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FROM THE

JOURNAL OF ANATOMY & PHYSIOLOGY

VOL. XXV.

THE FISSURE OF ROLANDO.[1] By D. J. CUNNINGHAM, M.D., *Professor of Anatomy and Chirurgery in the University of Dublin.* (PLATE I.)

THE most complete, and at the same time the most accurate, description of the fissure of Rolando, as it appears in the adult, with which I am acquainted, is that which has been recently given by Dr Oscar Eberstaller of Graz. In the present paper it is my intention to trace the history of this sulcus from its earliest appearance up to the period of its full development. For more than three years I have been collecting material for this purpose; and although I have not succeeded in obtaining specimens which illustrate every stage, I believe that I shall nevertheless be able to present a very nearly complete picture of its growth.

Historical.—The name of "Rolando" was first applied to the fissure in question by Leuret,[3] in 1839, and it has very generally been accepted in France, Italy, and England. At the same time it must be acknowledged that Rolando added little to what was at that time already known of the fissure. He describes the two convolutions[4] between which it lies, and likewise figures it; but many years prior to this it had been figured both by Vicq d'Azyr,[5] and by Gall and Spurzheim.[6] German observers, with the single exception of Pansch, apply to the sulcus the term "Centralfurche," a name which was first

[1] This paper is an abstract of a portion of a memoir which will be shortly published by the Royal Irish Academy—*Cunningham Memoir*, No. vii.

[2] *Das Stirnhirn*, Wien und Leipzig, 1890.

[3] *Anatomie Comparée du Système Nerveux*, Paris, 1839.

[4] "Della Struttura degli hemispheri cerebrali," *In Memorie del reale Accademia della Scienze di Torino*, t. xxv. p. 163, 1831.

[5] *Traité d'Anatomie et de Physiologie*, Paris, 1796.

[6] *Anatomie et Physiologie du Système nerveux en général et du Cerveau en particulier*, Paris, 1810.

introduced by Huschka.[1] If this term be applied to it with the view of indicating its nearly central position with reference to the frontal and occipital poles of the hemisphere, it must be admitted that it is singularly appropriate. But it was not with this signification that it was used by Huschka. Following the views which had been advanced by Leuret, he imagined that the fissure of Rolando passed through the midst of the arching convolutions of the carnivore brain, and separated them into an anterior and a posterior set. The term fissura centralis was founded upon this erroneous view of its homology, and it was owing to this that Pansch so strongly objected to its use.[2]

General Description.—It is customary to describe the upper end of the fissure of Rolando as falling short of the upper margin of the cerebral hemisphere; but, as Eberstaller has pointed out, this is not correct. In 52 hemispheres, taken from children and adults, I found the following:—

(*a*) In 60 per cent. the upper end of the fissure cut the upper border of the hemisphere and appeared on the inner surface.
(*b*) In 21 per cent. it just reached the upper border, but did not show upon the inner surface.
(*c*) In 19 per cent. it fell short of the upper border.

In those cases where the upper extremity of the fissure does not reach the superior margin of the cerebral hemisphere, as well as in those cases where it fairly turns over to reach the inner surface, the sulcus usually ends by bending directly backwards for a distance of about a quarter of an inch or more. On the inner surface of the hemisphere it approaches the upwardly directed end of the calloso-marginal sulcus, but I have never seen it join the latter. Benedikt[3] describes such a union. He says: "In several brains the fissure of Rolando, which in these cases projects far upon the mesial surface, also stands in connection with the fissura calloso-marginalis." Eberstaller also doubts the existence of this connection. In the large number of brains which he has examined, he has never met with an example.

Where the upper extremity of the fissure of Rolando just reaches the upper border of the hemisphere, but fails to turn round it, we do not as a rule see the terminal backward bend which is so characteristic of the two other forms of ending.

In the great majority of cases the lower end of the Rolandic fissure falls short of the fissure of Sylvius. In 19 per cent. of the same 52 hemispheres to which I have already referred, and which comprised a nearly equal number of male and female brains, a shallow connection

[1] *Schädel, Hirn und Seele*, p. 134, Jena, 1854.

[2] *Die Furchen und Wülste am Grosshirn des Menschen*, Berlin, 1879; also "Bemerkungen über die Faltungen des Grosshirns, &c.," *Archiv f. Psychiatrie*, Band viii. p. 244, Berlin, 1878.

[3] *Anatomische Studien an Verbrecher-Gehirnen*, Wien, 1879.

was established. The cases in which this was observed may be classified as follows:—

6 times on the right side.
4 times on the left side.
6 times in the male.
4 times in the female.
6 times in the adult.
4 times in children.

I may further state that although I examined 21 hemispheres of the new-born child, the connection was only present in one instance.

These results are very different from those which have been obtained both by Benedikt and Giacomini. The first of these authorities, in 38 hemispheres found a complete connection between the Rolandic fissure and the Sylvian fissure in eighteen cases, and an incomplete connection in other six.[1] Giacomini,[2] on the other hand, examined 336 hemispheres, and in only 21 of these was the communication present.

Eberstaller gives us what appears to me to be the true explanation of this occasional communication between the fissure of Rolando and the fissure of Sylvius. He points out that in most hemispheres a small variable tertiary furrow may be detected below the lower end of the Rolandic fissure. To this he gives the name of the inferior transverse furrow of the fissure of Rolando. It takes an oblique course upwards and forwards, and is usually separated from the under end of the fissure of Rolando by a superficial gyrus which connects the two central convolutions. Sometimes, however, the fissure of Rolando opens into the inferior transverse furrow, and in such cases the latter may appear as a transverse termination to the main furrow; or should the inferior transverse furrow be in connection with the Sylvian fissure, which it most frequently is, a direct communication between the Rolandic and Sylvian fissures is established. In either case, if the lips of the fissure of Rolando in its lower part be separated from each other, the superficial gyrus which intervenes between the two sulci under ordinary circumstances will be observed pressed down into the bottom. This marks the lower limit of the normal fissure of Rolando. Its shallow onward prolongation into the Sylvian fissure, or the transverse terminal branch, as the case may be, is in reality an additional element—the inferior transverse sulcus of Eberstaller. These facts I can verify in every particular. The connection between the fissure of Rolando and the inferior transverse sulcus is of late occurrence. In only one full-time fœtal hemisphere have I noticed it, and even in this the annectant gyrus was barely concealed within the fissure. On the other hand, at no time can one study more satisfactorily the inferior transverse sulcus than in the two last months of intra-uterine development. It is almost invariably

[1] *Anatomische Studien an Verbrecher-Gehirnen*, p. 96, Wien, 1879.

[2] *Varietà delle circonvoluzioni cerebrali dell' uomo*, Torino, 1882.

present, and it is almost always seen turning round the lower border of the operculum below the lower end of the fissure of Rolando (Pl. I. fig. 7, *a*.).

I believe that where the union between the fissure of Rolando and the inferior transverse sulcus takes place, it usually leads to a direct connection between the former and the fissure of Sylvius. In only four cases have I seen the deep annectant gyrus crossing the bottom of the lower end of the fissure of Rolando without such a connection being established.

In the Chimpanzee the deep annectant gyrus in the lower part of the fissure of Rolando, which indicates a union with the inferior transverse furrow, appears to be usually present. In only one out of four hemispheres in my possession is it absent. In the other three it is strongly marked, and in one of these there is a superficial connection between the fissure of Rolando and the fissure of Sylvius. Even in that hemisphere, in which there is no trace of the deep annectant gyrus, it appears likely that a fusion between the fissure of Rolando and the inferior transverse furrow has taken place, because the sulcus is not any shorter and it reaches as low down as in the case of the other hemispheres. The union, however, is of a more complete kind.

In the Orang, also, I find in two hemispheres a very distinct deep annectant gyrus crossing the bottom of the inferior part of the fissure of Rolando, and partially cutting off a small portion which probably represents Eberstaller's inferior transverse furrow. When I deal with the development of the fissure of Rolando I shall again have occasion to allude to this deep annectant gyrus, and to point out its importance from a morphological point of view.

Between its two extremities the fissure of Rolando pursues a sinuous course. Very seldom in the adult brain is it quite straight. As Eberstaller and others have shown, two of the bends, termed respectively the superior and inferior genua, are more conspicuous than the others. In typical cases these are placed at an equal distance from each other and from the two ends of the sulcus, so that they mark it out into three equal parts. The superior genu is usually much the weaker of the two and is directed backwards. The upper third of the fissure inclines downwards and slightly backwards. At the superior genu the sulcus bends suddenly in a forward and downward direction. The inferior genu is always strongly marked and looks forwards. Here the fissure again changes its direction and proceeds very nearly vertically downwards.

In almost every case the educated eye is able to detect these genua. Perhaps the most common deviation from the condition which we have described as being typical is one in which the central piece of the fissure of Rolando becomes considerably shortened and nearly horizontal in its direction. The two genua are thus more closely approximated, and the inferior may lie almost directly in front of the superior.

We have seen that when the lips of the fissure of Rolando are drawn widely asunder, a deep annectant gyrus is sometimes seen in its lower part. But this is not the only one which may be present. In the neighbourhood of the superior genu there is generally a marked shallowing of the fissure and a deep interlocking of its adjacent walls. Two of the interdigitating gyri—one projecting backwards from the anterior central convolution and the other forwards from the posterior central convolution—are always larger and more pronounced than the others, and in a considerable number of cases they unite at the bottom of the sulcus in the form of a distinct deep gyrus, which constitutes a marked interruption in its floor. All gradations between a mere shallowing with an interlocking of the adjacent walls of the fissure and the presence of a distinct deep annectant gyrus are met with. This is a point of considerable morphological importance, as we shall see later on.

In five Negro brains in my possession I find the deep annectant gyrus at the level of the superior genu present in each hemisphere. Not only is the condition more distinctly marked than in the European, but in one hemisphere, taken from a young Timanee Negress, the bridging gyrus is so strongly developed that it all but reaches the surface.

In the Chimpanzee this deep annectant gyrus appears to be commonly present. The four hemispheres which I possess show it in a pronounced form in each case. The Orang brain likewise gives evidence of the same condition, but not so distinctly. There is a slight shallowing of the fissure and an interlocking of the adjacent walls, but no distinct bridging gyrus.

In rare cases in the human brain the deep annectant gyrus in question rises completely to the surface and cuts the fissure of Rolando into two separate parts. I have never seen such a condition, although a very close approach to it is observed in one of my Negro brains. Wagner[1] described for the first time such an interruption of the Rolandic fissure in the brain of the celebrated physician Professor Fuchs. Heschl,[2] who examined no less than 2174 hemispheres, only found the anomaly in its complete form six times. Eberstaller met with it twice in 200 brains. It is therefore a condition of extreme rarity.

Development.—The results at which I have arrived regarding the development of the fissure of Rolando are based on the study of thirty-nine hemispheres which I have collected between the fifth and seventh months of development. I have also been supplied, through the kindness of Professor Victor Horsley, with photographs of the series of brain specimens in the Oxford Museum. Several of these show the fissure in its earlier stages.

[1] *Vorstudien zu einer wissenschaftlichen Morphologie und Physiologie des Menschlichen Gehirns als Seelenorgans*, 2 Abh., 1862, Tab. 1, s. 14.

[2] "Die Tiefen windungen menschlichen Grosshirns und die Uberbrückung der Centralfurche," *Wiener Medicinischer Wochenschrift*, 1877, No. 41.

The view which is generally entertained regarding the development of the Rolandic sulcus pictures it beginning as a slight furrow midway between the upper border of the hemisphere and the margin of the Sylvian fossa, and extending gradually and continuously in an upward and downward direction. That it may develop in certain cases this way I do not deny, but I have no direct evidence to show that it does so. In one somewhat advanced hemisphere—belonging to a brain approaching the seventh month—there is certainly an appearance which leads me to believe that the sulcus may have developed in the manner usually attributed to it. It is a clean-cut straight fissure, with its extremities equally distant from the superior border of the hemisphere and the Sylvian region; further, on breaking the hemisphere across in the line of the fissure, the latter is seen to present a uniform depth, and to be at no point interrupted by an elevation of the bottom.

There is some variability in the time at which the fissure of Rolando makes its appearance. The more usual time is the last week or ten days of the fifth month, but it is not uncommon to meet with hemispheres well on in the sixth month of development with no sign of the fissure.

As a general rule, the fissure of Rolando is developed in two separate and distinct pieces (Pl. I. figs. 3, 4, 6, r^1 r^2). The lower portion appears in the form of a shallow oblique groove, which represents the lower two-thirds of the fully-formed sulcus. It always makes its appearance before the upper piece (Pl. I. fig. 2). Its lower end is placed close to the coronal suture—perhaps, indeed, it may lie immediately subjacent to the suture—while the upper end lies further back, and reaches a point midway between the upper margin of the hemisphere and the Sylvian fossa. The upper piece of the fissure makes its appearance in the form of a deep pit or depression between the upper end of the lower portion and the margin of the hemisphere. An eminence separates the two portions of the fissure from each other. Soon, however, a faint furrow runs over the summit of this elevated intervening piece of the cortex, and the two primitive portions of the sulcus are partially united to each other (Pl. I. fig. 5, *r*). As development goes on the more complete does the union become, and the more fully is the intervening eminence borne down into the bottom of the fissure. As a rule the confluence takes place rapidly, but in many cases the process appears to be retarded. Amongst my specimens I have several hemispheres which, although close upon the seventh month, show still a complete severance of the two constituent elements of the furrow (fig. 6).

But the portion of cerebral cortex which intervenes between the two parts of the fissure is not entirely obliterated. It disappears from the surface, it is true, but it is still to be discerned, even in the adult brain, in the bottom of the fissure, in that shallowing or deep annectant gyrus which we have described at the junction of the upper and middle thirds of the sulcus. In some rare cases, as we have already stated, the two original portions of the fissure of Rolando remain quite distinct throughout life. In these the intervening bridge of cortex remains on the surface, and is not pressed down by the fusion of the upper and lower divisions of the fissure.

We have noted that the same deep annectant gyrus may be observed in the fissure of Rolando of the Chimpanzee and Orang. We may assume, therefore, that the interrupted form of development of this sulcus holds good amongst the anthropoid Apes as well as in Man. With regard to the lower Apes, we have no evidence one way or the other. The development of the fissures in the brain of the Ape is still virtually unknown; and if we examine the bottom of the fissure of Rolando and the other primary furrows in a low Ape we find a uniform depth throughout, and an absolute absence of deep annectant gyri. It is dangerous to argue from the adult condition alone, but still the appearances are such as would lead us to infer that the continuous and not the disrupted form of development of the primary fissures holds good amongst the lower Apes.

In Man and in the anthropoids the development of the fissure of Rolando is in every respect on a line with that of the other two radial "Primärfurchen" (viz., the praecentral and the intraparietal), the only differences being that it is unprovided with a horizontal part, and that its two vertical portions rapidly fuse with each other. In the case of the praecentral sulcus, the two vertical parts (viz., the praecentralis inferior and the praecentralis superior,) as a general rule remain apart. The intervening piece of cerebral cortex remains on the surface. The two vertical pieces of the intraparietal sulcus, on the other hand, usually run together, as in the case of the fissure of Rolando. In 26 per cent., however, of cerebral hemispheres they remain distinct; whereas the non-union of the two pieces of the Rolandic sulcus occurs in only 0·3 per cent.

But in Man, as we have observed, a third lower element may be added to the Rolandic fissure in the shape of the inferior transverse sulcus of Eberstaller. In the anthropoid Ape the connection of this element with the main furrow appears to be much more intimate than in Man. Of course, in Man it cannot be placed on the same footing as the other two elements, seeing that it appears so much later (eighth month), and that it may establish other connections besides that with the Rolandic sulcus.

As I shall point out further on, the fissure of Rolando is very much longer in the anthropoid Ape than in Man. If we represent the length of the fissure of Rolando in the human brain by the number 100, we find that in the Chimpanzee it is 130, and in the Orang 120. It appears to me, therefore, not improbable that this lower element, so variable and inconstant in its present connections, may have had at one time a closer association with the fissure of Rolando in Man. In all the anthropoid hemispheres in my possession, with one exception, the lower piece of the fissure of Rolando is partially cut off by a deep annectant gyrus.

It is not uncommon to find the lower piece of the praecentral fissure developed in the earlier part of the fifth month, prior to the appearance of the fissure of Rolando. I have six hemispheres which show this condition, and under these circumstances the praecentral sulcus is very apt to be mistaken for the fissure of Rolando. Its position in front of the middle of the hemisphere and in front of the coronal suture should, in all cases, enable us to detect its true nature (fig. 1, *p.c.i.*). At the same time, I may mention that it was not until I had obtained two hemispheres belonging to this early period, in which the fissure in question was strongly marked, and in which also there was a slight trace of the fissure of Rolando, that I was thoroughly satisfied as to its identity. I have never seen the third radial "Primärfurche" or intraparietal sulcus appear before the Rolandic sulcus.

The inferior genu of the fissure of Rolando always makes its appearance before the superior genu. About the seventh month it is usually well marked. This is exactly what one might expect, seeing that amongst the lower Apes the inferior genu alone is, as a rule, developed. In one specimen this genu is quite distinct upon the inferior piece of the fissure before it has joined the upper piece (fig. 3, r^1). As a general rule, however, the fissure remains straight until the union of its two elements is complete. The superior genu is developed at the point of junction, and it is not until a later period that it assumes any degree of prominence.

The upper end of the fissure of Rolando does not overstep the upper border of the hemisphere until the beginning of the last month of intra-uterine development. In the eighth month it just reaches the margin, and I have several specimens which show it in the process of turning over and in the process of developing the backward bend of its upper extremity.

From the seventh month onwards the growth of the two bounding banks of the fissure does not proceed at an equal pace. There appears to be a greater growth-energy in the posterior central convolution, and this leads to a partial overlapping of the ascending frontal convolution by the ascending parietal convolution. Heschl and Eberstaller have called attention to this. It is more obvious in the lower two-thirds of the fissure, or, in other words, opposite that portion of it which is formed by the lower element. It is owing to this that the adult fissure cuts into the cerebral surface in an oblique direction from before backwards.

Topography.—Since the time when Broca[1] in France, Turner[2] in this country, Hefftler[3] in Russia, and Bischoff[4] in Germany demonstrated the relation of the cerebral fissures and convolu-

[1] Sur le siége de la faculté du langage articulé," *Bull. de la Soc. Anatomique*, 1861.

[2] "On the Relations of the Human Cerebrum to the Outer Surface of the Skull and Head, *Jour. Anat. and Phys.*, 1873.

[3] "Izviliny golovnavo mozga ou tchelovieka i otnochenia ich k'svodou tcherepa," *Dissertation inaugurale chirurgicale à l'acad. med. chir. de St Petersburg*, 1873.

[4] *Die Grosshirnwindungen des Menschen*, &c., Munich, 1868.

tions to the surface of the cranium, an enormous amount of work has been done in this department of anatomy. Foulhouze[1] first called attention to the conditions which exist in this respect in children, and he was followed in this field by Féré,[2] Symington,[3] and others. The two latter observers have also made some observations on the position of the fissure of Rolando in the fœtus.

As a rule, each observer, in determining the position of the various cerebral sulci, has adopted a method of his own. In France, Broca's plan of introducing pegs through the cranium into the cerebrum, and then removing the brain, has been almost universally adopted. Bischoff independently employed the same means. Turner and Hefftler examined the brain *in situ*—a proceeding which is certainly very much to be preferred. Symington, and to a certain extent Féré, arrived at their conclusions by sections through the frozen head.

In my endeavours to arrive at accurate results regarding the topography of the fissure of Rolando, I have employed several different methods; but throughout the entire investigation I have recognised that the most reliable measurements could only be obtained from the brain while still within the cavity of the cranium. It would be impossible on the present occasion to indicate with any degree of detail the methods which I have pursued. In the case of fœtal brains, I removed in the first instance the parietal bone and subjacent dura mater on one side, and then mapped out the area on the surface of the cerebrum covered by this bone by inserting small pins at short intervals from each other. Féré adopted very much the same plan, but as he only sought to determine the absolute distance of the fissure of Rolando, the parieto-occipital fissure, and the Sylvian fissure from the coronal, lambdoid, and squamous sutures, he made his measurements on the fresh head. When the pins were accurately adjusted, I transferred the entire head into a chloride of zinc bath and afterwards into alcohol. This plan gave admirable results. Of course the cerebrum was considerably reduced in bulk, but the shrinkage was uniform; and as it was relative and not absolute results I desired, the diminution in bulk was not a matter of any consequence.

In the case of children and adults, models were made of the head, with the brain exposed *in situ*, by the method described in a previous number of this *Journal*.[4] Latterly some important modifications

[1] *Recherches sur les Rapports Anatomiques du Cerveau avec la voute du Crane chez les enfants*, Paris, 1876.

[2] Amongst a number of important papers published by Féré, we may specially mention, as bearing particularly on the present research, "Sur le développement du cerveau considéré dans ses rapports avec le crane," *Revue d'Anthr.*, 1879.

[3] *Topographical Anatomy of the Child*, Edinburgh, 1887.

[4] "Proceedings of the Anatomical Society," *Jour. Anat. and Phys.*, vol. xxii., April 1888, p. xiii.

upon the plan as it was originally described were adopted, but it is unnecessary to go into these at present. Twenty-eight models of the human head and of the head of the Ape were in this manner prepared, but it was a very laborious undertaking, and could only be carried out on a comparatively small number of individuals. It was therefore found to be necessary to supplement the facts obtained in this way by others acquired by a less lengthy process.

In dealing with young subjects and young Apes, in which the sutures are open, and in which, along the lines of union between the bones, the dura mater and periosteum stand in direct connection, I found that by simply removing the calvaria the pattern of the coronal and lambdoid sutures could easily be detected on the surface of the dura mater. Small pins were introduced into the cerebrum along these sutural lines, and the brain was either hardened *in situ* without removal of the dura mater, or it was at once extracted and plunged into a chloride of zinc bath.

There is still another plan which afforded excellent results. One half of the cranial vault was removed with the saw by a vertical cut a little to one side of the mesial plane, and a transverse cut a short distance below the highest point of the squamous suture. The cerebral hemisphere of that side was then removed, and the head placed so that it rested upon the opposite side. The falx cerebri was next detached, and the mesial surface of the hemisphere still in position exposed. Upon this it was easy to recognise the upper end of the fissure of Rolando from its position in relation to the upturned extremity of the calloso-marginal sulcus. The point at which the fissure of Rolando turns over the upper margin of the hemisphere being determined, a peg was here driven through the skull from within outwards and the remaining hemisphere removed. The falx cerebri was then stitched back in its place, so as to give the proper amount of tension to the tentorium, and a cast of the interior of the cranium taken. The peg, which projected slightly into the interior of the cranium, marked on the cast the position of the upper end of the fissure of Rolando, and before drawing the cast the sutural lines were mapped out on its surface by driving an awl through the skull at short intervals. The great disadvantage of this method is that it only gives us information regarding the topography of the fissures along the upper margin of the hemisphere.

But it was impossible to note the sutural relations in every instance. Time would not allow of it. A large number of my measurements have consequently been made upon brains removed from the cranial cavity. In every case, however, they have in the first instance either been carefully hardened *in situ* or plunged at once into a chloride of zinc bath, and thus fixed in their natural shape.

The points in the topography of the fissure of Rolando which I have chiefly endeavoured to arrive at are the following:—

1. The relative distance of the upper extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.
2. The relative distance of the lower extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.

To express these relations clearly, it is necessary to construct four indices, which may be respectively termed the mesial fronto-Rolandic, the mesial corono-Rolandic, the lateral fronto-Rolandic, and the lateral corono-Rolandic. In calculating the mesial indices the length of the upper margin of the hemisphere, measured by the tape from its anterior to its posterior end, is taken as the standard, and equal to 100; and in the case of the lateral indices the length of the cerebrum measured over its lateral surface between the same points is taken as the standard and equal to 100.

But in determining the length of the cerebrum, either along its upper border or its lateral surface, it is absolutely essential that the points between which the measurements are taken should be rigidly adhered to throughout, and it is by no means an easy matter to select points which are in every respect satisfactory. Eberstaller measures from the inner angle of the trigonum olfactorium to the point where the occipital lobe first touches the tentorium. There cannot be a doubt that this is a good method, and one which is calculated to give accurate results; but both of his points are on the under surface of the brain, and consequently it is impossible to adopt his plan when the brain is being measured *in situ*. I have been forced therefore to select different points from which to make my measurements. In front I fixed upon a point which corresponds to the level of the outer part of the superciliary margin of the frontal lobe. This border is very far from being horizontal. Its outer part is on a much higher level than the inner part. As it is traced inwards it is seen to take a sudden curve downwards towards the cribriform plate of the ethmoid bone, where it merges with the mesial border. A line drawn horizontally inwards from the high outer part of the superciliary border of the frontal lobe cuts the mesial border of the cerebrum at the point which I arbitrarily selected as the anterior end of the cerebrum. It lies, as a rule, just below the most projecting part. Behind I took the most prominent part of the occipital pole.

The upper end of the fissure of Rolando presented another difficulty. As we have noted, this usually cuts the upper border of the hemisphere, and I have always measured to the point at which it reaches this margin. But there are cases in which it falls short of the upper border of the hemisphere, and then it usually bends suddenly backwards for a short distance. In these cases I have measured to the angle of bending, and my reason for selecting that point is simply this : that even when the fissure reaches the mesial surface of the hemisphere we, as a general rule, see the same backward inflexion of its extremity, and the angle of bending corresponds with the point where it cuts the upper border of the hemisphere.

The following Table gives the average results of my measurements:—

Topography of the Fissure of Rolando in the Human Cerebrum.

Age.		Number of Hemispheres Measured.	Mesial Indices.		Lateral or Lower Indices.	
			Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
Intra-uterine Life.	5½–6½ months,	8	51·2	9·9	41·8	5·6
	6½–7½ ,,	6	52·9	11·9	43·2	3·6
	7½–8½ ,,	17	54·6	17·2	42·8	9
	Full-time fœtuses, .	18	53·5	18·2	42·6	10·7
Extra-uterine Life.	3 months, .	5	52·8	18·6	43·3	12·8
	6 ,, .	4	50·6	14·4	42·2	8·6
	12 ,, .	3	50·6	13·6	42·3	5·1
	4–5 years, .	14	52·6	16·5	43·3	11·3
	11–15 ,, .	6	51·8	16·1	42·3	8·8
	Adults, . .	37	52·7	16·7	43·3	12·9

The corono-Rolandic distance was not measured in every case, and therefore the average results for the corono-Rolandic indices which are given above are not based upon so large a number of measurements as in the case of the fronto-Rolandic indices.

This Table speaks for itself, so that little need be said about the various items which compose it. One point is very remarkable, and that is the constancy in the position of the fissure of Rolando on the surface of the cerebrum throughout all stages of growth. It will be seen on glancing at the fronto-Rolandic indices that the changes which it undergoes in its position from the time that it first appears on the surface of the cerebrum up to adult life are very slight indeed. Its lower end, as might be expected from the fact that it is first formed, shows the slightest change. As development and growth proceed it moves back slightly, but only to an almost inappreciable extent. When it first appears the lower fronto-Rolandic index is 41·8, but in a few weeks it soon establishes its proper relations, and from this time on it fluctuates between 42·2 and 43·3. These fluctuations can hardly be regarded as indicating differences of position at different periods of growth. If larger numbers of brains were examined, I am satisfied that they would disappear altogether.

The upper end of the fissure of Rolando is not so fixed in its relations at different periods of life. From the time that the fissure first appears there seems to be a tendency for the upper end to move backwards. At first the upper fronto-Rolandic index is 51·2. This increases steadily until the full period of intra-uterine life is nearly reached, when it is found to have mounted up to 54·6. No doubt this is brought about by an accelerated growth of the upper part of the frontal lobe during the period of the change. From the time of birth up to the third month the upper end of the fissure of Rolando moves in the opposite direction until the index of 52·8 is reached, and here it remains fixed. This is the position which I believe it holds ever afterwards. I do not lay any importance on the low indices seen in the Table in connection with the 6 months', 12 months', and 11 to 15 years' hemispheres. The number measured was too small to allow us to base any generalisation upon the indices which they afford us.

The position of the fissure of Rolando to the coronal suture at different periods of growth must next engage our attention. This is expressed in the series of upper and lower corono-Rolandic indices in the foregoing Table. We have seen that the position of the fissure of Rolando on the surface of the brain is subject to very slight alterations, and that in all probability we may consider that it becomes absolutely fixed at the third month of extra-uterine life. Very different, however, are its relations to the coronal suture at different periods in its history. The figures obtained, it is true, are somewhat puzzling and difficult to interpret, but one point is perfectly clear, and it is this:—The parietal bone and the area of brain immediately subjacent do not grow at an equal pace. In the early stages of its development the fissure of Rolando lies close to the coronal suture, but this does not mean that it lies far forward on the brain, but simply that the parietal bone forms at a later stage a relatively greater extent of the cranial vault. The maximum amount of the frontal lobe (the district in front of the fissure of Rolando) covered by the parietal bone is reached at the third month of extra-uterine life. The upper corono-Rolandic index at this period is 18·6 and the lower 12·8. From this stage on the coronal suture in its upper part falls back a little, and after a slight oscillation it assumes, at the fourth or the fifth year of childhood, a fixed position with reference to the fissure of Rolando. This is expressed by the index 16·5. The lower end of the suture shows changes in its position with reference to the fissure of Rolando which are less easy to understand. I can hardly believe that the oscillations which are exhibited in the lower corono-Rolandic indices give expression to the usual growth changes. To arrive at the standard of growth, a much larger number of heads would require to be examined than I have had at my disposal. One point, however, is rendered evident, viz., that the relative position of the coronal suture to the lower end of the fissure of Rolando is subject to very considerable variations.

Before leaving this branch of my subject it is necessary to take note of the work which has been done in the same field by Hamy, Foulhouze, Féré, and Symington.

In an article published in 1872, Hamy makes the following extraordinary statement:[1]—"Chez de jeune enfants dont la ligne suturale qui vient d'être nommé différait assez peu dans son inclinaison de celle de l'adulte, nous avons constaté que le sillon de Rolando *passait en avant* de l'articulation, de telle sorte que l'os frontal, dans ses parties laterales et inférieures, se trouvait recouvrir une petite étendue du lobe pariétal." This supposed forward position of the lower end of the fissure of Rolando he seeks to associate with the feeble development in the infant of the third frontal convolution. It is all the

[1] *Revue d'anthropologie*, p. 428.

more necessary to contradict this statement, seeing that Schwalbe appears to give some credence to it and has given it a place in his standard work on "Neurologie" (p. 575). As we have noted, the fissure of Rolando at no stage of its development lies in front of the coronal suture. In two instances I have seen the lower end just touching the sutural line, but these were cases in which it was in its earliest stage, prior to the development of its upper piece.

Foulhouze examined a large number of subjects of different ages, but although he brings out many important details in connection with the cranio-cerebral topography of the child, he only gives us absolute measurements, and consequently they have little bearing upon the present research. Féré, also, in a paper already quoted, furnishes us with much valuable information regarding the topography of the fissure of Rolando. He refuses to believe the views put forward by Hamy, and states that in all cases the fissure of Rolando lies behind the coronal suture. He only gives absolute measurements, and he seems to regard the coronal suture as being more fixed in its position than the fissure of Rolando. Symington was also led to doubt the accuracy of Hamy's statements.

I shall now give a Table which shows the position of the fissure of Rolando in the Ape, both in relation to the cerebral surface and the cranial wall. I have in my possession a very large series of facts in connection with this branch of the inquiry, but on the present occasion I limit myself to the anthropoid Ape, and only introduce one of the lower Apes for purposes of comparison.

Topography of the Fissure of Rolando in the Ape.

	Hemispheres Examined.	Upper Indices.		Lower Indices.	
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
Chimpanzee,	4	55·7	16	39·2	7·5
Orang,	4	55	20·7	39·2	11·1
Hamadryas,	1	50	13·3	42·1	5·2

Briefly stated, the following are the more interesting points which are brought out by this Table:—(1) In the Hamadryas the position of the Rolandic fissure, both in its relation to the cranium and the surface of the cerebrum, approach those seen in the early stages of the development of the fissure in Man.

(2) In the anthropoid Apes the upper part of the frontal lobe is more extensive, whilst the lower part is less extensive than in Man. (3) In the Chimpanzee the upper corono-Rolandic index is in accord with the corresponding index in Man, whereas in the Orang it is very different.[1]

Huschka, in his remarkable work entitled *Schädel, Hirn und Seele*, published in 1854, contends that marked sexual differences can be detected in the human cerebrum. He asserts that in the male a relatively greater mass of the hemisphere lies in front of the fissure of Rolando, whilst in the female a greater mass lies behind it. To use his own words—"Das weib ist ein *homo parietalis* und *inter-parietalis*, der Mann ein *homo frontalis*." Rüdinger[2] gives expression to somewhat similar views. He insists strongly upon the early appearance of sexual differences in the brain of the fœtus and new-born child, and specially mentions that "in the majority of male fœtal brains the frontal lobes appear more massive, broader, and higher than in the female." More recently Passet,[3] under the direction of Rüdinger, returns to the subject, and gives the results which he has obtained from an extended series of brain measurements. He comes to the conclusion "that the fissure of Rolando, relatively as well as absolutely, lies farther back in the male than in the female—or, in other words, that more brain matter lies in front of the fissure of Rolando in the male than in the female." He considers, however, that Huschka has somewhat overstated the sexual differences. Passet illustrates his views by a very ingenious diagram.

Eberstaller has gone into this question, in so far as it concerns the adult, with his usual care and thoroughness. He measured no fewer than 270 hemispheres (viz., 94 female and 176 male), and he found that the upper end of the fissure of Rolando occupies relatively the same place in the two sexes; what difference there is (0·5) is in favour of the female frontal lobe. It is to be regretted that he gives no measurements which would enable us to locate the lower end of the sulcus in the two sexes.

The results which I have obtained for the adult brain agree in every respect with those of Eberstaller, and I would add to

[1] I should mention here that I have measured six Chimpanzee hemispheres, and in four of these determined the corono-Rolandic indices. Two of the latter I have not introduced into the above Table on account of the very anomalous relationships which the fissure of Rolando presented. I shall not describe these at present, but merely state, that on both sides the fissure of Rolando was placed very much in front of its usual position. Further, its lower end lay in front of coronal suture. This brain will afterwards be described in full.

[2] *Über die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fœtus und Neugeborenen*, München, 1877.

[3] "Ueber einige Unterschiede des grosshirns nach dem Geschlecht," *Archiv f. Anthrop.*, May 1882.

what he has stated—(1) that the lower end of the fissure of Rolando also holds relatively the same place on the cerebral surface in the two sexes; and (2) that at no period of growth does the fissure of Rolando exhibit in its position what we might safely regard to be sexual differences.

The following Table gives the relative position of the fissure of Rolando at different periods of life in the two sexes:—

Topography of the Fissure of Rolando in the Two Sexes.

Age.	Number of Hemispheres Examined.	Upper Indices.		Lower Indices.	
Males.					
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
7½–8½ months,	5	54·5	16·3	44·2	9·6
Full-time fœtuses,	14	53·5	18·1	42·6	11·1
4–5 years,	8	52·3	16	43·1	10·1
Adults,	17	52·6	16	43·7	12·1
Females.					
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
7½–8½ months,	12	54·6	17·8	42	8·7
Full-time fœtuses,	4	53·7	18·5	42·8	9·6
4–5 years,	6	53·8	17·6	43·8	13·7
Adults,	20	52·9	17·5	43	13·9

Eberstaller, as we have mentioned, has shown that in the adult, if there is any sexual difference, it is one in favour of the frontal lobe of the female. It is curious to note that the above Table shows the same in each period of growth, but the differences are extremely trifling. This is interesting in the light of what we have already noted in connection with the upper end of the fissure in the anthropoid Ape. But there is one point which this Table brings out which appears to me to be a matter of some importance. It will be seen that the area of the frontal lobe covered by the parietal bone is relatively greater in the female than in the male. The corono-Rolandic index shows this. The fissure of Rolando is therefore situated at a relatively greater distance from the coronal suture than in the male.

Rolandic Angle.—By the "Rolandic angle" I mean the angle which is formed by the meeting of the upper end of the sulcus with the mesial plane. If we were to divide a cerebral hemisphere into an anterior and posterior portion along a line stretching from the point where the sulcus oversteps the upper border of the hemisphere to the lower end of the fissure, the angle which would then be formed by the cut surface of the anterior segment and the mesial surface would constitute the Rolandic angle.

Several authors have sought to establish a sexual distinction by means of this angle. Huschka remarks: "On an average the fissure of Rolando, with its bounding central convolutions, stands more perpendicularly in the female than in the male." Rüdinger says: "The more transverse direction of the fissure of Rolando, and the bounding central convolutions, appears in the female fœtal brain a striking arrangement. But as the oblique direction of the central convolutions in the female fœtal brain, and the transverse in the male, likewise occur, I might provisionally entertain the supposition that these differences might be produced less through sex than through differences in the shape of the head." His pupil, Passet, is less cautious, and states dogmatically that "the angle which the fissure of Rolando forms with the mesial plane is greater in the female and approaches more nearly to a right angle than in the male; in other words, the male fissure of Rolando, on an average, courses somewhat more obliquely from above downwards and outwards than in the female." This author represents the average male angle to be 60°·9, and the average female angle as 64°·2. More recently Dr Josef Victor Rohon,[1] another worker in the laboratory of Professor Rüdinger, goes so far as to assert that the same sexual distinction in the angle of Rolando may be detected in the Chimpanzee.

Giacomini gives the angle of the fissure of Rolando as varying from 57°·5 to 62°·5, whilst Hare,[2] who measured it *in situ*, found it to vary from 60° to 73°, the average being 67°. Eberstaller, on the other hand, who examined no less than 300 hemispheres, states that the Rolandic angle varies from 70° to 75°, and that he could discover no sexual difference in this respect.

[1] *Zur Anatomie der Hirnwindungen bei den Primaten*, München, 1884.

[2] "The Position of the Fissure of Rolando," *Jour. Anat. and Phys.*, vol. xviii. p. 717.

To measure this angle correctly is a matter of very great difficulty, and therefore we need not be surprised that the various authors I have quoted should have arrived at such divergent results. A very simple instrument, which I had constructed for the purpose, enabled me, I believe, to measure the angle accurately. The following are the results I obtained:—

Rolandic Angle.

	Age.	Number of Hemispheres.	Average Angle in Males and Females.	Males.			Females.		
				Number of Hemispheres.	Average Angle.	Average Cephalic Index.	Number of Hemispheres.	Average Angle.	Average Cephalic Index.
Intra-uterine Life.	5½–6½ months,	8	73°·6	...	...	...	...	...	...
	6½–7½ „	6	73°·5	...	...	...	...	...	...
	7½–8½ „	16	70°·8	5	74°·4	...	11	69°·3	...
	Full-time fœtuses, .	16	70°·6	13	70°·1	...	3	73°	...
Extra-uterine Life.	First 12 mths,	9	70°·6	...	...	...	9	70°·6	76·2
	4– 5 years, .	5	70°·6	4	70°	77·7	1	73°	81·5
	11–15 „ .	7	70°·1	4	71°·2	76·1	3	69°	74
	Adult, . .	8	71°·7	3	73°·6	79·7	5	71°·7	74
	Chimpanzee, .	4	68°	...	...	...	...	...	...
	Orang, . .	4	68°	...	...	...	...	...	...
	Hamadryas, .	1	71°	...	...	...	...	...	...

From the above Table it would appear that the average Rolandic angle may be regarded as being 71°. The results which I have obtained in this respect closely correspond with those stated by Eberstaller. Further, it will be observed that this angle is attained as early as the eighth month, and is maintained from this period up to adult life—another remarkable instance of the fixity of the fissure of Rolando, once its preliminary development is fairly established. In the first two months of its existence the Rolandic fissure presents a more open angle with the mesial plane. It traverses the surface of the hemisphere in a more transverse direction (73°·6), and this is quite in keeping with what we have already stated as to its topography. Hamy, in a paper already referred to, contends that in the young subject the Rolandic angle is only 52°, whilst in the adult it is 70°, and he seeks to associate this with the development of the third frontal convolution. It is needless to say that there is no foundation whatever for this statement.

Nor is there anything in the angle of the fissure of Rolando by which we could establish sexual distinctions. I quite agree with Eberstaller in this. The above Table shows differences, it is true, but the increase or diminution of the angle is as often found on the one side as the other. How can we account for these? Rüdinger was not far from the truth when he hinted that the form of the head might have some influence in this direction. Any one who studies the average cephalic indices which I have introduced into the table will see that the angle increases and decreases with the rise and fall of the cephalic index. In brachycephalic heads the angle is more open than in dolichocephalic heads. In the first twelve months of extra-uterine life all the specimens I possess are females. Collectively they present the average angle of 70°·6, but if we analyse the various items which go to form the whole, we find three hemispheres with an average angle of 67°·7, and the unusually low cephalic index of 71, whereas the others gave an average angle of 73° and an average cephalic index o f 79.

It is right to state that the results obtained by Mr Hare do not coincide with this view, and from the fact of his measurements having been made upon the brain *in situ* I attach a high importance to them. In five dolichocephalic heads the average angle was 68°·6, whilst in six brachycephalic heads it was 66°·6.

Length of the Fissure of Rolando.—Passet has endeavoured to prove that the fissure of Rolando is both relatively and absolutely longer in the male than in the female, and Rohon believes that the same sexual distinctions may be detected in the Chimpanzee. The absolute length of the fissure is of no importance, because this will vary with the absolute size of the brain, and therefore the increase in length in the male is what might naturally be expected. In order to get at the relative length, it is necessary to have some standard wherewith we may compare

[1] Welcker, Broca, and Calori hold that the head of the female is more dolichocephalic than that of the male. If this be the case, we would expect to find a more acute Rolandic angle. Weisbach, Arnold, and Mantegazzi, on the other hand, consider that it is the male head that shows the greatest amount of dolichocephaly.

it. As the most convenient standard I have taken the total length of the hemisphere measured by the tape along its superior border. This we shall regard as being equal to 100. The fissure was measured by a thread introduced between the lips of the fissure and following accurately all its flexures.

My results are very different from those obtained by Passet. It appears to me that three circumstances affect the length of the fissure:—(1) the depth of the portion of the cerebrum which lies above the Sylvian fissure; (2) the degree of flexuosity of the fissure; and (3) the union or non-union of the fissure with the inferior transverse furrow of Eberstaller. The following are my results:—

Length of the Fissure of Rolando.

Age.		Number of Hemispheres.	Average Relative Length (Male and Female).	Males.		Females.	
				Number of Hemispheres.	Average Relative Length.	Number of Hemispheres.	Average Relative Length.
Intra-uterine Life.	5½–6½ months,	8	16·7	...	...	...	...
	6½–7½ ,,	6	25·1	...	...	...	...
	7½–8½ ,,	10	35·4	2	29·7	8	36·8
	Full-time fœtuses, .	11	32·8	10	33	1	31
Extra-uterine Life.	First 12 mths,	8	35·8	...	...	8	35·8
	4– 5 years, .	7	33·9	5	33·4	2	38·5
	11–15 ,, .	6	36·1	4	33·7	2	38·9
	Adult, . .	30	39·3	14	38·6	16	40·1
	Chimpanzee, .	4	51·1	...	...	...	...
	Orang, . .	4	47·2	...	...	...	...
	Hamadryas, .	1	41·1	...	...	...	...

There are several points brought out by this Table which at present I do not pretend to understand, and consequently I shall not enter into them; but it is clear that if there is any sexual distinction in the length of the fissure, it is quite in the opposite direction from that stated by Passet and Rohon.[1] The

[1] In all probability it will be shown that the length of the fissure is greatly affected by the shape of the head. I have material in my possession for determining this point, but as yet I have not had an opportunity of working it up.

great relative length of the anthropoid fissure is very remarkable. This is partly explained by the fact that in the anthropoid Ape there is relatively more brain substance above the fissure of Sylvius than in man, in the proportion of 73 to 68. Further, the anthropoid fissure is more flexuous.

EXPLANATION OF PLATE I.

The figures in this plate have been drawn on the stone directly from photographs. Fig. 7 is considerably reduced; the others are the size of nature.

Fig. 1. Lateral surface of right hemisphere in the earlier part of the fifth month. The area of the parietal bone is indicated by shading. The inferior praecentral fissure (*p.c.i.*) is in position, and simulates the fissure of Rolando. Note its position in front of the coronal suture. *e.p.*, external perpendicular fissure of Bischoff.

Fig. 2. Lateral surface of a hemisphere approaching the sixth month of development. The lower piece of the fissure of Rolando is developed, and lies entirely behind the coronal suture. Area of the parietal bone indicated by shading.

Fig. 3. Lateral surface of a left hemisphere approaching the seventh month of development. The two pieces in which the fissure of Rolando is developed (r^1 and r^2) are well seen. The lower piece (r^1) is seen in the form of a groove, in which the inferior genu is already developed; whilst the upper piece (r^2) shows in the form of a pit. *p.*, intra-parietal sulcus of Turner; *p.c.i.*, sulcus praecentralis inferior; *p.c.s.*, sulcus praecentralis superior.

Fig. 4. Right hemisphere at a stage of development slightly in advance of that shown in fig. 3. Lettering the same.

Fig. 5. Hemisphere close upon the seventh month. It shows the stage in the development of the fissure of Rolando where the two pieces of the sulcus have united. Still a shallowing at the place of union may be seen. The area of the hemisphere covered by the parietal bone is indicated by shading. *r.*, fissure of Rolando; *p.c.*, sulcus praecentralis; *p.*, intra-parietal sulcus of Turner.

Fig. 6. Hemisphere close upon the seventh month of development. From a photograph of a specimen in the Oxford Collection. r^1, lower piece of the fissure of Rolando; r^2, upper piece of the sulcus of Rolando; *p.c.i.*, praecentralis inferior; *p.c.s.*, praecentralis superior; f^1, superior frontal; *p.*, intra-parietal sulcus of Turner; p^1, ramus verticalis inferior; p^3, ramus horizontalis; p^4, ramus occipitalis; *e.p.*, external perpendicular fissure of Bischoff; *p.l.*, parallel sulcus.

Fig. 7. Hemisphere between the eighth and ninth months of development. From a photograph of a specimen in the Oxford Collection. *a.*, inferior transverse furrow of Eberstaller.

[illegible] relative length of the anthropoid fissure is very considerable. This is partly explained by the fact that in the anthropoid the there is relatively more brain substance above the fissure [illegible] than in man, in the proportion of 73 to 63. Further, the anthropoid fissure is more flexuous.

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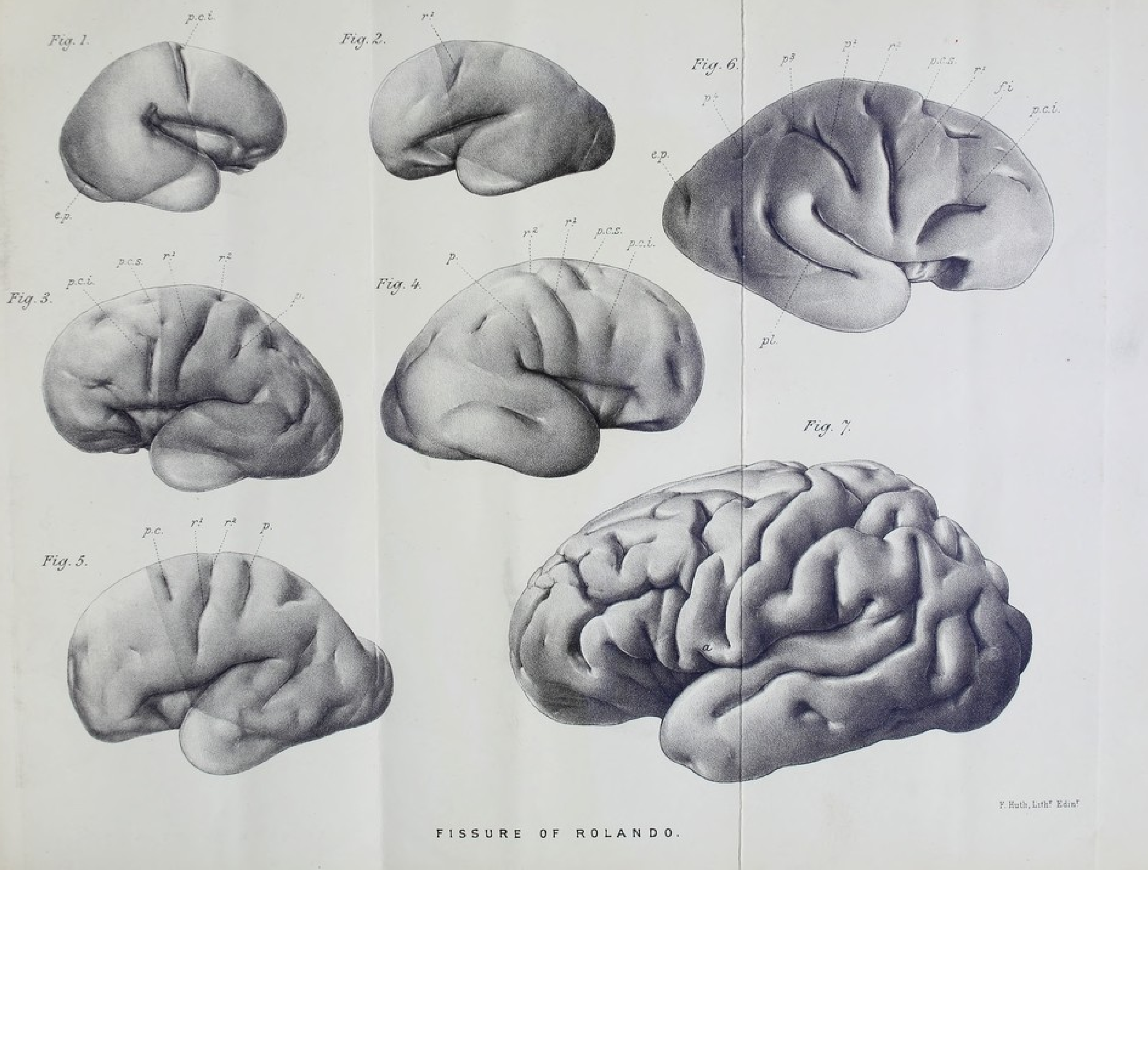
Fig. 6. Hemisphere close upon the seventh month of development. From a photograph of a specimen in the Oxford Collection. r', lower piece of the fissure of Rolando; r'', upper piece of the sulcus of Rolando; p.c.i., praecentralis inferior; p.c.s., praecentralis superior; [illegible]; i.p., intraparietal sulcus of Turner; [illegible], sulcus [illegible]; [illegible], sulcus [illegible]; [illegible], sulcus [illegible]; e.p., external perpendicular fissure of Bischoff; p.o., parieto-occipital.

Fig. 7. Hemisphere between the eighth and ninth months of development. From a photograph of a specimen in the Oxford Collection. [illegible] outline of the bones of the cranium.



F. Huth, Lith. Edin.

FISSURE OF ROLANDO.