THE BRAIN OF A MACROCEPHALIC EPILEPTIC.

BY J. WIGLESWORTH, M.D., F.R.C.P.,

AND

GEORGE A. WATSON, M.B., C.M.

PART I.

PART I.—CLINICAL HISTORY.

THE subject of this communication was a male epileptic who was admitted into Rainhill Asylum under our care in August, 1901, and died there in January, 1910. He was a single man, by occupation a piano-tuner, and his age on admission was 28. His family history was good. His father was an intelligent man, a Non-conformist minister, and there was no record of insanity, epilepsy, or allied neuroses in the family. The patient himself had always enjoyed good health, and had never had any serious illness except an attack of pleurisy. He was bright and intelligent as a child, and early showed promise of great musical ability, but he was always of a nervous, excitable disposition. At the age of 9 years he seems to have had an attack of *petit mal*, but the first distinct fit occurred when he was 16, and since that time he remained subject to epileptic attacks at variable intervals. For about a year before admission, the parents of the patient had noticed a gradual mental deterioration, which doubtless had been coming on insensibly for some time previously, but no attack of active insanity occurred until ten days before admission, when he became delusional, excited and threatening, which necessitated his removal to the asylum. He was on admission a man of good physique, 5 ft. 10 in. in height, and 12 st. 10 lb. in weight, with all his viscera apparently healthy. The limbs were well formed and symmetrical; there were no deformities of any kind. The circumference of his head was 25 inches. His mental condition was one of partial dementia. He was dull and weak-minded generally, slow of speech with prolonged reaction time, but was nevertheless fairly intelligent, could give a good account of himself, and was a useful worker. His history thenceforward was that of epileptics generally. The frequency of his fits increased in spite of treatment by bromides, so that whereas in the year 1902 his fits had averaged 5·9 per month, these had increased in 1907 to 9 per month. Along with this went steadily increasing impairment of memory and intelligence; he also had periodical attacks of excitement, lasting for a few days at a time, during which he was violent and dangerous, such attacks usually leaving him on their subsidence somewhat duller than before. Even when at his best he was markedly irritable and quarrelsome and showed much emotional instability. The steady mental deterioration was well shown by the fact that when first admitted into the institution in 1901 he was a useful worker in the place, but by the end of 1906 he had become useless as such, and in 1909 he had not sufficient mind to employ himself in any way. Concurrently with this his health gradually failed, and he finally died of an attack of broncho-pneumonia at the age of 37.

AUTOPSY NOTES.

Autopsy twenty-two hours after death. Temperature of mortuary 40° F. Height 69½ in.; circumference of shoulders 35½ in.; of head 25½ in. No deformities. Skull markedly dolico-cephalic and symmetrical; density average; average frontal thickness 6 mm.: occipital 8 mm. Dura mater congested, of normal thickness. The superior longitudinal and lateral sinuses contained dark fluid blood. Sub-dural fluid clear and in slight excess. Pia-arachnoid very congested and somewhat œdematous but showed no abnormal opacity; it stripped from the hemispheres a little more readily than naturally in the frontal region and about naturally elsewhere.

The brain generally was rather soft in consistence and somewhat œdematous. There was slight general wasting of the prefrontal region of both cerebral hemispheres but little or no obvious wasting elsewhere, and there were no local surface softenings. The lateral ventricles were slightly dilated, with slight excess of clear fluid. Large granulations were present in the third ventricle, anterior part of the lateral ventricles and in the lateral angles of the fourth ventricle. The main cerebral arteries were normal in distribution and appearance; veins congested.

The bodily organs generally were congested but showed no features of interest. The internal secretory organs all appeared to be normal. Areas of broncho-pneumonia were present in both lower lobes and a few patches of early atheroma in the thoracic and abdominal aorta, mostly in the latter. There were no signs of syphilis.

Weights of organs in grammes: Right lung 730; left lung 700; heart 235; liver 1,100; spleen 125; right kidney 155; left kidney 155.

The weight of the encephalon, immediately after removal from the body:—

Total weight, unstripped of membranes ...	...	2,130 grm.
Right hemisphere unstripped ...	947 grm.; stripped	918 grm.
Left ,, ,, ...	924 grm.; ,,	900 grm.
Cerebellum, pons and medulla, unstripped ...	...	228 grm.

The encephalon in this instance is thus 730 grm. above the average weight of the unstripped male encephalon, viz., 1,400 grm., as given by Marchand [14]. It may be calculated from Marchand's figures that 609 grm. is the average normal weight of each unstripped cerebral hemisphere. In this specimen this weight is exceeded by 338 and 315 grm. in the right and left hemispheres respectively.

The difference in weight of 23 grm. between the right and left hemispheres can scarcely be looked upon as unusual in view of the large size of the hemispheres, nor can the loss of 29 and 24 grm. occasioned by stripping the right and left hemispheres respectively, as 20 grm. is approximately the amount which the normal hemispheres lose in weight on stripping.

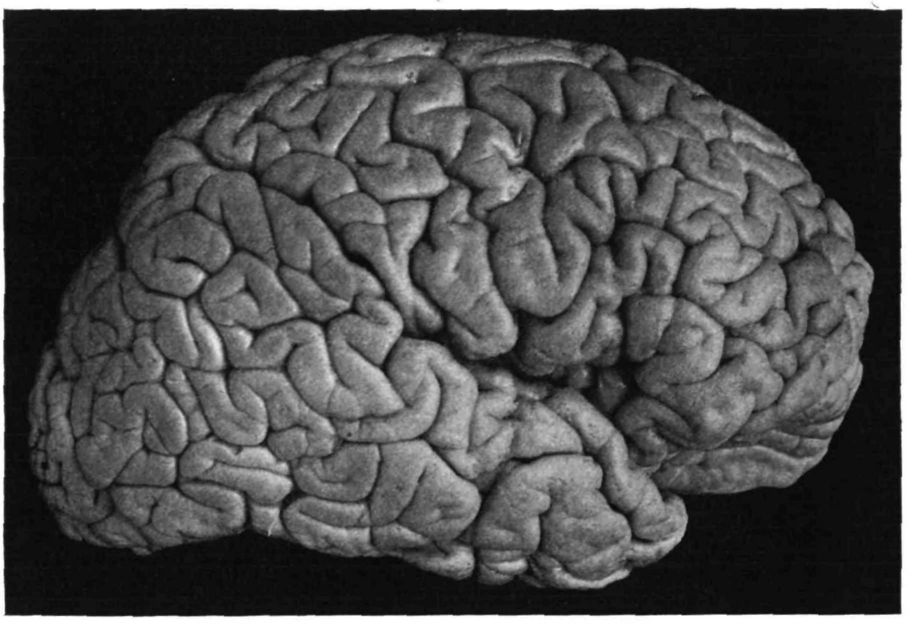

FIG. 1.

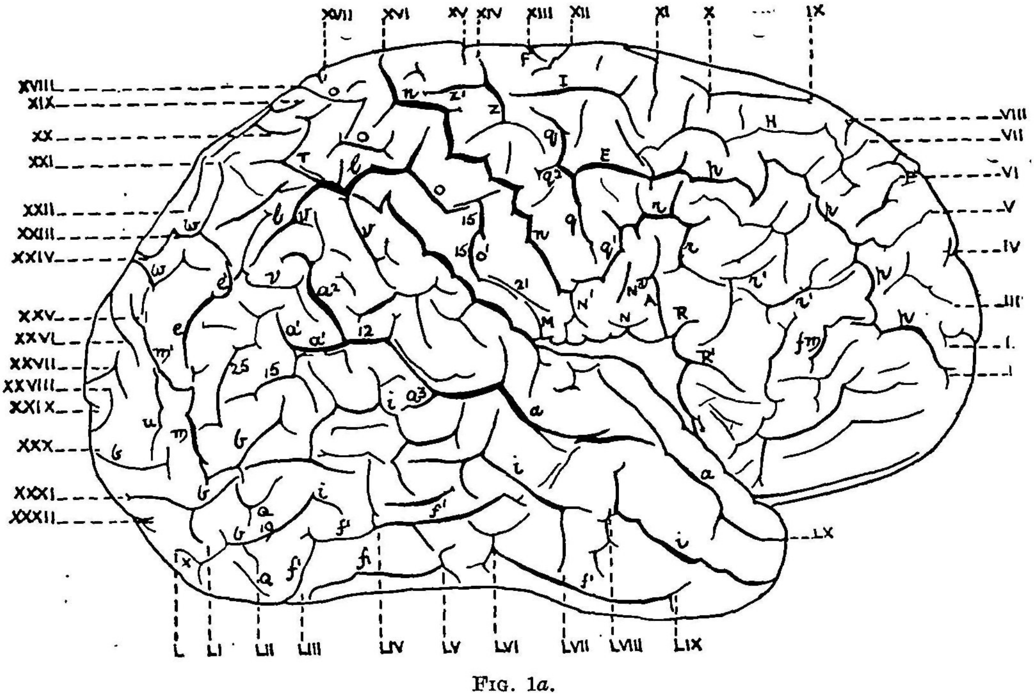
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FIG. 1*a*.

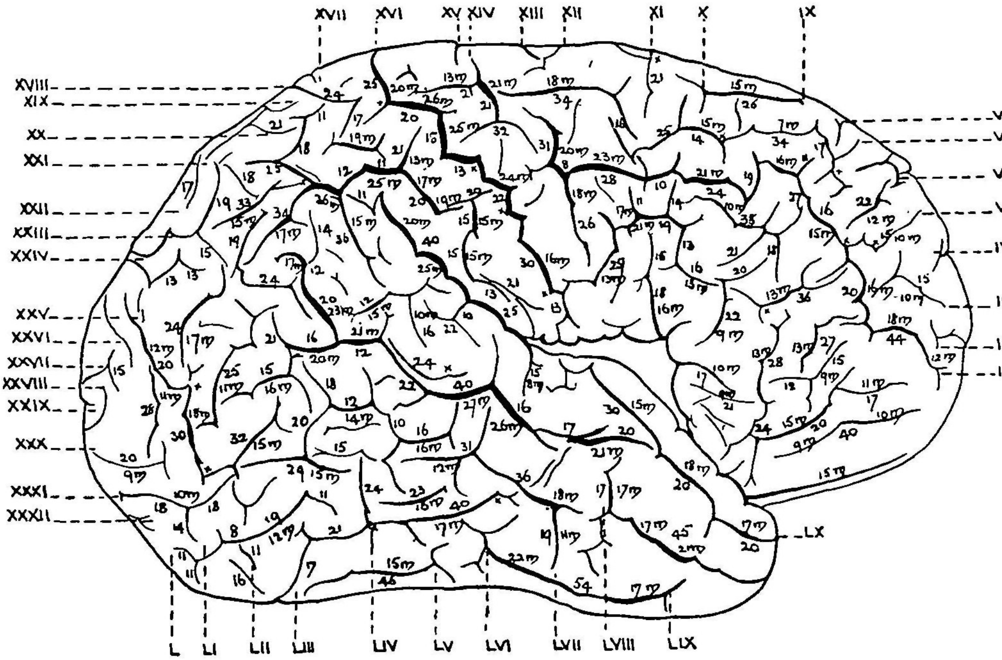
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FIG. 1b.

FIG. 2.

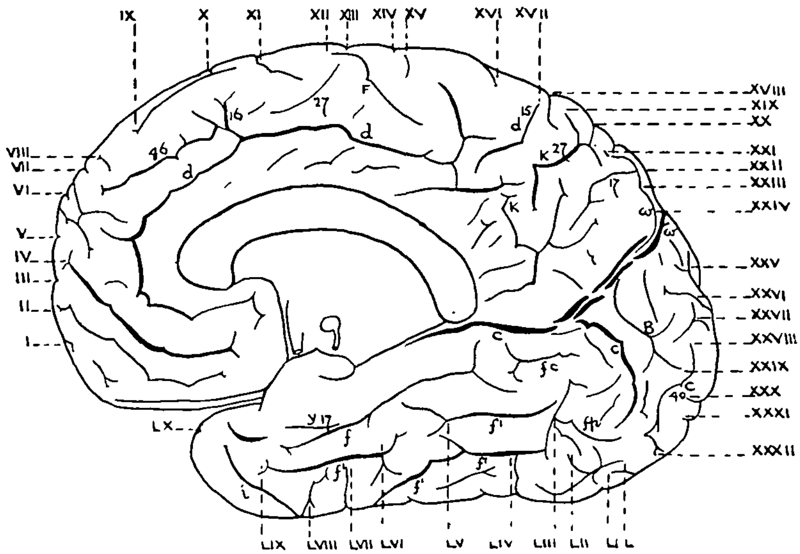
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FIG. 2*a*.

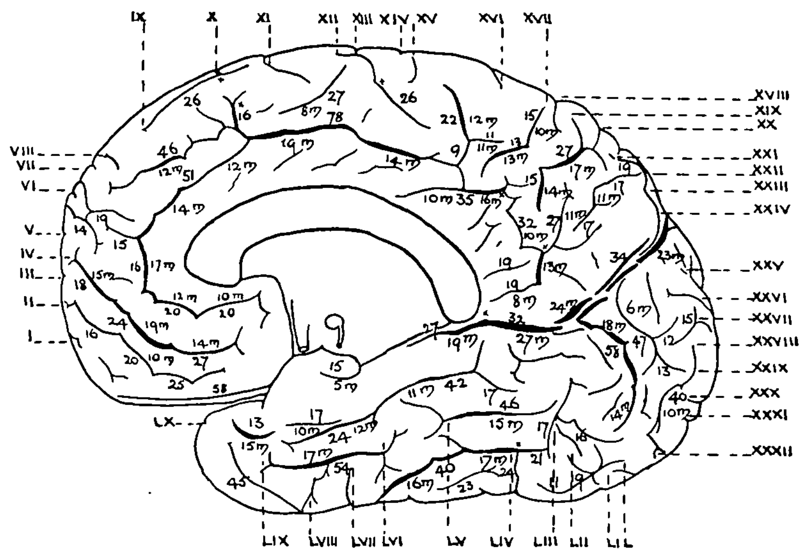
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FIG. 2*b*.

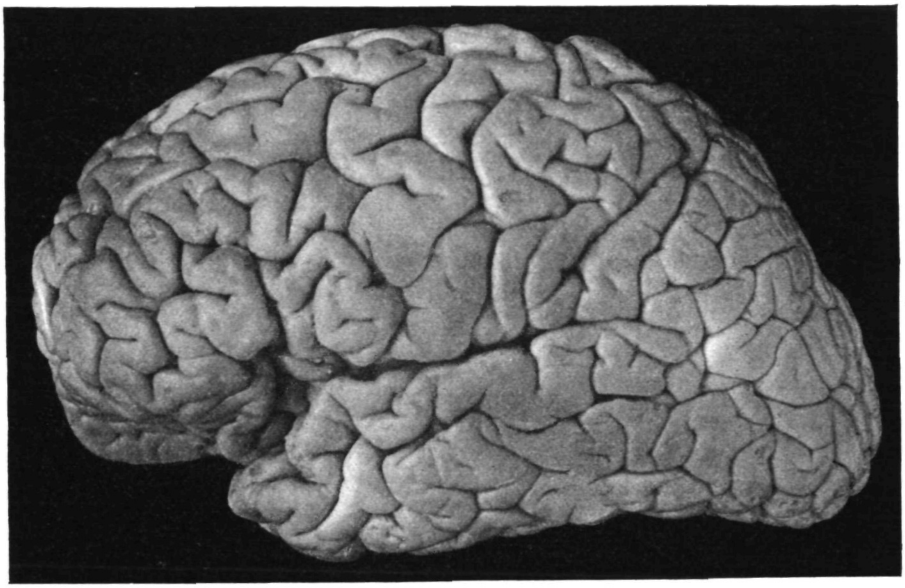

FIG. 3.

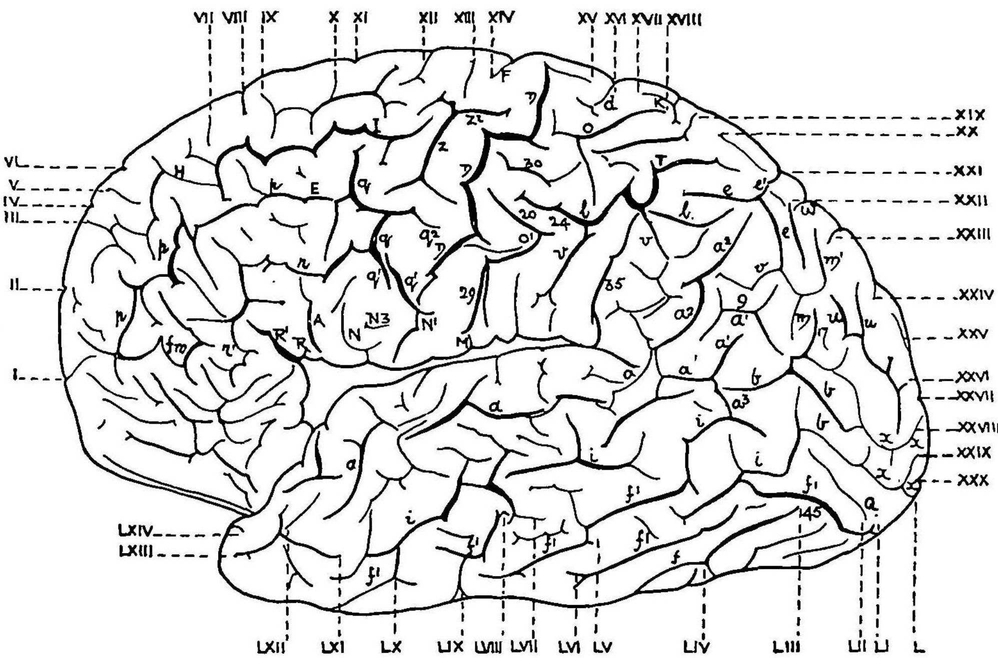
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FIG. 3a.

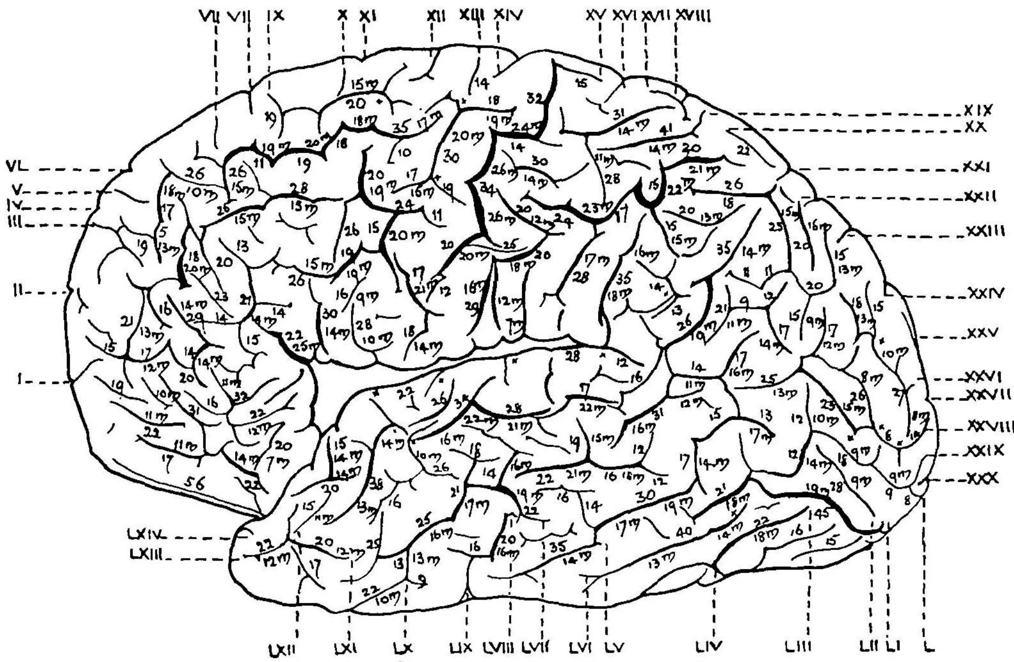
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FIG. 3b.

FIG. 4.

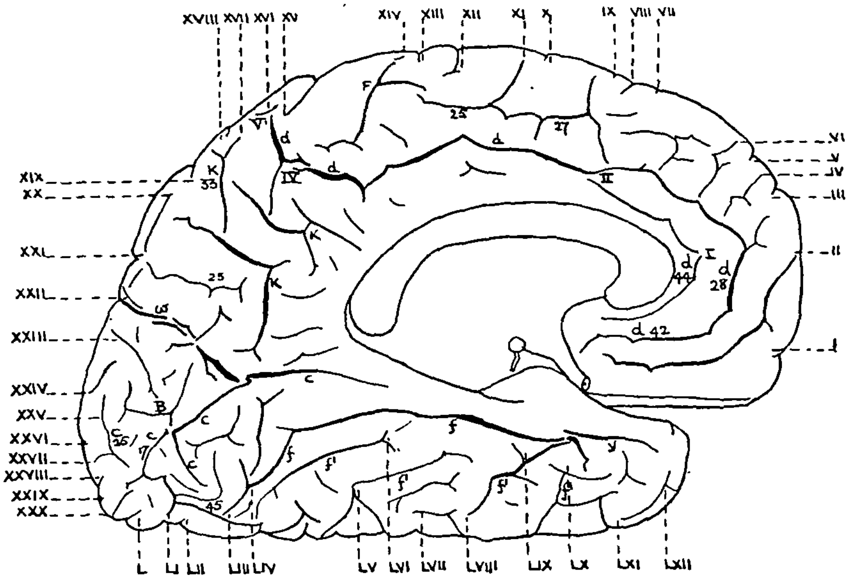
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FIG. 4*a*.

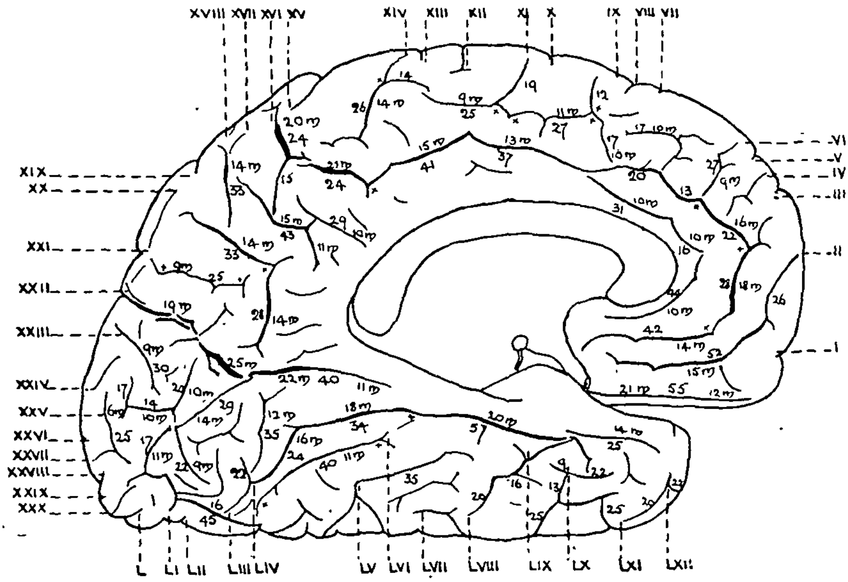
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FIG. 4*b*.

The normal ratio of the conjoined cerebellum, pons, and medulla to the cerebrum is given by Huschka as 13 : 87. In this specimen, the ratio being 10·6 : 87, the weight of the cerebrum relatively to that of the conjoined cerebellum, pons, and medulla is in excess of the normal.

FIG. 5.

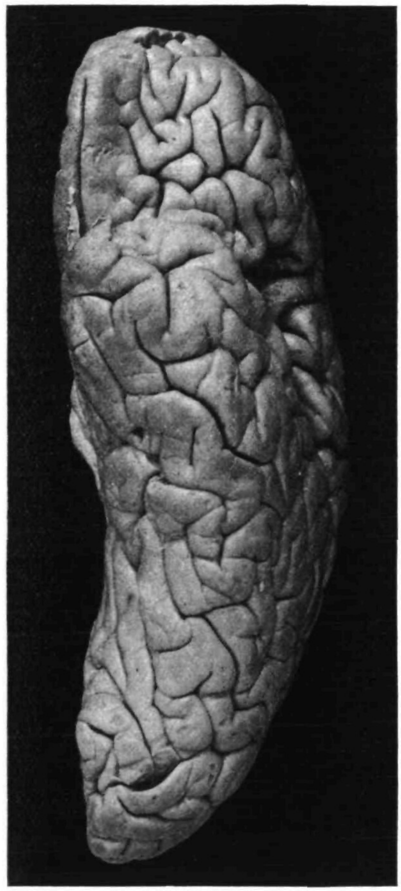

FIG. 6.

Looked at *generally* the cerebral hemispheres are unusually long as compared with their breadth. The different parts, however, appear to be in about normal proportion, excepting that the fronto-polar region on each side strikes one as being decidedly broad, relatively as well as absolutely, the superior portion of each third frontal gyrus is somewhat defective, and occipital lobes are relatively somewhat small.

The cerebellum, pons, and medulla appear as regards their shape and constitution to be in every way normally developed, and these parts are well covered by the cerebrum.

The encephalon is one of the largest—uncomplicated by any gross pathological change—of which there is any authentic record.[1] It is of interest to note that in several instances which have been reported of extraordinarily heavy brains the possessors have suffered from epilepsy.

The encephalon in this case much exceeds in weight that of the great majority of the 108 eminent men whose brain weights have been collected by E. A. Spitka [18], the nearest approach to it, in regard to weight, viz., 2,012 grm., being that of Turgenev, the Russian poet and novelist. The cerebral hemispheres are also, on the whole, about the most generally complex in pattern which we have hitherto seen. So far as can be judged from the drawings they are more complex than are those of any of the eminent men illustrated in Spitka's work, either those specially described by himself or by Retzius and others.

The Drawings of the Cerebral Hemispheres.

As illustrations supplementary to the photographs, drawings have been prepared something after the manner of Kohlbrugge [12] and [13] and of Cole [8]. These are freehand drawings based upon tracings of the photographs of the hemisphere. In the case of the lateral surface a considerable extension has been made towards the boundaries of the tracing so as to obtain in a single picture complete, or almost complete, views of the orbital surface, and of the fronto-polar and occipito-polar regions, as well as of the dorsal aspect of the hemisphere. The mesial aspect is shown in a similar manner, but as so much more of this surface, as compared with the outer, is almost flat a much less extension towards the boundaries of the drawing has been necessary. The drawings are thus, as Cole states with reference to his own, "a sort of Mercator's projection, though, of course, not mathematically exact. . . . The

[1] We have been able to find records of three human brains only, whether accompanied by pathological changes or not, of greater weight than the one under consideration, although it is possible that there are others which have escaped our search. These three are as follows:—

(1) Van Walsem's [22] case—2,850 grm.

(2) Sims' [17] case—2,400 grm. (Quoted by Anton [1] and Kohlbrugge [12].)

(3) A case mentioned by Hermann Pfister [16] 2,222 grm. There are reasons, however, for believing that there were gross pathological changes in this case.

longitudinal dimensions of the parts about the crest of the hemisphere are unavoidably exaggerated . . . but their transverse dimensions, radial in the drawing, are given as nearly as possible in their true proportion."

The drawings differ from those of Kohlbrugge and Cole in that an attempt has been made to give an adequate display of the sulci and gyri of the under surface of each hemisphere by making a considerable extension in this direction of the drawings of the lateral and mesial aspects. The position of borders, such as the superciliary and occipito-temporal, can be seen on comparison with the photographs.

The drawings are in three sets. In one set (figs. 1*b*, 2*b*, 3*b*, 4*b*), the Arabic numerals *without* the letter *m* adjacent to them show the estimated length in millimetres of the different sulci, or portions of these, against which they are placed. A small + is put against a point from which a portion of a sulcus was measured to its extremity or from point to point along the sulcus. These measurements thus do not convey the idea of length from point to point, but from them may be gathered the estimated length of a sulcus. The extent to which the drawings are necessarily inexact in certain places can be seen from these measurements.

The drawings give a more accurate idea of the composition of the sulci than do the photographs; annectants are usually more clearly indicated, and the representation of mere vascular grooves, which may appear as shallow sulci in the photographs, is omitted from the drawings.

The Arabic numerals *with* the letter *m* adjacent to them indicate the estimated depth, in millimetres, of the several sulci at about the points against which the numerals are placed. Owing to obvious difficulties, however, all these measurements can only be regarded as approximately correct, and are merely of relative value.

The Roman numerals have been employed after the manner of Kohlbrugge and of Cole (the former uses Arabic numerals for this purpose) as marks by which one may identify corresponding points in two views of the same hemisphere. For facility of reference in these very complex hemispheres a considerable number of these points have been indicated. Many of the sulci, or portions of these, appearing in different views of the same hemisphere may also be identified by the Arabic numerals placed against them.

In another set of drawings, viz., figs. 1*a*, 2*a*, 3*a*, 4*a*, the sulci, the identification of which is certain, or fairly certain, have letters placed against them corresponding to the letters used by Kohlbrugge in his drawings. For the sake of clearness all the numerals referring to measurements have been omitted in this set of drawings excepting certain Arabic numerals, similar to those employed in the first set of drawings, which have been placed against certain sulci referred to in the text, the identification of which is doubtful, or to which special attention is directed.

The third set of drawings, figs. 7 and 8, will be referred to under Part II.

Method of Hardening the Cerebral Hemispheres.

The cerebral hemispheres were hardened in 5 per cent. formalin after being stripped of their membranes, each hemisphere being laid on its mesial surface supported by wool. This method was adopted because it was originally intended to attempt micrometric measurement of sections from various regions of the cortex, and in order to obtain results comparative with other control cases it was considered advisable to strip the cerebrum in the fresh state. Unfortunately, although the tissue was fairly satisfactory for ordinary microscopical examination, it was found to be unsuitable for micrometric measurement.

Measurements of the Cerebral Hemispheres.

These are in three sets. The second and third sets, particularly, have been made according to E. A. Spitka's [18] system. This author states that those measurements are best which can be reduced from absolute to relative values wherein some unit of length, preferably the maximum cerebral length, is used as a basis of expression rather than so many inches or centimetres. Hence centesimals of the length of the cerebrum are used, so that all brains may be compared, "no matter what their size or what the degree of shrinkage may be, so long as there is no actual distortion."

The method of hardening above described unavoidably leads to a certain amount of distortion of the hemispheres. Consequently it is doubtful if the measurements of these given below are of much value, partly for this reason and partly because of the difficulty of finding fixed points. In fact some writers advocate the abandonment altogether of any attempt at such measurements, believing that they are not only worthless but actually misleading. It is possible, however, that such measurements would be of some interest and value if compared with corresponding ones made upon hemispheres hardened in a similar manner, and which were originally not markedly atrophied or soft and flabby.

Measurements of the Cerebral Hemispheres.

Compared with the average measurements, when obtainable, of the brains of ten ordinary and normal individuals (Spitka [18]). All the measurements are given in millimetres.

	Right hemisphere	Left hemisphere	Average when obtainable	
I.—Principal diameters, &c.				
Maximum length	216	223	172	
Maximum width	65	59	—	
Maximum width of cerebrum 124	—	—	139	
Cerebral index $\left\{\frac{\text{Breadth} \times 100}{\text{Length}}\right.$ .. 55·6	—	—	81	
Maximum depth	140	136	—	
Mesial length	382	380	—	
Lateral length	270	275	—	
Callosal length	103	113	—	
Precallosal length	42	38	—	
Postcallosal length	81	82	—	
Occipito-temporal length	172	173	—	
Sylvian angle	45°	28°	—	
Rolandic angle	66°	64°	—	
II.—Arc measurements, along the dorsi-mesial border.			R.	L.
Frontal arc	235	237	155	155
Parietal arc	79	79	55	57
Occipital arc	80	85	59	57
Cerebral indices (expressed in centesimals of the total fronto-occipital marginal arc)—				
Frontal index	59·6	59·1	57·7	57·7
Parietal index	20·1	19·7	20·4	21
Occipital index	20·1	21·2	22·1	21·3
III.—Horizontal distances (expressed in centesimals of the hemicerebral length).				
From cephalic point to—				
Lateral aspect (1) Tip of temporal lobe ..	20·3	22·4	23	24
Lateral aspect (2) Sylvian-presylvian junction	28·7	32·2	30	30·4
Lateral aspect (3) Ventral end of central fissure	40·7	40·8	42·2	44·4
Lateral aspect (4) Sylvian-episylvian junction	55·1	51·5	55·9	60·5
Lateral aspect (5) Caudal point	—	—	100	
Mesial aspect (6) Frontal edge of callosum ..	19	16·5	—	22
Mesial aspect (7) Porta (foramen of Monro)	34·2	36	—	41·2
Mesial aspect (8) Dorsal end of central fissure	69	67·6	—	63·9
Mesial aspect (9) Dorsal intersection of paracentral fissure	74	70·2	—	68·2
Mesial aspect (10) Caudal edge of callosum ..	65·7	66·2	—	64·2
Mesial aspect (11) Occipito-calcarine junction ..	79·6	79·5	—	74·7
Mesial aspect (12) Dorsal intersection of occipital fissure	92·5	90·3	—	86·2

Whatever view may be taken of the value of these measurements, a brief allusion may be made to one or two points revealed by them.

The length of the hemispheres as compared with their breadth is very great, so that the cerebral index, viz., 55·6, is remarkably low. This cannot be wholly accounted for by the method of hardening adopted, i.e., by a tendency for the hemisphere to spread out flat and thin when lying on its mesial surface. It is almost certain that the latter method has some influence in reducing the cerebral index, particularly in the case of brains which show much wasting and dilatation of the lateral ventricles. Yet the cerebral index in this specimen, which was little wasted, is decidedly smaller than is that of any of the other brains in our possession which were hardened in a similar manner, and which were measured for comparison, in spite of the fact that many of these control brains were much atrophied.

The measurements (6, series III) would suggest that the mesial part of the frontal lobe in front of the corpus callosum is relatively rather small, especially in the left hemisphere, but the remainder of the frontal lobe is in almost normal proportion.

The occipital index apparently shows that the occipital lobe is relatively rather small, especially on the left side.

Other departures from the average in the measurements may perhaps be accounted for, or at least partly so, by a certain amount of distortion of the hemispheres.

General Account of the Cerebral Hemispheres.

In view of the clearness and sufficient accuracy with which the course and dimensions of the sulci are represented in the drawings, no systematic description of these or of the gyri appears to be necessary. The following general account will serve to direct attention to the main features shown by the convolutional pattern of the hemispheres. The identification of the sulci has been in some instances a matter of considerable difficulty, and we are much indebted to Dr. S. J. Cole for valuable help in this connection. Dr. Kohlbrugge has also kindly revised the lettering of the sulci. We are ourselves, however, entirely responsible for all the opinions expressed.

In addition to comparison with the descriptions and drawings of the sulcal pattern of the numerous cerebral hemispheres given by Kohlbrugge [12] and [13], indications of departure from the usual and normal brain pattern, such as are regarded of importance by many other observers, have been carefully looked for. These have been summarized by Mickle [15] as occurring in the following directions: (1) In superiority, indicating active development and high evolutionary grade. (2) In aberrant irregularity and bizarre arrangement of the sulci and gyri, which is taken to signify formative activity, or over-activity but ill-directed. (3) In inferiority by defect: (*a*) either as a developmental defect, so that there is persistence, more or less, of fœtal characters in place of advance to adult form; (*b*) or as an evolutionary reversion to brain types of lower races of mankind, or to lower animal types.

The Sulci and Gyri of the Cerebral Hemispheres.

We will deal with the interlobar fissures first, and then with the sulci and gyri of the several lobes.

The Interlobar Fissures.

The fissure of Sylvius.—The general course of this fissure is more steeply inclined on the right side than on the left, but this is usually regarded as a normal difference between the two hemispheres both in man and in most of the apes; the macaque, according to Cunningham [9], showing an exception in this respect.

The main portion of the posterior limb of the fissure is, as is usual, considerably longer on the left side than on the right. The posterior limb ends on both sides in a shorter descending and a longer ascending ramus. It seems doubtful how much of the latter really belongs to the Sylvian system. It is broken by several deep interdigitations, and just above the mark 35 in the left hemisphere, and at a corresponding place in the right is a deep gyrus. Probably only the lower piece of the apparent ramus, below the deep gyrus, belongs to the Sylvian; the upper piece being a subsidiary sulcus of the inferior parietal lobule, although it does not actually join the sulcus interparietalis.

In the right hemisphere the anterior limb possesses two rami, a posterior one, R, which is short and deep—the apparent sulcus seen in the photograph joining this is merely a vascular groove—and an anterior one, R^1, having a forward and downward direction. On the left side the anterior limb shows only one well-formed ramus, R^1, the sulcus behind this, R, representing the ascending ramus, being quite small. Further reference to these rami is made on p. 51.

The sulcus centralis, n. N^1.—This sulcus follows a fairly usual course on both sides, excepting that in the right hemisphere it is straighter than is common, and the typical backward extension of its upper extremity is absent. Each sulcus shows several deep annectants, and the upper and lower buttresses of Symington and Crymble [19] are rather more distinct on the right side than on the left.

The small sulcus, lettered N^1, when in the position it occupies in these hemispheres, should probably be regarded as part of the s. centralis, for we have found in several cases that a similar sulcus forms a posterior limit to the Betz-cell area. The sulcus in question is on the left side, separated from the *n* sulcus by a narrow superficial bridge—the lower bridge of Mickle [15]. The presence of such a bridge, if broad, would probably be a mark of inferiority.

Superficial union of the right s. centralis with the s. precentralis, and with the Sylvian, by means of an intermediary sulcus (N^1) may also be noticed. This union, when present, is regarded by Mickle as aberrant.

A short, straight, smooth-walled s. centralis shallow relatively to the s. interparietalis resembles that of lower apes, and it has been asserted that in poorly-developed brains and in those of negroes the s. centralis is less sinuous than normal. But Mickle [15] states that this condition is not often a criterion of low type, for some decidedly inferior brains have sinuous or zigzag central fissures. In this case the right s. centralis, although rather straighter than usual, is of relatively good length, is of good depth, and possesses well-marked deep annectants.

The fossa parieto-occipitalis, w.—This is well closed on both sides. The sulci composing the complex, as seen on opening up the fossa, are somewhat diagrammatically shown in the drawings, for all the internal annectants are deeply placed. On the right side the dorsal elements forming the incisura are two in number (*w*, *w*) and the anterior of these especially is of considerable length. On the left side there is only one dorsal element, and this is short. The cuneo-limbic and cuneo-precuneal annectants are deep, and are very similarly disposed on the two sides.

The sulcus calcarinus, c. Right hemisphere.—The anterior portion or stem passes forwards for a somewhat unusual distance anterior to the splenium of the corpus callosum. The posterior portion curves markedly downwards and backwards in the main part of its course, its lower end bending slightly forwards. It is separated posteriorly by a broad superficial posterior cuneo-lingual annectant from an undulating sulcus (marked *c* 40), which also probably forms part of the calcarine system. The anterior cuneo-lingual annectant is somewhat small, and is for the most part deeply placed. Three small deep interdigitations are seen along the course of the posterior calcarine proper.

Left hemisphere.—The stem of the sulcus follows a usual course. The posterior division passes at first downwards and backwards, and then makes a sudden bend downwards and slightly forwards—the general direction of this portion of the sulcus being very similar to that on the right side. The small sulci behind (marked *c* 17 and *c* 25) probably also belong to the calcarine system. The anterior cuneo-lingual annectant is small and deeply placed, the posterior is superficial and narrow.

In both hemispheres the stem of the sulcus shows the normal obliquely downward cut into the brain substance, whilst the posterior portion, as is usual, incises the cerebrum at about right angles to the surface.

On the right side the posterior calcarine proper ends rather further forwards than is common in the well-developed human brain. This, together with the presence of the curving shallow sulcus behind, separated by a broad superficial annectant, may possibly be some indication of a phylogenetic reversion.

In the left hemisphere the irregular arrangement of the posterior calcarine and of the separate terminal pieces behind this is atypical, and perhaps may be regarded as a sign of aberrancy and inferiority.

The sulcus collateralis, f, fc; and *sulcus rhinalis, y.*—The right s. collateralis must probably be regarded as being defectively developed. It is in two pieces separated by a broad superficial annectant. Both portions of the sulcus are unusually shallow and are smooth walled. The sulcus marked *y* 17 represents a s. rhinalis; between this and the main portion of sulcus *f* is a narrow superficial gyrus rhinencephalo-temporalis posterior. There is in this hemisphere a short incisura temporalis.

The left s. collateralis is better developed than is the corresponding sulcus of the right side. It has a fairly usual course: is of good depth and shows three deep interdigitations in its posterior portion. The sulcus marked *y* represents a s. rhinalis and there is a fairly broad gyrus rhinencephalo-temporalis posterior, for the most part deeply placed, and a narrow gyrus rhinencephalo-fusiformis. No distinct incisura temporalis is seen in this hemisphere. The sulcus rhinalis on both sides probably forms a partial boundary to Brodmann's area of cortex No. 28.

The sulcus cinguli, d. Right hemisphere.—The pars anterior and pars intermedia are typically placed. No definite Brücke of Eberstaller is seen along the course of these portions of the sulcus, although several small deep interdigitations are present. The pars posterior (*d* 15) is separated from the pars intermedia by a broad superficial annectant representing either Brücke III or IV whilst a Brücke V (the gyrus arcuatus anterior of Retzius), arches round the upper end of the pars posterior. The pars intermedia forms a definite junction with the sulcus subparietalis (K) (see fig. 2*b*). Such a union is shown in some of the drawings by Kohlbrugge [12] and [13] of Malayan and Javan brains. It is looked upon by Mickle [15] as aberrant in the human brain and as pointing to a phylogenetic reversion, although probably a junction of the *K* sulcus with the pars posterior of the sulcus cinguli would be of greater significance in this respect.

Left hemisphere.—The anterior reaches of the sulcus in this hemisphere must probably be looked upon as being duplicated, the sulcus marked *d* 28, 42 forming a s. cinguli superior. But below and behind this, and having a somewhat similar direction in relation to the genu of the corpus callosum, is another but much shallower sulcus (*d* 44) which may be regarded as part of the sulcus cinguli. There are several deep interdigitations, but no definite Brücke occurs along the course of the pars intermedia and sulcus *d* 28, 42. But the lower and posterior sulcus, *d* 44, has an almost superficial annectant crossing it at the mark I, and it is separated from the pars intermedia by a surface annectant at the mark II. If this sulcus, *d* 44, be regarded as part of the s. cinguli then these annectants have the usual position of Eberstaller's Brücke I and Brücke II respectively. The pars posterior is in two divisions—horizontal and ascending—separated from each other by a Brücke IV. A Brücke V is also present.

Duplication of the forepart of the s. cinguli appears to be commoner in the left hemisphere than in the right (Mickle [15] and Kohlbrugge [12] and [13]), and, when present, may be regarded as a normal difference between the two hemispheres.

Mickle [15] states that it is not infrequently difficult to appraise correctly the significance of certain appearances of the sulci. "Like words in a sentence, their meaning varies with the context." Duplication or triplication of the sulcus cinguli may be taken as a case in point. This may sometimes mean the abnormal persistence in the adult of a fœtal character, and at other times aberrant formative activity, but such interpretations can probably only be placed upon the appearance if accompanying conditions show a defective, reverting or aberrant tendency. If these conditions evince a normal or high brain type, the duplication of the sulcus in question may probably be deemed to manifest fissure wealth.

The Frontal Lobes.

The external Surface.—The *precentral* system of sulci (F, *z*, *zi*—*q*, q^2,q^1) is well developed and is for the most part typical on both sides. The sulcus F, placed rather far forward in the right hemisphere, is a good example of the solco inflesso of Lussana, or inflected fissure of E. A. Spitka [18] or s. præcentralis mesialis. The ramus sagittalis posterior (*zi*) of the s. præcentralis superior is well developed in both hemispheres.

The *s. frontalis superior* (I and H) is comparatively simple and shallow in the right hemisphere as compared with the left, probably in association with the especially good development of the mid-frontal system in the former hemisphere.

The *s. frontalis mesialis* is fairly well developed on both sides, rather better on the left than on the right.

The sulci *q* and q^2 represent the *s. præcentralis medius* of some authors. The ramus horizontalis anterior of Eberstaller forms an important branch of this sulcus.

The *p* system of sulci (in part the *s. frontalis medius*) is unusually well developed on both sides. In the right hemisphere the anterior portions of this system form a typical *s. fronto-marginalis*, consisting of a stem and a mesial branch. There is also a lateral branch (*fm*), separated from the stem by an annectant, but the mesial branch in this instance, as is commonly but not invariably the case, is obviously the direct continuation of the main stem. The stem and mesial branch well represent a sulcus identified by Bolk [3] with the *s. rectus* of lower apes.

On the left side the arrangement is not quite so typical. The stem divides into a shorter mesial and a longer lateral branch, and it is not clear which of these two is the direct continuation of the main stem.

The sulcus q^1—in part the *s. præcentralis inferior*—appears to be duplicated in the left hemisphere. The posterior of the two sulci superficially joins the N^1 sulcus, but a deep gyrus crosses the sulcus almost opposite the lower end of the *n* sulcus. On the right side the q^1 sulcus is single but is somewhat unusual. It appears to be a lower portion of the s. præcentralis inferior forming an aberrant though shallow connection with the *n* sulcus and with the Sylvian fossa by means of an intermediary sulcus N^1.

The *inferior frontal* system of sulci *r*, r^1 is fairly typical in both hemispheres, but on the right side the different elements of the system are separate from each other, whilst on the left side they are joined.

The *subfrontal* region—using the term subfrontal according to Brodmann's [6] meaning—is on the whole comparatively small and simply convoluted. The orbital (or inferior) operculum is well developed on both sides. On the right side the anterior limb of the fissure of Sylvius possesses two definite rami, R, R¹, enclosing between them a relatively moderate sized intermediate (or triangular) operculum. In the left hemisphere this operculum is decidedly small, as there is only one well formed anterior limb of the Sylvian complex. The latter arrangement is probably more common on the right side than on the left. The superior operculum is somewhat defective, especially in the right hemisphere. The amount of exposure of the insula as seen in the photographs and drawings is no doubt exaggerated owing to the membranes having been stripped from the hemispheres before hardening. This would probably affect the position of the temporal more than that of the frontal opercula, and owing to a certain defect of the intermediate and superior frontal opercula it is probable that in the natural state there was some undue exposure of the insula.

A *sulcus diagonalis* is not easy to identify with certainty in these hemispheres. As Kohlbrugge [12] and [13] has suggested (and Bolk [3] agrees), a true s. diagonalis is part of the s. præcentralis inferior which has become detached owing to the rising up of a gyrus in the depths of the latter sulcus. The sulcus lettered A in both hemispheres in this specimen may probably be regarded as a s. diagonalis owing to its position in front of the sulcus identified as the s. subcentralis anterior (N), and owing to the close proximity of its lower end to the anterior Sylvian ramus.

A remark may here be made concerning the *sulcus arcuatus.* Cole [8] believes that the upper or horizontal limb of the arcuate sulcus of lower apes is often represented in the human brain by a part of the s. frontalis superior. According to this view the course of the s. arcuatus would probably be represented in this specimen on the right side by the sulci lettered q^1, the lower part of q and H, and on the left side by those marked q, q and I.

The mesial surface. The marginal gyri and paracentral lobules. —This surface is comparatively simply convoluted in the right hemisphere. In the left fairly-well developed branches marked 25, 27, constituting the *mesio-frontal intragyral sulcus* of Mickle [15] or *fissure fronto-marginalis* of Spitka[1] [18], divide part of the marginal gyrus into

[1] *Sulcus gyri marginalis* would probably be a more appropriate name for this sulcus than fissura fronto-marginalis, in order to avoid confusion with the sulcus fronto-marginalis.

two tiers. This sulcus on the right side is represented by the shallow furrow marked 27, and possibly also by the furrow marked 46 which makes a shallow connection posteriorly with the branch of sulcus *d* marked 16. The sulcus appears often to be better developed in the left hemisphere than in the right in common with the more frequent duplication in the former hemisphere of the anterior reaches of the s. cinguli.

The sulcus L of Kohlbrugge (*cephalic paracentral* of Wilder, *s. paracentralis* vel *præparacentralis*) is not present in the left hemisphere, and the branch of sulcus *d* marked 16 in the right is probably placed too far forward to represent the sulcus. Kohlbrugge regards the sulcus L as of little importance.

The *rostral* sulci are long, simple and typically placed in the right hemisphere, but in the left, if the sulcus, *d* 28, 42 is to be looked upon as a s. cinguli superior, only one rostral sulcus is present.

The left paracentral lobule is smaller than the right and is smooth. On the right side the lobule is scored by a long branched upturn of the s. cinguli.

The orbital surface.—There is some tendency to keeling of this surface in both hemispheres. The orbital sulcus shows the usual transverse and sagittal elements. The transverse element is of great length on the right side, and its outer end passes over the superciliary border for a considerable distance. The whole system, however, is much more complex in the left hemisphere than in the right, the sagittal elements being more numerous and more branched than is common in the former hemisphere, and they tend to almost completely insulate portions of the brain substance.

Remarks on the Frontal Lobes.

(1) The general size of these lobes is about normally proportionate to that of the remainder of the hemispheres. Each hemisphere, however, is distinguished by the great breadth and complexity of its fronto-polar region in contrast to the condition of the subfrontal region which on both sides is partially defective and is relatively simple in pattern. There is now much evidence, to mention only that brought forward by Flechsig [11], Bolton [4] and [5], and Brodmann [6], to show that the latest regions of the frontal lobe to develop, both ontogenetically and phylogenetically, are the subfrontal and prefrontal.[1] In the cerebral hemispheres of the insane it is common to find one or other,

[1] *i.e.*, the prefontal in the meaning of Bolton and not in that of Brodmann.

or both, of these regions especially affected, either as a congenital defect, or as the result of loss due to cerebral wasting. In this particular specimen it is therefore of interest to note that whilst the prefrontal region is of great breath and is complex in pattern, the subfrontal is relatively defective and comparatively simply convoluted.

(2) The main sulci are for the most part deep, much curved, and possess many secondary spurs. The development of the sulci has proceeded on fairly regular lines and, as we consider, in the direction of superiority. The only definite tendency to insulation of portions of the cortex has occurred in the right orbital region. This tendency to the formation of islands of cortex either by branching and re-uniting of primary sulci or owing to the presence of unusual sulci, is looked upon by Mickle [15] as a sign of aberrant formative activity. As regards the external surface of the frontal lobes the left hemisphere appears to be slightly more complex in pattern than the right, although in places the latter is a little better convoluted than its fellow. With respect to the mesial and orbital surfaces of the lobes, the left side is decidedly superior to the right in convolutional complexity.

(3) The good development of the external sagittally coursing sulci, especially of the sulcus frontalis medius, which on the left side in this specimen is remarkably well formed for a *left* hemisphere, divides this part of each frontal lobe into four distinct, and for the most part, broad gyri. The superior of these is still further partially subdivided by branches of the sulcus frontalis mesialis which is also rather better developed on the left side than on the right.

According to Kohlbrugge [13] this four tier type of external frontal conformation is the common arrangement for the brains of Australians. Mickle [15] states that, found in some criminals, lunatics and mental defectives, it has been said to indicate marked aberrancy, Benedikt indeed believing that it is a sign of grave reversion to the four tier type of certain lower animals. Mickle himself, however, argues that, at least in many instances, this four (and five) tier type marks a higher than usual and not a lower brain formation, especially when due to division of the first frontal gyrus by unusual development of the s. frontalis mesialis. The same applies, although less convincingly, to the four tier form produced by marked development of the s. frontalis medius. The author quoted believes, contrary to Benedikt, that the latter is the more common arrangement, and this is in agreement with our own experience. The type thus formed has not infrequently been seen in the larger cerebral hemispheres obtained at the Rainhill Asylum, and these hemispheres have, as a rule, belonged to people of originally good intelligence. Mickle, after concluding that instead of degradation and reversion, the four tier form must indicate in many cases a rather high position in brain evolution, remarks that, "this is indeed compatible with mental aberrancy, with unstable and labile mental activities, lively and powerful but not well directed—in a word, a brain function lacking in balance."

The Parietal Lobes.

The external surface.—The sulcus lettered M forms a fairly typical *s. subcentralis posterior* in both hemispheres.

The *sulcus post-centralis.* On the right side a series of sulci (o, o^1) make an almost complete boundary to the post-central gyrus, the annectants passing between this gyrus and the parietal lobules being narrow and mostly rather deep. In the left hemisphere the several elements of the post-central sulcus are for the most part widely separated from each other by broad superficial annectants. The superior branch (o) in this hemisphere shows the common arrangement of a stem bifurcating at its upper end to embrace the extremity of the s. cinguli (d). The sulci marked 21 and 29 in the right and left hemispheres respectively appear to belong to the post-central system, so that the inferior division of this sulcus is seemingly duplicated on both sides, as occasionally occurs. The furrows marked 20, 24 and 30 in the left hemisphere may perhaps be regarded as lateral branches of the s. post-centralis. The sulcus marked 20 on the left side (and more doubtfully that marked 15, 15, on the right) might be looked upon by some as constituting a form of *s. retrocentralis transversus* of Eberstaller, although rather shallow for this sulcus and placed somewhat high up in the hemisphere. Whatever name is given to this furrow there can be little doubt that, as Cole [8] has pointed out, a similar sulcus is of importance in the causation of the appearance of a large inferior Rolandic genu. Such a sulcus, as in this specimen, is usually better marked in the left hemisphere than in the right, presumably owing to the greater length of the posterior limb of the Sylvian complex in the former hemisphere.

The *sulcus interparietalis.* On the right side this consists of two independent portions, an anterior and longer (l) which is joined to a furrow taken to represent the middle part of the post-central sulcus, and a posterior and shorter (*e*), the *pars occipitalis* or *paroccipital sulcus* of Wilder. Behind the latter is a well marked *s. occipitalis transversus* of Ecker (*m*, *m*[1]). The sulcus numbered 25 in front of the sulci *e* and *m* may perhaps be regarded as a duplication of one or other of these furrows such as sometimes occurs in complex brains. In the left hemisphere the anterior division of the s. interparietalis is in two separate parts (*l*, *l*), the posterior of these being much shallower than the anterior. The posterior division of the sulcus *e* passes backwards and then rapidly downwards and backwards to join a typical s. occipitalis transversus (*m*, *m*[1]). The branch marked 17 behind the latter may probably also be regarded as belonging to the *m* system.

From the upper side of the s. interparietalis in both hemispheres springs a well marked branch, the *ramus medialis primus* (T). The *ramus medialis secundus* (*e*[1]) is short and deep, as is sometimes the case. It is typically placed on the left side, but is not so readily identified on the right.

From the under side of the *l* portion of the s. interparietalis in the right hemisphere arise three *rami ventrales* (*v*, *v*, *v*). The anterior of these is rather unusually well developed and forms a boundary between the supra-marginal and angular gyri. On the left side two ventral rami spring from the sulcus *l* and one from the sulcus *e*. The anterior of these in this hemisphere also is a long furrow.

The other sulci of this region can be more conveniently dealt with when considering the temporal lobes.

The mesial surface of the parietal lobes. Right hemisphere.—Whilst the posterior third of the precuneus is almost smooth, the anterior two-thirds are unusually complex. The lower sagittal division of the K system of sulci (the *s. subparietalis*) joins anteriorly the s. cinguli (see fig. 2*b*). The sulcus is much branched and cuts off the greater part of the precuneus from the gyrus cinguli.

Above this sulcus are two more transversely directed furrows (K27 and 17) such as one may find in this region. These may be regarded as *sulci præcunei.* The upper part of the anterior of the two sulci we think, however, forms a furrow which sometimes runs into or becomes a *sulcus parietalis superior* of Retzius. Reference is again made to this sulcus on p. 60.

Left hemisphere.—The precuneus is more simply and uniformly convoluted than on the right side. The branches of the K system are quite independent of each other and of other sulci. The two lower of these form a *sulcus subparietalis,* but broad annectants pass between the precuneus and gyrus cinguli. The remarks made concerning the sulci K 27 and 17 of the right hemisphere apply also to the sulci marked K 33 and 25 (for sulcus 25 see fig. 4*b*) in this hemisphere.

The Temporal Lobes.

The superior surface.—On the right side one very long anterior transverse gyrus of Heschl is separated from two smaller posterior gyri by a deep sulcus, the outer part of which cuts into the greater part of the breadth of the first temporal gyrus. In the left hemisphere there are only two transverse gyri of Heschl, a long anterior gyrus separated from a shorter posterior one by a sulcus which indents the edge of the lobe.

The lateral and inferior surfaces. Right hemisphere. The sulcus temporalis superior, a.—This consists of two separate parts. The anterior of these is placed relatively unduly close to the edge of the lobe and is deflected in the hinder part of its course towards the Sylvian fossa, so that the anterior part of the first temporal gyrus is narrow. Occasionally this deflection of part of the superior temporal sulcus is complete, the branch turning right into the Sylvian depths. Such complete deflection, when present, appears to be much commoner on the left side than on the right. It is regarded by Mickle [15] as a departure from the usual, which, other things being equal, is in the direction of increased formative activity, and, although a deviation from type, is yet not necessarily a sign of inferiority. But there are other considerations which lead one to suppose that the condition may sometimes mean the persistence of an occasional fœtal tendency.

The posterior division of the sulcus is deep, and along its course several broad, deep annectants occur. It inclines away from the line of the Sylvian fossa, giving great breadth to the hinder part of the first temporal gyrus. This part of the sulcus sends off spurs upwards and downwards, and ends posteriorly in a bifurcation, forming a long anterior ascending limb (a^2) and a shorter posterior branch (a^1). The anterior branch, a^2, would probably be identified by Elliot Smith [10], and also by Kükenthal and Ziehen,[1] as the *sulcus gyri angularis*, although Zuckerkandl [25] (and also Bolk [3] for the gorilla) would regard the posterior branch a^1 as representing this sulcus. Kohlbrugge [12] and [13] does not name a determined furrow a sulcus gyri angularis. The reasons

[1] We have been unable to obtain access to Kükenthal and Ziehen's original work, and are only acquainted with their views in so far as they are discussed by the authors quoted.

for the identification of the anterior branch as the sulcus gyri angularis are, as Dr. Cole suggests, that it is the original continuation of the main part of the sulcus temporalis superior, and that it is found in the older cortex (in which the sulcus first appears) common both to apes and man, whereas the posterior branch is situated in, or near to, the newer cortex further back. As is well known, modern histological research has thrown much light on the order of development of the inferior parietal lobule, and the point above alluded to is but another illustration of the fact that the identification of sulci on the ground of mere topical considerations is apt to be fallacious.

The horizontally directed branches marked 12, a^1, and 15 may perhaps be regarded as forming a *s. parieto-temporalis* of Elliot Smith, partially separating the inferior parietal lobule from the temporal lobe.

The *sulci temporalis medius* (*i*) and *inferior* (f^1). The different divisions of these sulci have a fairly typical disposition, and are mostly separate from each other, although some of the posterior branches of the sulcus f^1 join to almost entirely insulate a considerable area of smooth cortex. In the more simply convoluted human brains the s. temporalis inferior is often closely associated with the s. collateralis—an indication of a reverting tendency. In this hemisphere these furrows are widely separated. The sulci of the lingual lobule are simple and shallow.

The sulcus marked *b* (also 19) appears to form a *s. occipitalis inferior* of Wernicke and Elliot Smith.

The *s. temporalis transversus* of Retzius, which commonly forms a fairly definite boundary to a distinct histological area (area temporopolaris (38) of Brodmann and of Elliot Smith), is represented by a posterior transverse branch of the anterior segment of the s. temporalis medius.

The lateral and inferior surfaces. Left hemisphere. The sulcus temporalis superior, a.—This sulcus is complex and is made up of several irregular branches, but the first temporal gyrus is of more uniform width than in the right hemisphere. The part of the sulcus behind and below the posterior Sylvian termination is broken up and is unusually shallow. Hereabouts also it joins with other furrows to almost entirely insulate a slightly depressed area of cortex. Behind this shallow split-up portion the sulcus divides into two terminal rami. The anterior of those a^2 may probably be looked upon as a *sulcus gyri angularis*. This sulcus is shallower than is the corresponding one of the right side, but it is longer and reaches to within about 20 mm. of the superior border of the hemisphere. The horizontal portion of the sulcus marked a^1 forms together with the sulci lettered *b*, *b* a very typical *s. parieto-temporalis* of Elliot Smith, although the latter elements (*b*, *b*) may be regarded as a *s. occipitalis lateralis* of Eberstaller. The K shaped sulcus marked a^1 9, immediately above the posterior ascending terminal ramus a^1, appears to form a *s. occipitalis anterior* of Wernicke.

The *sulci temporalis medius* (*i*) and *inferior* (f^1). The branches of these sulci are fairly typically distributed, but are very numerous. Many are separate the one from the other, and are much forked and spurred, rendering on the whole the lateral and inferior aspects of the lobe markedly complex in pattern. One of the branches of the sulcus f^1 almost joins the s. collateralis. The *s. temporalis transversus*, apparently composed of transversely directed branches of the superior and middle temporal sulci, is more irregular than is the corresponding sulcus of the right hemisphere. The deep sulcus marked f^1 (also 45) is apparently a *s. occipitalis inferior* of Wernicke and Elliot Smith.

The Occipital Lobes.

The external surface.—The furrows of the mesial aspect of these lobes are fairly typical in distribution, but the arrangement of the sulci on the external surface of the lobes in this specimen, as is not infrequently the case, is not easily reconciled with any of the recognized descriptions of the sulci of this region. Dr. Kohlbrugge has been kind enough to letter the sulci of this region in these hemispheres according to the system used by him, and he has made the following observations :—

In every large brain a duplication of sulci may be seen, especially in the parietal and occipital regions. The sulcus *b* (which we have referred to as forming a *s. occipitalis lateralis* of Eberstaller) may be doubled in one or both sides. In this specimen the sulcus is tripled in each hemisphere. If the sulcus *b* is doubled the sulcus *x* is likely to be duplicated also, as in the right hemisphere in this case, the lower branch probably belonging to the *i* system (s. temporalis medius). In the left hemisphere this sulcus appears to be like a duplication of sulcus *b*. The sulcus *x* is also double and united with the *b* sulci in both hemispheres. The sulcus *u* is single on the right side but duplicated on the left. No sulcus which has the typical direction of a *s. paramesialis* is present in either hemisphere.

Remarks on the Parietal, Temporal and Occipital Lobes.

The general size of the parietal and temporal lobes of both hemispheres appears to be about normally proportionate to that of the remainder of the hemispheres. The lateral surface of the occipital lobes, however, strike us as being relatively somewhat small in both hemispheres, although the latter well covered the cerebellum in the natural state. This relative smallness of the occipital lobes is by some regarded as an indication of good cerebral development, although, on the other hand, relative defect in size of these lobes is not infrequently seen in inferior brains.

The parietal lobes.—The post-central gyrus, especially in its upper and middle parts, is rather broader on the left side than on the right, and is more split up by cross sulci. This, however, is a common and presumably normal difference between the two hemispheres.

Owing to the different position in the two hemispheres of the component parts of the sulcus interparietalis and of the Sylvian fossa, there are certain differences on the two sides in the shape, and to some extent in the size of the superior parietal lobule and of the several parts of the inferior parietal lobule. But these differences are usual ones and doubtless quite within normal limits. Thus, whilst the supramarginal and angular gyri cover much the same extent of surface in the two hemispheres, on the right side the portion of the former gyrus in front of the posterior ascending Sylvian ramus is much narrower than is this portion in the left hemisphere, but the deficiency in this direction is mostly compensated for by an increase in height. The reverse applies, though to a less extent, to the angular gyrus, i.e., what this gyrus lacks in height in the right hemisphere is compensated for by increase in breadth. The post-parietal gyrus of the right hemisphere is distinctly larger in every direction than that of the left. The superior parietal lobule is of a very uniform breadth on the right side, but on the left lobule is broader in front and narrower behind as compared with its fellow of the opposite hemisphere.

It is of interest from the evolutionary aspect to note that the posterior part of the inferior parietal lobule—a region of the human brain which, according to Flechsig [11], is very late to myelinate, and which is relatively small in apes—is exceedingly well developed as regards size and complexity in both hemispheres, but especially so in the right.

The hinder part of the superior parietal lobule and of the precuneus appears to be large as compared with the fore part, particularly on the right side. This is also of developmental interest. As Cole [8] has pointed out, "the sulcus parietalis superior probably marks the boundary between an area of earlier myelination in front and an area of later myelination behind. The area in front is a region which attains a high degree of development in the gorilla." In this specimen the anterior and superior sulci of the K system (K27 on the right side and K33 on the left) are probably the furrows partly separating these two areas, which, according to Flechsig [11], myelinate at different dates, as probably also they do the *area parietalis superior* B from the same named area A of Elliot Smith, regions which this observer [10] believes to be structurally distinct. In these hemispheres the region behind the sulci just referred to is of large size as compared with the region in front.

As regards their convolutional pattern the parietal lobes in general may be said to be markedly complex, and the sulci are for the most part developed on regular lines. Secondary spurs are numerous and many of the sulci are much curved, but some, especially of the inferior lobules, are relatively rather shallow. Attention has already been directed to the apparent duplication of certain sulci, particularly in the right hemisphere; in fact the latter hemisphere appears, on the whole, to be more complex than its fellow.

Duplication of the ordinary furrows Mickle [15] appears to regard as abnormal, as being indeed a perversion of developmental activity excessive in degree, but lower in kind or grade, ill-directed and aberrant. But it seems to us that if this duplication has occurred in a regular manner—as in most places in this specimen—it should be looked upon rather as a sign of superiority, especially as it is apt to occur in all hemispheres of a highly complex convolutional pattern.

The tendency to separateness of the different elements of the post-central and interparietal systems of sulci, especially on the left side, might be regarded by some as an indication of under persistence of fœtal characters owing to developmental failure, but judged by the context, i.e., by the complexity of the hemispheres generally, we consider that this should more probably be looked upon as a sign of increased formative activity in the direction of superiority.

In neither hemisphere is there any tendency to the formation of what Mickle [15] has termed a reversed occipital or posterior parietal operculum. This author regards such an appearance as a manifestation of over-activity on the part of the parietal with some relative defect of activity of the occipital region. The absence of such a formation in this specimen can probably be accounted for by the fact that the developmental activity of the occipital lobes, judging by the duplication of many of the sulci of their outer surface, has been as great, or almost as great, as that of the parietal.

The Temporal Lobes.

These appear to call for little comment. The different sulci are on the whole well developed, so that the several gyri are fairly distinctly marked off from each other. The left temporal lobe is decidedly more complex in pattern than the right, secondary spurs and forkings of the sulci being more numerous in the former hemisphere. This difference between the temporal lobes of the two hemispheres of the same brain is probably not uncommon.

The somewhat aberrant direction taken by the first part of the s. temporalis superior in the right hemisphere has already been mentioned.

There is an even more marked tendency to separateness of the different elements of the sulci of the temporal lobes than of the parietal lobes, and we think that the interpretation which was placed upon this in the instance of the latter lobes applies also to the former. At the same time we consider that there is greater irregularity and aberrancy of the sulci in the temporal regions, on the whole, particularly on the left side—as shown by the numerous spurs, forkings and tendency to insulation of areas of cortex—than occurs in any other part of the hemispheres.

The external parieto-occipital annectant gyri.—There is no clearly recognizable *sulcus lunatus* of Elliot Smith in either hemisphere, and sulci which may be regarded as homologous with an "affenspalte" are difficult to identify. In the left hemisphere, however, it may perhaps be said that the sulcus marked 17 and the anterior part of sulcus *b* bear a similar relationship to the *s. occipitalis transversus* to that which the "affenspalte" bears to this sulcus.

On the left side the course of the external parieto-occipital annectant gyri can be traced with some definiteness. The first annectant passes round the extremities of the ascending limb (m^1) of the *s. occipitalis transversus* and of the *parieto-occipital fossa*, and is bounded anteriorly by a short processus acuminis (e^1) and by the dorsal continuation of one of the *precuneal* sulci. The second annectant, superficial and of considerable size, forms a loop round the end of the descending limb (m) of the *s. occipitalis transversus*, and is bounded in front by branch of the sulcus identified as the *s. occipitalis anterior* of Wernicke (a^1 9). The third annectant passes across and around the anterior end of the s. occipitalis lateralis of Eberstaller (b) and is bounded anteriorly by branches of the superior and middle temporal sulci.

In the right hemisphere the course of the parieto-occipital annectants is difficult to follow with any degree of certainty excepting that of the first which is a broad irregular gyrus passing round the extremity of the upper branch of the *s. occipitalis transversus* (m'). But this gyrus is broken up by branches of the parieto-occipital complex and by sulci of the superior parietal lobule.

Zuckerkandl [25] has traced the course of the parieto-occipital annectant gyri in apes with much plausibility, but the attempt to identify these annectants in the human brain in every instance appears to us apt to lead to confusion. It seems by no means always clear which is which. In our experience the course of these annectants can not infrequently be more readily followed on the left side than on the right.

The insula; concealed areas of the frontal and parietal lobes. The limbic and olfactory lobes.—These parts, so far as can be seen without damage to the specimen, are, in both hemispheres, normally developed, have a size proportionate to that of the rest of the hemispheres, and show a convolutional pattern of at least average complexity.

Summary and General Remarks.

(1) The cerebral hemispheres are of good general shape, and the different lobes of each hemisphere appear to bear about a normal proportion to one another, excepting that the occipital lobes are relatively somewhat small. The subfrontal region on each side is also rather small and simply convoluted, but the deficiency of this region is relative only.

(2) The convolutional pattern of the hemispheres as a whole is exceedingly complex, and in the distribution of the several sulci little beyond the following has been detected which can be regarded as definite marks of inferiority. The right *sulcus collateralis* may be said to be defectively developed, and some signs of reversion or aberrancy are shown by the *calcarine* sulci, and perhaps by the right *sulcus cinguli*. There are tendencies to insulation of areas of cortex in the right orbital region and in the temporal regions; also to irregularity and aberrancy of the sulci in the latter regions, particularly on the left side. Some indications of defective formation or aberrancy of sulci, however, are to be found, we believe, in almost every human hemisphere, no matter how good the development in general may be. The duplication and triplication of the sulci such as occurs, especially in the occipital and parietal lobes in this specimen, we prefer to regard, for the reasons given, as departures in the direction of superiority.

(3) Many of the sulci are much curved, and on the whole they certainly exceed the average normal in depth, whilst having a depth which, for the most part, is normally proportionate to each other. In places, however, the sulci are somewhat shallow; e.g., some of the furrows of the left inferior parietal lobule, a portion of the left sulcus interparietalis, and the posterior part of the stem of the left sulcus temporalis superior.

(4) Certain differences exist in the convolutional pattern of the two hemispheres. These have been fully detailed in the foregoing pages, and we consider that in most instances they are only such as are very commonly found between two hemispheres of the same brain, and that probably they can be regarded as normal differences.

PART II.—MICROSCOPICAL EXAMINATION.

The method of hardening the hemispheres employed and the reasons for this have already been stated. As it was desired to preserve one of the hemispheres as an almost complete museum specimen, the majority of the blocks for microscopical purposes were removed from the left hemisphere.

Sections, cut in paraffin, from the various regions were stained, after Nissl's method, with polychrome blue or thionin, and also for showing blood-vessels and neuroglia by the Heidenhain iron-hæmatoxylin method, followed by counter staining with eosin. The latter method fails to stain normal neuroglia fibrils—which is often an advantage—whilst giving an adequate display of all actively proliferating and abnormal neuroglia.

In all thirty-seven blocks were examined from the two cerebral hemispheres, twenty-nine from the left and eight from the right. It is unnecessary to detail the regions from which these blocks were removed, for the exact site of most of them is marked on the drawings (figs. 7 and 8) by a dotted line, against which a number is placed indicating the type of cortex found in the different situations. The numerals correspond to those used by Brodmann [6] in his map of the distribution of the histological areas of the human cerebral cortex.

The microscopical findings in this case are of interest from two separate points of view. Firstly, as an example of unusually large cerebral hemispheres, and secondly, as a case of epilepsy. From the latter aspect, the appearances which other observers, and particularly Turner [21], consider to be characteristic of epilepsy were carefully

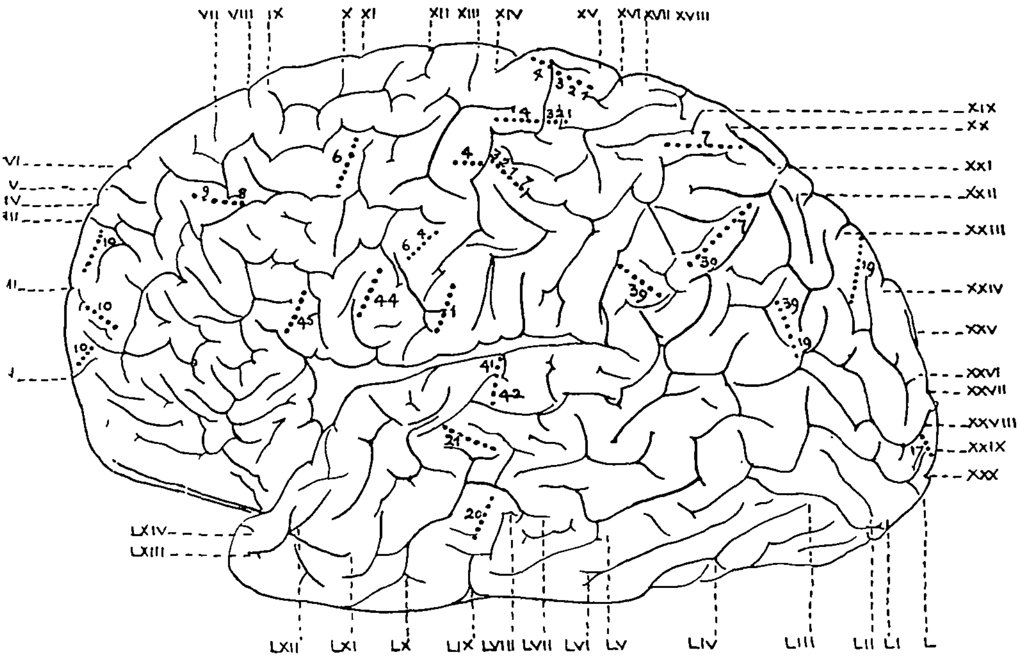

FIG. 7.—*In this and the following figure the site of each of the blocks removed for microscopical examination is indicated by a dotted line. The numerals placed against these lines refer to the type of cortex found in the different situations, and correspond to those used by Brodmann for this purpose.*

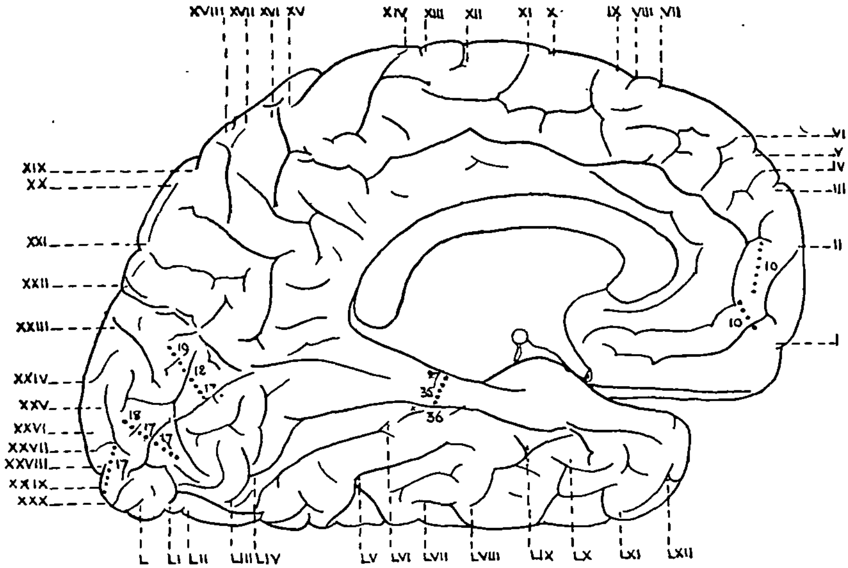

FIG. 8.

looked for during the examination of the sections. Allusion will be made to these in the course of the description which will be given under the following headings:—

(1) Types of cortex and their distribution.
(2) Structure of the cortex.
(3) Pathological changes.
  (*a*) The meninges.
  (*b*) The nerve-cells.
  (*c*) Gliosis and atrophy.
  (*d*) The blood-vessels—(i) structural alteration; (ii) perivascular and pericellular elements; (iii) congestion; (iv) intra- and extra-vascular clotting.

(1) *Types of Cortex and their Distribution.*

The different types of cortex found in all the regions from which blocks were cut are readily recognizable as usual to those regions, and in harmony with Brodmann's map of the distribution of the cortical fields of the human cerebral hemisphere, so that it may be said that the distribution of the different types of cortex in this specimen is normal, in at least so far as the hemispheres have been examined.

(2) *Structure of the Cortex.*

As regards its structure, the cortex of all the areas examined appears to be almost, if not quite, normal. The several laminæ of the cortex, so far as can be judged without micrometric measurement, are of good depth, and the individual nerve-cells are for the most part well formed. No cells were found in any region which could with certainty be described as under-developed, cells such as are commonly seen in cases of idiocy and imbecility. In the inferior parietal and middle temporal regions, however, the majority of the cells, particularly the smaller and medium-sized ones of the pyramidal layer, and many of those of the polymorphic layer, are somewhat globular or flask-shaped. As, however, degenerative change in the nerve-cells of those regions is considerable, it is impossible to state confidently that the shape of the cells, as above described, is due to congenital defect, and not to pathological alteration. At the same time it may be mentioned that, in our experience, under-developed cells are not infrequently met with in the brains of the insane in the inferior parietal and middle temporal regions, particularly in the latter.

The persistence of nerve-cells in the molecular layer, as seen by the ordinary staining methods and the presence of subcortical nerve-cells, are conditions usually regarded as stigmata of defective nervous development. In this case the only situation in which definite nerve-cells can be recognized in the molecular layer—and they are few in number—is the *para-insular* region, and the only one in which subcortical nerve-cells are present in any considerable quantity is in the anterior part of the *area frontalis granularis.*

The nerve-fibres, even by such an imperfect method for their display as that of the iron-hæmatoxylin method of Heidenhain, are seen in abundance, and, excepting where associated with areas of local atrophy, they have an apparently normal appearance. In particular, it may be stated that the tangential fibres of the molecular layer exist in great numbers, especially in those regions such as the central gyri and parts of the occipital lobe where normally their presence is readily demonstrable.

(3) *Pathological Changes.*

(*a*) *The meninges.*—Owing to the membranes having been stripped before the blocks were removed, only small portions of these can be seen along the sulci in some of the sections. When present, the meninges show considerable congestion, some fibroid thickening, and small-cell infiltration, but no hæmorrhages. A small amount of amorphous epicerebral exudate was found below the pia in one section from the left occipital region.

(*b*) *The nerve-cells.*—The nerve-cells show more or less marked degenerative changes, chiefly of a chronic nature, in the majority of the regions examined. With the exception of the Betz-cells of the precentral gyrus and the cells of the cornu ammonis, to which special reference will be made later, the cells most affected are the smaller, and to a less extent the medium-sized cells of the pyramidal lamina, although in places many of the cells of the polymorphic lamina are swollen and vacuolated. Nowhere, however, is any great loss of cells apparent excepting in a focus of atrophy in the post-central gyrus. The changes just mentioned, although not anywhere very marked, are most prominent in the following regions: the mid-frontal gyrus (*area frontalis granularis*); the inferior frontal (*area opercularis*); the middle and inferior temporal areas. They are next most marked in the prefrontal region (*area fronto-polaris*); the inferior frontal (*area triangularis*), and remainder of the frontal lobe examined including the precentral gyrus, and in the inferior parietal area. They are least evident in the various parts of the occipital lobe, in the post-central gyrus, in the gyrus of Heschl and superior temporal area, and in the para-insular and ectorhinal areas; in fact, the nerve-cells in many sections from the several last-named regions may be described as almost normal in appearance. It is of importance to note that in all parts where the nerve-cell changes are most marked, these changes are generalized rather than focal in nature, excepting in the area of atrophy of the post-central gyrus, to which allusion has been made. In certain parts where spaces exist between the nerve-cells, which might possibly be mistaken for areas of loss of nerve-cells, such spaces are normal to the type of cortex found in this particular region.

The Betz-cells.—These in all parts of the precentral gyrus examined are affected, and more so than the cells of the other laminæ of this region. Few, if any, of the hundreds of cells examined can be said to be normal; all show, at least, some chromatolysis, and great numbers of them have reached an advanced stage of degeneration. Many of the cells are swollen, whilst others are shrunken and are deficient in processes. Some cells stain deeply and diffusely, so that no definite chromophile elements can be distinguished. In the majority of the cells, however, the stainable substance is very deficient; the chromatolysis is sometimes diffuse or central, but in most cells it is of the axonal type. The nucleus of the cell is in some instances swollen, but more often it is shrunken; frequently it is displaced, and in many cells partially extruded. In view of the fact that the patient suffered from epilepsy, it is of interest to specially note that the affection of the Betz-cells is much greater than is that of the homonymous solitary cells of Meynert, in other regions which are for the most part practically normal in appearance.

(*c*) *Gliosis and atrophy.*—Sclerosis of the outer layer of the cortex is regarded by Bleuler [2] as characteristic of epilepsy, and in fact as an essential factor in the pathology of the disease. In this case a small amount of subpial neuroglial felting, forming a thin surface rim, is present in all the regions of the cortex examined, being most evident in the cornu ammonis and neighbouring subicular region, in the gyrus of Heschl, and in the para-insular region. In some parts also a few—usually a very few—proliferating glia-cells can be seen in the zonal layer. At no other level of the cortex, and in no part of the white matter in any region of the neopallium examined is there any definite proliferation of neuroglia, unless the moderate increase of the elements described below as "perivascular" and "pericellular" can be so regarded.

Turner [21] states that in none of his cases of epilepsy was the glial increase considerable—not indeed greater than is usual in cases of chronic insanity—and, if the cornu ammonis and gyrus dentatus be excluded, the same may be said with regard to this specimen.

The cornu ammonis.—Sclerosis of the cornu ammonis is regarded by many as highly characteristic of epilepsy (Worcester [24], Turner [21]). Turner found this condition in 48 per cent. of his cases, and he states that the microscropical appearances are chiefly of a negative character. "There is no increase of glia, the nerve-cells are few in number, and those present are generally degenerated, the vessels lie in wide lymph spaces and are collapsed and atrophied, or may have undergone hyaline degeneration. Small hæmorrhages are generally found in the cortex."

In this case the cornu ammonis appeared to the naked eye to be normal in both hemispheres. Only that of the left side was examined microscopically, and in this a very definite lesion was found, which, however, differed in appearance from that described by Turner [21]. In the cornu ammonis, gyrus dentatus, and to a less extent in the subiculum, there is below the condensed surface rim of glia already alluded to a marked generalized proliferation of glia near the surface and extending to a considerable depth, but there are no surface granulations. In addition to this, but separated from the more superficially proliferating glia is a deeper and extensive area of gliosis involving the greater part of the cornu ammonis and gyrus dentatus. In this area glia-cells are seen in all stages of formation. Most of them are giant cells, some with a large amount of lightly staining cytoplasm and with processes in various stages of condensation, others with a little darkly staining cytoplasm and numerous darkly staining processes. The glia-cells are massed chiefly around the blood-vessels and many processes are seen passing from them to the latter. The area appears to have started from several distinct foci. The nerve-cells of the stratum granulosum and stratum pyramidalium are in abundance, and although many of these are degenerated, they do not appear to have suffered any actual loss. The blood-vessels are not collapsed but well fill the lymph spaces, which are nowhere dilated. The vessel walls show only a moderate amount of hyaline degeneration and thickening. There is much congestion of the vessels, but there are no signs of intravascular clotting and no hæmorrhages. The condition is a definite gliosis, possibly following minute softenings, but of the latter there is no present evidence.

Several small areas of atrophy with little or no active gliosis are present. The largest of these is in the post-central gyrus near the top. It is an irregular wedge-shaped area involving all the laminæ of the cortex down to and including the granule layer. The atrophic patch contains a few scattered and stunted nerve-cells, and the lamination on either side of it is much disturbed, but there is little glial or vascular proliferation. Another area of atrophy was found in the precentral gyrus near the top. This is situated in the white matter and shows spaces crossed by swollen and varicose nerve-fibres. Other small areas of apparent atrophy without gliosis are seen in the white matter of the post-central gyrus, mid-temporal and prefrontal regions, but most of these are so minute that the possibility of their being artefacts cannot be altogether excluded.

(*d*) *The blood vessels.*—(i) *Structural alteration.*—There are no signs of endarteritis and the capillaries are practically normal. The only distinct change is some thickening and hyaline degeneration of the (microscopically) larger vessels. This varies considerably in different regions; it is usually slight and nowhere very marked. The vessels of the inferior parietal region are more affected than those elsewhere, not even excepting the cornu ammonis, and those of the right prefrontal region are rather more involved than those of the left.

(ii) *Perivascular and pericellular elements.*—The small perivascular elements are in general moderately increased in number. They adhere to the distal wall of the lymph spaces and are of various forms and staining reaction. Some appear to be lymphocytes and others, showing traces of cytoplasm, are probably neuroglia-cells, and possibly, as Turner [21] believes, mesoglia-cells of Ford Robertson. These elements are most numerous about the medium-sized vessels of the white matter and least prominent about the capillaries. There are no plasma-cells. The pericellular elements appear to be of a nature similar to the perivascular, and whilst nowhere very numerous, are most conspicuous in those regions showing the greatest amount of degeneration of the nerve-cells.

(iii) *Congestion.*—The veins and capillaries are intensely congested in most of the regions examined, but least so in the occipital region. The capillaries, owing to their engorgement, seem more numerous than normal. The distended veins, for the most part, completely fill the lymph spaces, but no varicosity was noticed. One or two minute capillary hæmorrhages were found in one block from the precentral gyrus.

(iv) *Intravascular and extravascular clots.*—In view of the important rôle which Turner [21] believes these clots to play in the causation of epilepsy, they were looked for with special care. Turner's thesis is that "epilepsy is a disease occurring in persons with a defect of the nervous system, either congenital or involutional, in whom also there is an abnormal state of the blood, characterized by a special tendency to clotting; and that the fits . . . owe their exciting cause to sudden stasis of the blood-stream in some (generally limited) portion of the cortex, resulting from the blocking of cerebral cortical vessels by these aforementioned intravascular clots."

Clots having features similar to those described by Turner as occurring with such frequency in epilepsy, and which he believes to be the result of a vital process, were found in some vessels in many of the regions examined. No fibrin formation was seen in any of the vessels, the clots taking the form either of minute round deeply staining granules or of larger, more or less spherical, hyaline bodies, or again of a finely granular fainter staining débris, sometimes immediately outside the vessels. The thrombosis, however, as seen by the staining methods used, was not anywhere very marked. In a given section from many of the regions perhaps only one or two vessels showed any evidence of intra- or extra-vascular clotting, and often this was slight. No thrombi at all were seen in or around the vessels in sections from the following regions; three out of five blocks from the left prefrontal region, the block from the anterior part of the area frontalis granularis, that from the upper part of the post-central region and all the blocks, excepting one, from the occipital and pre-occipital regions of both hemispheres. The clotting is slight but distinctly evident in all sections from the parietal and temporal regions excepting the middle temporal, where it is a fairly prominent feature. The vessels showing the greatest amount of clotting are, on the whole, those of the precentral gyrus, but even here much variability exists in different parts. The thrombi are more numerous in the vessels of the white matter than in those of the grey. On reference to the account of the regional distribution of the nerve-cell degeneration (see pp. 66, 67), it will be observed that there is no constant relationship between the severity of such degeneration and the amount of intravascular clotting as seen in the sections.

Summary of the Microscopical Appearances and Remarks.

(1) The presence of a considerable number of subcortical nerve-cells in the anterior part of the area frontalis granularis, and of a few nerve-cells (seen by ordinary staining methods) in the zonal layer of the para-insular region, together with the somewhat more doubtful existence

of under-developed nerve-cells in the inferior parietal and mid-temporal regions, are the only evidences found of defective nervous development.

(2) Otherwise the cerebral hemispheres, so far as examined, appear in every way to be normally constituted, and their great size and weight cannot be accounted for by the very slight increase in neuroglia and thickening of the vessels which existed.

(3) Certain abnormalities were found, however, which are obviously the result of pathological change.

(*a*) The lesion of the Betz-cells is remarkable in that almost all the cells examined are more or less profoundly affected, in great contrast to the condition of the great majority of the homonymous solitary cells of Meynert in other regions. The presence of an immature form of Betz-cell, characterized by its similarity to that seen in an early stage of axonal degeneration, is regarded by Turner [21] as an expression of congenital defect of the nervous system, which is of primary importance in the etiology of epilepsy. In our experience Betz-cells, either of an axonal type or otherwise congenitally defective, are almost constantly found in the precentral gyrus of idiots and low grade imbeciles, whether the patients have suffered from epilepsy or not. But it may well be that in this case, and probably in other cases of epilepsy occurring in subjects whose brains are apparently not at all, or only slightly, congenitally defective, the appearances seen in the Betz-cells are of a degenerative nature, the result of prolonged exhaustion occasioned by the epileptic discharges. One of us at least (J. W.) inclines to the view that the *fons et origo* of epilepsy must be sought for in the instability, and consequent loss of control, on the part of the higher motor nervous arrangements rather than in the congenital defect of the Betz-cells themselves.

(*b*) Other morbid changes, particularly in certain areas, and affecting especially the smaller and medium-sized cells of the pyramidal layer, are present, but these appear, for the most part, to be the expression of a generalized degeneration process rather than focal lesions due to local vascular occlusion. A certain number of limited areas of atrophy, however, do exist—one in the grey matter of the post-central gyrus and others in the white matter of various parts—but these, although of interest as local changes, are not numerous, considering the number of sections examined, and as compared with their frequency in the cases of epilepsy described by Turner [21].

(*c*) Apart from the area of pronounced gliosis found in the cornu ammonis the amount of glia proliferation is not greater than that commonly seen in cases of chronic insanity.

(*d*) Evidences of intravascular and extravascular clotting exist in many of the regions examined, but no definite correlation between the extent of this and the amount of neuronic degeneration could be determined.

PART III.—GENERAL REMARKS AND CONCLUSIONS.

The pathology of hypertrophy of the brain appears to be very imperfectly understood, and there seems to be little object in discussing the matter fully here, as in this case nothing has been found which throws light on the subject.

Cases of so-called cerebral hyperplasia may be divided into at least two distinct classes, unilateral or localised and general.

Apparently four cases of hyperplasia of one cerebral hemisphere have been recorded, notably one by Douglas Webster [23], who gives an account of the literature of the subject generally, and to whose paper we are indebted for some of the following particulars:—

In Webster's case there was also unilateral hypertrophy of the body and an acromegalic condition of the feet. Numerous glia-cells were found in the left insular region of the brain, one of the specially hypertrophied parts, and the left cerebral hemisphere was as a whole more richly vascularised than the right.

In a case reported by J. Batty Tuke [20] there was co-existent atrophy of the left side of the body and considerable glial increase especially in the left occipital lobe of the brain.

Our case falls into a different category and appears more closely to resemble an instance of general hypertrophy of the brain, recorded by Anton [1], in which few or no pathological changes were found apart from those usually associated with epilepsy.

Various conditions have been assigned a causal relation to the cases of cerebral hyperplasia reported. Amongst these the following appear to be the most important, although trauma, lead-poisoning, enteric fever and rickets have also been discussed.

Heredity, as in van Walsem's [22] case of an epileptic idiot, aged 21, who had two macrocephalic brothers.

Hydrocephalus: an acute hydrocephalus is suggested as a possible cause of the hypertrophy in Tuke's case.

Disturbances of internal secretion: Anton [1] discusses the relationship of the adrenals to cerebral malformation, but these organs, examined microscopically in Webster's case, appeared to be normal, as also was the hypophysis cerebri, except for some increase of the chromophile cells.

Hyperæmia: Webster [23] suggests as a more probable cause in his case vasomotor disturbance of one side of the body, particularly of the internal carotid artery and its branches.

Cases of very pronounced macrocephaly are of such comparative rarity that we think the record of our case may prove of interest even though the origin of the matter still remains obscure. None of the conditions which have assigned a causal relationship in this connection appear to have been present. The internal secretory glands were unfortunately not preserved for microscopical examination, but to the naked eye these all seemed to be quite normal.

The brain, although one of the heaviest on record, is, as will have been gathered from the detailed description, for the most part normal in appearance differing from the average brain mainly in its increased size and complexity of pattern. The microscopical changes found also do not at all necessarily bear upon the question of cerebral hypertrophy, being merely those usually present in the brains of chronic epileptics. On one point, however, the microscopical examination gave definite, although negative, results. There is no general hyperplasia of the neuroglia such as has been considered to form the basis of the cerebral hypertrophy in some cases.

Although there are some indications in places of defective development of the sulci and of reverting tendencies, these are not numerous, nor are they pronounced, probably not more so than are such indications in the majority of human brains, even in those which may be described as generally well developed.

There are, however, in the cerebral hemispheres many signs—apart from their large size—of a formative activity much greater than that usually seen. But we think that this increased developmental activity has proceeded, for the most part, on regular lines, and that on the whole the departures from the ordinary in the convolutional pattern of the brain are in the direction of superiority. On the other hand, the tendency to insulation of areas of cortex, and the marked spurring and forking of certain sulci, such as is seen particularly in the left temporal region, may probably be looked upon as indications of formative activity on irregular or aberrant lines. With this greatly increased developmental activity, whether in the direction of superiority or of aberrancy, it seems likely that there would be a tendency to instability.

It is of interest to note, in this connection, that unlike many other recorded cases of this class, the patient was neither idiotic nor imbecile, but was originally of at least average general intelligence, with special ability in music. Epilepsy, as in this instance, is a frequent complication of these cases, and this suggests the idea that even when the minute structure of the brain appears to be normally constituted—which it by no means always is in such cases—the usual size of the brain, apart from its increased complexity of pattern, cannot be largely exceeded without introducing a condition of instability which renders its possessor liable to suffer from some form of nervous breakdown, and especially from epilepsy.

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