JOURNAL OF ANATOMY AND PHYSIOLOGY

A NEW TOPOGRAPHICAL SURVEY OF THE HUMAN CEREBRAL CORTEX, BEING AN ACCOUNT OF THE DISTRIBUTION OF THE ANATOMICALLY DISTINCT CORTICAL AREAS AND THEIR RELATIONSHIP TO THE CEREBRAL SULCI.

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IN the last number of this Journal I called attention to the fact that by means of the naked-eye examination of sections of the fresh brain it is possible to recognise the differences in thickness and texture of various cortical areas, and so to map out the exact extent of each of the regions. In that communication I illustrated the method in its application to the visual areas of the cortex, which comprise the greater part of the so-called occipital "lobe" of the hemisphere. In the present memoir I propose to extend this survey to the whole of the surface of the cerebrum, and to present maps of the whole cortex, which I believe to be more complete and at the same time more exact than those obtained by the application of other more laborious methods. Nevertheless, the diagrams presented here are merely preliminary attempts at an adequate charting of the surface of the brain: in a series of further contributions to the consideration of this subject I propose to take up one by one each region of the cortex and discuss in much greater detail than the present sketch pretends to give the exact topography of each area and the wide range of variability and relationship to sulci which is found in every part of the human neopallium.

In my earlier communication I have insisted on the fact that in the process of folding of such a plastic material as cerebral cortex we find that as a rule sulci do not develop with mathematical precision at the exact boundary lines of adjoining areas or in the precise axis of any given territory. But while fully realising the accuracy of Professor Sherrington's observation that they "are not reliable as landmarks," we cannot be blind to the fact that each one of the vast majority of the furrows on the surface of the hemisphere presents a definite causal relationship to some given cortical area (or areas). This relationship can only be properly appreciated when a large number of specimens have been studied, because the edge of a cortical area may extend beyond or may not reach as far as the floor of a sulcus, which the examination of a large series shows to be causally related to it, or, in fact, its real limiting sulcus; and in many cases it happens that by mere chance the edge of an area may coincide with a furrow, which might thus come to be regarded as its morphological boundary if a more extensive study had not revealed the fact that the relationship was merely fortuitous. It will be understood from these preliminary remarks that the accompanying diagrams are intended to embody the results of the examination of a very large series of specimens, and that in no single example is the exact condition represented in these schemata likely to be realised in every particular.

A vast amount of work has been devoted to the elucidation of the localisation of the cerebral cortex, but so far as I am aware, only two writers have ever attempted to present *complete* charts of the distribution of the various areas in the human brain.

As the result of a long series of investigations into the chronological order of the process of medullation of the various districts of the cortex and its subjacent white substance, Professor Flechsig has been able to construct complete maps of the surface of the human brain (1, 2, and 3). A series of these diagrams will be found in his work, *Einige Bemerkungen über die Untersuchungsmethoden der Grosshirnrinde, insbesondere des Menschen* (3).

Another pair of most instructive maps compiled by Flechsig (2) are to be found in the sixth edition of Halliburton's *Handbook of Physiology* (1904, p. 696); the originals of these are not available to me at present (2).

Dr Alfred Campbell has recently published maps of the human cerebral cortex based on histological studies (4).

Many other investigators, such as Bolton, Vogt, and Brodmann, have recently studied the histological localisation of certain parts of the cortex cerebri of man and other mammals (see especially 5).

At the outset it is advisable to make it perfectly clear that no claim is made for this method other than that of enabling us to map out such areas as present contrasts in thickness, texture, and colouration to the naked eye. It is not pretended or in any way assumed that such contrasts in appearance necessarily imply physiological differences or even essential distinctions in histological constitution. Moreover, I am not unmindful of the fact that in basing this gross means of localisation on (essentially) one factor in the constitution of the cortex, *i.e.* the arrangement of the intracortical medullary matter, we are apt to overlook real differences and be deceived by spurious resemblances. Nevertheless the fact remains that there are obvious macroscopic distinctive features of the various cortical areas: these I have attempted to map out. The fact that most of these areas have precise relations to various stable sulci, and that their distribution agrees so nearly with those mapped out by Flechsig, using another method, seem to point to the condition that we are dealing with truly localised cortical areas which expand at unequal rates in the course of their development, and are, therefore, presumably of different function.

And when I add that by the grosser method it is possible to do the

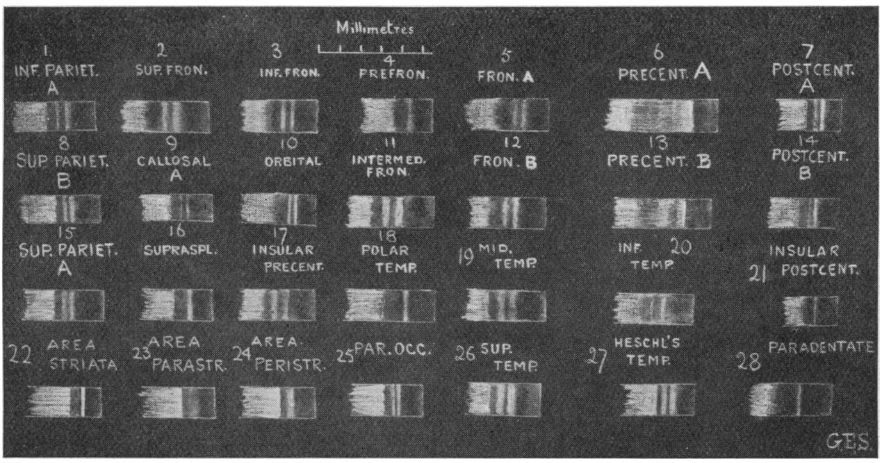

Fig. 1.

mere mapping out of a hemisphere in one hour, which would take an immeasurably longer time to do by either of the other methods, we can appreciate how useful this method becomes when it is necessary to examine large series of specimens to determine the relationships of sulci and localised areas. I have insisted on the relationship to the furrows so constantly because this research was begun with the intention of studying the meaning and origin of sulci; but in the course of the work the more striking results bearing on the localisation of the cortex have relegated the problem of explaining the sulci to a secondary place.

The Neopallial Areas and Sulci.

If a fresh cerebral hemisphere be taken and incisions be made in every part of it by means of a scalpel, more than thirty different types of cortex can be distinguished by the naked eye in the neopallium in addition to the various parts of the rhinencephalon. Twenty-eight of these types of cortex are represented in a semi-diagrammatic form in the accompanying figure (fig. 1), which is a photograph of a series of drawings made on a blackboard from a fresh brain—in all cases the surface is on the right side and the medullary matter on the left: every slice was accurately drawn to scale, and the attempt was made to represent the features of each region without any pronounced exaggeration. In the photograph the features have become intensified, so that the drawing seems more diagrammatic than the original chalk sketches were intended to be. This exaggeration is useful if it serves to fix the reader's attention on those delicate intracortical bands which anyone can see for himself in a fresh brain once he has been reminded of their existence and their general characters. The most distinct of all these bands is, of course, the stria Gennari found in the visual cortex (fig. 1, No. 22); but the others can be recognised with more or less ease after a little experience. Perhaps the greatest contrast is found in the upper part of the sulcus centralis, the anterior wall of which consists of the thickest cortex (almost 4 mm.) with a maximum amount of white matter widely diffused (fig. 1, No. 6), whereas its posterior wall is composed of one of the thinnest cortical areas (often only 1·5 mm. thick) with a pair of narrow, compact, white bands (fig. 1, No. 7).

There is a very widespread belief that the characters of one area merge gradually and imperceptibly into those of the neighbouring areas, but this is entirely mistaken. The changes in structure occur with the utmost abruptness, so that it is possible to determine with absolute precision the exact boundaries of each area. If the reader needs convincing of the accuracy of this statement let him cut a fresh brain at right angles to the calcarine, intraparietal (any part), central, inferior frontal, or parallel sulci, and he will find all the confirmation that is necessary. The very greatest variations in the distinctness of the intracortical bands will be found in different specimens. Many factors determine this variability—age, race, cause of death, the time that has elapsed after death, and other as yet unknown reasons. The bands are not all present in the form represented in the diagram (fig. 1), excepting in adults. In a new-born child all the cortical areas are uniformly grey and translucent, but a milky whiteness is visible in the subcortical matter around the central, calcarine, and superior temporal sulci. But it is not until long afterward that the intracortical medullary bands become recognisable to the naked eye in fresh, unstained sections. In a child of eight *years* the picture of the cortex obtained by the macroscopic examination of the fresh brain corresponds to that obtained by Flechsig in stained sections of the brain a month after birth. By twelve years of age all of the areas contain intracortical bands visible to the unaided eye; but many of these bands are (relatively to the rest) much fainter than they are in the adult, and all of them are less dense. As age advances the bands become denser and more pronounced, as we should expect from the results of Kaes' researches. So far as the mere chronological order of development is concerned—*i.e.* without being able to give the *actual dates* of the appearance of fibres—one can verify Flechsig's results by the examination of sections made with a scalpel in fresh brains of children ranging from the time of birth up to twelve years of age. This method has been of great service during the course of this investigation in enabling me to distinguish adjoining areas of similar appearance in the adult brain. But for the main purposes of this research I have employed the brains of adults of more than twenty years of age.

As a general rule I have found the brains of negroes more useful than those of other races. The cortex of the negro is often distinctly brown, and this enhances the contrast to the white bands.

Various pathological conditions, both general and local, profoundly affect the distinctness of the features of the cortex. Profound anæmia, such as occurs in ankylostomiasis, so blanches the grey matter that it is often quite impossible to see any band except the line of Gennari.

Within two or three hours after death the cortex has quite a translucent appearance, and the white bands stand out with extraordinary prominence. As the body cools the grey matter becomes cloudy and the bands more and more blurred and ill-defined.

The intracortical bands are usually quite distinct in specimens which have been fixed *in situ* by intravascular injections of formalin. In the course of this investigation such material obtained from the dissecting-rooms has been of the utmost value, because hardened specimens are so much easier to deal with and to make photographs and drawings from than fresh specimens are. Brains fixed and preserved in a bath of formalin are not nearly so satisfactory as those obtained from bodies treated by intravascular injection: in the former the cortex becomes "cloudy," whereas in the latter it retains more of the translucency of fresh material. In many specimens that have been kept in Müller's fluid, even for long periods, the bands are quite distinct. And in sections (cut by a microtome) of material fixed in almost any manner, when examined either in water or Farrant's solution, the cortical lamination is quite obvious, and, as a rule, the contrasts are greater and more striking than in sections stained by any method. Apart from the visual area (which was examined in more than a thousand hemispheres), this work is based upon the study of more than two hundred adult hemispheres.

This account is nothing more than a mere preliminary sketch to give some idea of the results to be obtained by the simple means of naked-eye examination of material cut with a scalpel. No attempt has been made in this communication to collate these results systematically and completely with those obtained by other methods of research.

This can only be done with any satisfaction when results obtained by both methods have been much more fully elaborated than is the case at present.

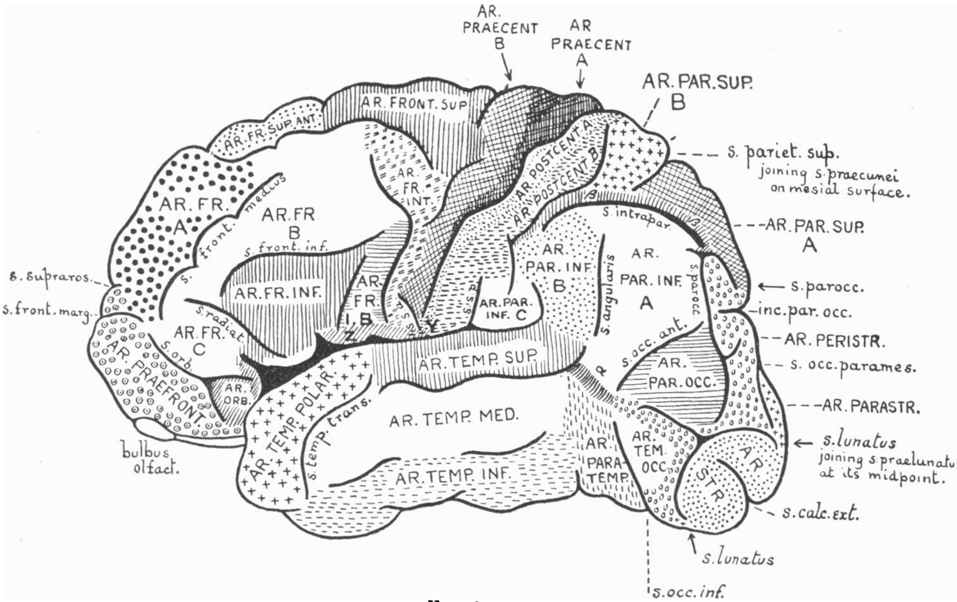

FIG. 2.

The Visuo-Auditory Band.

In my previous communication on the visual area I have described a forwardly projecting tongue of *area peristriata* which becomes folded in its long axis to form the *sulcus prælunatus* (mihi)—a furrow identical with that called *sulcus occipitalis lateralis* by most writers. From the anterior end of this band a narrow strip of cortex (sometimes no more than one centimetre in width) extends forward (fig. 2, a) as far as the upper end of the *sulcus temporalis superior*, in the floor of which it becomes continuous with the *area temporalis superior* (fig. 2, AR. TEMP. SUP.), which is the "audito-psychic area" of Campbell and other writers. This strip a, which I shall call the "visuo-auditory band," serves as a narrow connecting bridge between the *area peristriata*, which is the "visuo-psychic area" of Bolton and others, and the "audito-psychic area," so that it links together the outlying parts of those regions of the cortex which are given up to the functions of sight and hearing. This attenuated band is all that is left of the extensive bond of union between these two areas which in the lowlier mammals have co-extensive borders: in man and to a less extent in the apes the great development of the inferior parietal area (fig. 2, AR. PAR. INF.) above it and the temporal areas (fig. 2, AR. TEMP. MED.) below it have pushed these two parts asunder, leaving this narrow connecting bridge. In support of this hypothesis of the primitive nature of the band *a* I might call attention to the fact (which Flechsig has clearly established [*3*, Taf. II., fig. 4]) of its early medullation. In appearance the cortex of the visuo-auditory band closely resembles that of the *area peristriata* (fig. 1, No. 24) from which it is often quite indistinguishable. In other cases an indistinct doubling of the line of Baillarger occurs, so that it resembles the *area parieto-occipitalis* (fig. 2, AR. PAR. OCC., and fig. 1, No. 25).

It very frequently happens that the visuo-auditory band becomes folded in its long axis to form a horizontal sulcus which may join the *sulcus occipitalis lateralis.* Although this furrow is much more often present than absent, it has not yet received a distinguishing name, so far as I am aware. It occupies a position (fig. 2, *a*) which is seen to be the natural boundary line between the parietal and temporal areas: hence it might appropriately be called the "*sulcus temporo-parietalis.*"

The whole of the area between the *sulcus occipitalis lateralis* (*i.e. prælunatus*) and the *sulcus occipitalis inferior* is often occupied by a cortical area indistinguishable from and continuous with the *area peristriata*; but part of this region (marked "AR. TEM. OCC." in fig. 2) occasionally exhibits a faint doubling of the line of Baillarger, which calls for its separation from that area. I have called it the "*area temporo-occipitalis.*" In position and structure it is in many respects analogous to the *area parieto-occipitalis* (fig. 2, AR. PAR. OCC., and fig. 1, No. 25). The latter area is bounded in front by the *sulcus occipitalis anterior* (fig. 2, *s. occ. ant.*) and above (or behind) by the *sulcus paroccipitalis* (fig. 2, *s. parocc.*), which is the *ramus occipitalis* of the *sulcus intraparietalis.*

It often happens (especially in the brains of lowly human races, such as negroes and aboriginal Australians, and in the anthropoid apes) that the *sulcus occipitalis anterior*, together with the *sulcus occipitalis inferior*,[1]

[1] Most writers who have within recent years described the brain in the higher apes have confused the *sulcus occipitalis inferior* with the *sulcus occipitalis lateralis* (*prælunatus*). As the latter is usually absent in the apes, the suggestion implied in this mistaken application of terms is insidiously misleading.

form a large arc (parallel to the *sulcus lunatus*), forming the anterior limit of a great tongue of cortex, the tip of which often touches the upper end of the *sulcus temporalis superior* in those cases where there is no *sulcus temporo-parietalis*.

The presence of this great arcuate sulcus explains much of the misleading literature relating to the search for an "Affenspalte" in the human brain.

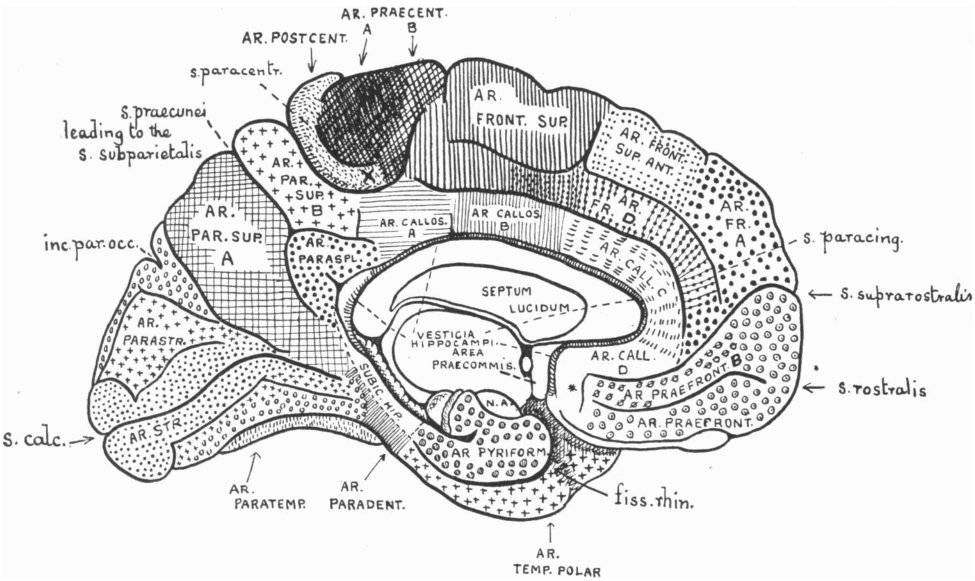

FIG. 3.

The Parietal Areas.

The *sulcus intraparietalis* of Turner (*interparietalis* BNA) consists of three morphologically and genetically distinct parts:—postcentral, intraparietal, and paroccipital respectively.

For the purposes of the present memoir the intermediate portion may be called simply "intraparietal," seeing that it is placed within and separates the two parietal lobules one from the other. It is phylogenetically one of the most ancient sulci in the brain, being undoubtedly the representative of the *sulcus lateralis* of other mammals.

The superior parietal lobule is composed of thinner cortex (2·5 mm.) than the main portion of the inferior parietal lobule (3·0 mm.). Both contain distinct double lines of Baillarger (fig. 1, Nos. 1, 8, and 15), but those in the superior lobule are denser and closer together than those of the inferior lobule.

The superior parietal lobule is crossed transversely by the *sulcus parietalis superior* on the dorsal surface and the *sulcus præcunei* on its mesial surface, the two furrows being often confluent. In most specimens I have found it quite impossible to distinguish the cortex of the area in front of these furrows (figs. 2 and 3, AR. PAR. SUP. B) from that placed behind them (AR. PAR. SUP. A): but it often happens that there is a distinct difference in the texture of the two parts (compare Nos. 8 and 15, fig. 1), the lines of Baillarger being somewhat narrower and denser in the *area parietalis superior anterior* (B) than in the *area parietalis superior posterior* (A). I am confirmed in drawing this distinction by the results of my examination of the brains of children, and by the definite evidence of the same nature which Flechsig has brought forward (*3*, Tafel II., figs. 3 and 4) by demonstrating that the anterior (B) district (his 16) becomes medullated some time earlier than the posterior (A) district (his 21).

There is another feature of this region brought to light by Flechsig which can be most clearly confirmed by the macroscopic examination of fresh sections of the adult brain. If a cut be made into the parietal region at right angles to the intraparietal sulcus, the lines of Baillarger in the superior parietal lobule will be found to become suddenly intensified (*i.e.* become denser and whiter) about 2 or 3 mm. from the upper lip of the sulcus, and this intensification is continued exactly to the bottom of the furrow. Flechsig has shown that this patch becomes medullated much earlier than the rest of the parietal region (*3*, Tafel II., fig. 3, No. 13). He has not shown that this band containing the intensified lines of Baillarger can be traced backward into continuity with the visual area in the floor of the *sulcus paroccipitalis* and forward into continuity with the *area postcentralis* (fig. 2, $\beta\beta$), that, in fact, it is a "*visuo-sensory band*" exactly analogous to the "*visuo-auditory band*" (a) of which I have spoken in the preceding pages. It is the attenuated fragment of that extensive connection between the visual and sensory areas of the brain which has remained after these areas have been pushed apart by the great expansion of the parietal areas.

In the great majority of cases I have found the large and important inferior parietal lobule composed of a cortex of uniform characters, if we exclude the small antero-inferior corner (fig. 2, AR. PAR. INF. C) which perhaps ought not to be considered as a part of the lobule. The rest of the lobule is almost invariably subdivided into two parts by the *sulcus angularis* (which many writers call *ramus ascendens sulc. temp. superioris*), and in many cases the lines of Baillarger are more distinct in the area behind this furrow (fig. 2, AR. PAR. INF. A) than they are in front (AR. PAR. INF. B).

The area that lies immediately above the posterior end of the fissure of Sylvius, between the upturned end of the latter and the *sulcus subcentralis posterior* (fig. 2, *s.s.p.*), presents the same general features as the rest of the parietal region, but it (fig. 2, AR. PAR. INF. C) is thinner and its lines of Baillarger denser than those of the rest of the inferior parietal lobule. As Flechsig has shown, it becomes medullated long before the rest of the inferior parietal lobule. For the sake of conciseness I shall use the name "*area parasylvia*" (in reference to its relation to the tail of the Sylvian fissure) for this area C (AR. PAR. INF. C). The anatomy of the regions around it presents many difficulties, to the consideration of which I shall return after studying the central convolutions.

The Central Convolutions.

Under this title are included the *area præcentralis* (subdivided into two parts, A and B), the *area postcentralis* (also divided into two parts, A and B), the continuation of these into the paracentral lobule and certain modifications of these formations at the two extremities of the convolutions (fig. 2, Y; fig. 3, X).

The structure of the two walls of the *sulcus centralis* forms a most striking contrast (fig. 1, Nos. 6 and 7).

The anterior wall of the sulcus in the upper (mesial) part of its extent is formed of cortex almost 4 mm. thick, which is so very rich in medullary matter that the inner two-thirds of its thickness is often uniformly pallid, and the line of demarcation between it and the white matter of the hemisphere is not so sharply defined as it is in other regions of the cortex (fig. 1, No. 6). The outer edge of the intracortical medullary matter is always denser than the rest, and sometimes two or even three faint bands can be seen in the cortex (fig. 1, No. 6). As the cortex is traced forward out of the sulcus into the exposed surface of the præcentral convolution the diffuse paleness gives place to a definite pair of lines of Baillarger, the inner of which is very broad and diffuse (fig. 1, No. 13). This is the *area præcentralis B.* The distribution of these areas is shown in the diagrams (figs. 2 and 3). As these areas are traced downward (toward the fissure of Sylvius), their outstanding features, as just described (and represented in fig. 1), become less pronounced, and the area A becomes restricted to the wall of the *sulcus centralis*. The naked-eye appearances of the præcentral areas is subject to a wide range of variation.

The *sulcus subcentralis anterior* (fig. 2, *s.s.a.*) is a limiting furrow of the præcentral area. The combined results of experimental, clinical, and histological evidence point to the fact that these præcentral areas represent the "motor area"—the region that is responsive to electrical stimulation.

Like the præcentral area the postcentral is subdivisible into two or even three distinct regions, which in the main occupy respectively the posterior wall of the *sulcus centralis,* the crest of the postcentral convolution, and the anterior wall of the postcentral sulcus. For simplicity I have grouped the latter two in the one *area postcentralis B* in figs. 2 and 3, but the part represented in fig. 1, No. 14, is the type of the anterior wall of the postcentral sulcus.

On the mesial surface these two postcentral areas are prolonged as a crescentic band into the paracentral lobule (fig. 3). This band stops posteriorly exactly in the floor of the upturned end of the sulcus cinguli, and anteriorly in a fairly constant sulcus parallel to the latter, which serves as the line of separation between it and the motor area. This may be termed the "*sulcus paracentralis,*" because it lies within the paracentral lobule. Below the motor area on the mesial surface (at the point marked X in fig. 3) the cortex seems to undergo a slight change in texture, the outer line of Baillarger (of the postcentral B type, fig. 1, No. 14) becoming markedly accentuated. This type of cortex lines the upper lip of the neighbouring part of the sulcus cinguli: exactly at the bottom of this furrow it gives place to another type distinguished by the presence of a pair of faint lines of Baillarger (fig. 1, 9). The distribution of this callosal area is shown in fig. 3 (AR. CALLOS. A).

At the lower end of the central sulcus the distribution of the various areas becomes so confused that it becomes an exceedingly difficult matter to interpret the appearances presented by sections of this region. This is rendered all the more difficult by the fact that the results obtained by the examination of one specimen do not accord with those that may be found in other cases. The *area postcentralis A* seems to be prolonged around the lower end of the *sulcus centralis* (at Y, fig. 2); but as it does so its bands of Baillarger become more attenuated, and this type of cortex (so far as can be judged by the naked eye) fringes the Sylvian fissure as far forward as the point marked Z in fig. 2.

I have already called attention to the presence of a curious cortex which lines the upper wall of the *sulcus intraparietalis* (fig. 2, β): when the latter sulcus approaches the *sulcus postcentralis* this area β occupies the little gyrus in the space between the two furrows (fig. 2); but in those cases in which the two sulci become confluent the visuo-sensory band (β) passes into the anterior wall of the inferior postcentral sulcus, and when it thus becomes brought into juxtaposition to the *area postcentralis B* it becomes difficult in many cases to distinguish these formations the one from the other. So far as I can interpret the appearances seen in my specimens—but I must confess that I make these suggestions with some hesitancy—the *area postcentralis B* is always placed entirely in front of the *sulcus subcentralis posterior* (fig. 2, *s.s.p.*), but the area β (visuo-sensory band) sometimes does not reach as far as this sulcus, at other times attains its anterior wall, in other cases its posterior wall, or even invades the territory of the *area parietalis inferior C* (fig. 2).

A study of the results obtained by other writers does not help us to reach a satisfactory solution of this difficulty. Thus Campbell represents a downward prolongation of the superior parietal lobule passing *in front of* the *sulcus subcentralis posterior* in the human brain (*4*, Plate I.), but in the Chimpanzee's brain the *area postcentralis B* is shown extending back as far as this sulcus. This exactly agrees with the variations that I have found in the human brain.

In many specimens the cortex, that emerges from the lower end of the postcentral sulcus and extends downward to form the anterior lip of the *sulcus subcentralis posterior*, certainly differs in structure from all of the neighbouring areas—the inner line of Baillarger becomes so faint as to be hardly recognisable and the outer line becomes markedly intensified. This is a region in which histological investigation might be used with advantage to clear up the difficulty.

The Frontal Region.

As we pass forward from the thick præcentral cortex with its very diffuse pair of bands of Baillarger (fig. 1, No. 13), we come in succession to a series of areas in which the cortex becomes thinner and its bands more attenuated, until eventually we reach the thin præfrontal cortex (No. 4), in which one can see, as a rule, only one very pale band in an unusually clear and translucent grey substance.

The accurate mapping out of this area presents great difficulties, because the contrasts between adjoining areas are often exceedingly slight and at times quite impossible to detect. The diagrams of this region which I have made for this account (figs. 2 and 3) are, I believe, on the whole accurate representations of the average condition met with in a large series; but certain points may require revision at a later period.

In the area which Campbell (*4*, Plate I.) has allotted to the "intermediate præcentral" formation, there are found various types of cortex ranging from 3 mm. to only 1·75 mm. in thickness, and no less than five distinct localised districts of different structure can be recognised by naked-eye examination. These are the superior frontal (figs. 2 and 3, AR. FRONT. SUP., and fig. 1, No. 2), the intermediate frontal (AR. FR. INT. and No. 11), the posterior inferior frontal (fig. 2, AR. FR. I. B), the inferior frontal (AR. FR. INF. and No. 3), and finally the orbital (AR. ORB. and No. 10). The contrast between the narrow sharply-defined bands of the last three and the broad diffuse bands of the first two areas is obvious at a casual glance. The *area frontalis superior* is distinguished from the *area frontalis intermedia* by the fact that its bands are broader and more diffuse. [This contrast has not been sufficiently clearly depicted in fig. 1, which is, however, an accurate representation of a series of types taken from *one individual specimen*. In most specimens, however, the contrast is most marked.] These two areas are about 3 mm. thick, although the intermediate frontal is often a little thinner.

The inferior frontal area is about 2·25 mm. thick, *i.e.* about three-quarters the breadth of the intermediate and superior frontal areas. It contains much narrower bands of Baillarger, with sharper edges (fig. 1, No. 3), and the whole cortex is clearer and more translucent than the superior frontal. The dorsal boundary of this area is the *sulcus frontalis inferior*, its posterior boundary is the *sulcus diagonalis*, and its anterior boundary the *sulcus radiatus* of Eberstaller, although it must be admitted that its relations to these morphological boundaries is rarely, if ever, preserved with mathematical exactness.

The strip of cortex (fig. 2, AR. FR. I. B), included between the *sulcus diagonalis* and the inferior præcentral sulcus, differs in structure from both neighbouring areas. It is thicker than the inferior frontal area, and its bands of Baillarger are less dense than those of the areas in front and behind it.

The *area orbitalis* (fig. 2, AR. ORB.) is limited in front by the two posterior limbs and the transverse portion of the orbital sulcus, and it extends as far back as the edge of the orbital operculum. At its lateral angle it becomes continuous with the inferior frontal area. It is composed of very thin cortex, often only 1·75 mm. thick, and it is distinguished by the presence of a pair of very narrow dense lines of Baillarger, placed so close together that they often have the appearance of forming one band (fig. 1, No. 10).

Flechsig has shown that it becomes medullated much earlier than most of the other frontal areas.

The *area frontalis superior anterior* is the strip of cortex included between the anterior part of the *sulcus frontalis superior* and the *sulcus cinguli* (figs. 2 and 3). In structure it resembles the *area frontalis* described below, but its bands of Baillarger are more distinct and also more diffuse.

The general features of the frontal area (fig. 1, No. 5) resemble those of the other parts of the frontal region already described, but it is thinner (never more than 2·5 mm.), and its intracortical bands much more slender and less dense than those of the superior and intermediate frontal areas. It is divided into two main parts by the *sulcus frontalis medius* (fig. 2), which, in its typical form, is an obliquely-directed series of loops extending from the neighbouring ends of the *sulcus orbitalis* and the *sulcus fronto-orbitalis* of Wernicke upward toward the anterior end of the *sulcus frontalis superior*. The *area frontalis B*, placed behind the sulcus, is thicker (2·5 mm.) than the *area frontalis A* (2·0 mm.), which lies above and in front of the *sulcus medius*, and its bands are slightly denser and broader than those of the latter.

The *area frontalis C* resembles the area *B*, but in some cases it is thinner.

The anterior part of the *sulcus cinguli* is frequently separated from the rest of the furrow, and in such cases it is often prolonged obliquely upward and forward to form the boundary between the frontal and præfrontal areas (fig. 3, *S. suprarostralis*). That part of the marginal convolution, which is included between this suprarostral sulcus and the paracentral lobule, is often subdivided by a furrow which may be called "paracingular," into two parts (fig. 3, *S. paracing.*). The strip of cortex (AR. FR. D) which is placed between the cingular and paracingular sulci is often indistinguishable in structure from the parts adjoining it on the other side of the paracingular sulcus. However, that part of the gyrus which is placed below the anterior part of the *area frontalis superior* never resembles the latter, but may be considered as part of the *area frontalis superior anterior*; and the more anterior part of the convolution often differs from the *frontal area* in having the outer of its two lines of Baillarger distinctly intensified. The callosal convolution can be divided into a series of areas which are probably in some way influenced by the marginal areas, because they undergo changes similar to the frontal areas above them. The callosal area B (fig. 3) has much more delicate bands than the area A; and in the callosal area C, which surrounds the genu, the lines of Baillarger have become so faint that they are hardly visible at all: in the area D and the region marked with an asterisk (*)—the parolfactory area of His—no structure at all is visible in the cortex to the naked eye.

At the other end (*i.e.* near the splenium) of the callosal convolution there is a small wedge-shaped area (fig. 3, AR. PARASPL.). This *area paraspleniulis* is exactly bounded by the *sulcus subparietalis*, which contains a very dense white band (fig. 1, No. 16).

The antero-inferior part of the frontal region is composed of the præfrontal area—a very thin clear cortex with a very fine single line (on rare occasions doubled) of Baillarger (fig. 1, No. 4). On the mesial surface it is bounded by the suprarostral sulcus, *i.e.* the prolonged form of the anterior segment of the *sulcus cinguli* (fig. 3); and on the outer surface by the *sulcus orbitalis*. Although its upper boundary is always near the *sulcus fronto-marginalis* of Wernicke, it is only very rarely that it exactly

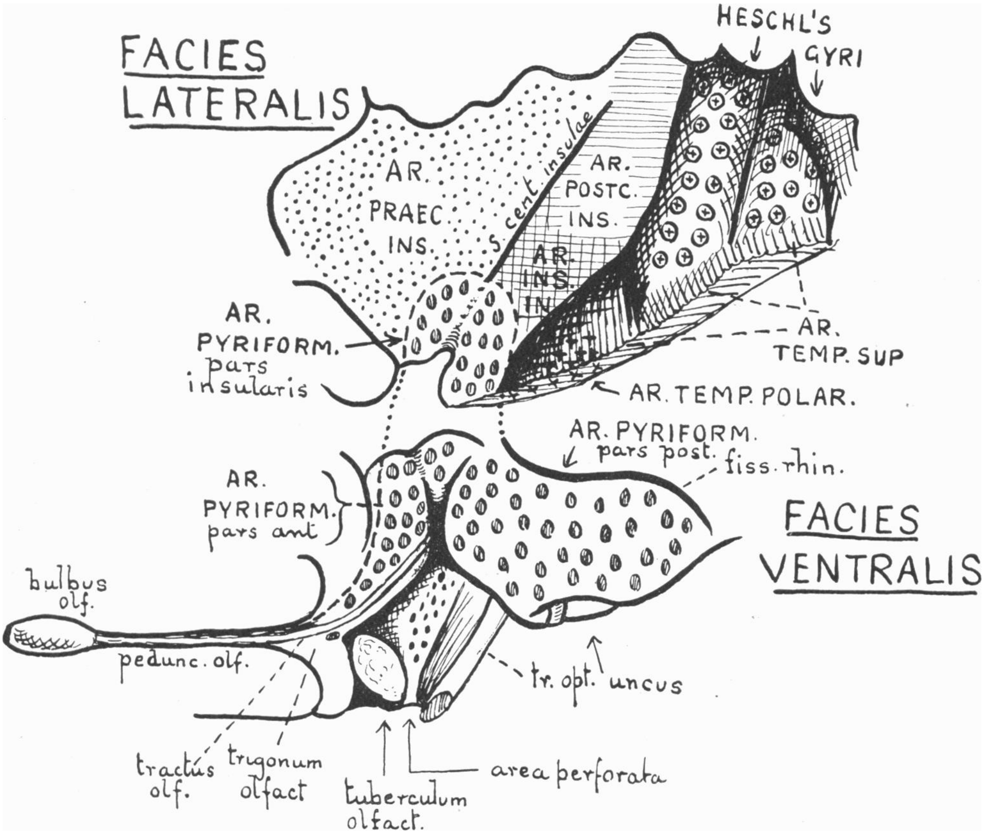

Fig. 4.

coincides with it. In most cases it just crosses this furrow to reach as far as the suprarostral sulcus (fig. 2, *S. supraros.*). The mesial part of the præfrontal area is subdivided by the *sulcus rostralis*, and the strip of cortex (fig. 3, AR. PRÆFRONT. B) which is placed between this furrow and the *sulcus cinguli* (*suprarostralis*) is distinguished from the rest by a pronounced intensification of the line of Baillarger.

That part of the *insula Reilii*, which is placed in front of the *sulcus* *centralis insulæ* (fig. 4, AR. PRÆC. INS.), may be conveniently grouped with the frontal areas, because its appearance (fig. 1, No. 17) closely resembles the *area frontalis*, although its bands of Baillarger are very much more faintly marked. At the *sulcus limitans insulæ* the bands become more pronounced to form the inner lining of the frontal part of the opercula.

The Temporal Areas.

The two transverse gyri of Heschl, entirely buried in the fissure of Sylvius behind the insula (fig. 4), represent a sharply-defined anatomical area of thin cortex (1·75 mm.) occupied by two very dense bands (fig. 1, No. 27). All the available evidence—clinical, physiological, embryological, and anatomical—points to this region as the receptive area for impressions conveyed by the cochlear nerve.

The area surrounding it on the surface of the superior temporal convolution is composed of thicker cortex (fig. 1, No. 26) with less dense bands. Its distribution is shown in fig. 2 (AR. TEMP. SUP.). The area of insula adjoining Heschl's gyri is composed of thin translucent cortex with a single very delicate line (fig. 1, No. 21 ; fig. 4, AR. POSTC. INS.). The insular area below this (fig. 4, AR. INS. IN.) is composed of a thicker cortex, in which it is difficult to recognise any definite distinctive features.

The tip of the temporal lobe—both on its lateral, mesial, and insular aspects—is occupied by an area which I shall call "polar," because it occupies the pole of the temporal region (figs. 2, 3, and 4, AR. TEMP. POLAR.). It is a moderately thick, clear cortex with a single sharply-defined band (fig. 1, No. 18). It is often separated from the rest of the outer surface of the temporal region by a sulcus, which I have called "*temporalis transversus*" (fig. 2, *s. temp. trans.*). This is commonly regarded as part of the *sulcus temporalis superior*.

The rest of the outer surface of the temporal region is composed of an extensive district which in many brains presents a uniform appearance on section. But the upper half (fig. 2, AR. TEMP. MED.) will be found to be thicker (3·0 mm.) than the lower (2·5 mm.), and its bands stand out more clearly because there is less white matter in the surrounding cortex to blur the lines (fig. 1, Nos. 19 and 20).

Interposed between these two temporal convolutions (fig. 2, AR. TEMP. MED. and AR. TEMP. INF.) and the *sulcus occipitalis inferior* there is a narrow strip of thinner cortex with closely placed bands (fig. 2, AR. PARATEMP.). It passes obliquely forward on the tentorial surface (fig. 3).

On the mesial surface, the *area pyriformis* stops sharply opposite the tip of the acorn-like uncus (fig. 3). The strip of cortex (*gyrus paraden-*

tatus),[1] which extends upward from the pyriform area as far as the posterior end of the corpus callosum, is divisible (even on examination of the surface only) into two parts: the anterior strip (fig 3, SUBIC. HIP.), covered with a thick white layer (*substantia reticularis alba Arnoldi*), is a mere appendage of the hippocampus; is, in fact, the *subiculum hippocampi*. The posterior part of the gyrus (fig. 3, AR. PARADENT.), which may be called *area paradentata*, consists of a thin, clear cortex containing a very delicate, sharply-defined line (fig. 1, No. 28). As this formation is traced forward it merges into the *area temporalis polaris*, the cortex becoming thicker and the line denser (fig. 1, No. 18).

THE OLFACTORY PARTS OF THE HEMISPHERE.

Within the last few years so much has been written concerning the morphology of the parts of the cerebral hemisphere concerned with the sense of smell, that I am loath to return to the discussion of this region, which has so often engaged my attention in this Journal and elsewhere; but it seems necessary once more to emphasise some of the salient features of the rhinencephalon of the human brain, which has been so thoroughly and precisely described and so beautifully illustrated in Gustaf Retzius's monographs, because no other writer, so far as I am aware, has correctly identified even such fundamental features as the tuberculum olfactorium or the real boundaries of the pyriform lobe (fig. 4), the former being confused with the trigonum olfactorium and the latter with various adjoining areas. This is very difficult to understand when it is recalled that it is eleven years since Retzius indicated, in a manner that is quite convincing and final, the real nature and position of these parts of the human brain (*Das Menschenhirn*, 1896, Taf. xxxii.); and two years later he clinched the matter by instituting a detailed comparison of this region in the brain of man with that of other mammals ("Zur äusseren Morphologie des Riechhirns der Säugethiere und des Menschen," *Biologische Untersuchungen*, Bd. viii., No. 2, 1898). Perhaps the reason for the failure on the part of most writers to grasp the true state of affairs is to be attributed to the misleading method of describing this part of the brain that was introduced by His and has been perpetuated by the Basel Nomenclature Commission. I refer to the subdivision of the region under consideration into anterior and posterior lobules by means of the morphologically unimportant "fissura prima." It is unnecessary to discuss this matter any further, seeing that I have called attention to the common inaccuracies and the places where the true account of the region can be found. In the accom-

[1] This Journal, vol. xxxvii. p. 325.

panying diagram (fig. 4) I have embodied the facts that I wish to emphasise: the position and relations of the pyriform area, especially in the insula; and the situation of the tuberculum olfactorium. The other features of the rhinencephalon represented in fig. 3 have been so often described in this Journal that there is no need to do more than refer to the diagrams themselves.

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