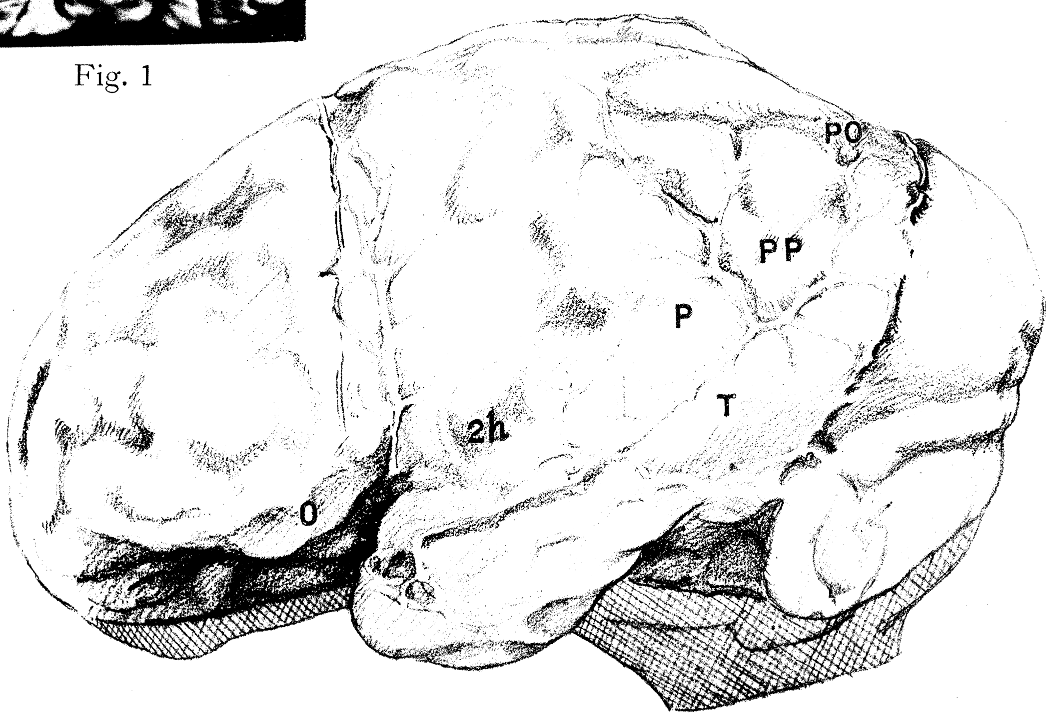

Fig. 5

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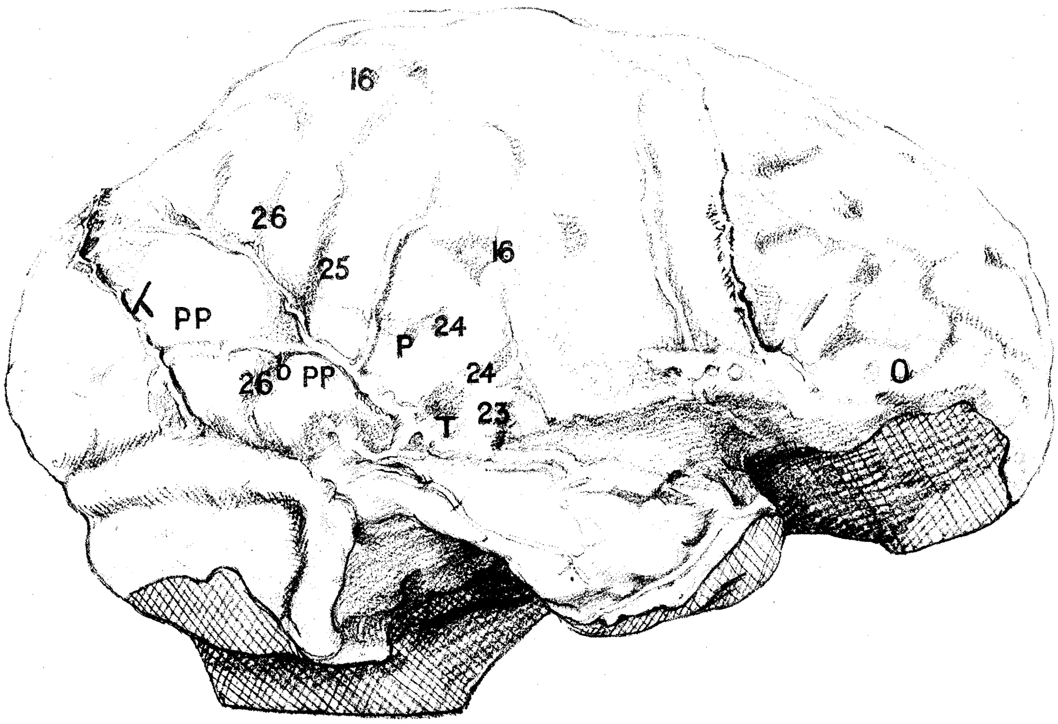

Fig. 9

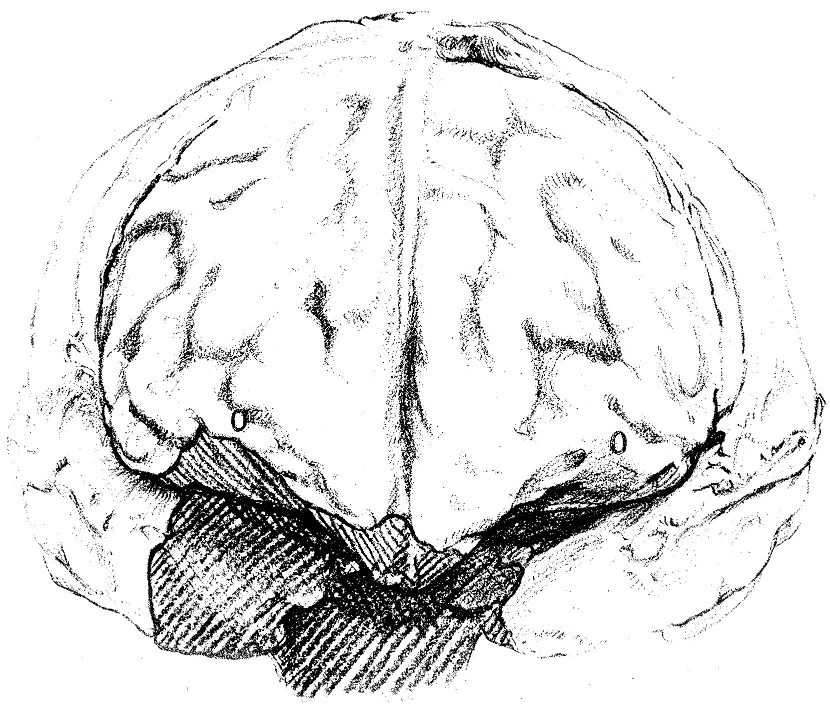

Fig. 16

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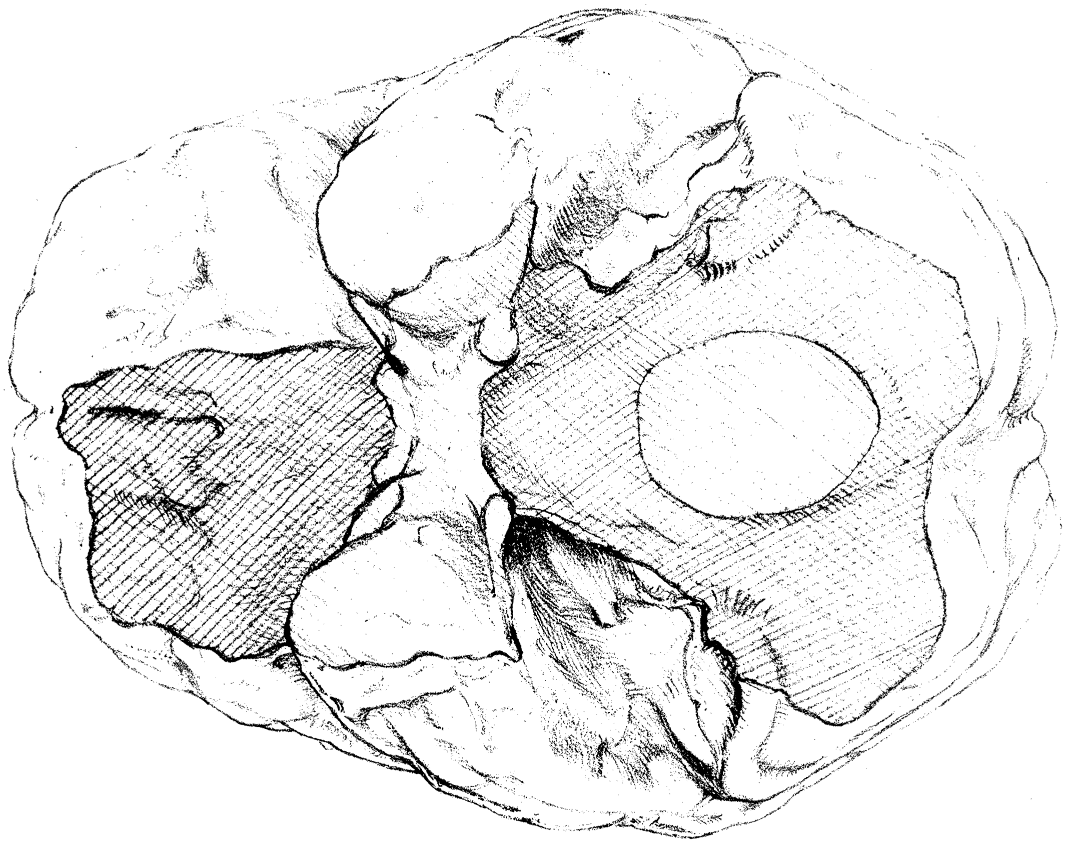

Fig. 17

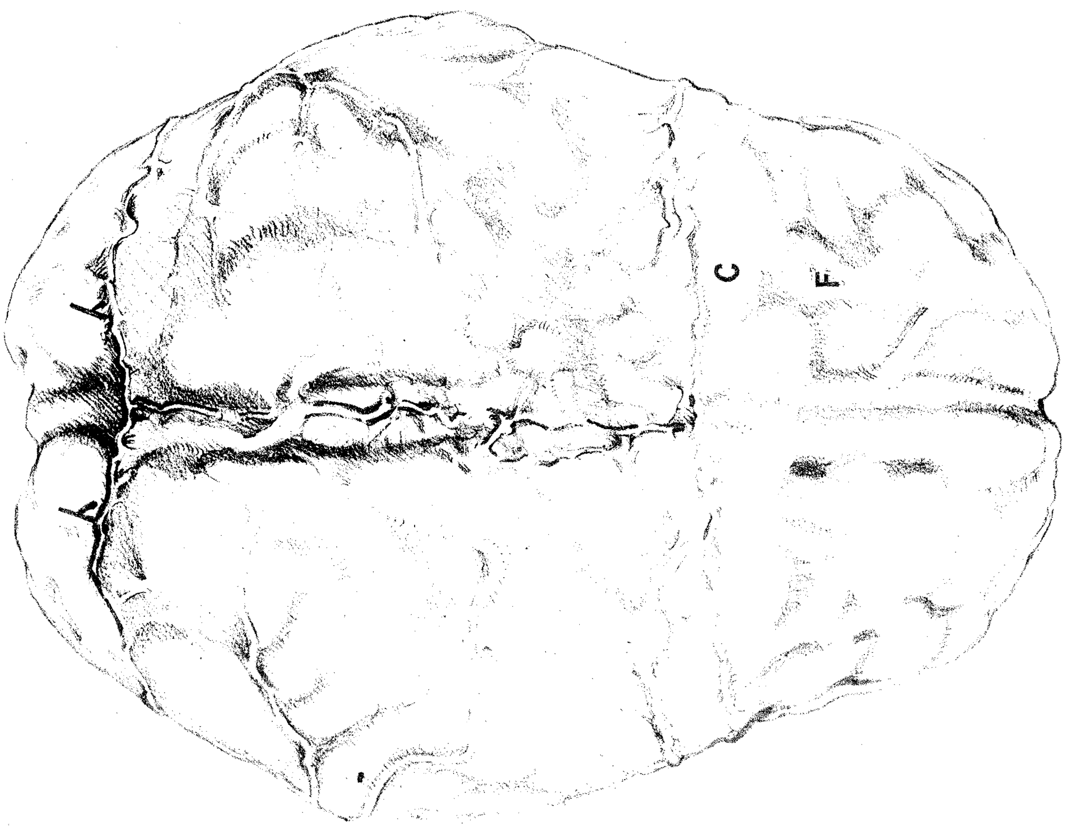

Fig. 15

DESCRIPTION OF PLATES.

Key to Lettering of the Plates.

C. Coronal eminence.
F. Frontal depression.
O. Thickened orbital margin of the frontal lobe.
P. Parietal eminence.
P.O. Parieto-occipital depression.
P.P. Postparietal eminence.
S.P. Superior polar eminence.
I.P. Inferior polar eminence.
T. Temporal eminence.
L.S. Lateral sinus.
λ. Lambdoidal suture.
2*a*. Ascending anterior limb of fissure of Sylvius.
2*h*. Horizontal limb of same.
3. Sulcus radiatus.
4. Sulcus frontalis medius.
5*a*. Anterior horizontal arm of sulcus præcentralis inferior.
7. Sulcus frontalis medius.
9. Sulcus fronto-marginalis of Wernicke.
11 α, β, γ. Elements of the sulcus frontalis superior.
14. Sulcus centralis.
15*i*. Sulcus postcentralis inferior.
15*s*. Sulcus postcentralis superior.
16. Sulcus intraparietalis.
18. Sulcus lunatus.
19. Sulcus calcarinus externus.
20. Sulcus retrocalcarinus.
23. Parallel sulcus.
24. Superior parallel sulcus.
25. Sulcus angularis.
26*a*. Superior element of the sulcus occipitalis anterior.
26*b*. Inferior element of the same.

Plate 53.

Fig. 1.—A photograph of the posterior aspect of the brain of an Orang-utan showing a type of occipital modelling very similar to that in *Sinanthropus*.

Fig. 3.—The posterior aspect of the cast of *Sinanthropus*.

Fig. 5.—The left lateral aspect of the cast of *Sinanthropus*.

Plate 54.

Fig. 9.—Right lateral aspect of the cast of *Sinanthropus*.

Fig. 16.—Frontal aspect of the cast of *Sinanthropus*.

Plate 55.

Fig. 15.—Superior aspect of the cast of *Sinanthropus*.

Fig. 17.—Basal aspect of the cast of *Sinanthropus*.

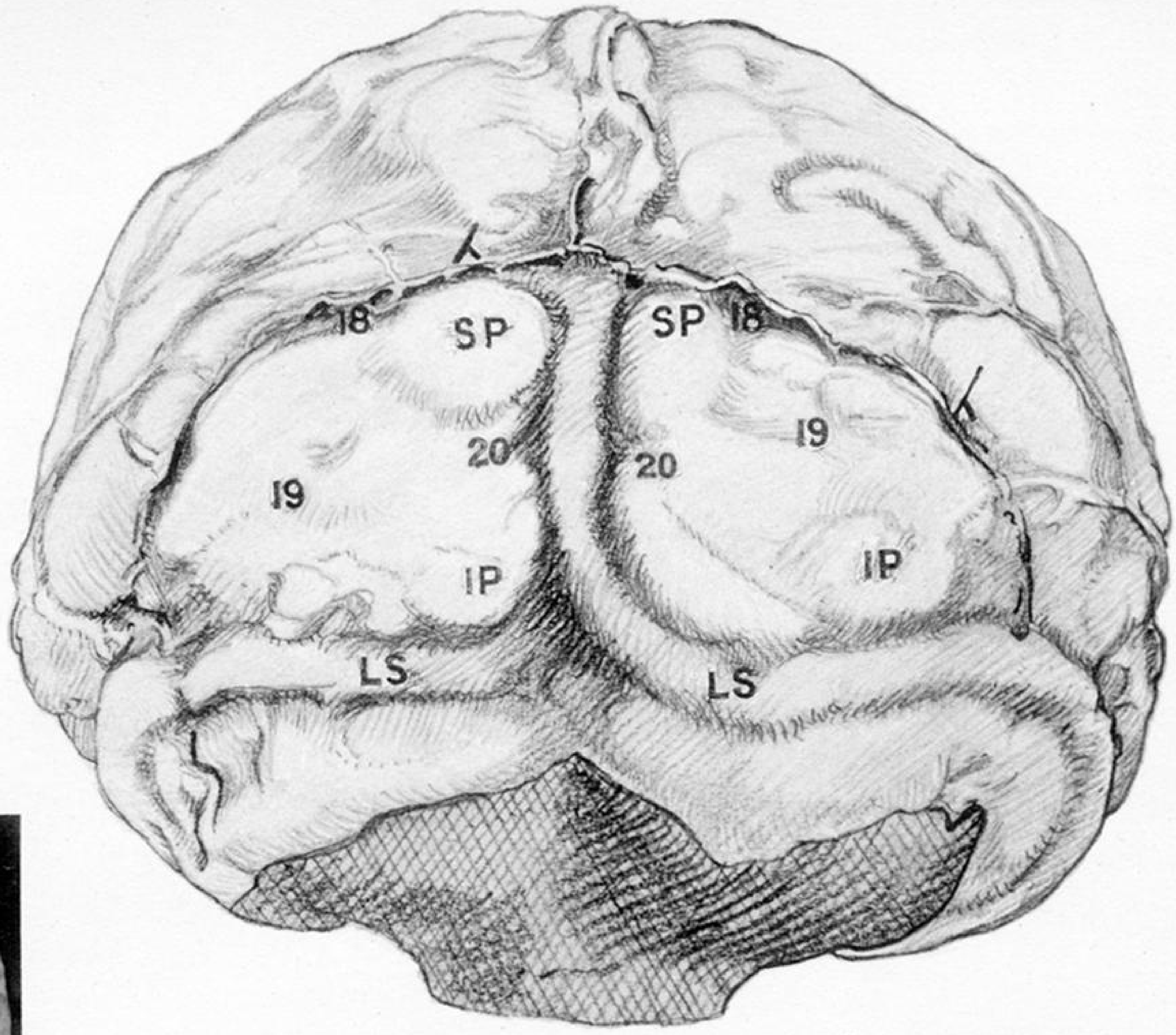

Fig. 3

Fig. 1

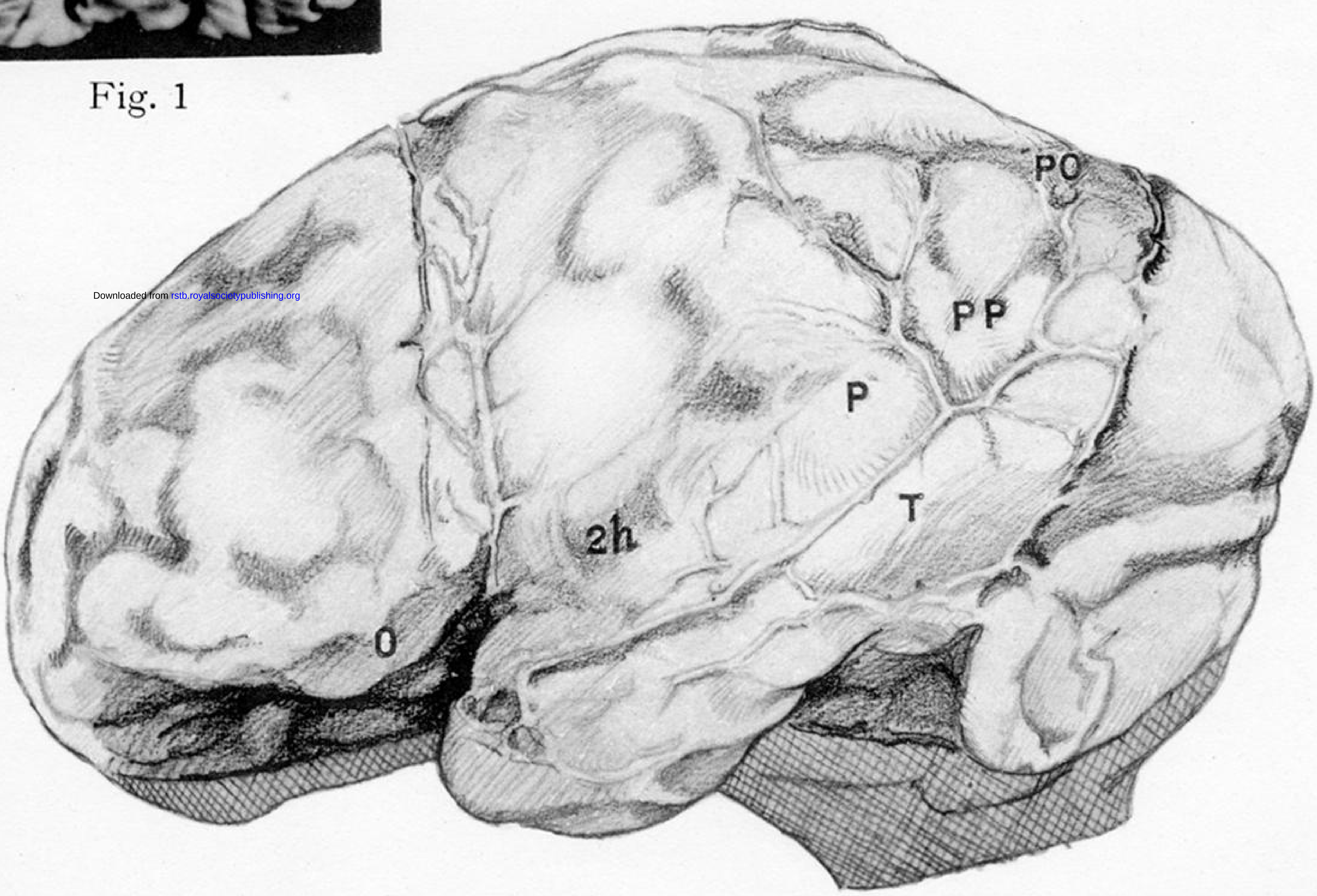

Fig. 5

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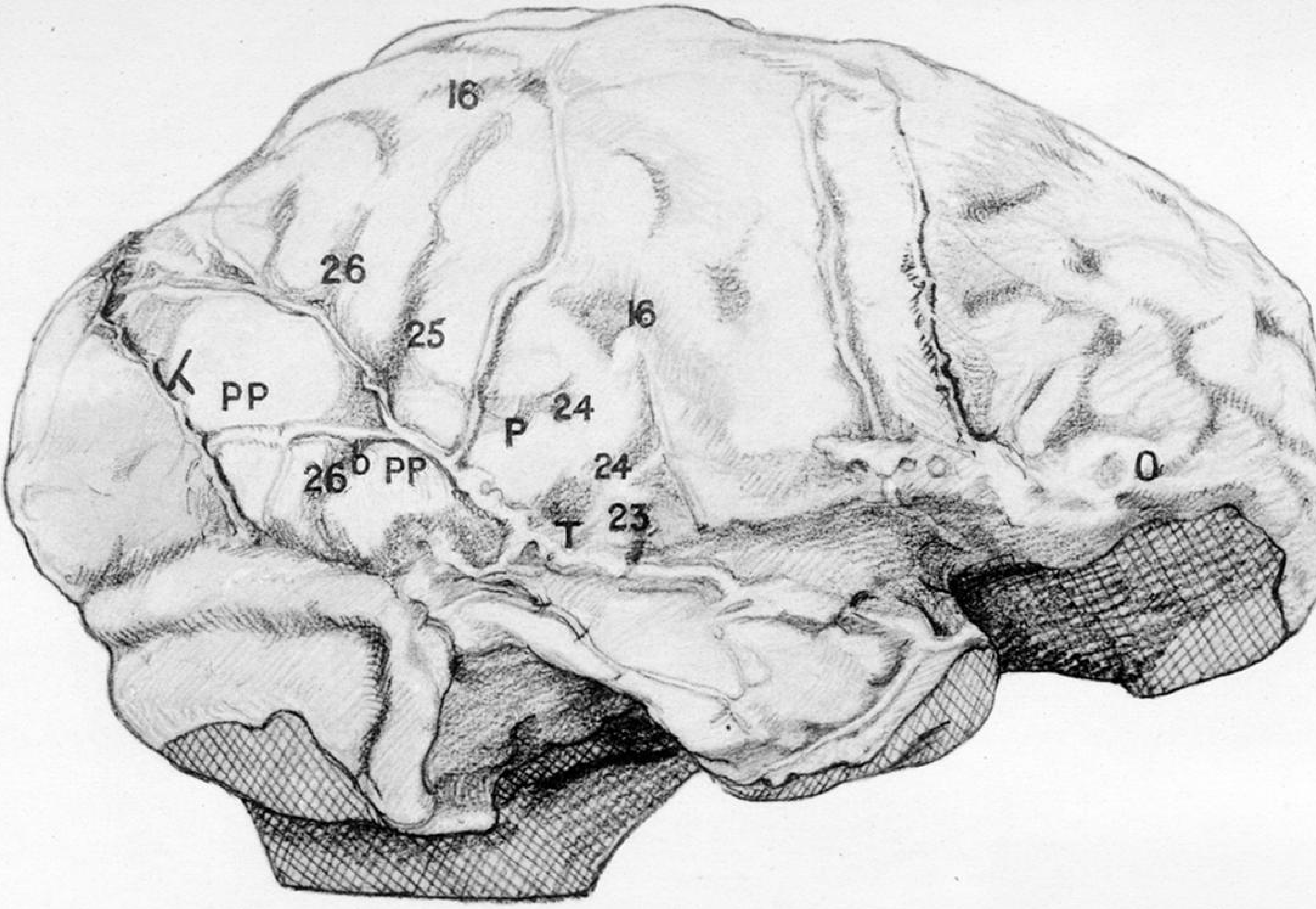

Fig. 9

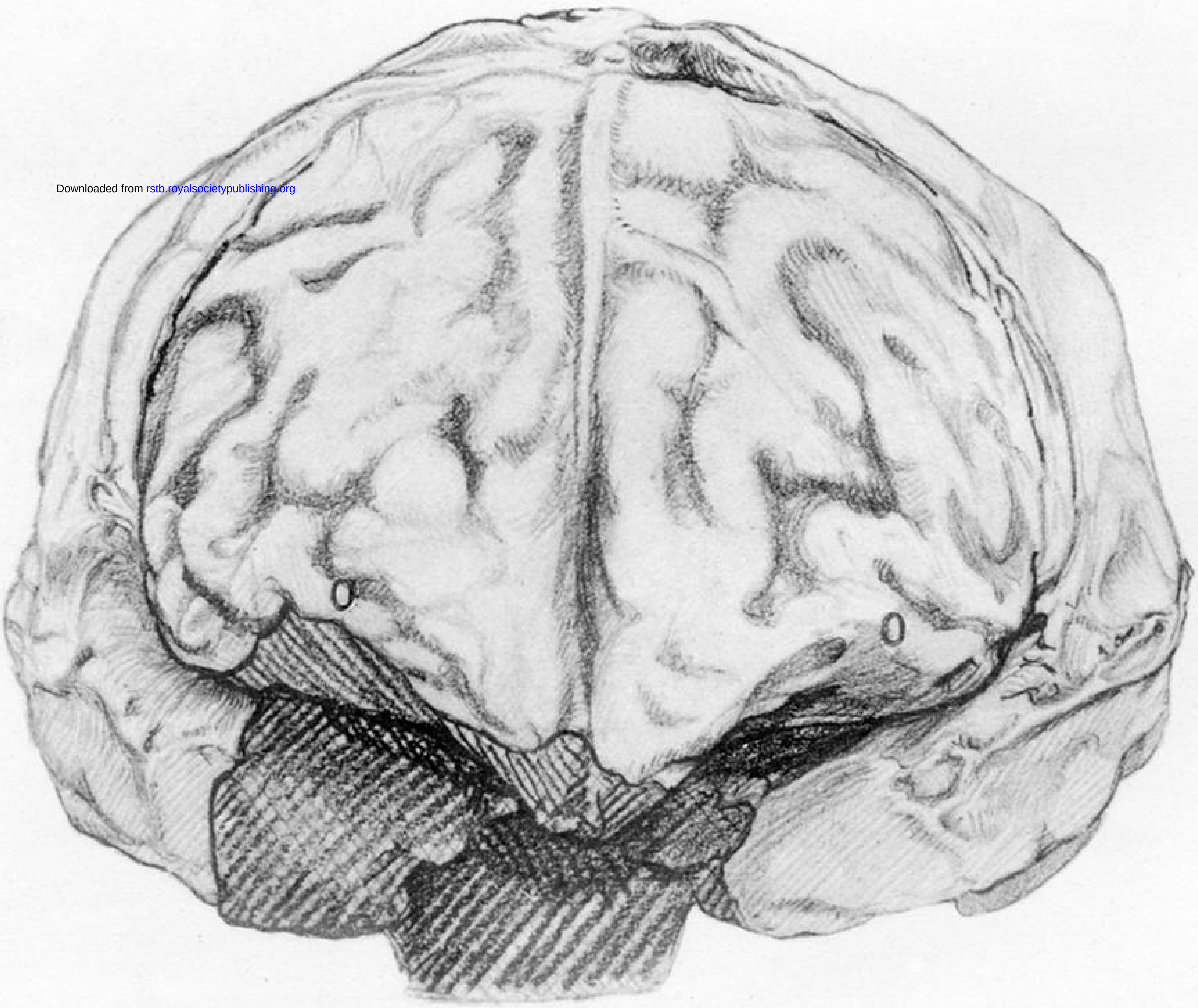

Fig. 16

PLATE 54.

FIG. 9.—Right lateral aspect of the cast of *Sinanthropus*.

FIG. 16.—Frontal aspect of the cast of *Sinanthropus*.

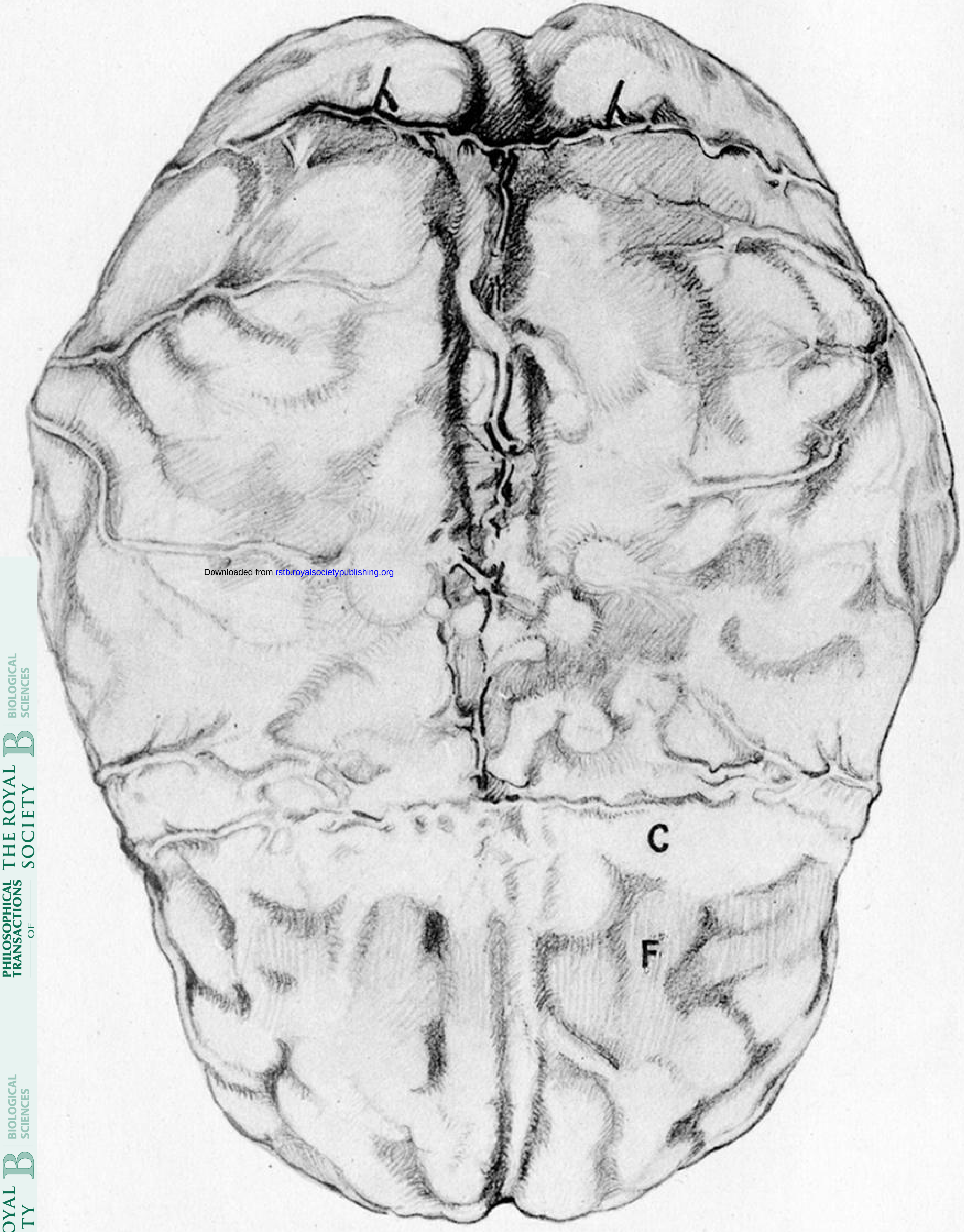

Fig. 15

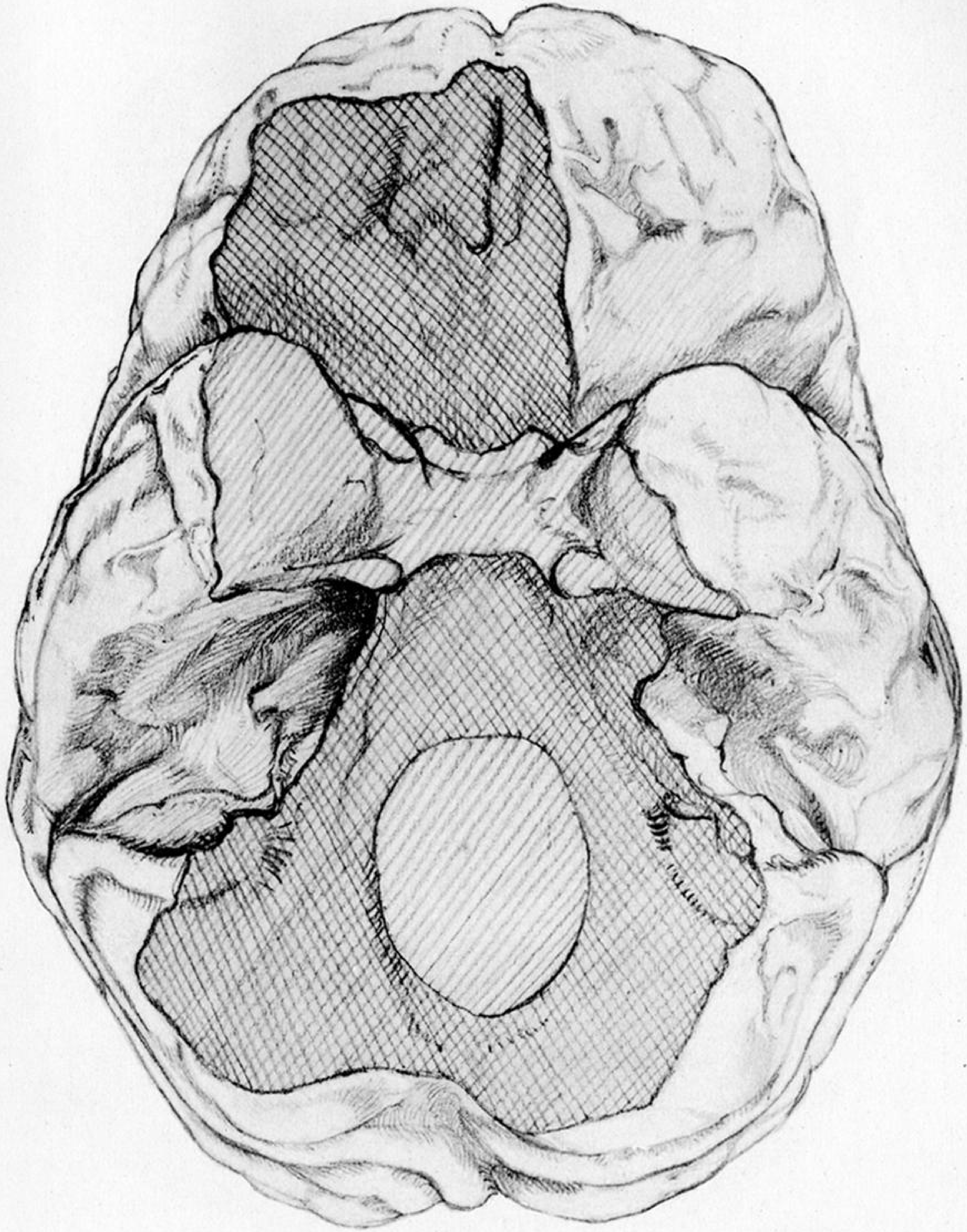

Fig. 17

PLATE 55.

FIG. 15.—Superior aspect of the cast of *Sinanthropus*.

FIG. 17.—Basal aspect of the cast of *Sinanthropus*.