17. Of the fissura arcuata the hinder part alone is preserved as the fissura hippocampi. The fore part, which is generally supposed to be retained as the callosal fissure, is in reality obliterated.

18. Synchronous with the appearance of the radial transitory fissures on the mesal face of the hemisphere two fissures appear, which lie in series with the former and occupy the ground afterward held by the parieto-occipital and calcarine fissures. These may be termed the precursors of these fissures.

19. The precursor of the parieto-occipital fissure sometimes shows an unbroken continuity of existence with the parieto-occipital fissure of the adult brain. In other cases it is obliterated, and its place is afterward taken by a secondary sulcus, which attains, however, a very great depth.

20. In the adult brain the parieto-occipital fissure, even in its complete form, does not form any eminence on the inner wall of the posterior horn of the ventricle, because it does not extend downward as far as the cavity. Above its lower end the hemisphere is solid.

21. The posterior end of the calcarine precursor is in every case obliterated, and the anterior part retained. The extent of the part obliterated varies considerably in different brains.

22. The anterior preserved portion of the calcarine fissure forms the "stem" of the >— shaped fissural arrangement on this part of the hemisphere, and its hinder part corresponds to the calcar avis.

23. In the place of the hinder portion of the calcarine precursor, which is obliterated, a secondary furrow appears. This may be termed the posterior calcarine sulcus.

24. The posterior calcarine sulcus is formed in two pieces which run together and also form the "stem." In this way the entire length of what in anatomical language is called the calcarine fissure is formed.

25. The posterior calcarine sulcus is not a complete fissure.

26. In the ape the entire length of the calcarine fissure is represented by that portion of the fissure which in man is termed the "stem," and by that alone. The posterior calcarine sulcus does not exist in any form in the apes.

27. The cuneus, therefore, has a different morphological value in the apes and in man. In connection with this compare the abnormal human hemispheres. These exhibit certain conditions which approximate to those present in the apes.

The Fossa and Fissura Sylvii.—The sign of the Sylvian depression appears at the end of the second month of development. Dr. Cunningham summarizes his investigation as follows:

"1. As growth proceeds the outline of the Sylvian fossa changes considerably. At first nearly circular, it elongates in a vertical direction and then backward on itself, and assumes a triangular outline.

"2. The high prominent mantle border or rim which surrounds the depression is divided by intervening angles into four sections, viz.: the *temporal* (postoperculum), or lower; the *fronto-parietal* (operculum), or upper; the *frontal* (preoperculum), which is formed by an opening out and flattening of the primitive single anterior angle; and an *orbital* (suboperculum), or front portion.

"3. Each of these portions of the bounding rim acts as an independent line of growth, and consequently, in course of time, four opercula grow over the Sylvian area so as to enclose it. The temporal and fronto-parietal opercula appear first; the frontal and orbital do not develop until a much later period.

"4. The so-called three limbs of the fissure of Sylvius are formed by the meeting over the Sylvian area of the contiguous lips of the four opercula; the posterior horizontal limb intervenes between the fronto-parietal and the temporal opercula; the anterior ascending limb between the frontal and fronto-parietal opercula; the anterior horizontal limb between the frontal and the orbital opercula.

"5. The frontal operculum is therefore the same as the 'cap de Broca,' and it shows great variations in its length. It may be absent altogether, and then the two anterior limbs of the Sylvian fissure are fused into one. When the frontal operculum is reduced in length we have the **Y**-condition of the two anterior Sylvian rami.

"6. The Sylvian fossa once mapped out on the surface of the hemisphere, it extends very rapidly. The growth is not proportionate with that of the hemisphere, it is much more rapid.

"7. During intrauterine life the anterior end of the insula maintains a very nearly fixed position with reference to the anterior end of the cerebrum, while the posterior end of the cerebrum moves rapidly toward the occipital pole. After birth the posterior end of the insula is fixed, while the anterior end, as growth advances, oscillates slightly—at first approaching and then retreating from the anterior end of the cerebrum.

"8. An anterior limb of the Sylvian fissures can be determined only by the following tests: (*a*) it must cut right through the entire thickness of the operculum and reach the furrow surrounding the island of Reil; (*b*) it must lie in front of the precentral sulcus.

"9. A single anterior limb of the Sylvian was present in 30 per cent. of the hemispheres examined; the two anterior limbs, quite distinct and separate, were present in 37.5 per cent.; the **Y**-shaped condition of the two limbs was present in 31.5 per cent.

"10. The two orbital limbs of the Sylvian fissure cannot be regarded as belonging to the same category of the true anterior limbs. They are not developed as primitive deficiencies in the orbital operculum.

"11. The posterior insula is not connected with the extremity of the temporal lobe, as Erbstaller has asserted, but with the limbic lobe.

"12. On the surface of the fœtal insula there appear three radial furrows which correspond in every respect with the three 'Primärfurchen' on the outer surface of the mantle (viz., the fissure of Rolando, the inferior precentral sulcus, and the vertical limb of the intraparietal sulcus). The radial furrows on the insula clearly belong to the same fissural system and intermediate links between the three radial fissures on the outer surface of the hemisphere, and the three radial fissures on the insula may exist in the form of secondary sulci, cutting the margin of the fronto-parietal operculum.

"13. The fissure of Rolando is clearly the proper boundary of the frontal lobe. Above, it is separated only from the calloso-marginal fissure, which bounds the lobe internally, by a narrow but superficial gyrus; below, the inferior transverse furrow of Erbstaller acts as an intermediate link between it and the sulcus centralis insulæ. The sulcus centralis insulæ and the calloso-marginal sulcus are brought into close relationship at the anterior perforated spot on the base of the brain. An almost continuous fissural system, therefore, marks out the limits of the frontal portion of the cerebrum.

"14. The temporal pole is formed entirely by the forward growth of the fore part of the temporal operculum.

"15. In the adult brain the insula is proportionately longer in the male than in the female. At all periods of growth it would seem that the insula is relatively longer on the left side than on the right side. In the negro brain it would appear that the insula is relatively shorter than in the European brain.

"16. In the anthropoid ape the so-called anterior limb of the Sylvian fissure is not homologous with either of the anterior limbs in man.

"17. In the chimpanzee and orang there are only two opercula, viz., the fronto-parietal and the temporal. The frontal and orbital opercula of the human brain are entirely absent in the anthropoid cerebrum.

"18. Restricting the term insula to that part of the hemisphere surface which is concealed from view by opercula, the extent of this area in the ape is very much less than in man. The central index is 18.2 in the chimpanzee and 21.5 in the orang; in man the central index is 29.6. In the lower apes the central index is higher than in the anthropoids.

"19. In man the field of the insula shows marked

changes with reference to the cranial wall during intrauterine life. More and more of its area comes to lie under cover of the parietal bone, and relatively less under cover of the frontal bone, as development proceeds. In the adult the coronal line cuts the insula in such a manner that thirteen per cent. of its length lies in front of it and eighty-seven per cent. behind it.

"20. In the chimpanzee and the low apes no part of the insula lies in front of the coronal line; in the orang the upper and anterior corner of the insula projects slightly in front of this line.

"21. In the human infant and young child, as well as in the ape, the point at which the stem of the Sylvian fissure reaches the outer surface of the hemisphere is situated relatively farther back than in the human adult.

"22. The Sylvian fissure is relatively longer in the left hemisphere than in the right, and in the ape than in man. . . .

"28. In the Cebus (Figs. 853 and 854) the Sylvian fissure lies above the level of the squamous suture; in the macaque, homadryas, and orang, it lies immediately subjacent to the fore part of the suture; in *Cynocephalus anubis* and the chimpanzee the fissure is situated in its fore part below the level of the front part of the suture.

"29. The relative depth of the parietal and temporal lobes in the lower apes resembles that in the human child; in the anthropoid ape the relative parietal depth of the hemisphere exceeds that in the human adult."

The Fissure of Rolando.—Cunningham found that in sixty per cent. of the brains examined the upper end of

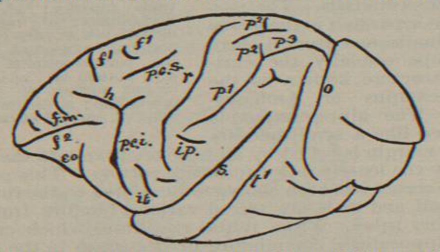


FIG. 852.—Left Cerebral Hemisphere of a Chacma Baboon. *p*, Various parts of the intraparietal system of furrows; p^1, sulcus postcentralis inferior; p^2, two parts of the sulcus postcentralis superior; p^3, ramus horizontalis; *i.p.*, sulcus postcentralis transversus; *o*, occipital operculum.

the fissure of Rolando turned over the mesal border of the hemisphere; in nineteen per cent. its ventral end was connected by a shallow transverse sulcus with the Sylvian fissure. The fissure of Rolando appears in two parts; the lower two-thirds appears before, and independently of, the upper third. The relative position of the fissure of Rolando is remarkably constant. The upper fronto-Rolandic index is 53.3, the lower 43.3. In anthropoids the upper end of the fissure of Rolando is placed relatively farther back than in man. The average Rolandic angle in the human brain is 71.7. The average relative length of the fissure of Rolando is 39.3.

The Intraparietal Sulcus.—"1. The entire sulcus, single and continuous in some of the lower apes (*e.g.*, Cebus), becomes broken up in the human brain into a group of furrows which present different relations to each other in different cases.

"2. Three of the elements of the sulcus in the human brain, viz., the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the original fissure; one, the sulcus postcentralis superior, is a superadded element (Fig. 859).

"3. In the development of the sulcus in the human fœtal brain, all the four segments of the sulcus have, as a rule, an independent origin, although, as Pansch has shown, the sulcus postcentralis inferior and the sulcus horizontalis very frequently appear as one continuous furrow.

"4. The sulcus postcentralis inferior usually appears first; then the ramus horizontalis and ramus occipitalis; and last of all the sulcus postcentralis superior.

"5. In Cebus there is no sulcus postcentralis superior; it is present, however, in most of the old-world apes, *e.g.*, the baboon, macaque, gibbon, chimpanzee, orang, and gorilla (Fig. 858).

"6. In the chimpanzee and orang there is reason to believe that this segment of the postcentral sulcus consists of two elements, one placed above the other (Figs. 856 and 857).

"7. Eberstaller's third and lower segment of the postcentral sulcus (viz., the sulcus postcentralis transversus) is not only present in man, but also in the majority of the old-world apes.

"8. In the apes the intraparietal sulcus is deeper than the fissure of Rolando; the opposite is the case in man. This would seem to indicate that the morphological value of the sulci is different in man and the apes. The phylogeny and ontogeny of these furrows are in apparent variance with each other. The fissure of Rolando appears first on the developing cerebrum of the human fœtus, yet it is the intraparietal sulcus which first makes its appearance in the evolution of the primate cerebrum. . . .

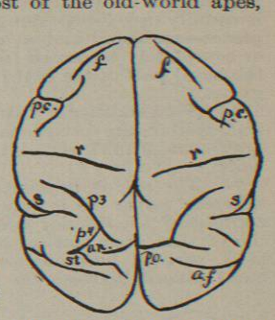


FIG. 853.—Cerebrum of Cebus Albifrons. *f*, Sulcus frontalis inferior; *p.c.*, sulcus postcentralis inferior; *r*, fissure of Rolando; *s*, Sylvian fissure; *p*, intraparietal sulcus; p^3, ramus horizontalis; p^4, ramus occipitalis; *st*, furrow corresponding to sulcus transversus occipitalis of Ecker; *p.o.*, parieto-occipital fissure; *an.*, first annectant gyrus; *a.f.*, ape cleft.

"11. In man there appears to be a general tendency toward a union of the two originally distinct postcentral elements of the sulcus, and a divorce from the lower of those of the ramus horizontalis. . . .

"13. The ramus occipitalis was connected with the ramus horizontalis in 63.7 per cent. of the adult human hemispheres examined.

"14. The union between these two elements of the sulcus, as Ecker and Wilder have shown, is much more common on the left side than on the right.

FIG. 854.—The Outer Surface of the Cerebrum of Cebus Albifrons. *r*, Fissure of Rolando; *p.c.i.*, sulcus præcentralis inferior; *h*, ramus horizontalis; f^2, inferior frontal sulcus.

"The sulcus transversus of Ecker is not the homologue of the 'Affenspalte' in the apes, but merely a terminal bifurcation of the ramus occipitalis."

The Sulcus Præcentralis.—"1. The sulcus præcentralis inferior in the human brain is composed of a vertical and a horizontal limb. The latter is carried forward into the middle of the frontal convolution.

"2. This furrow is the earliest to appear on the outer surface of the frontal lobe of the fœtal brain. In some cases it is seen in the fifth-month cerebrum in the form of a long, deep, vertical sulcus, which subsequently undergoes a retrograde development before its adult condition is reached. In many cases, in its early condition, it presents a form in every respect comparable with that ob-

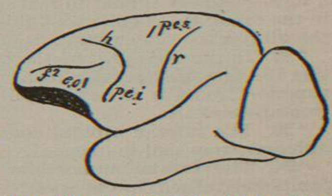


FIG. 855.—Another View of the Same. *p.c.s.*, Sulcus præcentralis inferior (?); *e.o.*, a slight trace of the sulcus fronto-orbitalis. Other letters as in Fig. 854.

served in the cerebrum of the low ape (Cebus). Frequently it is developed in several pieces.

“3. The sulcus præcentralis superior is closely connected with the basal part of the first frontal furrow. It is usually developed along with it. It consists of two pieces—an upper and a lower—which may be partially or completely separated from each other, as well as from the basal part of the first frontal furrow by an annectant gyrus.

“4. Two additional furrows belonging to the precentral system are occasionally present, viz., the sulcus præcentralis medius and the sulcus præcentralis marginalis.

“5. The sulcus præcentralis medius may arise in two different ways: (*a*) It may be formed by the ramus horizontalis of the inferior precentral sulcus divorced from the vertical stem and assuming a very oblique or an almost vertical position; (*b*) it may consist of a new element placed between the superior and inferior precentral furrows, but showing a closer connection with the former. . . .

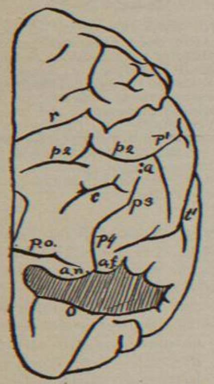


FIG. 856.—Cerebral Hemisphere of Young Female Chimpanzee, as seen from above. The operculum on each side has been removed. *r*, Fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, two portions of sulcus postcentralis superior; p^3, ramus horizontalis; p^4, ramus occipitalis; *b*, terminal bifurcation of the intraparietal sulcus; *p.o.*, parieto-occipital fissure; *a.n.*, first parieto-occipital annectant gyrus; *a*, deep annectant gyrus in the course of the intraparietal sulcus; *c*, secondary sulcus in the superior parietal lobule; *a.f.*, bottom of the “ape-cleft”; *o*, cut surface of occipital operculum; t^1, parallel sulcus.

“12. The superior frontal gyrus and the middle frontal gyrus are each partially subdivided into two tiers or subdivisions by furrows which may be respectively termed the sulcus frontalis mesialis and the sulcus frontalis medius.

“13. Both of these furrows have secured a firm footing in the human brain, but only one (viz., the frontalis medius) has established itself upon the brain of the chimpanzee (Fig. 856). . . .

“17. The sulcus frontalis mesialis is absent or poorly developed in the brain of the negro. . . .

“20. The sulcus præcentralis inferior and the inferior frontal sulcus are the furrows which are most firmly impressed upon the brain of the apes. In Cebus they alone are present; in Calithrix there are also traces of the sulcus præcentralis superior and sulcus fronto-orbitalis; in the baboon there are, in addition, a rudimentary sulcus frontalis superior, and perhaps (?) traces of a sulcus frontalis medius (Figs. 852 and 853).

“21. In the chimpanzee and the gorilla the sulcus frontalis medius is often present in a form precisely similar to that seen in the human brain; in the orang the condition of this sulcus is doubtful; in the gibbon the sulcus frontalis medius is absent.

“22. In the chimpanzee, therefore, the same convolution ties may be seen as in man, with this exception: the superior frontalis is never split into two by a sulcus frontalis mesialis.

“23. The inferior frontal convolution of apes is very different from that in man.

“24. The frontal and orbital Sylvian opercula are completely absent in the apes.

“25. Consequently, a portion of the island of Reil is uncovered and exposed on the surface of the cerebrum.

“26. The sulcus fronto-orbitalis of apes corresponds to the anterior limiting sulcus of the island of Reil in man.

“27. There are no anterior limbs of the Sylvian fissure in the anthropoid apes. The so-called anterior limb of the Sylvian fissure corresponds to the anterior free border of the fronto-parietal operculum.

“28. About the seventh month of fœtal life the inferior precentral sulcus of the human brain attains a position which it retains unaltered throughout all the subsequent changes of growth; previous to this it is placed relatively farther back on the surface of the hemisphere.

“29. At first it is placed in front of the coronal suture. The sutural line, however, moves forward so that the sulcus ultimately comes to lie behind it.

“30. In the ape cerebrum the inferior precentral sulcus lies relatively much farther forward than in the cerebrum of man. It may be placed subjacent to, or in front of, the coronal line.”

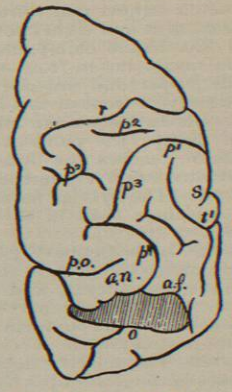


FIG. 857.—Right Hemisphere of a Male Orang, Six Years Old. *r*, Fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, two parts of sulcus postcentralis superior; p^3, ramus horizontalis; p^4, ramus occipitalis; *a.n.*, first parieto-occipital annectant gyrus; *p.o.*, parieto-occipital fissure; *a.f.*, bottom of “ape-cleft”; *o*, cut surface of occipital operculum; *s*, fissure of Sylvius; t^1, parallel sulcus.

The Hippocampus. — The median part of the mantle, that portion which adjoins the opposite hemisphere and the thalamus, is very early separated from the rest of the cortex by a total fissure consisting of the hippocampal fissure, the fissura calcarina, and the (temporary) fissura parieto-occipitalis. The portion so separated is the gyrus marginalis, and from it there develops caudally the curious structure known as the hippocampus or Ammonshorn. The hippocampus is enrolled like a scroll and its mesal margin is rolled by an inverse curve into the space left by the loosely rolled fornicate portion. This portion of the cortex has been shown to be related to the function of smell, and to it are traced various bundles from the olfactory tuber. From it also rise fibres which cross in the hippocampal commissure or decussate in the fornix

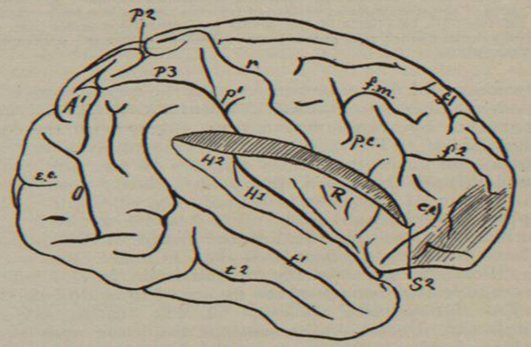


FIG. 858.—Right Cerebral Hemisphere of a Male Orangoutang, Six Years Old. f^1, Sulcus frontalis superior; f^2, sulcus frontalis inferior; *f.m.*, sulcus frontalis medius; *e.o.*, sulcus fronto-orbitalis; *p.c.*, sulcus præcentralis inferior; *p.c.s.*, sulcus præcentralis superior; *p.c.i.*, sulcus præcentralis inferior; *r*, fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, sulcus postcentralis superior; p^3, sulcus horizontalis intraparietalis; *e.c.*, external calcarine fissure; t^1, parallel sulcus; t^2, second temporal sulcus; H^1, H^2, H^3, transverse temporal gyri of Heschl; *R*, insula; A^1, first annectant gyrus; S^2, anterior free border of the fronto-parietal operculum; *O*, anterior edge of the occipital operculum.

body and thence descend by the columns of the fornix to the thalamus. Some of the fibres pass to the tuber cinereum and enter the mammillary bodies.

The Olfactory Region.—From a part of the hemispheres near the cephalic end of the gyrus marginalis, in lower

animals at the cephalic extremity of the brain, while in higher mammals the point is ventrally folded, there arises a protuberance called the olfactory lobe. Still cephalad the ventricle is produced to form a dilatation of the wall—the olfactory tuber. The actual means by which the tuber is formed may be discovered by watching the early stages of development. At a very early period the front of the hemispheres comes into actual

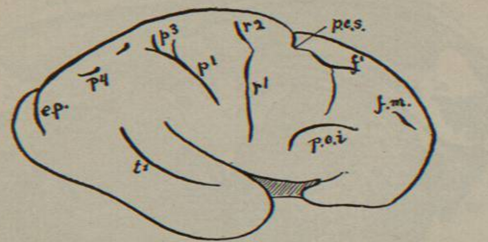


FIG. 859.—Outer Surface of a Cerebral Hemisphere in the Early Part of the Seventh Month. t^1, Parallel sulcus; *p.c.i.*, inferior frontal; f^1, sulcus frontalis primus; *p.c.s.*, sulcus præcentralis superior; *r*, fissure of Rolando; *p*, intraparietal sulcus; p^1, sulcus postcentralis inferior; p^3, ramus horizontalis of the intraparietal sulcus; p^4, ramus occipitalis; *e.p.*, fissura perpendicularis externa.

contact with the depressions of the skin forming the olfactory fossa (Figs. 863 and 864). In this fossa there develop the ganglion cells of the olfactory from the proximal end of which the olfactory fibres make their way into the hemispheres. In this way the hemispheres are connected

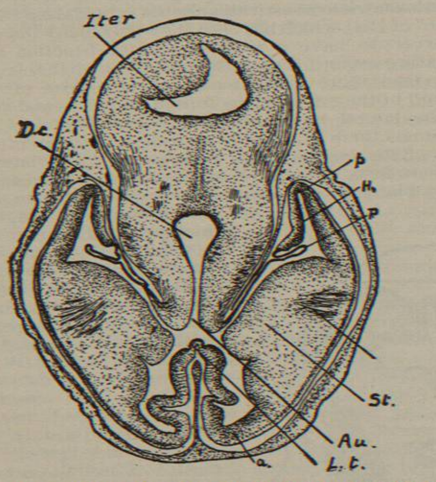


FIG. 860.—Horizontal Section of Guinea-Pig Head. *Dc.*, Diacele; *St.*, striatum; *Au.*, aula; *L.t.*, lamina terminalis; *P.*, plexus; *H.*, hippocampus; *a.* and *p.*, proliferating areas; *x.*, inner capsule.

with the epithelium and the connection is retained from this time on. In some cases, as in certain fishes, the growth of the head causes the brain to be withdrawn a long distance from the olfactory fossæ, and the tuber is drawn out into an almost thread-like stalk which has often been mistaken for the olfactory nerve. In other cases the tuber has refused to be separated from the brain, and the fibres connecting with the olfactory epithelium have been extended and have been usually called the olfactory nerve, though here again incorrectly, for in a strict sense there is no olfactory nerve and this bundle should be called the root. In the tuber two portions can be distinguished, the unaltered protrusion of the brain called the pes, and a slipper-like enlargement covering the pes, called the pero. In the latter is developed what is known as the glomerule zone, in which the final branches of the olfactory root fibres mingle with the arborizations of the

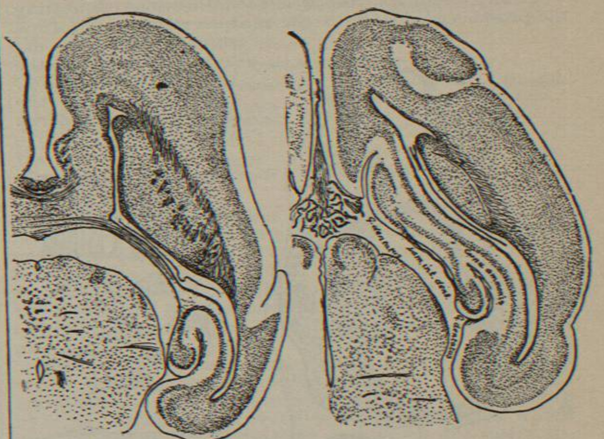


FIG. 861.—Two Horizontal Sections of Brain of Young Opossum, to Show Hippocampus and Fimbria.

special mitral cells of the pero. Fibres from the latter pass backward to the region of the hippocampus.

The Diencephalon and Mesencephalon—The external characters of the thalamus have already been mentioned in sufficient detail. Within there develop a number of clusters of cells which are better known in lower animals than in man, but in all cases the exact function remains problematical. It seems certain that the several tracts from organs of special sense here find rendezvous and from these temporary stations extend to the cortical areas. From the cerebellum fibres enter the nucleus ruber. From the geniculate nuclei the optic radiations

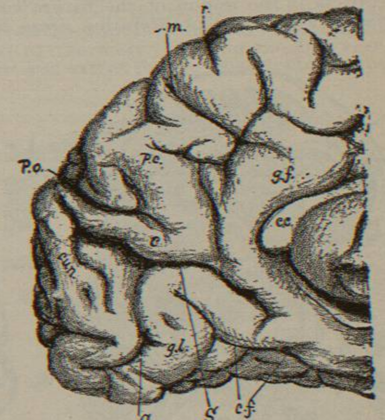


FIG. 862.—Hinder Portion of Cerebral Hemisphere of Full-Term Fœtus, Showing Conditions Approximating to Those of Anthropoid Apes. *r*, Upper end of fissure of Rolando; *c.m.*, calloso-marginal sulcus; *p.o.*, parieto-occipital fissure; *cun.*, cuneus; *c*, gyrus cunei; *p.c.*, præcuneus; *g.f.*, gyrus fornicatus; *c.c.*, callosum; *c.f.*, collateral fissure; *C*, posterior secondary calcarine fissure; *S*, “stem” of calcarine fissure.

pass to the occipital cortex. The rapid growth of the roof of the mesencephalon, as well as the curvature of the base due to the midbrain flexure, tends to fill the midbrain vesicle, and in mammals the narrow iter alone remains. The basal or pes portion develops the several centres for visual co-ordination, while the dorsal longitudinal fasciculus lies immediately beneath the iter. Ventrally the fibres passing in both directions connecting the prosencephalon with the medulla oblongata form a thick mass on the external aspect of the pes, called the crusta, through which the fibres of the third nerve find exit.

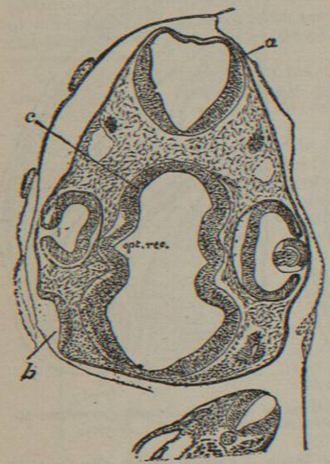


FIG. 863.—Section through Head of Garter-Snake Embryo. *a*, Midbrain; *b*, olfactory pit; *c*, infundibulum.

FIG. 864.—Epithelium of Olfactory Pit in Proliferation.

The Medulla Oblongata and the Cerebellum.—Reference has already been made to the relation of the cerebellum to the medulla, and also to the fact that this massive organ is built up partly from proliferations from the lateral walls of the fourth ventricle and partly from the concrescence of masses proliferated at the cephalic margin of the tela. In some mammals, at least, the writer has described a process of actual eversion of a sac from the lateral walls of the fourth ventricle in the region of the future cornucopia to give rise to superficial proliferating areas to supply the surface when cut off from the direct replenishment from the ventricles by the intrusion of the white matter. (*Cf.* Figs. 865–868.) In an entirely similar way Professor

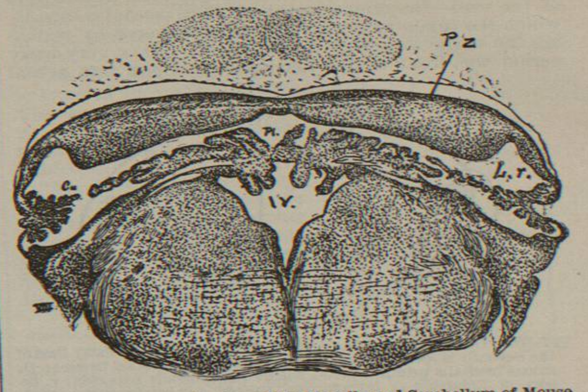


FIG. 867.—Transverse Section of the Medulla and Cerebellum of Mouse Embryo. *P.z.*, Superficial proliferating zone derived from the epithelium of everted lateral recess; *L.r.*, lateral recess; *Pl.*, plexus; *c.*, cornucopia; *VIII.*, root of eighth nerve; *IV.*, fourth ventricle.

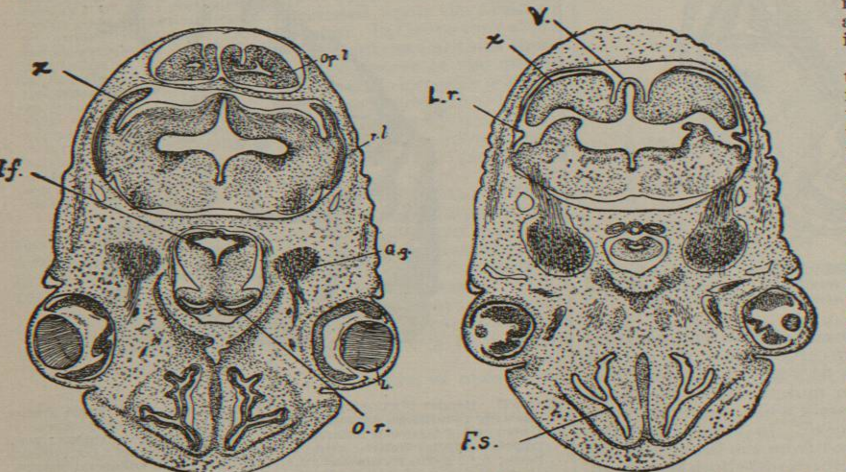
His explains the origin of the olives by the eversion of the walls of the fourth ventricle at a lower level and the final envelopment of the proliferating epithelium in the parietes of the medulla.

The margin of the cellular portion of the roof of the fourth ventricle constitutes the rhomboidal lip ("Rautenlippe" of His), which has been shown by many independent observers to have a most important function as a proliferating organ for both the medulla and the cerebellum.

In man there is a greater development of nervous matter in the roof of the fourth ventricle and the walls of the lateral recess than in lower mammals. In all mammals there is a caudal as well as two lateral protrusions of the membranous walls (tela). The lateral protrusions form the lateral recesses just mentioned, while the caudal projection in man becomes perforate, forming the foramen of Magendie or metapore. This pore is characteristic of anthropoids, but is absent in lower mammals.

Even as early as the end of the third week the forebrain forms almost a right angle with the medulla, and during the fourth and fifth weeks the pons flexure increases till the base of the mesencephalon is separated from that of the medulla only by the narrow and deep "saddle cleft." From the dorsal extremity of this cleft arises the fossa Tarini. The pons flexure gives opportunity for the development of the cerebellum by providing a place for it. The flexure finds reciprocal expression in the choroid fold or inward loop of the tela.

The cerebellum is divided into a median vermis, and, on either side, a pileum, paraflocculus, and flocculus. The regions which form the pilea are first developed and the vermis is last to appear. The first sulci also appear on the lateral parts and not on the



FIGS. 865 AND 866.—Horizontal Sections through the Head of Embryo Guinea-Pig. (Compare also Fig. 860 from the same series farther dorsad.) Fig. 865 passes through the level of the eyes and infundibulum. The extension of the ventricle of the optic recess into the stalks of the optic nerves is shown at *O.r.* *G.g.*, Gasser's ganglion; *L.*, lens; *Op.l.*, optic lobes, roof of mesencephalon; *r.l.*, lateral recess of fourth ventricle extending upward within a fold of the rhomboidal lip to cover the lateral aspects of the cerebellum, as at *x*. Fig. 866 passes at a somewhat lower level, and shows the extension of the lateral recess near the tip of the cerebellum. At *L.r.* the beginning of the cornucopiæ is shown; *F.s.*, frontal sinuses.

vermis. At about the middle of the third month four or five transverse convolutions appear on the vermis. By the fifth month the definitive form of the cerebellum is clearly defined. By this time the prepedunculi connect with the midbrain, and the valvula is formed by the

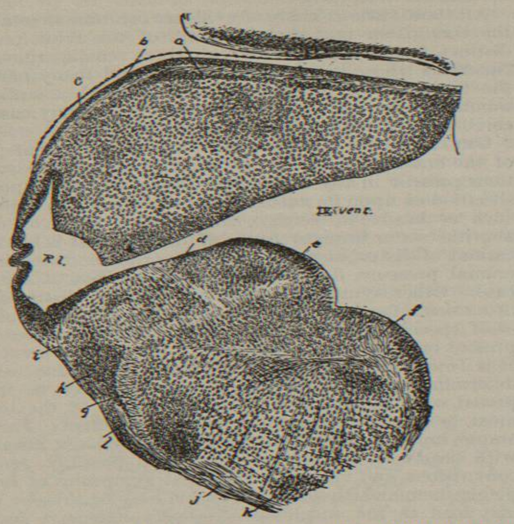


FIG. 868.—Portion of Similar Section to Show the Double Proliferating Zone with Fibre Layer Between, at *a*, *b*, *c*.

thinning of the dorsal walls cephalad of the vermis. As early as the third month the restiform bodies connect with the lateral lobes to form the postpedunculi. In the fourth month the medipedunculus and pons become obvious.

The formation of the pons by the decussating fibres of the medipeduncle of the cerebellum greatly modifies the cephalic part of the organ and leaves an isthmus region between the cephalic border of the pons and the mesencephalon which otherwise would perhaps hardly rise to the value of a recognized portion of the brain. At different levels in the medulla the sensory and the motor bundles connecting the cord with the upper parts of the brain decussate, and by this means the simplicity of structure seen in the cord is entirely destroyed in the myelencephalon. Added to this is the remarkable differentiation of the centres of the several cranial nerves (*q. v.*), which also obscures the original uniformity of arrangement. The effect of the increased emphasis laid upon a particular sense is well illustrated in fishes, in which, for example, huge excrescences arise on the medulla in the region of one or other of the cranial roots, almost equal to the cerebellum in size.

Several authors have observed even in human brains serially arranged eminences in the floor of the fourth ventricle, but whether they indicate neuromeres in the sense in which that term is now used in morphology, and what their fate may be in the adult, remain points of dispute. At the end of the second month there may be recognized in sections of the medulla four somewhat distinct regions: (1) the region of the motor nuclei; (2) the substantia reticularis; (3) the region of the lateral nuclei and the substantia gelatinosa, and (4) the region of the olives. To these in later stages are added a vast number of tracts and scattered nuclei which may best be studied in the adult brain.

The various regions of the brain developed in the manner above described have been given a great variety of names, and there has as yet been no general agreement as to the connotation of many names in common use. The system proposed by Professor His is given below because of its completeness, though it will require to be modified in detail to adapt it to more general usage.

I.	Medulla oblongata, Myelencephalon I.		Rhombencephalon I.–III.		Encephalon.
II_1.	Pons	Metencephalon II.			
II_2.	Cerebellum				
III.	Isthmus rhombencephali III.				
IV_1.	Pedunculi cerebri	Mesencephalon IV.			
IV_2.	Corpora quadrigemina				
V_1.	Pars mammillaris hypothalami		Diencephalon V.	Prosencephalon	
V_2.	Thalamus	Thalamencephalon			
V_3.	Metathalamus				
V_4.	Epithalamus				
VI_1.	Pars optica hypothalami		Telencephalon VI.		
VI_2.	Corpus striatum	Hemisphærium			
VI_3.	Rhinencephalon				
VI_4.	Pallium				

The term epencepahalon is often applied to the cerebellum, but, in spite of its great size in man, it is only an extension of the lateral walls of the medulla. It has been proposed to use oblongata as the brief substitute for the full form, "medulla oblongata," but the substantive seems the more natural part of the binomial, as the objection that medulla is ambiguous is of no practical moment.

Prosencephalon has been generally used as synonymous with telencephalon as applied by His, and by using metencephalon instead of rhombencephalon we have a series of terms, founded on a sound embryological basis, which may be considered correlative and which are easily applied, viz., meten-, mesen-, dien-, and prosen-cephalon.

Closely related to the prenatal changes above described are their postnatal consequences. There is no sharp line to be drawn between the phenomena of growth before birth and those which continue in after life. Changes in proportion during the adolescent period affect the relation between head and body and between brain and the remainder of the central nervous system. Brain development proceeds in advance of that of the body at large, though in cases of defective development of the brain the body may attain a considerable degree of perfection, as has been shown by Lenowa. In a fœtus of twenty-one weeks, according to Bischoff, the percentage weight of the brain to body is 18.5, in new-born male children 15.8, in new-born female children 12.2, at sixteen years of age the percentage is 3.9, in adult males it is 1.9, and in adult females 2.1. At birth the weight is nearly alike in the two sexes, but the absolute weight is, of course, influenced by the size of the body. During the first year, and to a somewhat less extent for the three following years, the

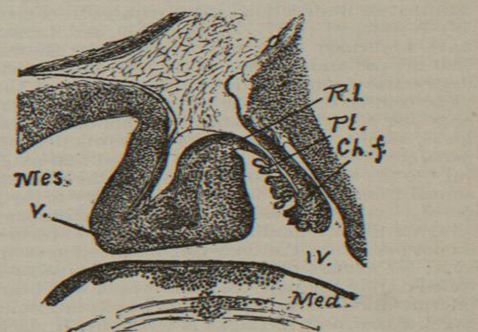


FIG. 869.—Longitudinal Section of Cerebellum of Early Mouse Embryo. *Mes.*, Mesocele or iter; *V.*, valvula; *R.l.*, rhomboidal lip, and proliferating area derived from it; *Pl.*, plexus; *Ch.f.*, choroidal fold; *IV.*, fourth ventricle; *Med.*, medulla base.

growth is very rapid. By the seventh year the encephalon has nearly attained its full weight. After about the fiftieth year a gradual loss of weight becomes apparent.

The continuous and unequal demands made upon various parts of the brain operate to stimulate growth, waste, and repair to an unequal degree in different parts. In this connection it is important to note that there are laid up in store in certain parts of the brain nascent or latent cells (granules) which may interpolate themselves among the depleted cells of older growth.

Education in its broadest sense includes all changes in the brain due to reactions of the organ upon afferent stimuli. It is usual to state that all the elements (cells, etc.) of the brain are preformed in it at birth. If this were so, then education would consist in the progressive modification of these cells and the perfection of a wide range of intercommunications between them. Leaving out of the account the possibility of the proliferation of new cells from a germinative epithelium, there can be no doubt that the latent cells above mentioned are called into activity by exercise, and increased brain power and a more extended range of activity are thereby secured. It would apparently follow that activity of mind would hasten the period of senility and brain decline; but as the reverse is the case, it may be assumed that proliferation or an analogous process really takes place.

C. L. Herrick.

BRAIN DISEASES: DIAGNOSIS OF LOCAL LESIONS.—History.—Although it was known in the first century that each hemisphere of the brain is in functional relation with the opposite half of the body, the facts upon which the prevailing theory of the localization of different functions in separate parts is based were not discovered until 1822. At that time Thomas Hood, in England, and Bouillaud, in France, noticed that disturbances of speech were caused by disease in the frontal lobes of the brain. M. Dax (1836) was the first to limit the area governing speech to the left frontal lobe, and Broca (1861) located it more exactly in the left third frontal convolution. The discussion of aphasia in the Academy of Medicine in Paris in 1864 awakened general interest and led to further investigation. Until that time scientific men, rejecting the unwarrantable conclusions of Gall and the phrenologists, had believed the teachings of Flourens, that the brain acts as a whole, its various parts not possessing various powers. The pathological evidence against this position collected by Broca, and strengthened during 1864–67 by facts observed by Hughlings Jackson and Meynert, received confirmation in 1870 from a new series of physiological experiments made by Fritsch and Hitzig in Berlin. These investigators found that in animals the anterior portion of the convexity of the brain is motor; that its irritation by electricity causes coordinated motions in the limbs of the opposite side, and that its destruction causes paralysis. Ferrier (1873–76), Nothnagel (1877), Munk (1881), and Luciani (1884) have confirmed these results, and have shown further that the posterior portion of the convexity is sensory, its destruction being attended by impairment of the powers of perception through the various senses. Goltz, though opposing a strict limitation of functions to definite regions, admits that the results of destruction of various parts are different, and he has noticed that extensive injury to the anterior portion changes the character of an animal from kind to vicious, while injury to the posterior portion has the opposite effect. The conclusions of physiologists differ regarding the results of experiments, but do not overthrow the theory of localization as applied to man; for a mass of pathological evidence has been collected during the past ten years which will bear but one interpretation. Charcot and his pupils in France, Nothnagel, Exner, and Wernicke in Germany, H. Jackson and Ferrier in England, and others, have gathered, classified, and analyzed a very large number of cases of brain disease of limited extent, which were accompanied by definite symptoms, and have established a causal relation between lesions of certain portions of the brain and disturbances of certain functions, both motor and sensory. It has also been discovered that deficient development of an organ is accompanied by deficient development of that part of the brain which is in functional relation with that organ, and *vice versa* (von Gudden).

Further, the researches of Flechsig (1877–84) have proven that an anatomical connection exists between certain organs and certain parts of the brain by means of tracts, which can be distinguished from one another by peculiarities in the time and process of their development. To these same tracts are limited the secondary changes which ensue when the active organ at one extremity of the tract is destroyed.

All these various kinds of evidence combine to establish the conclusion that definite parts of the brain possess distinct functions, and although there remain numerous functions whose location is unknown, and many parts of the brain whose function is undetermined, a sufficient number of facts is available to warrant in many cases of cerebral disease a localization of the lesion.

General Considerations.—Since the different parts of the brain preside over different functions, the symptoms present in any lesion will depend as much upon its situation as upon its nature. Certain general symptoms, such as headache, vertigo, convulsions, coma, or optic neuritis, occur in many forms of disease, and being indications of disturbances of nutrition, or of increased intracranial pressure, do not indicate the position of the disease. Other symptoms, however, such as disturbances of motion, of sensation, of sensory perception, of memory, or of speech, are known as local symptoms, since each is present only when a certain part of the brain is involved. It is from these that the localization of a lesion can be determined. Local symptoms must, however, be interpreted with caution, and the direct effect of the lesion must be distinguished from its indirect effect. For example, immediately after a cerebral hemorrhage, attended with headache, vertigo, or coma, and possibly general convulsions and vomiting, the local symptoms of hemiplegia, hemianæsthesia, and aphasia may be present, and may lead to the suspicion of a very extensive lesion. After a few days, however, there may remain only a partial hemiplegia, all other symptoms having subsided. In such a case the hemiplegia is the only direct local symptom; the indirect local symptoms—aphasia and hemianæsthesia—being incidental to the pressure on, or to disturbance of, circulation in parts adjacent to the actual seat of disease. It is only when a lesion is single, its effects stationary and of some duration, that a diagnosis of its position is to be made.

In diagnosticating the position of a lesion it is necessary to distinguish disease in the cortex from disease within the hemisphere. The functions of these parts are different. The gray cortex receives and initiates impulses. The white matter within the hemisphere transmits the impulses. The impulses sent along white tracts to the cortex become conscious perceptions only when they reach their destination in the gray matter. The impulses passing along the white tracts from the cortex have been started in the gray matter as conscious volitions by effort. Thus sensation or motion may be suspended either by disease in the cortex or by disease in the tracts within the hemisphere. The cortex has another function. A sensation once perceived, or a motion once acquired, leaves behind it a trace, whose nature is unknown, which shows itself in a disposition in the cells of the cortex to react more promptly to a similar impulse than to a dissimilar one. This is the physical basis of memory. Since similar impulses always enter by the same sensory organ, and since each organ is connected with its own region of the cortex, it follows that the various memories are distributed in various regions. But these memories are often associated in consciousness, and this association is secured by means of white fibres which pass between and connect the various regions. It becomes evident, therefore, that diseases of memory may afford an important clue to the location of a lesion; and that the distinction between a disease of the gray cortex involving a loss of a certain kind of memory, and one of the white tracts within the hemisphere interfering with the proper association of ideas must not be overlooked. No part of the gray matter can act vicariously for another part. Each tract conveys its own impulses.

Diagnosis.—I. Cortex Cerebri.—1. Lesions involving the frontal lobes upon the base may destroy the olfac-

tory bulb or tract and produce anosmia on the side of the lesion. Lesions in the other convolutions of the frontal lobes, excepting those in the posterior part of the third convolution of the left side, present no distinctive local symptoms. Some disturbance of mental action, manifested by an inability to concentrate the attention, to think connectedly, and to control the emotions, or even by a condition of imbecility, may be caused by disease in this region.

These convolutions are often defective in idiots, and their comparative development in animals determines the mental power of the individual. But disease in this region in man does not cause a loss of any particular mental faculty, and for the higher powers of mind no location can be determined. Normal mental action implies the integrity of the entire brain. When general symptoms of cerebral disease are present, but no local symptoms can be found, the possibility of disease in the frontal convolutions is to be considered, and the occurrence of the mental disturbance mentioned affords a presumption in favor of this location.

Lesions in the posterior part of the third frontal convolution on the left side in right-handed, and on the right side in left-handed persons give rise to ataxic or motor

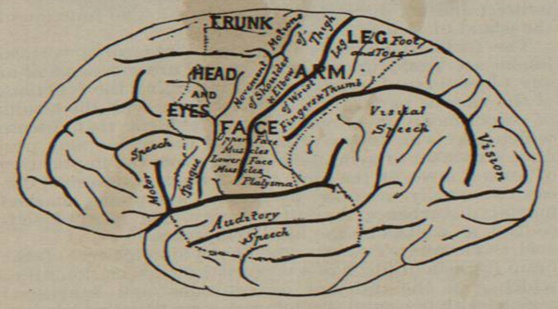


Fig. 870.—Diagram of the Fissures and Convolutions of the Convexity of the Left Hemisphere of the Brain, with the areas presiding over various functions. The speech areas are shown on this hemisphere. The motor area is more extensive on the left than on the right hemisphere.

aphasia (Fig. 870). In this area are located the memories of the combination of motor acts necessary to the pronunciation of words, memories which have been acquired by practice. If these memories are blotted out, the ability to initiate the impulse required to produce a given sound is lost, and speechlessness results. When this convolution alone is affected the patient can understand what is said to him, and may be able to write, but cannot talk (see *Aphasia*).

2. Lesions of the anterior and posterior central convolutions and of the paracentral lobule produce disturbances of motion (Fig. 870). The motor tracts which connect these convolutions of each hemisphere with the body decussate partially in the medulla, and the degree of the decussation differs in different individuals. In the large majority of persons the tracts which cross to the opposite side are so much larger than those which go to the same side that the symptoms of cerebral disease are noticed only on the side of the body opposite to the side of the lesion. In all cases, however, except in those in which the decussation is complete (one in sixty), the side which is apparently normal is slightly affected. The disturbances of motion may be in the form of spasms and convulsions, or in the form of paralysis. Lesions irritating the motor region give rise to the former; those which destroy the cortex to the latter. The lower third of the anterior central convolution is in functional relation with the muscles of the face and tongue (Fig. 870). The middle third of both central convolutions governs the arm (Fig. 870), the motions of the shoulder, elbow, and hand lying from before backward and from above downward in the order named. The upper portion of both convolutions and the paracentral lobules contain the motor centres for the body and leg, the motions of the hip, knee, and foot lying from before backward and from above downward in the order named. The area related to the movement of the eyes is located by Landouzy and Exner in the inferior parietal lobule. As these areas for each part are distinct, cortical lesions of limited extent may affect one alone, or two adjacent areas; but it is only lesions of very great extent which can destroy them all. Monospasms, or monoplegia, are, therefore, prominent symptoms in disease of the motor region. An irritation beginning in one area may extend to adjacent areas, in which case a convulsion may commence in one part and then involve other parts. The relative position of the areas, then, determines the order of progress of the convulsion, face, arm, and leg being successively affected, or *vice versa*; and face and leg never being involved together without affection of the arm. When the entire side is involved the convulsion may become general. The seat of the initial irritation may, therefore, be indicated by the order in which the spasms extend. After such a spasm there remains a paresis in the muscles affected, those last and least involved recovering first (see *Epilepsy*). If the irritating lesion becomes a destroying lesion the monospasm is succeeded by monoplegia, and from the part of the body affected the area in the motor region which is destroyed can be determined. In cortical disease it is seldom that the lesion involves a single area without encroaching upon adjacent areas; hence, associated monoplegiæ of face and arm, or arm and leg, are more frequently met with than paralysis of one part alone. But even in these cases the disturbance of motion usually begins or is more marked in one part, rather than in both equally, and the order of extent of paralysis may indicate the direction in which the disease is progressing, and the place from which it started.

In paralysis from cortical lesion there is a loss or marked impairment of the muscular sense, and there may be some disturbance of general sensation. A loss of motor memories, *e.g.*, the motions involved in writing, playing an instrument, using a tool, occurs in cortical disease, and may indicate that the seat of the lesion is in the area of the arm. The limits of the region receiving impulses which awaken the perception of touch, temperature, and pain are not fully determined. It is thought, however, that the motor and sensory regions coincide, while it is probable that the sensory region extends beyond the motor and includes the parietal lobules which lie posterior to the motor area. Ferrier, however, teaches that the gyrus hippocampus is the region in which these sensations are received. Lesions affecting the posterior central convolution give rise to combined motor and sensory symptoms, the sensory areas lying in the same order as the motor areas, face, arm, and leg in the lower, middle, and upper thirds respectively. Lesions in the motor area anterior to the fissure of Rolando usually produce paralysis without anæsthesia. Lesions in the parietal lobules may produce anæsthesia but do not cause paralysis.

Each sensory area is in functional relation with the opposite limb to a much greater degree than with the limb of the same side. Monoanæsthesia may therefore occur from cortical lesion. The loss of sensation is rarely total, as it is probable that the decussation of sensory impulses is rarely complete. The degree of impairment of sensation is to be ascertained only by comparison of the affected limb with the other three. If the sensory area is not destroyed but is only irritated, subjective sensations in the limb whose area is affected occur, and such monoparæsthesiæ are valuable indications of cortical lesion, when disease in other parts is excluded.

Monospasm and monoplegia, monoparæsthesia or monoanæsthesia, are therefore the chief symptoms of cortical disease in the sensorimotor area. The two former indicate an affection lying anterior to the parietal lobules. The two latter may occur when these also are involved. No other local symptoms of disease in the parietal lobules are known, the disturbances of speech or