II. *The Convolutional Pattern of the Brains of Identical Twins: a Study on Hereditary Resemblance in the Furrows of the Cerebral Hemispheres.*

By F. Sano, *M.D.* (*Brussels*), *Physician in Chief of the Asylum for Acute Mental Cases at Antwerp* (*Belgium*).

Communicated by Prof. F. W. Mott, *F.R.S.*

(From the Pathological Laboratory, London County Asylums, Maudsley Hospital, Denmark Hill, S.E.)

(Received March 1,—Read March 16, 1916.)

Contents.

1. Introduction.

The study of the similarity of the convolutional pattern of the brains of relatives has been the subject of considerable attention in the Pathological Laboratory at Claybury, under the direction of Dr. F. W. Mott. At his request Dr. Fisher has been forwarding to the Laboratory a number of fœtuses and children born dead that have occurred in his practice at Shoreditch Infirmary. It has thus happened that full term identical twins came into Dr. Mott's possession. Realising the scientific value of a correct description of the similarity of the convolutional pattern in the brains of these twins, he has handed them to me and I have carefully studied the same on the lines previously adopted by Schuster in his description of the brains of relatives dying in the London Asylums. I have also made a study of the nervous plexuses and other morphological points of interest.

I have been able to give my whole attention to laboratory research owing to the liberal grant made by the Medical Research Committee, and this study is a small part of the work which I have accomplished during the last year. But it was thought by the Director to be of sufficient scientific interest to present to the Royal Society, especially having regard to its being a morphological contribution to the important observations of the late Sir Francis Galton on the history of twins.

2. Description of the Leading Characteristics of the Two Bodies.

The male twins were stillborn at full term, unlucky war babies of healthy parents.

Upon first examination hardly any differences could be observed between the two well developed, well nourished, quite healthy bodies, although A seemed a little smaller than B. As stated below the measurements confirmed this opinion, and a closer investigation gave the following details :—

—	Weight of the brain.	Weight of the body without brain and calvaria.	Length from seventh cervical vertebra to the anus.	Chest circumference.	Whole length of the body (approximately).
	grm.	grm.	cm.	cm.	cm.
A . . .	420	2375	23	28	50
B . . .	460	2545	24	30	51

The boy called A has a more receding forehead ; the nose is more turned up ; the distance between the root of the nose and the superior border of the upper lip smaller (6·5 mm. *v.* 8 mm.), hence the mouth remains more open. The chin is more receding. The ear of A is closer to the head, has very little enrolment of the border, and its lobule is adherent, while the second boy's ear is more unfolded and graceful (*vide* fig. 1).

There is no noticeable difference between the hands of both twins, but B has larger feet than A, and his toes are more spread out, while those of A are overlying irregularly. The whole of the foot in A is 3 mm. less than the foot in B.

The whirl-point of the hair is on the right occipital region in A and on the left in B. There is very little difference in pigmentation. A is a little darker and has more hair than B, but there is no difference in the iris pigmentation, which is rich and equal in the four eyes.

The pattern of the furrows on the finger tips cannot be determined. The lines on both palms of hands and soles of feet are similar, although the secondary lines are more marked in B.

The heart of A is a little smaller than that of B. The arch of the aorta and the main vessels did not show any abnormality nor any differences.

No differences were found in the main visceral organs, in the lobes of the thymus, lungs, liver, spleen, kidneys. The length of the appendix was exactly the same in both cases.

As I have previously called attention to the variations of the phrenic nerve,* I examined its apparent origin on both sides in both boys ; evidently in A the origin

* 'Journal Médical de Bruxelles,' October, 1898, and "Localisation des Fonctions Motrices dans la Moëlle Epinière," 'Rapport Congrès des Aliénistes et Neurologistes Français,' Pau, 1904.

was symmetrical in the third, fourth and fifth nerve roots; in B symmetrical in the fourth and fifth; no origin in the third was found for B.

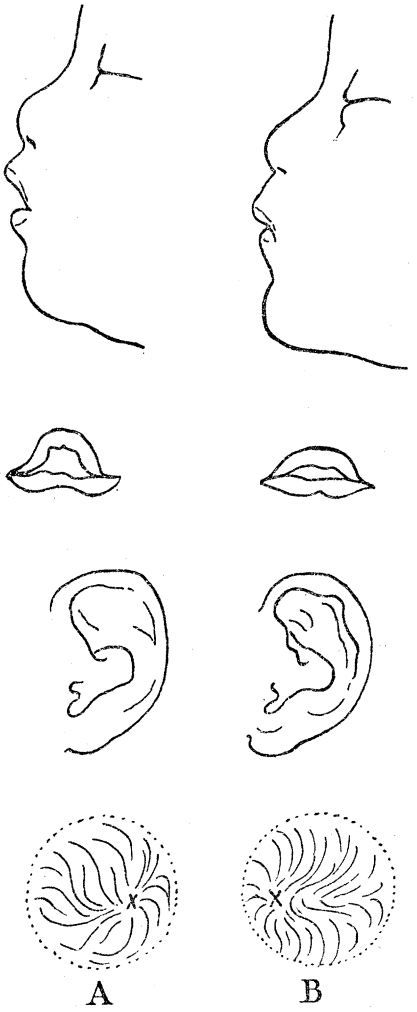

FIG. 1.—Profile, mouth type, ear and whirl-point of the hair in the twins examined.

The brachial plexus was symmetrical and on the common pattern in both boys on both sides. To the above-mentioned difference in the origin of the phrenic nerve only one difference is to be added; on both sides in A the first dorsal nerve joins the eighth nerve just where the posterior branch separates to contribute for the constitution of the radial nerve. In boy B the first dorsal joins the eighth nerve immediately outside the spine, just above the first rib, and remains enclosed with it in the same sheath for 1 cm. before the posterior branch separates. Thus the brachial plexus of boy B shows on its apical and caudal ends an indication of greater condensation, which is a higher evolutional type of nervous arrangement, but not a fundamental difference in this arrangement.

The axillary artery is in its normal place, in front of the radial and between the seventh and the eighth nerve branches.

The lumbar plexus is similar in all its origins and branches in both boys; it belongs to the high form, the crural nerve coming from 3, 2, 4, 1L, the obturator from the 3, 2, 4, 1L (see 'Quain's Anatomy'). The only difference is that in boy A the two branches from 2 and 3 remain separated by a muscle bundle of the psoas and join only on the lower third of this muscle.

No differences are to be observed in the sacral plexus.

3. Hereditary Circumstances.

Dr. Fisher, who delivered the infants, and the maternity nurse give the following account of the conditions of the confinement. The woman had had slight *ante-partum* hæmorrhage; the labour was easy; the first baby came by the feet and was peeling; there was a moment of rest before the head passed the cervix. The second baby came immediately afterwards, without difficulty, by the head; he was also macerated. It was then 10.45 A.M., August 31, 1915. The placenta came at 11.10 easily. There was no further complication. Temperature 98° (37° C.), pulse 112.

We examined the woman M. October 6, 1915. She is well developed, of normal physique. There were never as far as she knows any twins in her family. Her father was born in London and died comparatively young. Her mother was born in the country and was a healthy individual who died at a good age. The families on both sides were numerous; no indication of any case of consumption, insanity or epilepsy could be given. M. had three brothers and one sister; three children died in early life. She is the fifth living child and the one most resembling her mother, and is now 34 years old. She has always enjoyed good health. The superior incisor teeth are destroyed down to the root, the other teeth are in good condition. In August, 1914, she suffered from pneumonia and remained for seven weeks in St. Bartholomew's Hospital. During the last weeks before the confinement she fainted several times. Her legs were swollen, although there are no varicose veins at all. She complained of pain in the hypochondriac regions. She is now still anæmic and there is a murmur in the heart as a result of the poor condition of her blood. She married and had six children and two miscarriages. The series begins with a girl and alternates regularly, boy, girl, boy, girl, boy, the eldest being 16 years, the youngest 5. Her husband suffered of late years from kidney disease and died three years ago of tubercular nephritis (?). She is unable to give any description of any value for our study of the eyes or morphological details of her first husband.

She had lived with the father of the twins six months when conception took place. He is a tall and strong individual 39 years of age, who had bad alcoholic tendencies, and for this reason she left him, and he has gone to the Dardanelles.

As to the principal object of this examination, I noticed that the profile of baby B most resembles the mother, whose chin is also more prominent. Her nose has an intermediate form to those of the babies. The eyes of the mother are in form and

pigmentation absolutely uniform and similar to the four baby-eyes, dark brown. There is no facial asymmetry. The shape of the ears is the same as in baby B but the lobules are adherent as in baby A.

Owing to the whirl-point of the hair being different-sided in the babies, the mother astonished us by the fact that in her case it was quite in the middle of the scalp. The use of combing did not leave a nice whirl as it was found in the twins, a main line, quite on the sagittal suture, going straight on backwards, dividing into two secondary lines; the left of these takes a direction to the lateral side lower down than the other going on the right. The lines and furrows in the hands are like those of the children. The feet are normally formed, without any pathological condition.

The conclusion is that the male twins under examination are very similar to each other and also to their mother. No essential differences were to be found.

4. Previous Work.

The previous work on the question has been reviewed by Edgar Schuster, and in the following description of the hemispheres we will adopt his method in describing the similarities and the differences in the furrows of the hemispheres.

Edgar Schuster has called attention to the papers of Karplus and Spitzka. He considers that the contribution of Waldeyer does not deal with hereditary resemblances, but we shall have to analyse Waldeyer a little more than Schuster did. For the two former authors we refer to Schuster's review.*

The description of Waldeyer concerns three pairs of twins and three groups of triplets, the majority being of different sexes.

Waldeyer recalls the researches about the sexual differences of the brain published by Rudinger, Passet, and Mingazzini, but he cannot agree with them that constant differences are demonstrated, and thinks with Karplus and Retzius that more careful observations are needed.

According to Rudinger the Sylvian fissure should close earlier in males, and the insula should be sooner concealed. The type of the sulci should be sooner fixed in males.

Mingazzini thinks that the central fissure is longer in males; it should be more oblique on the left than on the right in females; the frontal lobe should be more complex in males, and the calcarine fissure should be deeper and more irregular; the insula should be longer (antero-posterior measurement of Cunningham) in males; the

* Edgar Schuster, "Hereditary Resemblance in the Fissures of the Cerebral Hemispheres," 'Archives of Neurology,' vol. 6 (1914). Karplus, Y. P., "Ueber Familienähnlichkeiten an den Grosshirn Furchen des Menschen," 'Arbeiten Neurologischen Institute Wiener Univ.,' vol. 12 (1905); "Zur Kenntniss der Variabilität und Vererbung am Zentralnerven System des Menschen und einiger Säugethiere," Leipzig-Wien, 1907. Spitzka, "Hereditary Resemblance in the Brains of Three Brothers," 'American Anthropologist," vol. 6 (1904). Waldeyer, "Gehirne von Zwillingsfrüchten Verschiedenen Geschlechtes," 'Sitzungsberichte der Königlich Preussichen Akademie der Wissenschaften,' No. IV, February 7, 1907; 'Zeitschrift für Ethnologie,' vol. 40 (1908).

relative greater height of the arch of the sulcus parieto-occipitalis and the greater length of the interparietal sulcus should be characteristic of the brain of females.

RETZIUS concludes that a typical difference resulting from a characteristic peculiarity in one of the sexes is not to be found in the fissures nor in the convolutions.

CUNNINGHAM could not find any difference for the sulcus centralis. KARPLUS got negative results from the examination of triplets, although a male out of triplets, and having a weight between that of the two other female siblings,* could be considered as more advanced in his brain pattern.

The greater number of the brains of twins and triplets examined by WALDEYER belong to individuals too young to give any satisfactory comparison. In two pairs of twins of seven months the boys had a longer fissure of Sylvius and a less exposed insula.

WALDEYER concludes "that the brains of males have—at the same age—a little more advanced sub-division of the sulci and convolutions;" but he adds that in some cases this was not confirmed, and therefore we are not yet able to speak of a "constant relation" (Gesetzmässig Verhalten) as RUDINGER does.

It is a fact that WALDEYER, looking for sexual differences, did not call enough attention to the great importance of the similarity existing in the brains examined, although he signalises the problem of hereditary resemblances. The work of WALDEYER gives only negative results in the research of sexual differences; but it seems to be very important to note that his work also suggests two facts, the importance of which he does not lay enough stress upon, viz.:—

(1) The great similarity of the brains of twins and triplets.

(2) The greater complexity in the pattern of the heaviest brains.

WALDEYER calls attention to the larger development of some lobes in the larger brains, particularly in the case of the temporal lobe. There are no figures illustrating the papers of WALDEYER on this subject; but the brains examined have been preserved at Berlin for those who would like to see them. The notes of WALDEYER are mere general impressions; they are not systematic. The work of WALDEYER is an interesting guide to more extensive work.

5. TECHNIQUE AND ABBREVIATIONS.

The figures of SCHUSTER consist in drawings and photographs. The author remarks that "his figures are tracings from photographs, modified so as to accentuate the more important and deeper fissures. In the best of the original photographs of a brain shallow grooves appear as conspicuous as the deepest fissures, while the arrangement of the lights and shades in some parts is such that important sulci are rendered practically invisible. Hence tracings such as here included, being fairly diagrammatic, give in many ways a truer representation of the essential features."

* Siblings—Offspring of a single pair of parents, translation of the German "Geschwister" (KARL PEARSON).

I think that a serious modification has to be introduced in the technique of reproducing the examined brains. First of all, it seems absolutely indispensable and elementary to harden the specimens, suspended in good conditions in the necessary quantity of liquid, to avoid any deformations. The figures must be *projection figures*, without perspective, just as, *e.g.*, anthropologists obtain them with the apparatus of BROCA for the examination of the skull.

The outer line may be the reproduction of the brain mass. All the lines inside this line must be as much as possible only the lines of the furrows, otherwise some contours would appear as sulci. The figures must be such as are used by architects, and the compass must be able to control most of the measurements, which is not the case in a photograph, nor in an artistic drawing "in relief."

For the position of the brain the *norma verticalis* (BLUMENBACH) and the alveolocondylar line should be used. If the alveolocondylar line cannot be determined, the brain may be put on a horizontal plan, the occipital pole being on the same level in all the figures. Attention should be given to the eccentric development of the brain (ECKER).

Although I would have preferred to follow the abbreviations and denominations of DEJERINE, whose book is better known, I have taken nearly the same abbreviations as SCHUSTER for the purpose of an easier comparison.

Our mind becomes sooner accustomed to the use of abbreviations than to that of long Latin words. It is therefore very important to take the most accurate abbreviations, and those which are the nearest to the original terms. Some of the abbreviations of SCHUSTER are not the best he could have chosen; but I quite agree that it is very difficult to abandon all old errors and to establish a logical general rule. If the Rolandic sulcus is called *sulcus centralis*, why not admit *fissura lateralis* for the *fissura Sylvii?* Why does SCHUSTER speak of a "*fissura*" collateralis and "*sulcus*" calcarinus? Fissura ought to be reserved for the deeper grooves holding the main vessels.

In the comparative tables *superior* should always come before *inferior*, and *anterior* before *posterior*; a single difference should not be expressed in three manners in the same table. For example:—

sulcus fronto-marginalis continuous
divided into two pieces
,, ,, three pieces

should better be concentrated in the single sentence: number of pieces. As far as possible I followed the tables of SCHUSTER, although each series of brains could have its own tables when a great number of details are reviewed.

I tried to make a table of comparison which would be useful for the summary of the special tables obtained in each study (p. 56).

List of Abbreviations used in Figures. Arranged in Alphabetical Order.

arc int	Arcus intercuneatus.
c	S. centralis.
cal	F. calcarina.
col	S. collateralis.
fi	S. frontalis inferior.
fl	Fissura lateralis.
fm	S. frontalis medius.
fma	S. fronto-marginalis.
fms	S. frontalis mesialis.
fpo	Fossa parieto-occipitalis.
fs	S. frontalis superior.
h	R. horizontalis cutting the g. cent. ant.
im	S. retrocalcarinus.
ima	S. intermedius primus (anterior).
iml	sulcus calcarinus lateralis.
imp	S. intermedius secundus (posterior).
imv	R. verticalis of S. retrocalcarinus.
ip	S. interparietalis proprius.
ipo	Incisura parieto-occipitalis.
lpr	S. limitans præcunei.
lsi	S. lingualis.
lss	S. cunei.
lun	S. lunatus.
marg	S. præcentralis marginalis.
oa	S. occipitalis anterior.
oi	S. occipitalis inferior.
ol	S. occipitalis lateralis.
olf	S. olfactorius.
om	S. occipitalis medius.
oprm	S. occipitalis paramesialis.
orbs	S. orbitalis sagittalis.
orbt	S. orbitalis transversus.
pc	S. præcunei.
p col	S. paracollateralis.
po	F. occipito-parietalis.
poi	S. postcentralis inferior.
pol i	S. polaris inferior.
pol s	S. polaris superior.
pos	S. postcentralis superior.

pri . . . . . S. præcentralis inferior.
prm . . . . . S. præcentralis intermedius.
pr med . . . . S. præcentralis medialis.
prs . . . . . S. præcentralis superior.
ps . . . . . S. parietalis superior.
r . . . . . S. radiatus.
ra . . . . . R. anterior ascendens of fissura lateralis.
rh . . . . . R. anterior horizontalis of fissura lateralis.
rhi . . . . . Sulcus rhinicus.
rpa . . . . . R. posterior ascendens of fissura lateralis.
rpd . . . . . R. posterior descendens of fissura lateralis.
rti . . . . . S. rostralis inferior.
rts . . . . . S. rostralis superior.
rtt . . . . . S. rostralis transversus.
sc . . . . . S. cinguli.
sca . . . . . S. subcentralis anterior.
scp . . . . . S. subcentralis posterior.
sp . . . . . S. subparietalis.
sri . . . . . S. rhinencephali inferior.
ti . . . . . S. temporalis inferior.
tm . . . . . S. temporalis medius.
tr . . . . . S. occipitalis transversus.
ts . . . . . S. temporalis superior.
ttr . . . . . S. temporalis transversus.

A . . . . . the smaller baby.
B . . . . . the bigger baby.
L . . . . . left side.
R . . . . . right side.

When speaking about left B, *e.g.*, it means left hemisphere of baby B.

In the next paragraphs, 6 and 6^1, the description of the left hemispheres is given on the pages to the left, viz., 46, 48, 50, 52; the description of the right hemispheres on the pages to the right, viz., 47, 49, 51, 53; thus enabling at once a comparison of the left conditions with those of the right.

Attention therefore is particularly drawn to the fact that the text of page 46 continues on page 48, and so on.

6. Comparison of Hemispheres.

Left Hemispheres.

The *Fissura lateralis* (*Sylvii*) (*fl*) has in A one anterior ascendent (*ra*) and one horizontal *ramus* (*rh*); in B, two anterior ascendent (*ra*) and one horizontal *ramus* (*rh*).

The *insula* is partially exposed; the second and third *gyri breves* may be seen, also part of the first. The anterior rami open separately in the *fl*, except the two ascendent of B. The two posterior rami, *rpa* and *rpd* of *fl*, are similar and small in A and B, but the inferior of A goes farther, and is superficially connected with the first temporal (*ts*).

The *sulcus centralis* (*c*) in both cases cuts the superomesial border; it does not join the *fl*; in A the end of *c* turns forwards in the direction of the *sulcus subcentralis anterior* (*sca*), in B that end turns backwards and remains at a good distance of *sca*. Both *sca* extend 12 mm. on the surface of the *operculum centrale*.

Frontal Lobe.—The *sulcus præcentralis inferior* (*pri*) in both cases, at its lower end, remains at a good distance from the *fl*; its lower end turns backwards in A and is vertical in B; its superior end is very close to the *sulcus præcentralis superior* in both cases.

There is no *sulcus præcentralis intermedius* (*prm*).

The *sulcus præcentralis superior* (*prs*) is longer in A than in B. In both it falls short of the mesial border, and in B it has two secondary rami into the *gyrus centralis anterior*. A secondary fissure, *ramus horizontalis* (*h*), cuts the *gyrus centralis anterior* on an ascending line for A, arriving on the inferior end of *prs*, and on a horizontal line for B, arriving at 12 mm. from the end of *pri*, but in both cases at a distance of 28 mm. from the inferior beginning of *pri*.

pri	measures	in A	28	mm. ;	in B	38	mm.	taken in straight lines.
prs	,,		26	,,	,,	16	,,	,, ,,
			54			54		

The *sulcus frontalis mesialis* (*fms*) is badly developed in A, and joins the *prs* in its middle. It is markedly regular in B, except at the end that does not join *prs*, but it comes far down on the anterior face of the lobe.

The *sulcus frontalis superior* (*fs*) is continuous in A, but divided in B. In both cases it joins the *prs*, at a distance from the mesial line measuring in A 20 mm. and in B 19 mm. The lower end in B joins the *fma*.

The *sulcus frontalis medius* (*fm*) practically does not exist. The *gyrus frontalis medius* is cut by three transverse sulci in A and by four in B. In A a short sulcus *fm* joins *prs*.

The *sulcus frontalis inferior* (*fi*) is short in A, joins *pri*, but not the *sulcus radiatus* (*r*); it is well developed in B, joins *pri* and the *r*, without any deep gyrus.

(*Continued*, p. 48.)

6[1]. Comparison of Hemispheres.

Right Hemispheres.

The *Fissura lateralis* (*fl*) has in A one *ra* and one *rh* anterior, in B two *ra* and one *rh*. The difference on both sides is due to the concealment in A of a gyrus exposed in B between the two *ra*.

The *insula* is partially exposed as on the left. In right A same details as in left A, but the *rpa* is longer on the right. In right B same details as in left B. These differences are secondary and without importance.

The *sulcus centralis* (*c*) in both cases cuts the superomesial border, it does not join the *fl*; in A the end of *c* goes straight on and approaches *fl* on the place where *sca* is indicated; in B that end turns backwards and runs parallel to *sca*, at a good distance; *sca* in B is very small, and extends but 3 mm. Thus the type of *c* in B is highly developed, due to the greater development of the inferior frontal convolution. But the difference exists only in the direction of *c*, not in peculiarities of superior or inferior endings, nor in connection with the other sulci.

Frontal Lobe.—The *sulcus præcentralis inferior* (*pri*) is very different. In A it is separated from the *sulcus diagonalis* (*d*) and from *prm*, it joins *fi*, but does not join the *sulcus frontalis medius* (*fm*); in B it does not join *d*, but joins *fi*.

There is an independent *prm* in A.

The *sulcus præcentralis superior* (*prs*) is the same in A as in B, but in B it has two sections and reaches with its end the mesial border. The *gyrus centralis anterior* is not cut as in the left hemisphere.

pri measures in A	29 mm.;	in B	26 mm.	taken in straight lines.				
prm	,,	23	,,	,,	0	,,	,,	,,
prs	,,	26	,,	,,	32	,,	,,	,,
		78			58			

These differences are due to the fact that in A the *prm* is parallel with *pri* on its lower, and with *prs* on its higher part. Without *prm* the measurement would be 55, nearly the same as on the left hemispheres.

The main resemblance is the cutting of the *gyrus centralis anterior* by a *ramus horizontalis*, which exists in both left and not in both right hemispheres. The left B has more resemblance to the left A than to its own homologue right hemisphere.

The *sulcus frontalis mesialis* (*fms*) is badly developed in A, and exists only on the superior part. In B *fms* is divided into three pieces; the superior does not join *prs*, the inferior does not join *fma*.

The *sulcus frontalis superior* (*fs*) is in A extended from *prs* to *fma*, with a small gyrus near its end; it is continuous in B from *prs* to *fma*. *fs* is easily determined and is regularly less distant from the mesial border in A than in B on both sides.

(*Continued*, p. 49.)

There is a good *sulcus radiatus* (*r*) in both A and B.

The *sulcus diagonalis* (*d*) in A joins *fl* and *fi*, in B it is half size, but what has been considered as a second *ra* is similar in form and condition to *d* of A. The reason why we consider this fissure as a *ra* is because of its situation and its next combination with the real *ra*.

The *sulcus fronto-marginalis* (*fma*) is divided into two segments, similar in A and B; its internal part receives the lower end of *fs* in B.

The accessory branches of the *sulcus orbitalis* (*orb*) extend less to the external border in A than in B; accessory branches coming from *fma* replace this lack of extension.

In A there is one *sulcus rostralis* (*rt*); in B there are two down to the first branch joining the superomesial border with the *sulcus cinguli* (*sc*).

In the pars orbitalis of the lower frontal convolution there is an antero-posterior secondary sulcus, not existing in both right hemispheres.

Parietal Lobe.—The *sulcus postcentralis inferior* (*poi*) in A joins superficially *fl*, but not *ip*. There is a marked and deep *sulcus subcentralis posterior* (*scp*), joining *fl*, *ip*, and *pos*, but a deep gyrus connects the *gyrus supramarginalis* with the *gyrus centralis posterior*. In B *poi* joins superficially *fl* and *ip*; in B there is also a marked *scp*, joining *fl*, but not *ip*, and a horizontal branch cutting the *gyrus centralis posterior*.

The *sulcus postcentralis superior* (*pos*) in A joins *scp* and *ip*, but, as has been said before, a deep gyrus connects the *gyrus centralis posterior* and the *gyrus supramarginalis;* above this connection the *ip* continues in the *gyrus centralis posterior*, which is cut by a horizontal branch, but a gyrus joins both parts of the *gyrus centralis posterior* on the border of *c*. In B the *pos* takes an oblique direction forwards and reaches nearly *c*; it joins *ip*, but not *scp*.

The *sulcus parietalis superior* (*ps*) is simple and straight in A; in B it divides at its end, and the two rami include a small gyrus not to be found in A.

The *sulcus interparietalis* (*ip*) is a sinuous line in A, coming from *scp* and ending in the *sulcus occipitalis transversus* (*tr*). In B *ip* is more straight, and ends also in *tr*. There are no deep gyri. In A the sulcus is large, and contains parts of gyri not reaching the surface, but not really concealed. This is especially the case with a small tip of the supramarginalis just above the first lower intermediate sulcus (*ima*); a similar part in B is connected with the upper parietal gyrus, but it remains on the surface. In A the *sulcus intermedius primus* (*ima*) is very anterior; it is behind, and not so deep in B. The *sulcus intermedius secundus* (*imp*) is well developed in A, and is just indicated in B. There is an *ascendent intermediate sulcus* going upwards in A and backwards in B.

The *sulcus cinguli* (*sc*) is quite similar in A and B, except at its end, the paracentral convolution being larger in A. In A two sulci of little depth divide the surface of the paracentral lobe. In B the *sulcus paracentralis* is very marked, and its three

(*Continued*, p. 50.)

The *sulcus frontalis medius* (*fm*) practically does not exist. The *gyrus frontalis medius* is cut by three transverse sulci in A and by three in B. In A a short branch has an anteroposterior direction.

The *sulcus frontalis inferior* (*fi*) is short in A, joins *d* and *r*; it is well developed in B, joins *pri* and *r*, not *ra*; near to the junction with *r* there is a small deep gyrus.

As a result of the short *fi* in A there are two *sulci radiati* (*r*), one of which is very high up.

The *sulcus diagonalis* (*d*) in A joins *fi* and *fl*. In B it joins *fl*. The two *d* in A are different from the two *d* in B. This is a result of the greater development of the inferior frontal gyrus in the brain of B.

The *sulcus fronto-marginalis* (*fma*) is similar in both cases. On both sides this sulcus is a little more complicated in B than in A.

The accessory branches of the *sulcus orbitalis* (*orb*) show the same differences as in the two left hemispheres.

In A there is one *sulcus rostralis* (*rt*); in B there are three *rt*.

The frontal lobes are developed more on their mesial part and on the third frontal in B. As a result of this the mesial frontal sulcus is better developed in B, and there is a greater complexity in the secondary branches of the different sulci. But these differences are not essential, and, as a rule, the arrangement is the same in the two brains.

Parietal Lobe.—The *sulcus postcentralis inferior* (*poi*) is continuous in A with the *sulcus postcentralis superior* (*pos*) and with *fl*, where a deep gyrus closes its valley; there is another deep gyrus at 15 mm. from the first, connecting the *gyrus centralis posterior* with the *g. supramarginalis*. *poi* joins also *ip*. In B *poi* is very long and limited by a small gyrus, nearly concealed, joining the *g. supramarginalis* and the *gyrus centralis posterior;* it joins *ip* and *fl* superficially. For B there is a small distinct *pos* joining *ps*.

In B the condition is similar to that of its left homologue, and there is a well-developed *scp*, which is but indicated in A.

As in the left hemisphere of B, the *gyrus centralis posterior* is cut in its middle by a horizontal branch, but here it is coming from *c* and does not reach the *poi* on the right side, as it does on the left.

Thus the main characteristic in both brains consists in the presence of a large *scp*, but which does not exist in the right A. The distance of *poi* to *c* is:—

In A	17 mm.	on the left	and	10	on the right.
In B	16 „	„		18	„

The *sulcus parietalis superior* (*ps*) is transverse in A and isolated as in left A. In B it joins *pos* and *ip*, as in the left hemisphere of B.

The *sulcus interparietalis* (*ip*) is sinuous and continuous, joining *poi* and *tr* in A;

(*Continued*, p. 51.)

branches are well developed, one nearly reaching the superior border. The central sulcus extends more on the mesial face in A than in B.

There is no *sulcus intralimbicus* (Dejerine) (*intrafornicatus*) (*intracingulatus*).

The *præcuneus* of both hemispheres is completely isolated from the paracentral gyrus, but the lower limit of the præcuneus is not similar. In A two sulci interrupted by a connecting gyri separate the præcuneus from the *gyrus cinguli*. A part of the cerebral cortex belonging to the latter in B is connected to the former in A. The *sulcus præcunei* (*pc*) is represented in A by three lines—one isolated, one joining superficially *fpo*, one joining *sp* (subparietalis); in B by four lines—one joining *ps*, one *sp*, one *fpo*, one small *sp*.

The *sulcus subparietalis* (*sp*) is continuous with *sc*.

Temporal Lobe.—The *sulcus temporalis superior* (*ts*) is one continuous sulcus in A, with a connection to *ft* just down to *poi*, and behind the first transverse temporal. In B *ts* is divided into three segments; from the first a connection goes in the direction of *c* into *ft*, where it continues backwards and turns then also behind the first transverse temporal gyrus. The second segment is connected with the second temporal sulcus; the third section also with the *tm*.

The end of *ts* in A has three rami, disposed "en éventail"; the end in B is single and straight, nearly reaching *ip*.

In both cases there is a *sulcus temporalis transversus* (*ttr*) joining *ts*.

The posterior Heschl convolution, *gyrus temporalis transversus posterior*, lies deep, and is badly developed in B.

The *sulcus temporalis medius* (*tm*) is represented by at least four sections in A, and three in B. In the third section of B a small isolated gyrus is in the depth, slightly exposed. In A the *tm* joins *ts* once; in B it joins twice. In B, *tm* is connected with the *sulcus occipitalis lateralis* (*ol*) (*oα*).

The *sulcus temporalis inferior* (*ti*) is divided into two sections in A, the second joining at its end the *col*, the anterior joining the *tm*. In B, *ti* lies on the inferior surface, and joins the *sulcus occipitalis inferior* (*oi*).

Occipital Lobe.—It is in the occipital lobe in which perhaps the most marked differences may be observed. In A the *fossa parieto-occipitalis* is markedly indicated, and the surrounding gyrus entirely unsectioned, whilst in B the main part of that convolution is rejected to the mesial surface by the development of two secondary convolutions, which, however, lie deeper; thus on the mesial side the space of the fossa is occupied in B by a large convolution existing in A on the lateral surface.

The *sulcus lunatus* (*lun*) has no connections with other sulci; in A it is at 18 mm. from the mesial line; in B at 21 mm. The *fissura calcarina* (*cal*) approaches to it in A by a straight line (*iml*); in B the *cal* ends in a transverse line (*iml*), the lateral end of which goes towards the *lun*.

The *sulcus occipitalis transversus* (*tr*) is not to be seen on a lateral projection, as the prominence of the *gyrus angularis* covers it; it extends only 14 mm. from the mesial

(*Continued*, p. 52.)

the same deep gyri exist in this hemisphere as on the left, but they are more concealed. In B the *ip* is interrupted by a gyrus (concealed in A). The *ima* is short and deep in A, and does not exist in B. The *imp* exists in A and also in B; well developed in the latter.

In both cases there is an *ascending intermediate sulcus.*

The left hemispheres and the right A have a continuous *sulcus cinguli* (*sc*), in the right B it is interrupted by a large gyrus, 4 mm. broad. In A the *sulcus paracentralis* is double and independent, in B it is unique and joins *cs.* The *c* extends more on the mesial face in A than in B.

There is no *sulcus intralimbicus* (*intrafornicatus*) (*intracingulatus*).

The *præcuneus* is isolated from the paracentral gyrus, its lower limit is more similar in the right hemispheres than in the left. In the right hemispheres there is a central multibranched *pc*, not connected with the *c* nor with the *parieto-occipitalis.* In B its superior part is less developed, but a branch of the *ps* comes down in the præcuneus until 10 mm. from the supramesial border. In both cases a descending branch of *sp* comes into the præcuneus.

Temporal Lobe.—The *sulcus temporalis superior* (*ts*) is continuous in both A and B, without connection with *fl*; it ends in three ascending branches in A, the second of which has a double length compared with that of the opposite side. In B *ts* ends in two branches, the lower being also divided in two secondary branches, one of which represents the third of B. The left hemisphere of B is thus the most dissimilar from the others.

In both cases there is only an indication of *sulcus temporalis transversus* (*ttr*).

The two Heschl convolutions are well developed in the right hemispheres as in the left A.

The *sulcus temporalis medius* (*tm*) is in three pieces in A and a vertical sulcus coming from *ti* sections the cortex between the two first *tm.* The latter condition does not exist in B, where the posterior *tm* ends in a vertical sulcus joining *ts*; in B *tm* is in four pieces.

The *sulcus temporalis inferior* (*ti*) is divided in two sections in A, the first ending in the mentioned vertical sulcus and the posterior being nearly parallel to that vertical sulcus. In B an anterior *ti* comes on the lateral surface and joins *tm*; the posterior *ti* is very low, contouring the vertical sulcus in which *tm* posterior ends.

Occipital Lobe.—In A the *fossa parieto-occipitalis* is not so deep as it is in the left homologue hemisphere; the *ipo* takes a descending direction and measures 14 mm. In B it is quite transverse and measures 13 mm. Both conditions are more similar to left B than to left A.

In A the *fissura calcarina* (*cal*) ends in two branches, together 9 mm. high; in B 22 mm.; near to this a small depression is indicated in A, but in B there is a three-branched sulcus. The two left hemispheres are similar to each other and this is also the case in the right hemispheres.

(*Continued*, p. 53.)

line; in B 26 mm. But in A there is a second sulcus *tr* (*os*) which joins *om*, and which in B is practically confounded with *tr*.

The *sulcus occipitalis inferior* (*oi*) is in two sections in A, the lower ending in *ti*; in one section in B, connected on its middle with *col* and *ti*.

On the mesial surface the *sulcus retrocalcarinus* (*im*) makes with the *fissura calcarina* (*cal*) an angle of 90° in A, one of 115° in B. In A there are two vertical *sulci cunei* (*lss*), the anterior branching on its upper end and reaching by one ramus the *fossa parieto-occipitalis*, the posterior coming on the lateral surface. In B, as a result of the rejected *gyrus parieto-occipitalis*, there is a first incisure of *tr*, separated from the *sulcus præcunei* by that gyrus. From the two vertical sulci the anterior gives one branch coming in the sulcus *parieto-occipitalis mesialis* (*po*), and one coming on the lateral surface; a transverse branch joins the two *sulci cunei*. The posterior *lss* does not join a lateral sulcus. A small supplementary *sulcus cunei* exists in the anterior angle of the cuneus in B.

The *sulcus collateralis* (*col*) is very similar in both cases; it joins *oi* and *ti*.

In both cases the *sulcus lingualis* (*lsi*) commences in *col*, and ends independently.

---

7. Comparison with the Work of Karplus.

Comparative Tables of Schuster 1–8.

		Left.		Right.	
		A.	B.	A.	B.
1	Whether the sulcus centralis does or does not form an anastomosis with the sulcus præcentralis superior	+	−	−	−
2	Whether the sulcus centralis does or does not cut the superomesial border	+	+	+	+
3	Number of segments of sulcus præcentralis (continuous or not) .	2	2	3	2
4	Number of segments of sulcus postcentralis (continuous or not) .	2	2	1	2
5	Whether the sulcus centralis does or does not cut the operculum centrale	−	−	−	−

+ means "yes"; − means "no."

These main indications, the first four of which were considered by Karplus as valuable points of comparison, show the great similarity of the examined brains.

(*Continued, pages* 54, 55, 56.)

The *sulcus occipitalis transversus* (*tr*) is very similar in both cases, but the *gyrus postparietalis* is more developed in B. In A a deep gyrus is partially exposed, just as in the left hemisphere.

The *sulcus occipitalis inferior* (*oi*) is large in A, but small in B. In both cases it is joined by *col*.

The *sulcus retrocalcarinus* (*im*) makes with the *cal* an angle of 125° in A and is sinuous, where it was nicely curved in the left A; in B it is more open than it is in the left B, and reaches 110°.

The *sulcus cunei* (*lss*) in A is more complicated than it is in the left A, but still less than in B; in none does it join the *tr*, and the occipital lateral sulcus does not come on the mesial surface, as it does in left B.

The *sulcus collateralis* (*col*) is nearer to the mesial surface than to the lateral in A, where transversal branches of *ti* come on to the inferior surface. In B the *col* is more similar to the condition of the left hemispheres, and a transverse sulcus unites *col* with the *sulcus lingualis* (*lsi*), which is independent in A.

---

8. General Considerations and Conclusions.

The following general remarks might be made in support of the value of examinations of the brain furrows. The significance of the furrows has been abundantly discussed, and Brodmann holds that they are very secondary productions. But a number of anatomists from Baillarger to Ariëns Kappers have fully demonstrated the importance of their study. Fissuræ and sulci indicate the regions where the cortex has been first developed, both phylogenetically and ontogenetically, and where the projection fibres are first organised, and thereby the fissures and sulci retain their depth. The progressive concealment of gyri within the sulci and fissures thus formed constitutes a most interesting problem.

The study of hereditary resemblances in the brain should not be limited to the sulci only, but with every work a beginning is needed, and the future may augment the material, as well as the opportunity of further detailed anatomical investigation. Thus a parallel examination of the architectonic fields might be undertaken; in fact Edgar Schuster has already examined the extension of the striation of the occipital pole. The measurements of the gyri are also indispensable for the determination of the furrows. As a rule the supplementary sulci or differences in their direction appear as a result of a greater development of the neighbouring convolutions.

The brain A was smaller than the brain B. The larger size of B exists in every lobe of the brain. It is clearly apparent in the frontal, the parietal and the occipital lobes, less in the central convolutions. This gives the different lobes of B a fuller,

COMPARATIVE Table (No. VI, First of SCHUSTER).

	A = the smaller brain. B = the larger brain. + means "yes"; − means "no."	Left.		Right.	
		A.	B.	A.	B.
Fissura lateralis . .	Number of anterior rami	2	3	2	3
	Number of posterior rami	2	2	2	2
Sulcus centralis . .	Anastomoses with :—				
	Sulcus præcentralis superior	+	−	−	−
	Sulcus præcentralis inferior	−	+	−	−
	Sulcus postcentralis superior	−	+	−	−
	Sulcus postcentralis inferior	−	+	−	−
	Sulcus subcentralis anterior and *fl*	−	−	−	−
	Sulcus subcentralis posterior and *fl*	−	−	−	−
Sulcus præcentralis superior	Anastomoses with :—				
	Sulcus præcentralis inferior	−	−	−	−
	Sulcus frontalis superior	+	+	+	+
	Divided into two pieces	−	−	−	−
prm	Sulcus præcentralis intermedius present . . .	−	−	+	−
Sulcus præcentralis inferior	Anastomoses with :—				
	Sulcus diagonalis and *fl*	−	−	−	−
	Sulcus subcentralis anterior and *fi*	−	−	−	−
	Fissura lateralis direct	−	−	+	−
	Sulcus frontalis superior	−	−	−	−
	Ramus horizontalis separate	−	−	−	−
	Ramus horizontalis anastomoses with sulcus frontalis medius	+	−	−	−
Sulcus frontalis superior	Anastomoses with :—				
	Sulcus frontalis medius	+	−	+	−
	Continuous	+	−	+	+
fm	Sulcus frontalis medius slightly indicated (+) or absent (−)	+	−	+	−
Sulcus frontalis inferior	Superficial posterior annectent gyrus	−	−	−	−
	Superficial middle annectent gyrus	−	−	−	−
	Superficial anterior annectent gyrus	2	1	2	1
	Anastomoses with :—				
	Sulcus diagonalis	+	−	+	−
fma	Sulcus frontomarginalis: number of pieces . . .	2	2	1	2

Comparative Table (No. VI, Second of Schuster).

	A = the smaller brain. B = the larger brain. + means "yes"; − means "no."	Left.		Right.	
		A.	B.	A.	B.
Sulcus postcentralis superior	Continuous with sulcus postcentralis inferior	−	−	+	−
	Anastomoses with:				
	Sulcus centralis	−	+	−	−
	Sulcus interparietalis	+	−	+	−
	Sulcus subcentralis posterior	+	−	−	−
	Sulcus parietalis superior	−	+	−	+
Sulcus postcentralis inferior	Anastomoses with:—				
	Fissura lateralis	+*	+*	+	+*
	Sulcus centralis	−	+	−	−
	Sulcus interparietalis	−	+	+	+
	Sulcus subcentralis posterior	−	−	−	−
Sulcus interparietalis proprius	Continuous	+	+	+	−
	Anastomoses with:—				
	Ramus ascendens sulci temp. sup.	−	−	−	−
	Ramus ascendens sulci temp. med.	−	−	−	−
	Sulcus intermedius primus	+	+	+	−
	Sulcus occipitalis transversus	+	+	+	+
	Sulcus parietalis superior	−	−	−	+
Sulcus parietalis superior	Independent	+	−	−	−
	Number of segments	1	2	1	2
	Anastomoses with sulcus præcunei	+	+	−	+
Arcus	Intercuneatus superficial	−	+	+	+
oa	Sulcus occipitalis anterior (lateralis) present	+	+	+	+
Sulcus temporalis superior	Number of segments	1	3	1	1
	Anterior interruption present	−	−	−	−
	Middle	−	+	−	−
	Posterior	−	+	−	−
ttr	Sulcus temporalis transversus joining *ts*	+	+	−	−
rhi	Sulcus rhinicus present	+	+	+	+
Sulcus cinguli	Number of segments	1	1	1	2
	Anastomoses with sulcus subparietalis	+	+	+	+
sp	Sulcus subparietalis interrupted	−	−	+	+
Angle	Of calcarine fissure, the right A different from the three others	90°	115°	125°	110°

* Superficially.

COMPARATIVE Table for Hereditary Resemblances in the Furrows of the Hemispheres.

(By the Author.)

No.	A = the smaller brain; B = the larger brain.	Number of quotations.	Per cent.
		56	—
	Similarities.		
1	Number of cases where the four hemispheres have the same condition	21	37·5
2	Number of cases where three hemispheres have the same condition .	24	42·7
3	Number of cases where the two left hemispheres are similar . . .	29	51·8
4	Number of cases where the two right hemispheres are similar . . .	40	71·5
	Similarities of Differentiation between the Left and the Right Hemispheres.		
5	Cases in which occurs the formula (+ + − −) or (− − + +), the two left similar, and the two right similar, but the right condition being different from the left condition	2	3·5
	Peculiarities in one Hemisphere.		
6	Number of peculiarities special to left A (− + + +) or (+ − − −) .	7	12·5
	Number of peculiarities special to left B (+ − + +) or (− + − −) .	8	16·1
	Number of peculiarities special to right A (+ + − +) or (− − + −) .	5	8·9
	Number of peculiarities special to right B (+ + + −) or (− − − +) .	4	7·1
	Confirmed Dissimilarities.		
7	Number of cases where left A is similar to right A, and left B to right B (+ − + −) or (− + − +)	5	8·9
	Whether there is Inversion of Similarity.		
8	Number of cases where left A is similar to right B (the cases where the four hemispheres are similar excepted) (+ + − +) or (− − + −)	14	—
9	Number of cases where right A is similar to left B (*id.* excepted) (− + + +) or (+ − − −)	10	—
10	Number of cases where the two former similarities (8 and 9) co-exist for the same quotation (+ − − +) or (− + + −)	0	0
11	1 and 2 show that, in 56 cases, 45 times three hemispheres at least showed the same condition, or 156 times on 224 chances; 5 shows a condition of the same value as 1, thus 8 more similarities		73·2

0·732 is the apparent index of similarity. 0·089 is the apparent index of dissimilarity. 732 ÷ 89 = **+8·23** is the absolute index of comparison. There is a remnant of 0·179, resulting from peculiarities and incomplete resemblances.

The two brains examined are at least eight times more similar than dissimilar.

rounder aspect. A result of the larger size of the convolutions is a greater multiplicity of secondary and transversal sulci in the larger brain.

The larger size of B exists with a greater concealment of deep sulci in the parietal and occipital lobes, especially in the interparietal sulcus and in the fossa parieto-occipitalis. But the fossa lateralis was similar in both brains. There is no indication of any true *inversion of similarity*; in other words, when a condition of the *left* A is similar to that of the *right* B, the *right* A will never be similar to the *left* B, except, of course, when the four conditions are the same; thus the formulæ $(+ - - +)$ or $(- + + -)$ never happen. (In the Tables of SCHUSTER this happens five times, but for very secondary peculiarities.) All the differences are of secondary importance if we try to summarise the general impression which the comparison gives. There is a very remarkable similarity in the disposition of the furrows. The bigger brain is the more highly developed; the left hemisphere of this brain is the most advanced and the most dissimilar from the three others.

In his 'Inquiries into Human Faculty and its Development,' Sir FRANCIS GALTON calls attention to the great importance of the history of identical twins; this study being most valuable in affording some insight into the relative powers of *nature* and *nurture*. The evidence in his inquiries proved decisively that the power of nature was far stronger than that of nurture, when the nurtures of the persons compared were not exceedingly different.

The brain being the organ of mind, this study of the morphological similarities in the convolutional pattern supports the investigations of GALTON regarding the functional similarities in every kind of mental temper and activity.

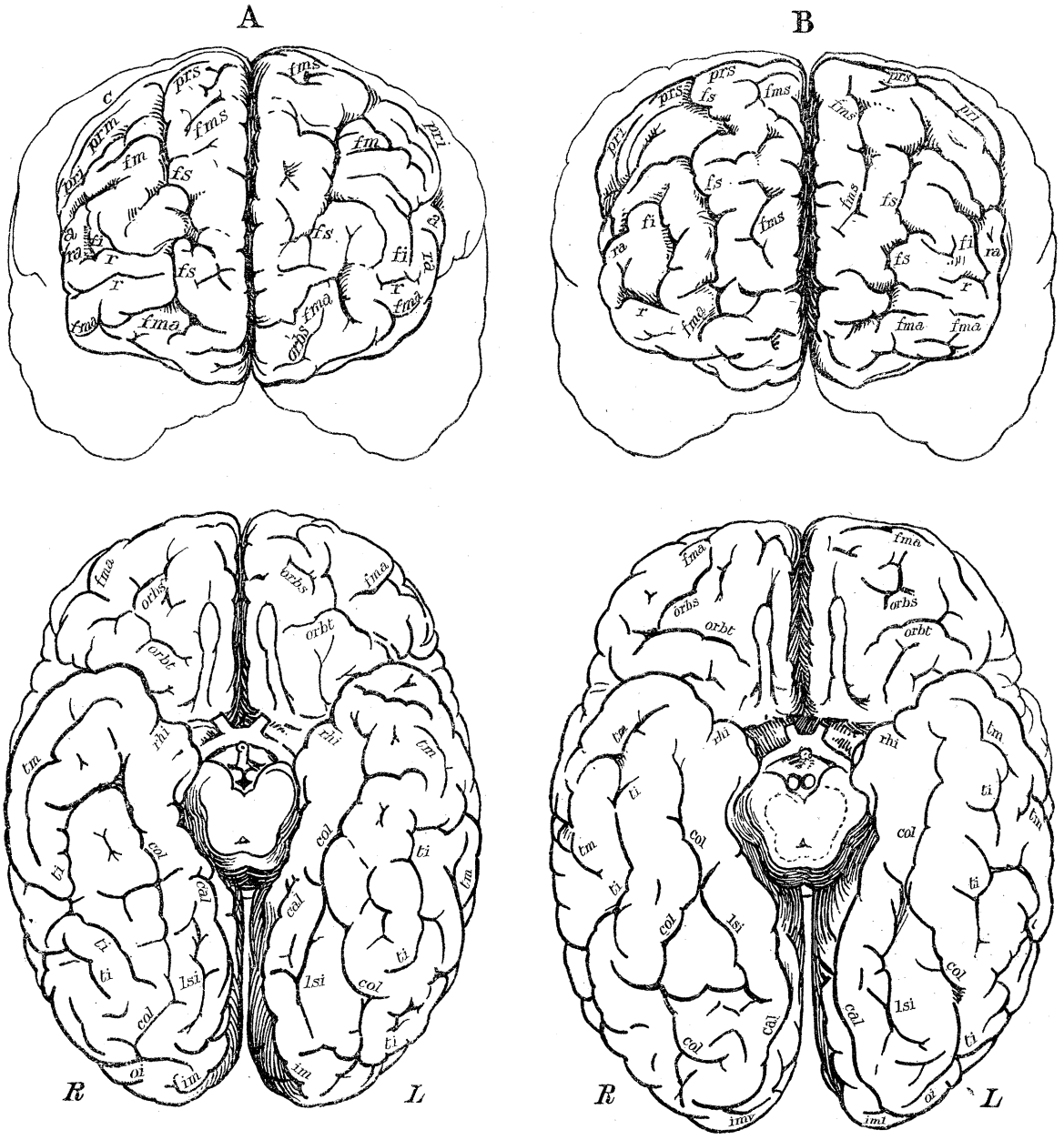

FIG. 2.—Frontal and inferior surfaces of the two brains.

Projection figures reduced 0·82 to the originals ; abbreviations explained in the Table of Abbreviations, p. 44

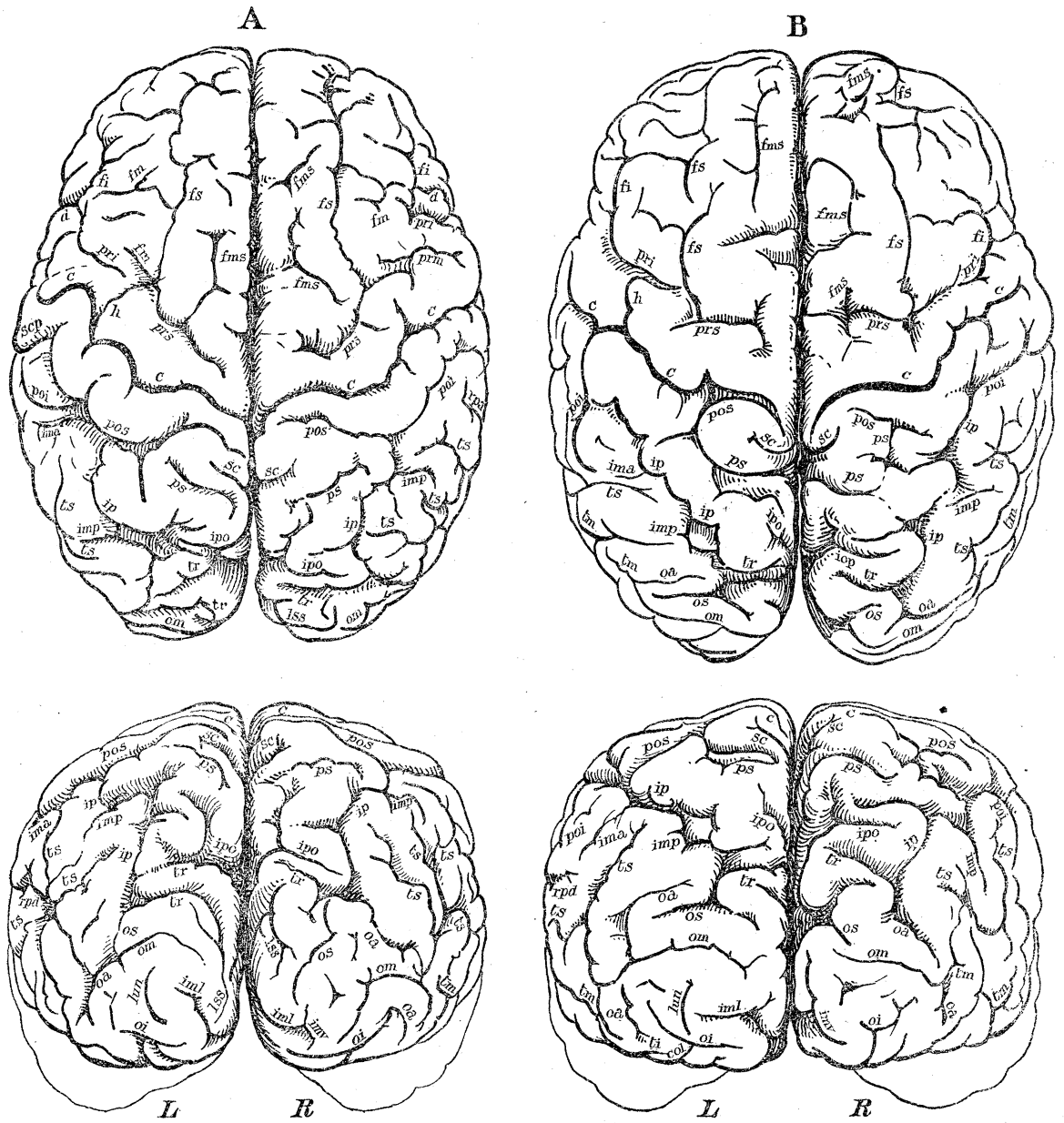

FIG. 3.—Superior and occipital surfaces of the two brains.

Figs. 2 and 3 were made after the surface had been stripped, but before the hemispheres were divided from each other.

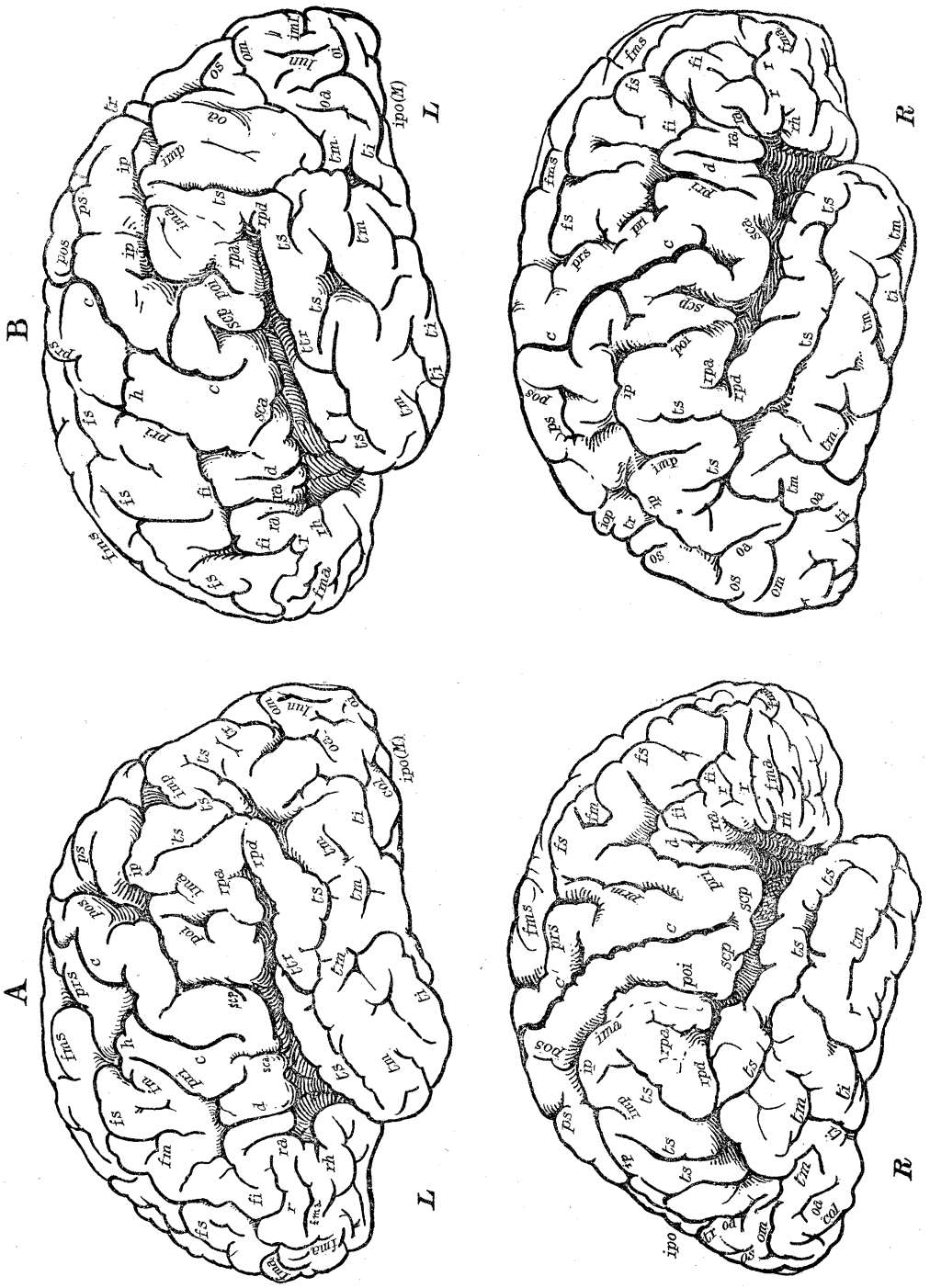

FIG. 4.—Left and right lateral surfaces of the hemispheres.

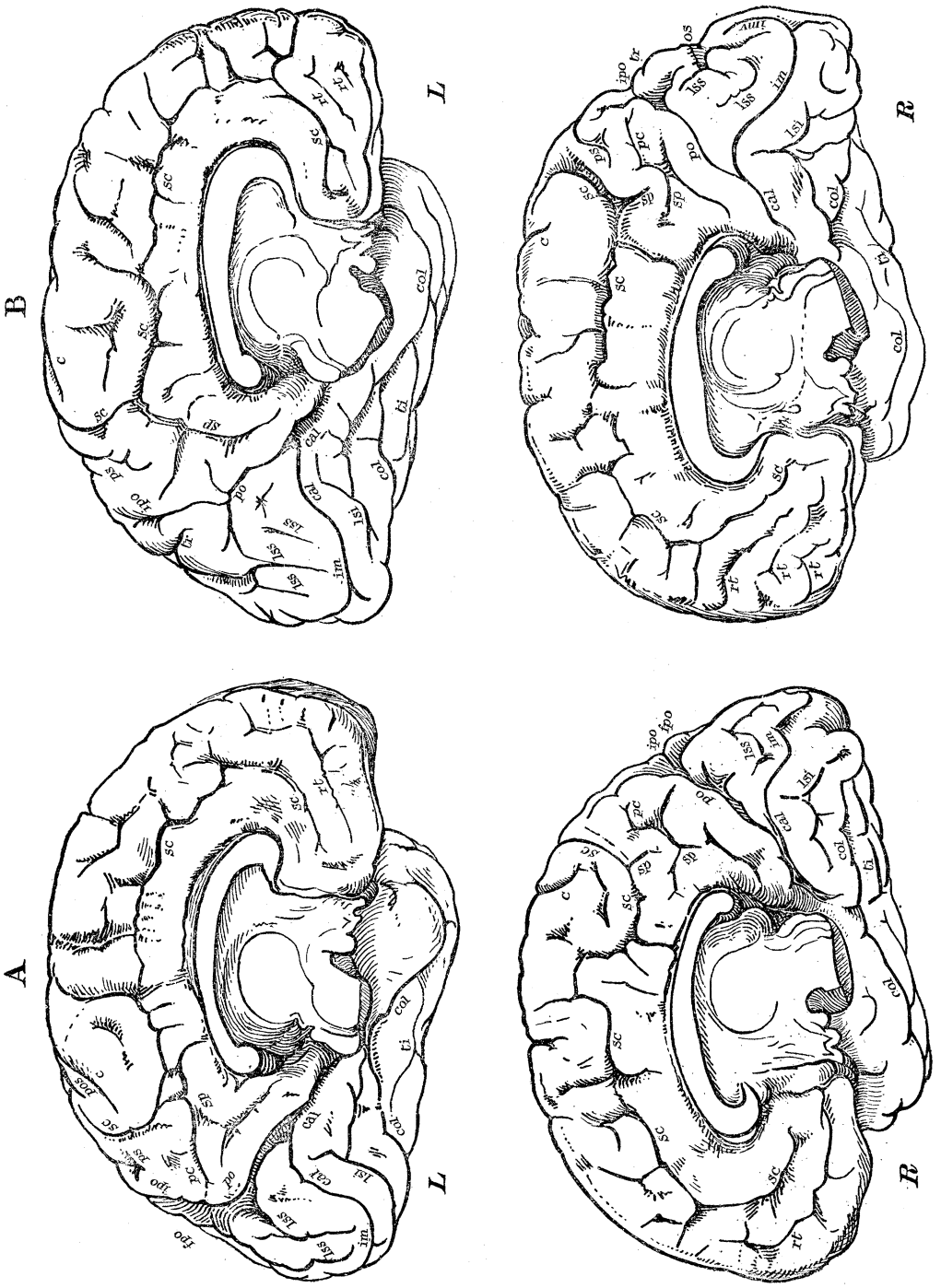

FIG. 5.—Left and right mesial surfaces of the hemispheres.