

A PRELIMINARY REPORT ON THE ASYMMETRY OF THE BASAL GANGLIA

RICHARD W. HARVEY

From the Hearst Anatomical Laboratory, University of California

SIX FIGURES

Recent studies on the lateral ventricles of the brain (Harvey '11) have led to the observation that in a majority of the brains studied the volume of the left anterior horn was greater than that of the right. The brains on which these studies were made have been carefully preserved, and a further investigation of them has resulted in the observation that not only the anterior horns of the ventricles but also the basal ganglia of the cerebrum are asymmetrical. It seems very probable from a study of the relations between the ventricles and the ganglia that the asymmetry of the former is influenced in part at least by the asymmetry of the latter.

Asymmetry of the brain has long been maintained and the preponderance of weight of the right or left hemisphere given by different investigators. Broca, quoted in Testut, finds the right hemisphere to be heavier by 2 grams in the male, while in the female it is only a few centigrams heavier. He also finds that the frontal lobe has a preponderance of from 2 to 2.5 grams on the left side, so that the difference in favor of the right hemisphere is said to be due to the preponderance of the parietal, occipital, and temporal lobes. According to Mall, however, the frontal lobe is between 43 and 44 per cent of the weight of the cerebrum. It would seem from this, therefore, that the preponderance of a hemicerebrum depends largely on that of the frontal lobe.

Reichart infers from the literature collected by Ilberg and Ziehen that the question whether the hemispheres are alike in weight or whether one exceeds the other is by no means settled. Hitzig comes to the same decision. The former reporting from the Würzburg clinic says that an extraordinary number of brains show absolutely equal hemisphere weights. This similarity of weights is especially remarkable to him on account of the generally accepted belief in the greater function of the left hemisphere and in asymmetry of the skull which is so often encountered. Obersteiner also expresses the opinion that the hemispheres are of nearly equal weight, while Poirier and Charpy consider the difference in weight too small to be significant.

Franceschi, with whom a number of observers agree, finds the left hemisphere to exceed the right in weight in about the same number of cases as the right exceeds the left. Liepmann also considers the left hemisphere to predominate, and Pfister in weighing children's brains finds a preponderance of the left hemisphere.

Such diverse conclusions may be accounted for in part by the various methods employed in dividing the brain. Broca, for example, adopted as the limit of the frontal lobe the sulcus centralis (Rolandi), and the section was made probably to include that portion of the basal ganglia lying in the frontal lobe. Huschke, on the other hand, determined the boundary of the frontal lobe by cutting the brain at the sutura coronalis. Meynert, using still another method, divided the pallium from the brainstem and cut off the pallium of the frontal lobe at the sulcus centralis, therefrom obtaining the weights of the frontal lobes distinct from the basal ganglia.

It is evident that on account of the difficulty of separating the component parts of the brain and the resulting variety of methods used to obtain this separation, that at the present time there is no definite proof of a preponderance of weight in either hemisphere. The differences between the hemispheres that are found may be accounted for by the different methods of dividing the cerebrum, or by error in making the division.

The explanation of variations of brain weight is regarded by Donaldson as mainly dependent on the size of the constituent nerve elements. He believes the left hemisphere to be heavier than the right although he failed to find it so. He believes the greater part of the difference in weight due to axones and their medullary sheaths. In the larger brains the difference in weight is due to first, the greater number of neurones, second, the more generous development of the axones, and third, a combination of both these factors.

Smith finds frequent morphological asymmetry in the brains of Egyptians, the occipital pole of the left hemisphere projecting much further backward than the right in about 80 per cent of cases. This asymmetry of the brain influences the form of the cranium to such an extent that a distinct depression is formed in the left superior fossa of the occipital bone. Not only is the cranium almost invariably asymmetrical, but the projecting left occipital pole seems to bend the left superior longitudinal sinus to the right. It is suggestive that asymmetry of the brain and cranium may have a racial significance. Smith finds that while a symmetrical arrangement of the visual cortex occurs in less than 10 per cent of Egyptian brains, it is found much more often than not in the negro. The symmetrical cranium of the negro is therefore a sign of inferiority since there is not the greater specialization of the two hemispheres as in the white races in which cranial asymmetry is the rule.

When the observation of asymmetry of the anterior horns of the ventricles was made, an association between the excess volume of the ventricles and the preponderance of the frontal lobe was at once considered. The position of the caudate nuclei lying in the floor of the anterior horns and the bodies of the lateral ventricles, with the heads of these nuclei lying in the frontal lobes suggested that if they were found to be asymmetrical they might explain in part the excess weight of one of the frontal lobes.

Franceschi, quoted by Donaldson, shows a slight excess in weight of the basal ganglia of the left side, but an examination of the literature reveals nothing else definite on the asymmetry of the

basal ganglia. In view of the paucity of information on this subject it has seemed profitable to undertake the present investigation.

In considering the asymmetry of brains hardened in formalin there must be taken into account the unequal shrinkage of brain tissue due to the preservative, and also the changes by drainage and evaporation, after the removal of the brains from the formalin. Likewise post-mortem alterations should be very carefully borne in mind.

Mall has shown that while the absolute weight of the cerebrum varies with changes in the strength of the formalin and during a period of nearly a year, the relative weight of one part of the cerebrum to the whole remains very constant. It therefore seems reasonable to presume that the relative volumes of the brains used in this study would remain fairly constant, since the relative densities probably would not vary greatly. The brains, which had been kept in 10 per cent formalin for periods exceeding one year, were those from which casts of the ventricles had been made. Since using them for that purpose they have been kept moist in a tight jar, subject to the same elements of drainage and evaporation. No data as to age, sex, race or condition at autopsy are available.

For the purpose of facilitating removal of the casts of the ventricles without tearing the brain tissue coronal sections were made at the level of the anterior extremities of the ventricles, at the foramina of Monro, and at the level of the pulvinar. Later, in order to compare the cross sections of the ganglia of the two sides an additional section was made between the latter two, passing approximately through the middle of the thalami.

Since dissecting out the basal ganglia for the purpose of obtaining their weights presents many difficulties and leads to many inaccuracies, while differentiation between the grey and white substance is sufficiently sharp to permit tracing the outlines of sections of the basal ganglia, a modified Born's method of reconstruction by means of wax plates is used in the preparation of models of the ganglia, by means of which the morphological features of the two sides may be compared.

The frontal and occipital poles were removed from the brains by coronal sections, and the mid-portion of each brain containing the basal ganglia was cut into coronal sections on a brain microtome. Each section was 3.5 mm. thick. Wax plates were rolled out to the same thickness. The outlines of the sections of the ganglia were transferred to the wax in the following manner: A film of celluloid which is transparent was laid on a section and a tracing of the outline made on it in india ink. The tracing was then laid on the wax plate and transferred to it by means of a style. The tracings on the wax were cut out with a knife and trimmed down to agree with the celluloid pattern. The models were constructed by piling the wax plates, using as a guide line a point on the corpus callosum, and fusing the plates together with a hot iron.

The models yield nothing new so far as the morphology of the ganglia themselves is concerned, but assist in the objective conception of their form and relations to each other. In addition to this they show marked asymmetry. Detail in the morphology of the ganglia is of course lacking because of the thickness of the sections; but for purposes of comparison between the two sides and between different brains the models furnish a consistent picture.

The model shown in a dorsal view (fig. 1) presents on each side the caput nuclei caudati tapering dorsad into the cauda nuclei caudati, and extending from the substantia perforata anterior in a curve to the level of the foramen interventriculare. The convex surface looks dorsad and mesad, and is curved to form the floor of the cornu anterius. The oval thalamus lies ventrad to the nucleus caudatus and separated from it by the stria terminalis. The nucleus lentiformis is joined ventrad to the caput nuclei caudati, thus forming the corpus striatum. Between the nucleus lentiformis laterad and the thalamus mesad lies the capsula interna. Beneath the nucleus lentiformis (fig. 2) on each side lies the nucleus amygdalae in which terminates the cauda nuclei caudati.

With regard to the points of asymmetry exhibited by this model (No. 7) the caput nuclei caudati of the left side is slightly

larger than the right. The thalami are fairly symmetrical. The left nucleus lentiformis is decidedly larger than the right. The dorsal view shows it to be longer anteroposteriorly, and the ventral view (fig. 2) emphasizes the greater transverse diameter.

Model No. 1 (fig. 4) is one of the largest of the series and shows marked asymmetry. Although the area of the dorsal surface of the left caput nuclei caudati is about the same as that of the right, the volume of the left is greater than the right. There is a marked bend in the body of the right nucleus, also seen in other models,

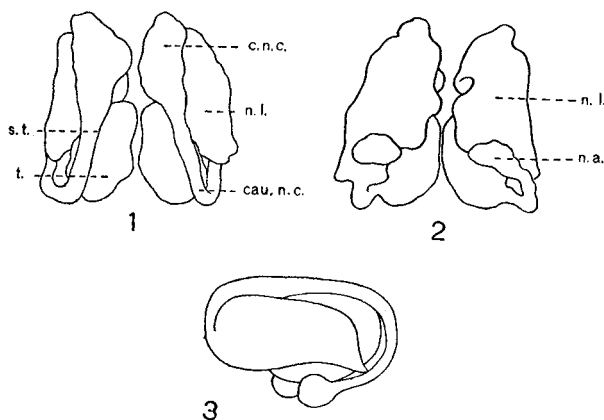


Fig. 1 Dorsal view of model No. 7 of basal ganglia; *c.n.c.*, caput nuclei caudati; *cau.n.c.*, cauda nuclei caudati; *n.l.*, nucleus lentiformis; *t.*, thalamus; *s.t.*, stria terminalis.

Fig. 2 Ventral view of model No. 7 of basal ganglia; *n.l.*, nucleus lentiformis; *n.a.*, nucleus amygdalae.

Fig. 3 Side view of model No. 7 of basal ganglia.

as though produced by the fiber bundles of the internal capsule. This bend is especially prominent at the genu. The left nucleus lentiformis is placed further anteriorly than the right. The volumes of these nuclei are about the same. The right thalamus is about 3 mm. longer than the left while the vertical and horizontal diameters of one side about equal those of the other.

A model of brain No. 2 was not reconstructed.

Model No. 3 (fig. 4) is one of the smallest of the series. It also shows marked asymmetry. The caput nuclei caudati of

the left side is larger than the right. The right nucleus lentiformis has a greater horizontal diameter than the left, and the fusion with the head of the caudate is less extensive. The left thalamus is much larger than the right. The body of the caudate on both sides shows the bend of the genu of the internal capsule.

No. 4 (fig. 4) shows the left nucleus caudatus to exceed greatly the right in size. The bend in the body on the right side is slight, on the left it is absent. The brain from which this model was reconstructed was somewhat torn, so the cauda nuclei caudati on each side is not shown. The right nucleus lentiform is about equal in size to the left, but its anterior extremity is less fused

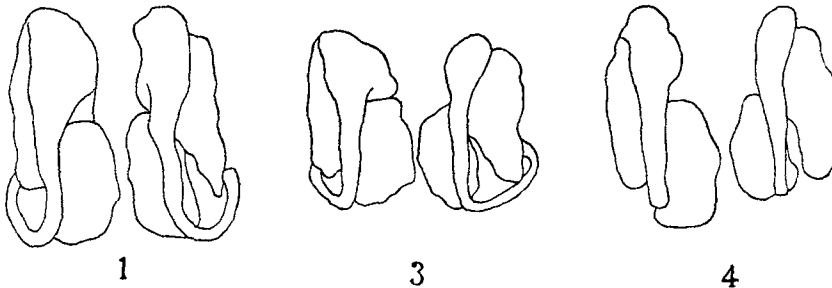


Figure 4

with the caput nuclei caudati. The left thalamus is much longer than the right, and the shorter horizontal diameter of the left is compensated by the longer vertical diameter of that side. It is to be noted that the thinness of the thalamus occurs on the side on which the capsula interna shows a thicker posterior limb.

Model No. 5 (fig. 5). The volume of the left caput nuclei caudati is greater than that of the right. There is a noticeable bend in the body of the left nucleus at the genu of the capsula interna. The right nucleus lentiformis greatly exceeds the left in volume. The right thalamus is longer than the left (not shown in the drawing), while its horizontal diameter is less than that of the left. Likewise on the right side the posterior limb of the capsula interna is thicker than the opposite side.

In model No. 6 (fig. 5) the volumes of the left caput nuclei caudati is slightly in excess of that of the right side. No bends in the bodies occur. The right nucleus lentiformis greatly exceeds the left in volume. The right thalamus is smaller than the left, and on this side the posterior limb of the capsula interna is thicker.

Model No. 8 (fig. 6) shows the bends in the bodies of the nuclei caudati. The nuclei themselves are fairly symmetrical. The right nucleus lentiformis preponderates. The tuberculum anterius thalami is more prominent on the right side, and the horizontal diameter of the thalamus is greater on the right side

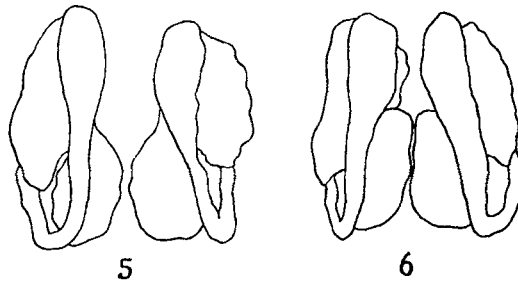


Figure 5

than on the left. The thickness of the posterior limb of the capsula interna of the right side corresponds with the lateral compression of the thalamus on the same side.

No. 9 (fig. 6). The volume of the right caput nuclei caudati exceeds the left. There is a marked bend in the body of the left nucleus. The right nucleus lentiformis is larger than the left. The volume of the left thalamus exceeds the right.

Model No. 14 (fig. 6). The only striking point of asymmetry is the excess volume of the right thalamus, although its lateral compression as compared with the opposite side is marked. Corresponding with this compression is the greater thickness of the posterior limb of the capsula interna on this side.

A comparison of the nine models shows that the convex surface of the caput nuclei caudati is more extensive on the left side

than on the right in about 78 per cent of cases. Since the left is the side on which the excess volume of the anterior horns was found, it seems possible that the extent of the floor at least partly determines the volume of the ventricle. This view is supported by the observation that those brains in which the left anterior

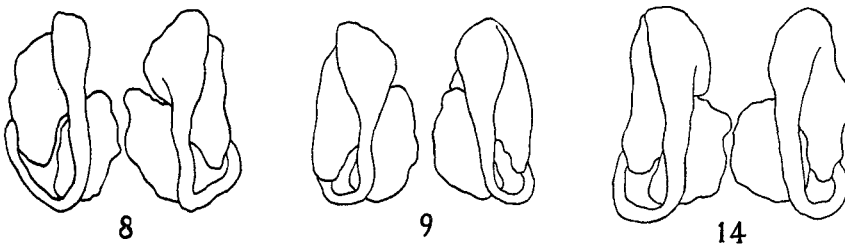


Figure 6

horn was enlarged showed a corresponding extension of the dorsal surface of the left nucleus caudatus. In table 1 the volumes of the anterior horns are given in cubic centimeters. Those underlined correspond with the surfaces of the caudate nuclei showing the excess areas.

TABLE 1

	NUMBER OF CAST									
	1	2	3	4	5	6	7	8	9	10
Left.....	3.5	8.2	<u>5.7</u>	<u>3.2</u>	<u>5.5</u>	<u>1.2</u>	<u>0.6</u>	7.2	1.0	2.4
Right.....	3.9	7.3	4.4	2.9	4.3	1.0	0.5	<u>7.4</u>	<u>2.0</u>	1.7

The areas corresponding with cast No. 1 were about equal on both sides. The brains from which casts Nos. 2 and 10 were made were so torn in removing the casts that they could not be used in the reconstructions.

The left nucleus caudatus, then, exceeds the right in size in 78 per cent of the cases; the right nucleus lentiformis exceeds the left in 55 per cent; the left thalamus exceeds the right in 55 per cent, although the transverse diameter of the right exceeds the

left in the same number of cases. The posterior limb of the capsula interna is thicker on the left side in 55 per cent of the cases, or in other words, it is thicker in those cases in which the thalamus seems to be laterally compressed. This series of models seems to show that the asymmetry of the basal ganglia is an element to be considered in determining the preponderance of a hemisphere. As stated before, it seems impracticable to weigh the nuclei, but if it be assumed that in the larger nuclei there is a difference in weight due to the greater number of nerve elements, then the preponderance of the left caput nuclei caudati will partly account for the asymmetry of the frontal lobes. The asymmetry of the remainder of the cerebrum also should be slightly influenced by the asymmetry of the basal ganglia.

The asymmetry of the posterior limbs of the internal capsules, suggested by this series of models, leads to the question of an excess of axones on one side.

Throughout the animal body there are repeatedly exemplified the morphological interrelationship of organs and parts of organs, and the morphological characters of organs resulting from the processes of growth. For example, the relation of the cranium to the pallium during development may be a factor in the production of the gyri, because as the cortical grey substance increases in amount in accordance with an increased bulk of body, the surface area may be limited by the capacity of the cranial cavity. The pallium is therefore thrown into folds. On the other hand, that the form of the cranium may be influenced by the asymmetry of the brain has been shown by Smith. It may be presumed that structures so intimately related as the basal ganglia and the internal capsule influence one another morphologically. The models show this in the bending of the nucleus caudatus at the genu of the capsula interna. Further, the genu conforms with the interval between the tuberculum anterius of the thalamus and the caput nuclei caudati.

SUMMARY

1. In nine brains the nucleus caudatus on the left side exceeds the right in size in 78 per cent of the cases.

2. The increased size of the left caput nuclei caudati seems to determine partly the greater volume of the left anterior horn of the lateral ventricle. The excess volume of the anterior horn of the left lateral ventricle corresponds in all cases examined with the increased size of the left caput nuclei caudati.

3. The right nucleus lentiformis exceeds the left in about half the series of brains, and the left thalamus exceeds the right in a like number.

4. The interrelations of the basal ganglia and the internal capsules may determine the morphological characters of these structures.

In conclusion, it seems possible that not only may the preponderance of a hemiserebrum depend on the pallium, but also on the asymmetry of the basal nuclei. The entire question of asymmetry of parts of the brain is one requiring prolonged study to which the present paper is but preliminary.

BIBLIOGRAPHY

- DONALDSON, H. H. 1905 The growth of the brain. Contemporary Science Series, vol. 24.
- FRANCESCHI, G. 1888 Bullettino della Scienze mediche (Bologna), no. 1-2, 3-4.
- HARVEY, R. W. 1911 The volume of the ventricles of the brain. Anat. Rec., vol. 5, no. 6.
- HITZIG, E. 1898 Neurol. Zentralblatt, S. 1119.
- HUSCHKE, E. 1854 Schädel, Hirn und Seele. Jena.
- ILBERG Allgem. Zeitschrift f. Psychiatrie. Bd. 60, S. 346.
- LIEPMANN H. 1905 Neurol. Zentralblatt, S. 1016.
- MALL, F. P. 1909 On several anatomical characters of the human brain, said to vary according to race and sex, with especial reference to the weight of the frontal lobe. Am. Jour. Anat., vol. 9.
- MEYNERT, TH. 1867 Vierteljahrschrift für Psychiatrie. Bd. 1.
- OBERSTEINER, H. 1901 Anleitung beim Studium der Nervösen Zentralorgane. S. 144.

PFISTER, H. 1903 Neurol. Zentralblatt.

POIRIER ET CHARPY 1899 Traite d'anatomie humaine, vol. 3, p. 744.

REICHARDT, M. 1906 Über die Untersuchung des gesunden und kranken Gehirns mittels der Wage. Würzburg.

SMITH, G. E. 1907 On the asymmetry of the caudal poles of the cerebral hemispheres. Anat. Anz. 30, p. 574.

TESTUT, L. 1911 Traite d'anatomie humaine, vol. 2, p. 731.

ZIEHEN, TH. 1899 Lehrbuch der Anatomie des Nervensystems, S. 382.