A COMPARISON OF ENDOCRANIAL CAST AND BRAIN OF AN AUSTRALIAN ABORIGINE

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A comparison of an endocranial cast with the corresponding brain is the obvious method of determining how much accurate information about the brain can be obtained from the cast. Symington (1915) using human European material made such a comparison. His studies showed that very little of the detail of the sulcal pattern was evident on the cast—he was able to identify only the lateral sulcus and its posterior branch, the superior and middle temporal sulci and the sulci related to the orbital surface of the frontal bone. He also showed that the sulcal pattern, especially of the vault, was obscured by the structures lying between brain and skull, viz. meninges, arachnoid granulations, cerebrospinal fluid, cerebral veins and lacunae, venous sinuses and meningeal vessels. On the basis of these investigations he criticized (1916) the interpretations of a number of workers on casts from fossil skulls.

Le Gros Clark, Cooper & Zuckerman (1936) made a similar study in the chimpanzee and concluded that little information about the convolutional pattern of the brain could be derived from the cast—they were able to identify with certainty the rostrum of the lateral sulcus, the fronto-orbital sulcus, the superior and inferior frontal sulci and the inferior pre-central sulcus; vaguely or inconstantly marked were the lunate sulcus, the central sulcus, the parallel sulcus, the angular sulcus and the inferior temporal sulcus.

Both of the above-mentioned investigations showed that there were depressions on the casts not corresponding to the positions of sulci, indicating that the mapping of sulci on an endocranial cast without the brain for comparison would be liable to error.

The endocranial cast of the Australian aborigine has been used in morphological studies, mainly for comparison with other casts, by Keith (1925), Elliot Smith (1928), Kappers (1929), Shellshear & Elliot Smith (1934) and Hirschler (1942); Shellshear (1934) described the cranio-cerebral relations of one cerebral hemisphere. No direct comparison of cast with corresponding brain has been published. Therefore, it seemed of value to make such a comparison, in order partly to bridge the gap between Symington's findings for the European and those of Le Gros Clark *et al.* for the chimpanzee.

MATERIAL AND METHODS

The brain and endocranial cast were from a full-blooded male Australian aborigine aged 64 years. The body had been injected with a solution containing 5 % formalin. Nine days after the injection the skull-cap was sawn through and removed, and the brain removed *in toto*, the brain stem being cut at the level of the foramen magnum. The brain was in good condition with no distortion and no obvious shrinkage; photographs and measurements were made on the day of removal, before any drying could occur.

The dura was stripped as cleanly as possible from the whole of the inside of the skull—some difficulty was encountered in the region of foramina—and a cast was prepared, using melted printer's gelatin. A hole (20 mm. diameter) was bored through the skull near the vertex, the skull-cap was firmly fixed in position and the gelatin poured in through the hole. From the gelatin cast a plaster mould was prepared and finally a plaster cast, using fine dental plaster of Paris in both procedures. The volume of the cast was estimated and measurements taken. Hirschler's base-line joining the hindmost point of the cast to the most medial point of the marking of the fronto-marginal sulcus (B.N.A.) was employed. Using an oblique beam of light the depressions on the cast were carefully marked in pencil; this was done without reference to brain or skull. Tracings of photographs of various views of brain and endocranial cast were then superimposed (with correction for slight differences in size) and the general contours were compared; any sulci corresponding to depressions on the cast were noted, particular attention being paid to the central, lateral and lunate sulci. Obvious eminences on the cast were outlined and compared with corresponding regions of the brain.

The terminology of the brain sulci is in the main that used by Shellshear (1937) in his study of brain morphology of the Australian aborigine.

MEASUREMENTS

The measurements made on brain and cast are given in the following Table. The brain stem was cut in the region of the foramen magnum and the cerebral peduncles were divided at their junction with the pons. The weight includes pia-arachnoid and blood vessels.

	Brain		Cast
Weight	Forebrain and midbrain	920 g.	
	Hindbrain	171 g.	
	Total	1091 g.	
Volume (water displacement)	Forebrain and midbrain	1010 c.c.	1270 c.c.
	Hindbrain	142 c.c.	
	Total	1152 c.c.	
Maximum length	Left side	166 mm.	Left side 173 mm.
	Right side	160 mm.	Right side 166 mm.
Maximum breadth		112 mm.	117 mm.
Base line (Hirschler)	Left side	160 mm.	Left side 166 mm.
	Right side	155 mm.	Right side 162 mm.
Height index (Hirschler*)	Left side	38·1	Left side 45·1
	Right side	37·2	Right side 44·0
Depth index (Hirschler*)	Left side	21·9	Left side 18·1
	Right side	22·8	Right side 18·4

* Hirschler's height index is the greatest height of the brain above the base-line, expressed as a percentage of the base-line. His depth index is the maximum depth of the temporal lobe below the base-line expressed as a percentage of the base-line.

Duckworth (1903) found the average capacity of 150 Australian aboriginal skulls to be 1246 c.c. Davis (1869) estimated the average weight of 17 male brains to be 1197 g. Thus the cast here studied is above average volume but the brain is less than average weight.

GENERAL CONTOUR

A brief description of the contour of the cast is given and mention made of the regions in which the cast does not give an accurate indication of the corresponding surface of the brain.

Superior midline region (Figs. 1–4, 7 and 8; throughout, the odd-numbered figures are of the cast and the even-numbered of the brain)

The frontal lobes of the cast slope upwards from the rounded symmetrical poles with an even convexity (comparable with that of the brain) as far as a centrally placed bregmatic eminence, which is an obvious midline elevation with its centre approximately at the bregma and measuring 45 mm. long by 40 mm. wide—this eminence does not correspond to any elevation of the brain, which is rather flattened in this region. It almost certainly marks the position of the bregmatic 'pool' of cerebrospinal fluid. Arachnoid granulations cause irregularities on its surface.

Immediately behind this 'pool' the contour of the midline is obscured by the hole bored in the skull to make the cast. Just posterior to this region and on either side of the midline are two oval longitudinal elevations, not well defined at their periphery and not symmetrical; their surfaces are made irregular by the markings of several arachnoid granulations. On the left side the approximate size is 50 by 30 mm.; on the right the elevation is slightly longer and rather narrower. The brain in this region shows no definite elevations, although it is at the maximum convexity of curvature at the upper part of the occipital lobes. The elevations are probably due to 'parietal pools' of cerebrospinal fluid.

Behind these eminences the surface of the cast is flattened, but there is no definite depression. The curvature of the corresponding brain surface is regular and rounded, suggesting that the area of flattening on the cast is determined mainly by the presence of the 'parietal pool' eminences lying in front of it.

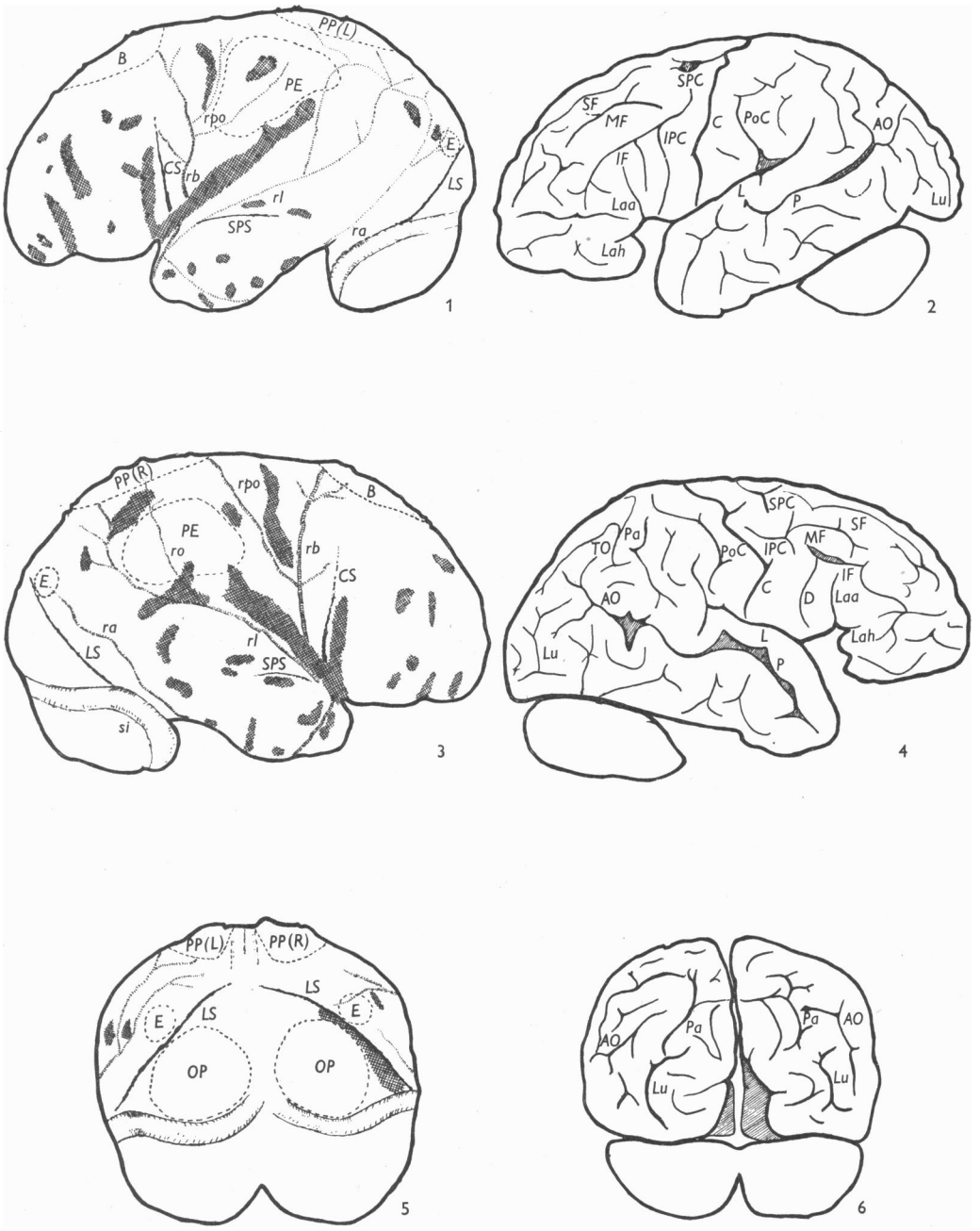
The occipital poles are very prominent on the cast; they are asymmetrical, the left being more pointed and projecting more posteriorly; both poles lie well behind the lambdoid suture markings and overlap the cast of the cerebellum by about 10 mm. There is a comparable asymmetry and overlap in the case of the brain.

Lateral regions (Figs. 1–8, 11 and 12)

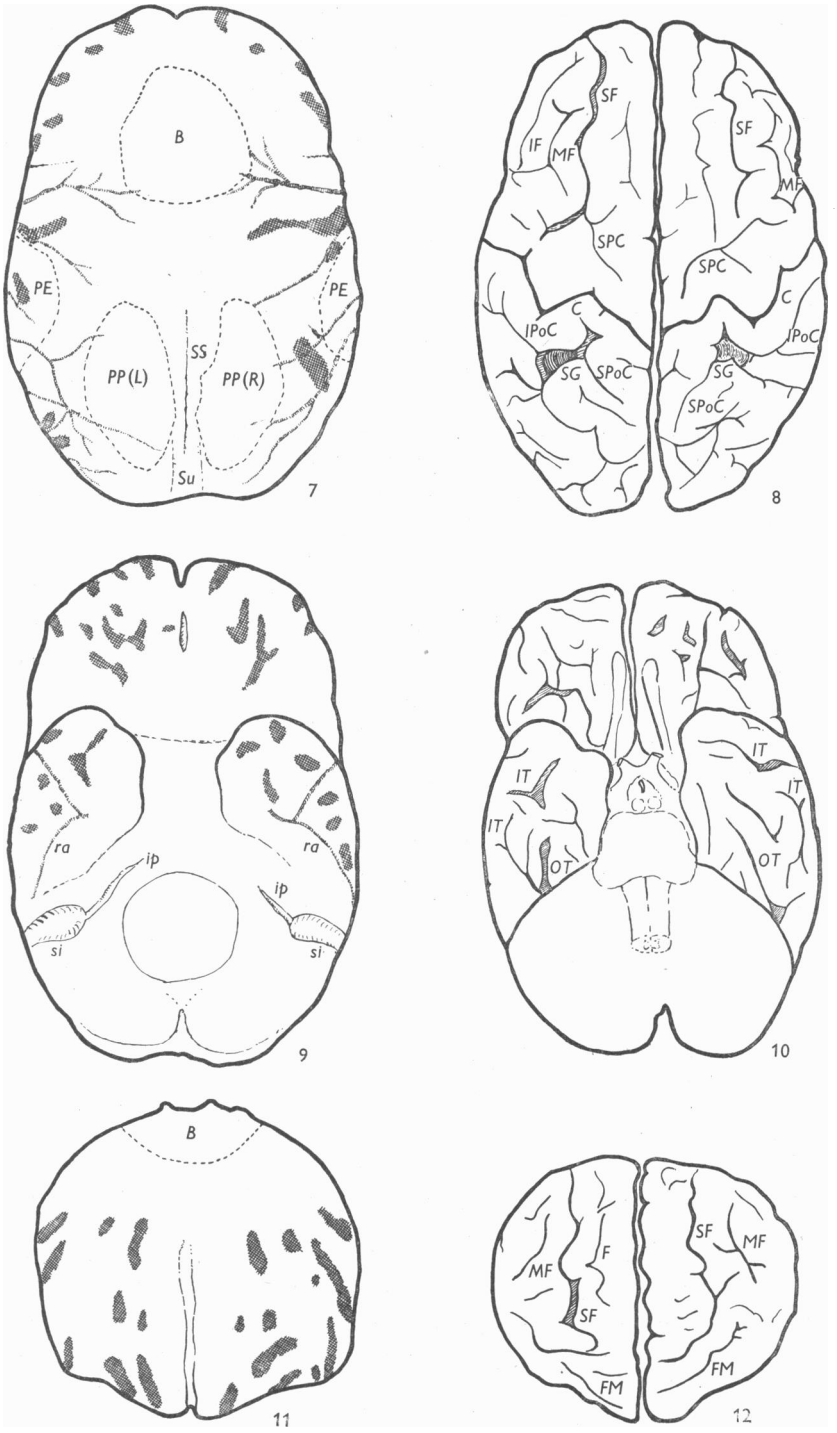
The most obvious features of the cast are the parietal eminences (outlined in Figs. 1 and 3); they are definite elevations on both sides lying just above and behind the posterior limb of the lateral sulcus; at the periphery the eminences are ill-defined, but their shape is on the whole circular. There are similar but less obvious elevations of the brain formed by the lower part of the post-central gyrus and the inferior parietal lobule. The parietal eminence on the right side of the cast is slightly more prominent than on the left, and this difference is present in the brain also.

Also noticeable is the tendency to constriction of the cast immediately in front of the coronal suture markings; the brain is constricted to a similar degree.

Situated just in front of the markings of the lambdoid sutures and approximately 35 mm. lateral to the lambda are two small rounded elevations of diameter less than



Figs. 1–6. For explanation see end of article.



Figs. 7–12. For explanation see end of article.

20 mm. They are symmetrical in position, the right is slightly more obvious than the left, but neither is well defined. There are no corresponding elevations on the brain.

The contours of cast and brain over the remainder of the lateral regions correspond fairly accurately and need no further description.

Frontal and inferior regions (Figs. 1–4 and 9–12)

Near the midline the rounded frontal poles of the cast continue inferiorly into a rather blunt orbital keel which projects downwards for only a short distance. Compared with the brain the keel is slightly broader and projects downwards a little more, but it represents quite closely the brain contour.

The orbital surfaces of the cast are concave from side to side and less markedly so from before backwards. As the medial border formed by the keel projects farther downwards than does the lateral, the orbital surfaces look laterally as well as downwards. The lateral border has several notches in it and ends posteriorly in a projection marking the position of the orbital operculum, which is more obvious on the left side of both cast and brain. These opercula are more prominent on the cast and in frontal view give a quadrangular outline compared with the more rounded contour of the brain.

In the brain the insula is partly exposed on both sides, particularly on the right, whereas on the cast the notch at the stem of the lateral sulcus is wider on the left.

The contour of the temporal lobes of the brain is accurately shown by the cast.

SULCAL PATTERN

Frontal region (Figs. 9–12)

On the orbital surface of the frontal lobe of the cast there is some sulcal pattern present, but it does not accurately represent the sulci of the brain—some of the widest sulci not being represented on the cast, while some small but wide depressions on the gyri are well marked on the cast. On the upper and anterior surfaces of the frontal lobe there are several ill-defined depressions on the cast; on both sides, those corresponding to the superior frontal sulci can be made out fairly readily. On the right side comparison with the brain shows that there is a depression on the cast corresponding to a wide longitudinal furrow on the superior frontal gyrus. Two other depressions lie along the line of the front-marginal sulci. None of the other grooves accurately corresponds to a sulcus but several of the smaller ones coincide with short wide depressions on gyri.

Parietal region (Figs. 1–4)

The stem of the lateral sulcus and its posterior limb are accurately indicated on both sides of the cast by a well-marked groove extending to just below the parietal eminence. The anterior horizontal rami are not indicated on either side. On both sides of the cast there is a definite short groove lying just in front of the coronal suture marking: the anterior ascending rami lie mainly just anterior to these grooves although the lower part of the left anterior ascending ramus coincides with the lower part of the groove. It is probably more accurate to say that the groove indicates the depressed part of the brain between the fronto-parietal and frontal opercula. On

neither side of the cast is the central sulcus accurately indicated. On both sides there is a depression lying posterior to the upper part of the bregmatic branch of the middle meningeal artery and in each case the lower part of this groove coincides with the position of the middle of the central sulcus, the coincidence being more exact on the left side. The upper parts of the central sulci lie posterior to the groove. No other grooves of the parietal region accurately correspond to any sulci. There is a definite short depression just above and posterior to the right parietal eminence which corresponds with a partly depressed gyrus (the anterior part of the superior parietal lobule) lying immediately posterior to the upper end of the post-central gyrus. However, on the left side of the brain there is a similar sunken gyrus but no groove on the cast.

Occipital region (Figs. 5, 6)

There is no sulcal pattern obvious in this region of the cast. On the right side there is a groove lying immediately behind and parallel to the lambdoid suture marking, but this does not correspond to any sulcus on the brain. The lunate sulci are situated entirely posterior to the lambdoid sutures. The sulcus on the left side is wide and deep compared with that on the right, but it is not represented on the cast. The lunate sulci are farther from the lambdoid suture than Shellshear (1934) found in his material.

Temporal region (Figs. 1–4, 9 and 10)

In this part of the cast there are some short, relatively well-marked depressions on the lateral and inferior surfaces. They do not lie accurately along the line of the sulci on the right side, but on the left side four such small notches mark the position of the anterior end of the inferior temporal sulcus. The parallel sulci are not represented on the cast, in spite of the fact that on the right side of the brain the sulcus is widely open.

MARKINGS OF VESSELS AND CRANIAL SUTURES

These markings are very similar to those on endocranial casts of European man. They are illustrated in Figs. 1, 3, 5, 7 and 9. The well-marked ridges formed by the middle meningeal vessels are named according to Ruggeri (1913), and the pattern of the ridges corresponds to type I of that author's classification for modern man. The pattern also agrees in basic plan with that depicted by Schepers (Broom & Schepers, 1946).

DISCUSSION

In general, the endocranial cast here described may be said to give a fairly accurate indication of brain shape and contour. The main discrepancies are due to provision for cerebrospinal fluid circulation, the bregmatic and the two parietal 'pools' causing definite elevations near the midline. It is probable that lacunae laterales and cerebral veins as well as arachnoid granulations take part in forming these eminences. The apparent flatness of the cast in the region between the parietal 'pools' and the occipital poles can be interpreted as due to contrast with the adjacent elevations. This interpretation is strengthened by considering the brain contour, which is more

convex than that of the cast in the region concerned. Shellshear & Elliot Smith (1934) have mentioned a lack of development in the pre-occipital region of the Australian aborigine, but it is not clearly evident in this brain. Although there is some fullness of the cast in the region of the coronal suture, there is no definite evidence of any subcoronal stream of cerebrospinal fluid as described and depicted by Keith (1931) for modern man and some lower types.

The sulcal pattern is poorly marked on the cast; this is in general agreement with the other brain/cast comparisons made in the European and the chimpanzee.

A number of short, relatively deep depressions on the cast coincide in position with widely open pits or furrows along the course of some gyri (most obvious in the temporal region), or with widely open parts of sulci (e.g. the left inferior temporal sulcus). These findings support those of Hirschler who has pointed out that widely open rather than deep depressions on the brain are more likely to correspond with depressions on the cast, and that such depressions are of little value in working out the sulcal pattern. On the other hand, a number of depressions on the cast do not appear to coincide with any hollows of the brain surface. Hirschler has also mentioned that a depressed gyrus may cause a groove on the cast, and this is shown on the right side of this cast. However, as the groove is situated between the elevation of the right parietal 'pool' and the right parietal eminence, there must be some doubt about this interpretation; the more so when one considers that on the left side of the cast there is no depression corresponding to a similar sunken gyrus. There are other instances of widely open brain depressions (e.g. the right parallel sulcus and the left lunate sulcus) not obscured by the bregmatic or parietal 'pools' and yet not represented on the cast. Obviously, the various structures and the cerebrospinal fluid lying between brain and skull must play a part as 'obscuring factors'.

The sulcal pattern of the cast is also made more difficult of interpretation by the markings of the meningeal vessels. The main vascular markings are well-defined ridges which give the impression that there is a groove on either side of them. The most obvious example of this is in relation to the marking of the central sulcus whose middle part coincides with a groove between the bregmatic branch of the middle meningeal vessels and the parietal eminence. The lower part of this groove does correspond in position to the middle of the central sulcus, but whether there is a direct relationship seems more doubtful.

Hirschler and others have indicated the difficulty of deciding from a cast the degree of exposure of the insula. This is well borne out here, for, on the cast, the stem of the lateral sulcus is wider on the left side, while, on the brain, the insula (because of the poorly developed orbital and frontal opercula) is more exposed on the right. The explanation of this discrepancy is not apparent.

The brain/endocranial cast studies on primates so far made all show the difficulty of correctly inferring the sulcal pattern from the cast markings, even in those regions where there are well-marked grooves. It seems probable, therefore, that the interpretation of the sulcal pattern on endocranial casts from fossil skulls is likewise liable to error. It is suggested that such casts might well be restudied after an extensive preliminary comparison of brain and endocranial cast in living primates.

SUMMARY

1. An endocranial cast prepared from the skull of a full-blooded Australian aborigine is compared with the corresponding brain.

2. The shape and contour of brain and cast correspond fairly accurately except superiorly, near the midline, where elevations on the cast are produced by collections of cerebrospinal fluid, arachnoid granulations and probably, also, by lacunae laterales and cerebral veins.

3. The sulcal pattern is poorly marked on the cast and few sulci are easily identified; a number of the grooves on the cast do not coincide with the position of sulci. Some of these grooves indicate the situation of short wide depressions on the brain, usually along the course of gyri, but sometimes along sulci.

4. On the other hand, several wide sulci or parts of sulci are not represented on the cast.

5. The markings on the cast caused by vessels and sutures are illustrated. These markings (and the midline elevations) tend to give an erroneous idea of the presence of grooves lying alongside them.

6. The degree of exposure of the insula cannot be inferred from the cast.

7. These results are in general agreement with those of other more recent brain/endocranial cast comparisons in modern man and the chimpanzee.

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EXPLANATION OF FIGS. 1–12

All drawings are reduced to just less than half-size.

Figs. 1, 3, 5, 7, 9, 11 are tracings from photographs of different views of the endocranial cast. Depressions are indicated by cross-hatching; elevations, vascular and sutural markings are also shown.

Figs. 2, 4, 6, 8, 10, 12 are tracings from photographs of comparable views of the brain. Widely open sulci are indicated by shading; the sunken gyri are also shown. The main sulci are labelled according to Shellshear (1937).

Abbreviations

AO	anterior occipital sulcus	*OT*	occipito-temporal sulcus
B	bregmatic 'pool' eminence	*P*	parallel sulcus
C	central sulcus	*Pa*	paroccipital sulcus
CS	coronal suture	*PE*	parietal eminence
D	diagonal sulcus	*PoC*	post-central sulcus
E	small eminence above lambdoid suture	*PP (L)*	left parietal 'pool' eminence
F	longitudinal furrow on superior frontal gyrus	*PP (R)*	right parietal 'pool' eminence
		ra	ramus astericus
FM	fronto-marginal sulcus	*rb*	ramus bregmaticus
IF	inferior frontal sulcus	*rl*	ramus lambdaticus
ip	inferior petrosal sinus	*rpo*	ramus pre-obelicus
IPC	inferior pre-central sulcus	*ro*	ramus obelicus
IPoC	inferior post-central sulcus	*SF*	superior frontal sulcus
IT	inferior temporal sulcus	*SG*	sunken gyrus (anterior part of superior parietal lobule)
L	lateral sulcus		
Laa	anterior ascending branch of lateral sulcus	*si*	sigmoid sinus
		SPC	superior pre-central sulcus
Lah	anterior horizontal branch of lateral sulcus	*SPoC*	superior post-central sulcus
		SPS	squamo-parietal suture
LS	lambdoid suture	*SS*	sagittal suture
Lu	lunate sulcus	*Su*	superior sagittal sinus
MF	middle frontal sulcus	*TO*	transverse occipital sulcus
OP	occipital pole		