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Left-Right Dissymmetry, Handedness

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The presence of functional dissymmetry (or asymmetry) between the two sides of the brain seems to have been suggested in the fifth century BC by Hippocrates, when he pointed out that wounds on one side of the head usually caused seizures on the opposite side of the body (1). At approximately the same time the Biblical psalmist said, "If I forget you, O Jerusalem, let my right hand wither! Let my tongue cleave to the roof of my mouth if I do not remember you"[2]; a tongue that does not move well, associated with right-upper-extremity weakness, would suggest speech difficulty caused by a stroke in the left hemisphere. Somewhat more scientifically, Marc Dax noted in 1836 that aphasia in right-handed individuals was generally associated with lesions in the left hemisphere. This concept was generally ignored until after Broca's work on aphasia was presented in 1865 (2).

Although numerous articles did appear in the first two-thirds of the present century, mainly by anatomists and anthropologists, describing some morphologic brain asymmetries, the differences were so small that correlation between the asymmetries and cerebral function were considered by many scientists to be probably irrelevant (3). Advances in technology have made it easier to discover structural dissymmetries in the cerebral hemispheres. We are now trying harder to relate them to brain function.

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[2] Psalm 137: 5–6. Revised Standard Version of the Bible. This interpretation was passed on to the author by E. Isaacs, Director of the Institute of Semitic Studies, Princeton, NJ.

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Handedness

Handedness refers to the preference of an individual for performing tasks with one or the other of his/her hands, and to the common experience that most—but not all—individuals show greater facility and skill in the use of one of their hands. In our populations, most individuals strongly favor use of the right hand. A small number strongly prefer to use their left hands; a proportion have no strong preference and use either hand, sometimes interchangeably, sometimes favoring one hand for one task and the other for a different task.

As will be shown, strong *right* handedness is commonly associated with asymmetrical development of the brain. "Left-handedness" may be associated with either 1) mirror-image, left-right reversal of these brain asymmetries or 2) reduced degrees of brain asymmetry. The group of so-called "left-handers" does not simply show mirror image reversal of brain anatomy. Indeed, "Cerebral asymmetries of structure and function are less pronounced in left handers as a group than in right handers as a group, and variability is greater in left handers" (4). Therefore, it would appear to be more useful to think of individuals as being either right-handers or *non*-right-handers, rather than as being right-handers versus left-handers.

In reading this communication, therefore, please view the data as indicating 1) definite asymmetry of the brain, most frequently seen in strongly right-handed individuals; 2) true reversal of brain asymmetry, seen in some strongly left-handed individuals; and 3) less asymmetry of the brain (ie, more nearly symmetrical brain anatomy), usually seen in non-right-handers.

Planum Temporale

In 1968, Norman Geschwind and Walter Levitsky (5), studying 100 adult brains at postmortem, all free of significant pathology, found marked anatomical asymmetries between the right and left temporal lobes in a region that included part of Wernicke's speech area. They noted that an area on the posterosuperior surface of the temporal lobes, the planum temporale (Fig. 1), was larger on the left in 65 of the brains examined and larger on the right in only 11. Some earlier authors had reported similar findings, but in a much smaller number of brains (6, 7, 8). Other articles are listed in a review of functional and anatomical asymmetries of the brain by Witelson and Kigar (8). Since the Geschwind/Levitsky publication (5), numerous scientists have studied dissymmetries of the planum temporale, some showing differences in right- and left-handed individuals (9, 10). Planum asymmetries have been described in neonatal and fetal brains (11–13) as early as the 29th week of gestation. Even in early life the left planum is more often larger than the right.

Galaburda et al (14) have reexamined the same brains studied by Geschwind and Levitsky and offered new comments concerning the asymmetries. They found that when the planums developed more symmetrically, the right planum became larger. Excellent detail of the region can be, and has been, obtained by carefully performed computed tomography (CT) and magnetic resonance (MR) studies (15, 16). There is still, however, some difficulty in defining the borders of the planum temporale and the exact posterior margin of the Sylvian fissures (2, 11, 14). At the present time, therefore, more research needs to be done on this area before it can be used in routine radiographic studies of cerebral asymmetries.

Besides directing attention to asymmetries in the temporal speech area, the Geschwind/Levitsky article stimulated new interest in the relationship between anatomical and functional asymmetries. Since the middle cerebral arteries course over the region of the planum temporale, the findings of Geschwind and Levitsky stimulated others to check the tracks of these vessels for significant asymmetries.

Left-Right Arterial Dissymetries

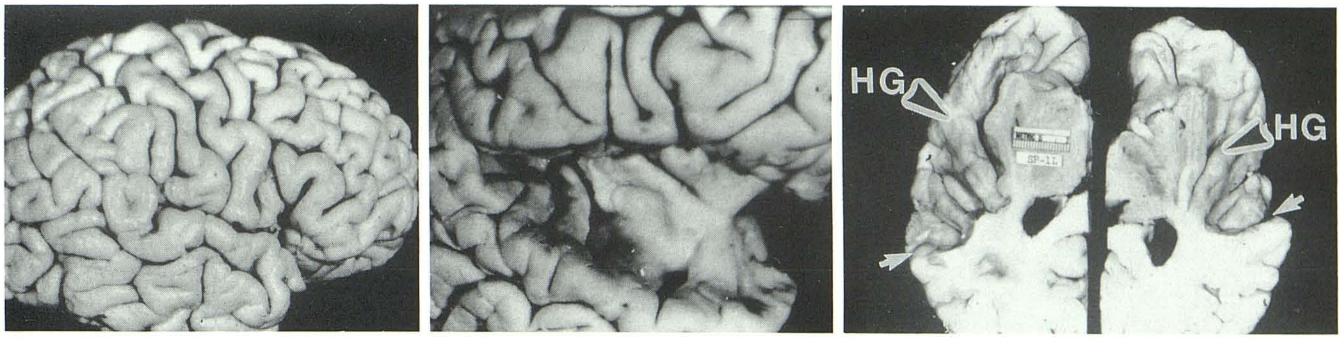
Analyzing the vascular asymmetries in the region of the planum in 1972 (17), LeMay and Culebras found significant asymmetries of the branches of the middle cerebral arteries as they left the posterior ends of the Sylvian fissures and looped under the lower margins of the parietal opercula to reach the convex surfaces of the parietal lobes (Figs. 2 and 3). In frontal projections, the angle formed by the branches of the middle cerebral arteries as they leave the sylvian fissures reflects the size of the parietal operculum. When the parietal operculum is large, these loops are crowded together and form a narrow angle. When the parietal operculum is small, the loops of the middle cerebral artery are broad and wide. LeMay and Culebras found that the angle formed by the vessels leaving the posterior end of the sylvian fissures was wider on the right (smaller parietal operculum) in 38 of the arteriograms studied and wider on the left in only four. Since statistically about 90% of these patients were probably right-handed, the significance of these findings was tested by reviewing the bilateral angiograms of 18 left-handed patients. In only three of the 18 cases were the angles formed by the right middle cerebral artery, leaving the sylvian fissures wider than the left. In 13 patients, the right and left middle cerebral artery arches were essentially equal, and in two of the left-handed patients, the left arch was wider. The findings in this study were confirmed in a larger follow-up study in which handedness of all the patients was known (18). Thus, in the population as a whole, the middle cerebral artery arches are narrower on the left because most people are right-handed and, in right-handed individuals, the parietal operculum is commonly larger on the left.

A difference in the size of the temporal lobes and in the heights of the posterior ends of the sylvian fissures can also be shown on the lateral surfaces of the brains—of fetuses, of modern adults, and even of Neandertal man (19) (Fig. 4).

Superficial Venous Dissymmetries

Superficial Draining Veins

The superficial draining veins represent another area of asymmetry. In 1961, 6 years before the planum temporale paper of Geschwind and Levitsky, DiChiro (20) reviewed the arteriographic studies of patients who had Wada Tests to determine hemispheric dominance for speech. DiChiro found that the superficial vein of Labbe was more prominent than the vein of Trolard on the side of



A B C

Fig. 1. *A*, Lateral surface of the right hemisphere of a human adult brain.

B, Spreading of the Sylvian fissure and exposing the superior surface of the temporal lobe.

C, Slices through the right and left hemispheres, showing asymmetry of the superior surfaces of the temporal lobes. The planum temporale are defined anteriorly by Heschl's gyrus (*HG*) and posteriorly by the posterior margin of the Sylvian fissure (*white arrows*). The latter frequently is longer on the left, and the left planum is commonly larger than the right.

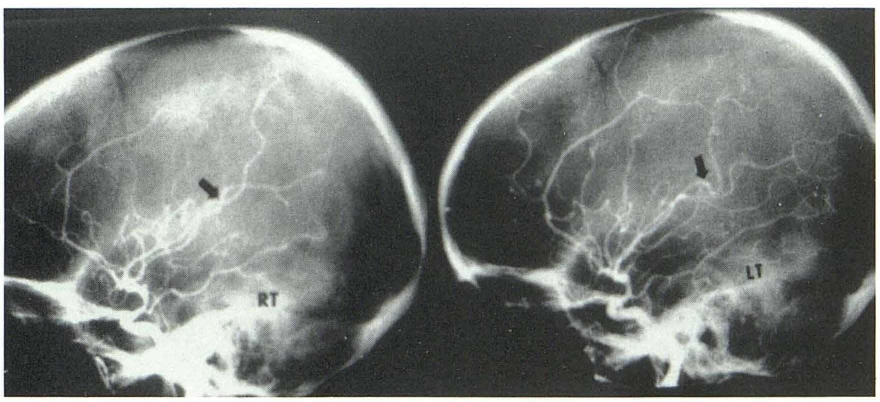


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Fig. 2. Right and left carotid angiograms. As the main middle cerebral branches leave the posterior end of the Sylvian fissure, the one on the right (*arrow*) commonly curves gently superiorly, while the left middle cerebral artery loops below (*arrow*) the adjacent parietal operculum before reaching the outer surface of the brain.

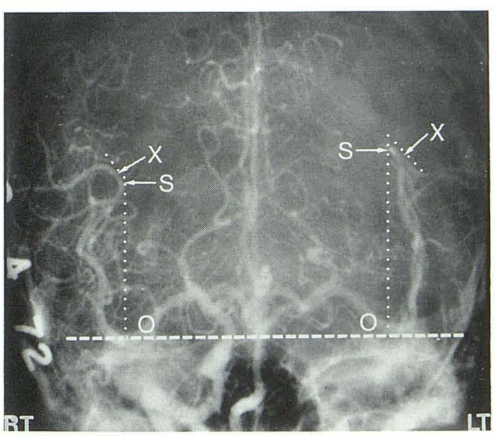


Fig. 3. Angles formed by the middle cerebral arteries leaving the posterior ends of the Sylvian fissures. *S* = posterior end of the fissure. A second point, *X*, made on the artery 1 cm lateral to *S*. The Sylvian point angle was formed by a line drawn from *X* to *S* and a line drawn down from *S* to form a perpendicular angle with a supraorbital line (18).

cerebral dominance. Hochberg and LeMay (18) similarly found that the vein of Labbe also was the major drainage vein on the left side in right-handed individuals, ie, on the side of cerebral dominance.

Superficial Draining Sinuses

Blood draining from the superior longitudinal sinus flows more commonly into the right transverse sinus than into the left. This was noted in 61% of 111 carotid angiograms (18). In only 12.6% was the main flow to the left. This preference is already established in fetal brains. In 1915, Streeter (21) found that blood in the superior venous channels, "plexus sagittalis," flowed mainly into the right transverse sinus in fetal brains. The distal end of the longitudinal sinus more often lies slightly to the right of the midline. The right transverse sinus is commonly higher than the left. In the Hochberg and LeMay study (18), the right transverse sinus was higher than the left in 54% of 102 arteriograms of right-handers. In angiograms of 16 left-handers, 69% of the transverse sinuses were equal in height or higher on the left side. The position of the distal

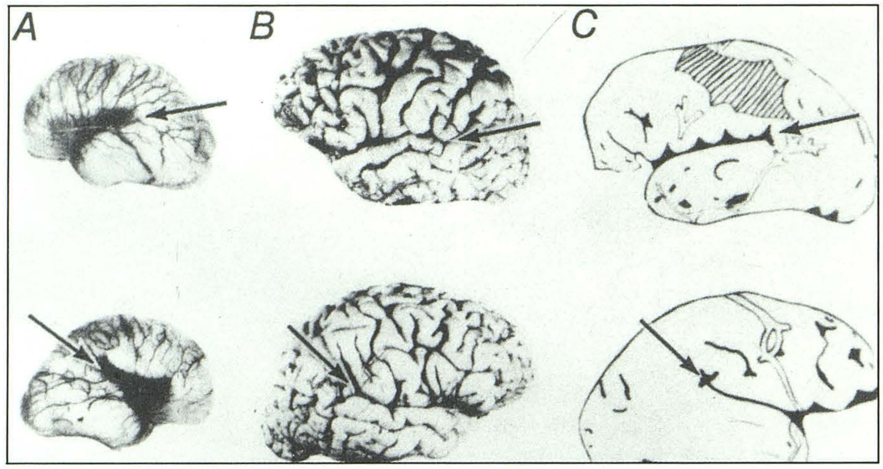


Fig. 4. Lateral surfaces of the brains of *A*, 16-week-old fetus; *B*, an adult; *C*, La Chapelle-aux-Saints Neandertal skull (after Boule and Anthony drawing from an endocast) (17). *Arrows* show the posterior ends of the right Sylvian fissures to curve upward. The posterior portion of the right temporal lobe is larger than the left and the posterior portion of the left parietal operculum is larger.

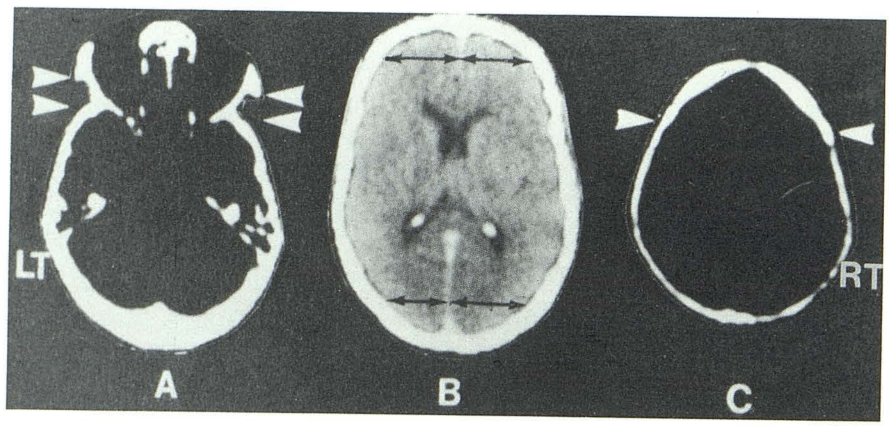


Fig. 5. Axial CT scans of a 70-year-old left-handed man.

A, Scans taken through the orbits, middle, and posterior fossae. *Arrowheads* show the outer margins of the left orbit and the anterior margin of the middle fossa to be more forward on the left. The inner table of the right posterior fossa extends slightly more posteriorly than the left.

B, CT scan shows the anterior portion of the left hemisphere to be wider and to extend slightly more forward than its counterpart. The width of the right posterior hemisphere is wider and the glomus of the choroid plexus of the right lateral ventricle is more posterior than on the left. The scan taken below this one shows, as on scan *A*, the right hemisphere to extend further posterior than the left.

C, *Arrowheads* show the left coronal suture to be more forward than the right.

portion of the longitudinal sinus to the right of midline, and the lower position of the left than right transverse sinuses, probably occurs because the posterior portion of the left hemisphere is usually wider than the right.

Dissymmetries of the Cerebral Hemispheres

The posterior end of the left cerebral hemisphere commonly extends further posteriorly than does the right. This posterior protrusion—designed petalia—often causes localized thinning and protrusion of the skull. Anatomists and anthropologists early in this century noted these findings and even associated them with handedness. The anthropologist A. Keith (22), in 1910, argued that a skull found in Gibraltar was of a right-handed individual, because the left occipital pole was longer than the right. In 1925, G. Elliot Smith (23), a well-known anatomist, suggested that the so-called "London skull," found when excavating for the building of Lloyds Bank of London (and which he referred to as "the Lady of Lloyds") was left-handed, because the right occipital bone protruded further than the left.

In 1968, McRae et al (24) published a seminal radiographic article on right-left brain asymmetry and handedness. In right-handed individuals with pneumographic evidence of asymmetry of the occipital horns, the left occipital horn was five times more likely to be longer than the right. In left-handed individuals with asymmetrical occipital horns, a longer right horn occurred as often as a longer left one. They also noted that in studies of patients with recurrent focal seizures, the occipital horn lengths did not correlate well with handedness. Strauss and Fitz (25), also studied the pneumoencephalograms of 75 young individuals between the ages of 5 months and 18

TABLE 1: Frontal and occipital petalia[a] of the heads of black and white Americans, South African blacks, and fetal black and white brains

	Handedness	Frontal			Occipital		
		R↑	=	L↑	R↑	=	L↑
American whites							
Female	RH	62	23	15	6	10	84
	LH	10	6	7	5	2	16
Male	RH	54	35	11	15	18	67
	LH	10	7	3	6	2	12
Total M + F		136	71	36	32	32	179
American blacks							
Female	RH	21	23	25	23	13	33
	LH	5	2	9	6	3	7
	?H	22	16	31	29	15	25
Male	RH	16	18	14	17	6	25
	LH	3	1	3	3	0	4
	?H	8	10	26	28	4	13
Total M + F		75	70	108	106	41	107
South African blacks (Sotho, Zulu, Mixed)							
Female	?H	4	22	13	14	10	15
Male	?H	20	48	31	39	29	31
Total M + F		24	70	44	53	39	46
Fetal brains (20–30 weeks gestation age)							
Black female		5	0	1	1	0	5
White female		4	0	1	1	0	4
Black male		7	0	1	1	0	7
White male		3	0	1	1	0	3
Total black M + F		12	0	2	2	0	12
Total white M + F		7	0	2	2	0	7

[a] An area of protrusion of one hemisphere beyond the other has been referred to as frontal, occipital, or parietal petalia in anthropologic and anatomical literature. There has been some controversy about the origin of the word "petalia." As the word "centripetal" denotes "seeking" or "spreading" *inward*, "frontal petalia" refers to "spreading" *forward*.

years, but without note of handedness. They noted the left occipital horn was commonly longer than the right. However, in patients who had a history of cerebral damage occurring before 2 years of age, the occipital horns tended to be more often equal in length or the right was longer than the left. The lengths of the occipital horns of the lateral ventricles often cannot be compared as accurately on CT and MR studies because of variations in the angulation of the scans, but there does appear to be some correlation between the position of the glomus of the choroid plexus of the lateral ventricle, and posterior extension of the brain and skull on the same side.

The introduction of CT has been accompanied by an explosion of literature on functional and morphologic asymmetries of animal and human brains. The relationship between handedness and asymmetries of the hemispheres is far from absolute. A few authors have even denied any relationship, but more anatomical, and even biochemical, brain asymmetries are being found and related to function.

Some modern studies have agreed with the opinion of earlier anatomists and anthropologists that there is a relationship between the occipital portions of the skull and handedness. CT studies have shown a statistical correlation between handedness and 1) protrusion of the occipital bone (occipital petalia—see Table 1), 2) protrusion of the frontal bone (frontal petalia), and 3) the transverse dimensions (widths) of the frontal and posterior portions of the hemispheres (26–29). In right-handers, the anterior portion of the right hemisphere and the posterior portion of the left hemisphere were commonly found to be wider and to protrude further than their counterparts. Left-handers, particularly those with a his-

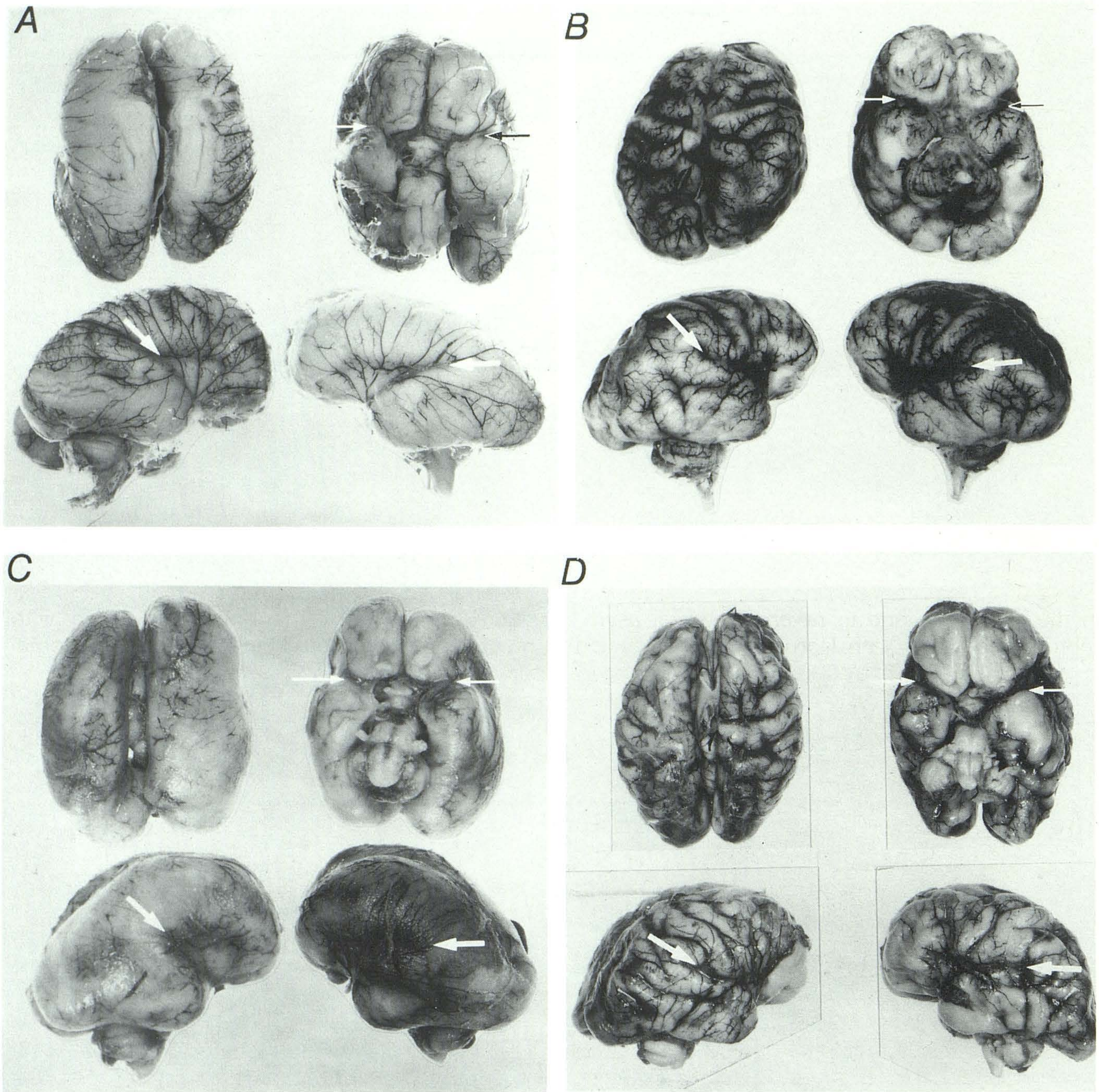


Fig. 6. Superior, inferior, right, and left surfaces of fetal brains. *Small arrows* mark the anterior tips of the temporal lobes. *Larger arrows* show the posterior ends of the Sylvian fissures. *A*, 23-week-gestational age (GA) black girl; *B*, 29-week GA black girl; *C*, 22-week GA white boy; *D*, 29-week GA white boy.

tory of other left-handers in the family, tended to show less asymmetrical findings and often showed a reversal of the type of asymmetry commonly seen in normal right-handed individuals. Since the size and shape of the skull are influenced by brain growth and shape, some of the gross asymmetries of the hemispheres seen on CT studies are reflected in the shape of the skull and in the face of the individual (30) (Fig. 5).

The term "left-handed" is somewhat ambiguous. Sinistrality may be natural or hereditable (31), or may be due to environmental causes such as trauma or toxins, in fetal or early life (32–36). Geschwind and Behan (37) reported an increased incidence of left-handedness in patients, and their

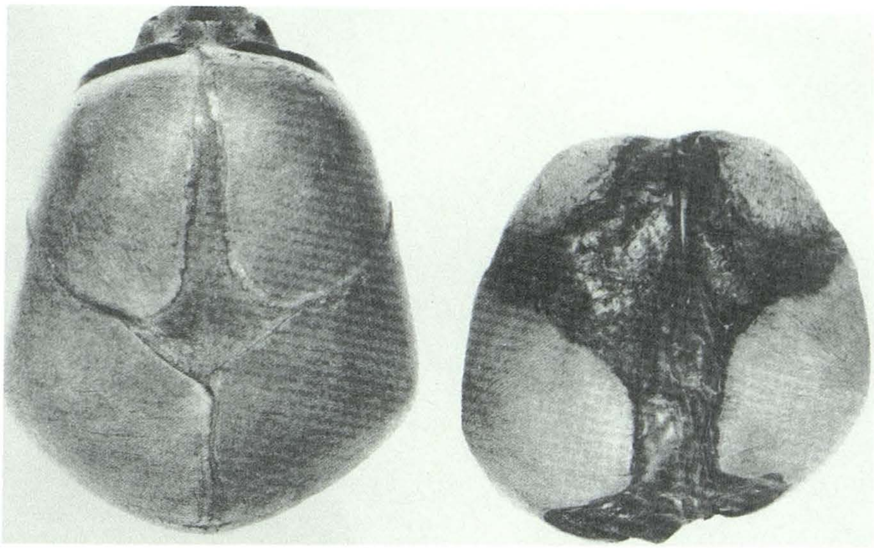


Fig. 7. Fetal skulls.

A, the bone over the right frontal region, coronal suture, and the lower rim of the orbit are further forward than on the left.

B, Upper surface of a young fetus with hydrocephalus. There is forward extension of the right frontal region and posterior extension of the left occipital region and of the bone islands of the developing vault.

families, with autoimmune diseases, eg, Crohn disease and Hashimoto thyroiditis, and in those with learning disabilities. Galaburda has added new data to this study (38). There is an increase in the symmetry and in *reverse* cerebral asymmetry, in patients with learning disorders, such as dyslexia (39), but only some of the dyslectic individuals, and their relatives, show an increase in left-handedness (40).

Injuries in early life, sometimes resulting in recurrent seizures, may influence functional lateralization, ie, speech and handedness, in the brain. Such individuals should not be included in studies as "normal" individuals (41).

Dissymmetry of Fetal Brains

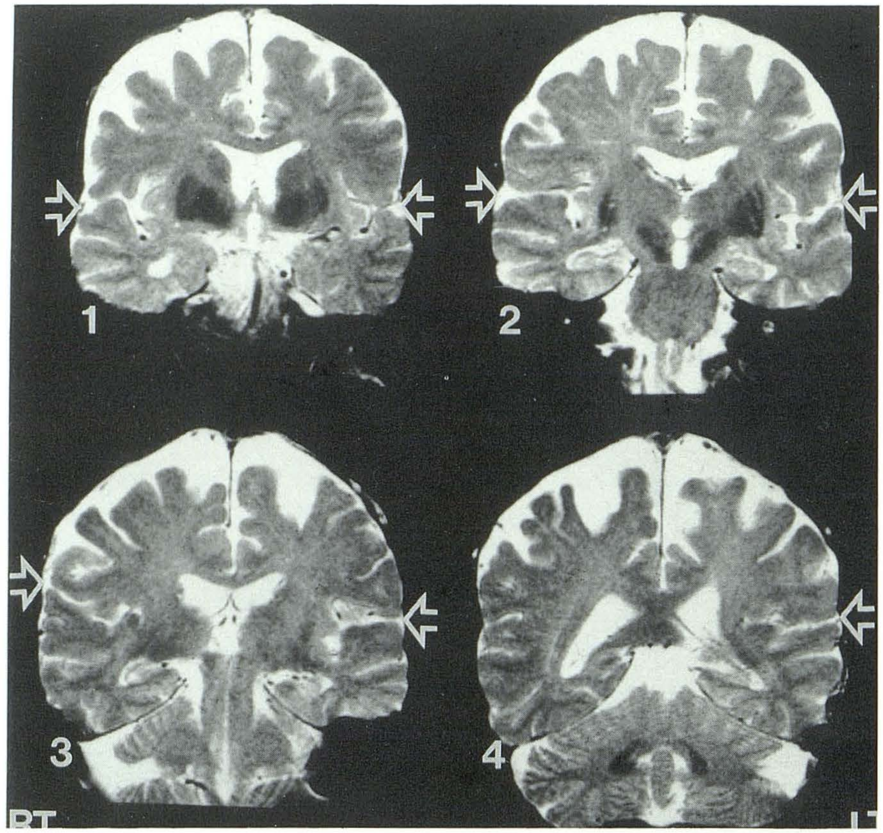
Many of the gross asymmetries seen in normal adult brains are also found in fetal brains. Weinberger and his colleagues (42) measured the volumes of the anterior and posterior portions of 40 "normative" brains in the Yakovlev collection at the Armed Forces Institute of Pathology in Washington, DC. Volumes of the frontal lobes were measured on coronal sections of the brains, beginning from the anterior margin of the genu of the corpus callosum, forward; posterior portions of the hemispheres were measured from a point midway between the splenium of the corpus callosum and the occipital margin of the brain, posteriorly. Twenty of the brains were from fetuses and infants. Statistically, the volumes of the right anterior and left posterior hemispheral sections were larger than their counterparts in fetuses as well as in adults.

Recently I made measurements of the frontal and occipital petalias on photographs of 23 whole fetal brains, 21–42 weeks gestational age, in the Yakovlev collection in Washington, DC. Again, a right-left torque of the brain was noted with greater anterior protrusions of the right frontal and posterior protrusion of the left posterior hemispheres. These data are shown in Table 1. Figure 6 shows photographs of four fetal brains from the collection. The forward projections of the right frontal lobe and tip of the right temporal lobe, and the posterior extension of the left occipital lobe, are more striking in these fetal brains than in most adult brains. Views of the lateral surfaces of the brains also show asymmetries of the posterior ends of the Sylvian fissures, as displayed in the 16-week-old fetal brain in Figure 4.

Nearly a half century ago, Gesell and Ames (43) studied the direction a neonate preferred to turn its head in early life, particularly during the first 12 weeks. In one study of normal but premature neonates, 22–40 weeks gestational age, 77% turned their heads to the right. The authors noted that infants with round heads did not posture their heads as frequently as ones with a prominent occiput on one side. This neonatal head turning was, and probably still is, usually referred to as a "tonic neck response." Gesell and Ames followed 19 cases for 10 years. In 14 of the children, the way the head turned in early infancy predicted the side of handedness found at age 10 years. Four of the cases showing left head turning were left-handed at 10 years. Liederman and Kinsbourne (44) reported right head turning of an infant to be more frequent when

Fig. 8. *A*, Right-hander: Coronal MR scans of a 74-year-old, well-functioning man, except for slight loss of vision in the right eye following a small left occipital infarct. *1*, Scan through anterior margin of the third ventricle. The Sylvian fissures are fairly symmetrical in position. *2*, Scan through midportion of the third ventricle. The Sylvian fissure on the right is slightly higher. *3*, Scan through the brain just posterior to the third ventricle. The right Sylvian fissure angles upward as it leaves the insular region and extends to the surface of the brain. *4*, Scan further posterior. The right Sylvian fissure is no longer seen.

B, Left-hander: Coronal MR scans of a 41-year-old woman mathematician with slight galactorrhea. Her father was also left-handed. The Sylvian fissures are fairly symmetrical in position and the right one extends as far posteriorly as the left.



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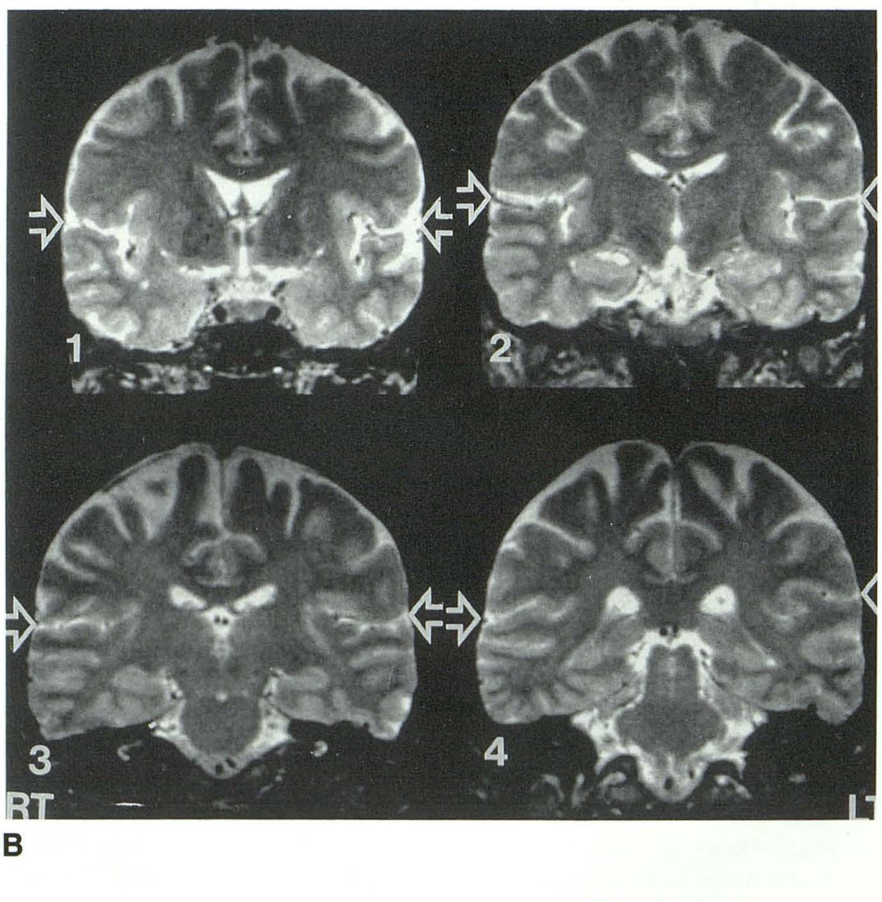

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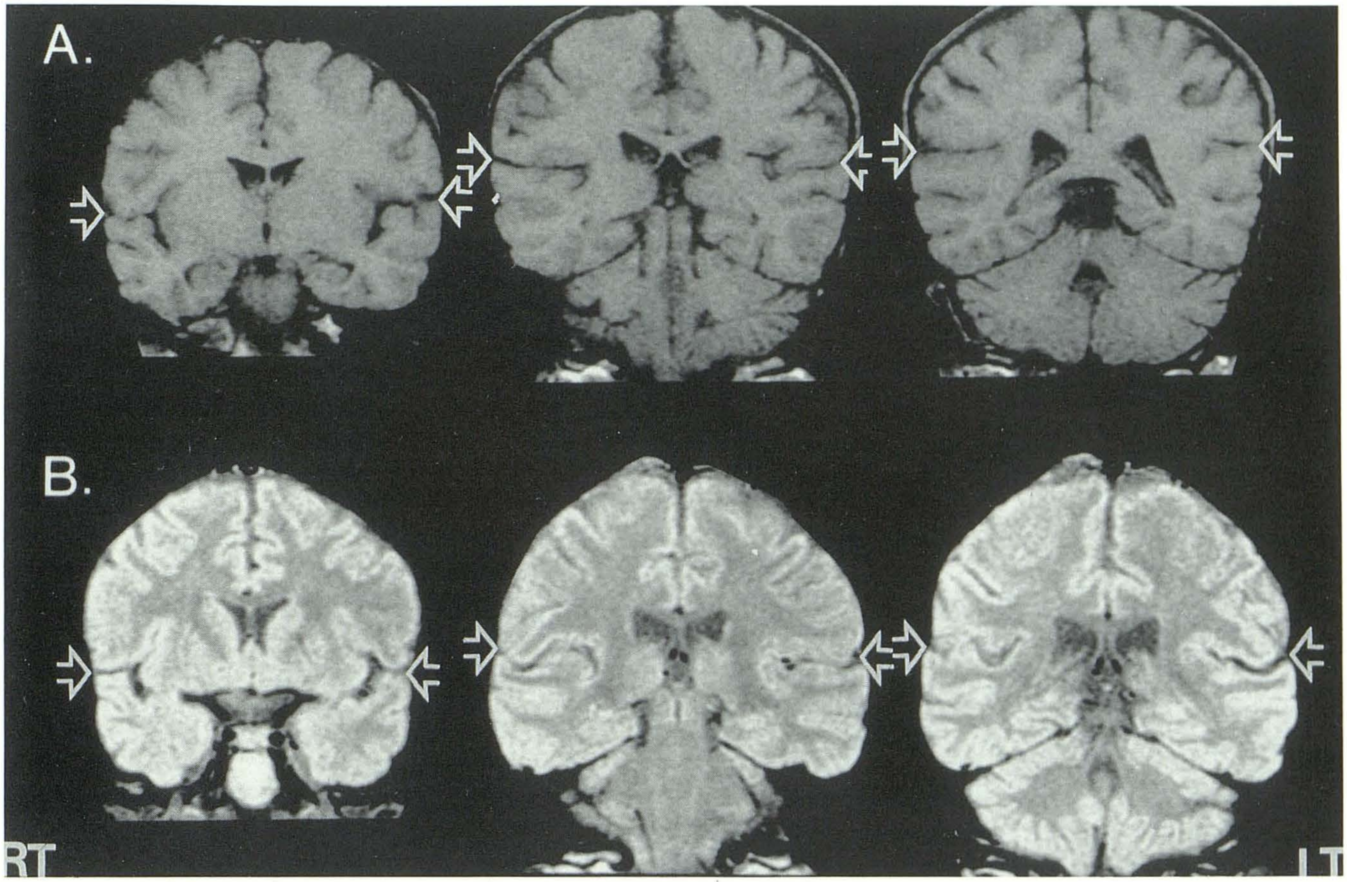

Fig. 9. *Right-handers:* Coronal MR studies of two normal black women. *A*, 41 years old; *B*, 53 years old. The Sylvian fissures are fairly symmetrical in length and position and resemble those seen in Figure 8B of a left-handed white woman.

both parents were right-handed than when one of the parents was non-right-handed. Figures 5 and 7 show how the shape of the skull is influenced by the brain. Thus it would seem plausible that the prominent left occipital petalia that is present in the majority of fetal brains may be a strong factor influencing the turning of the head to the right in early life. It could also have some influence on the position of the head at delivery, which has been reported to have some association with handedness (45).

There is an increase of left-handedness in children with a history of premature birth and extremely low birth weight (35). Newborns with premature birth have been reported to turn their heads as often to the left as to the right (46). Infants who have had considerable exposure to alcohol, and/or to nicotine, *in utero* also have significantly lower brain weights and have been reported to show an increase in head turning to the left in early life (47). Additional studies with neuroimaging should be helpful in correlating head turning, type of brain asymmetries, and handedness in such individuals.

Dissymmetries on MR Studies

Coronal MR is superb for studying brain asymmetries. In the posterior sylvian region, MR shows differences in the hemispheres (Fig. 8) similar to those that have been found in right- and left-handed white individuals on arteriographic studies, shown in Figure 9.

These asymmetries are usually seen more clearly on scans taken parallel to the floor of the fourth ventricle. This plane is essentially similar to the bone axis of the brain stem (Meynert's axis).

Caveat

And now for the caveat. Most of the early CT scanning of brains was performed on white individuals, from whom the early statistics on CT imaging of brain asymmetries were obtained (26). G.E. Smith (23), working in Cairo in the early part of this century, noted that skulls of blacks tend to show fewer asymmetries in the occipital region than do Egyptian skulls. I had noted similar differences on head CT scans between American

TABLE 2: Frontal and occipital petalia of skulls of American Indians and Eskimos (petalia determined by direct visualization)

	Handedness	Frontal			Occipital		
		R	=	L	R	=	L
New Mexico (Pecos)							
Male and female	?H	37	3	19	19	3	37
Arizona (Awatovi)							
Male and female	?H	59	8	31	32	7	59
NorthWest (Washington and Oregon)							
Male and female	?H	21	1	7	7	1	21
California							
Male and female	?H	15	3	2	2	3	15
Utah							
Male and female	?H	7	3	1	2	2	7
Eskimo (Labrador and Alaska)							
Male and female	?H	39	5	1	3	6	36
Massachusetts							
Male and female	?H	15	4	2	4	6	11

TABLE 3: Comparative widths of the cerebral hemispheres of black and white Americans, black South Africans, and white females with breast cancer

	Handedness	Frontal			Occipital		
		R>	=	L>	R>	=	L>
American whites							
Female	RH	66	17	17	17	11	72
	LH	7	9	7	9	7	7
Total		73	26	24	26	18	79
Male	RH	56	27	17	19	13	68
	LH	10	5	5	7	2	11
Total		66	32	22	26	15	79
Total M + F		139	58	46	52	33	158
American blacks							
Female	RH	18	27	24	24	18	27
	LH	4	3	9	7	3	6
	?H	16	20	33	31	13	25
Total		38	50	66	62	34	58
Male	RH	15	21	12	18	12	18
	LH	2	3	2	2	3	2
	?H	8	9	28	29	6	10
Total		25	33	42	49	21	30
Total M + F		63	83	108	111	55	88
South African blacks (Sotho, Zulu, Mixed)							
Female	?H	17	8	8	18	6	9
Male	?H	47	29	20	47	27	22
Total M + F		64	37	28	65	33	31
White females with breast cancer	RH	25	15	39	41	15	23
	LH	8	1	5	5	1	8
	?H	22	23	18	19	13	31
Total		55	39	62	65	29	52

whites and blacks. I also found that blacks more frequently showed an increased widening of the posterior portion of the right hemisphere. Because of these findings, I went to Johannesburg in 1983 and spent several weeks studying head CT scans at Baragwanath Hospital, a 2000-bed well-run hospital with mostly black patients. The occipital asymmetries there resembled those I had seen on CT studies of American blacks. P.V. Tobias (48), professor of anatomy at the University of Witwatersrand, Johannesburg, did a very extensive study on the intra- and inter-racial variability of the occipital bones in African blacks and pointed out that a prominent curvature of the occipital bone is present in black African infants and neonates, but that the curvature tends to flatten out about the time the permanent teeth begin to erupt. He also suggested that some spatial relationship exists between the brain and the occipital and parietal bones. This would correlate with the differences of CT asymmetries seen in American black and white *adult* brains versus the similarity seen between black and white fetal brains seen in the Yakovlev collection (Figs. 6A and 6B).

D. McShane, now at the University of Utah, has studied mental health among American Indians. With his colleagues, he compared CT differences in brain asymmetries among blacks, whites, and American Indians (49–51). (Incidentally, an increase in left-handedness is seen in some talented groups such as mathematicians, architects, and artists. Their brains would be expected to show less asymmetry, and/or an increase in width and length of the right hemisphere than that seen in normal white individuals.) In the brains of American Indians and blacks, McShane et al found 1) less asymmetry than in whites, and 2) an increase in width of the posterior portion of the right hemisphere. I have seen few, if any, head CT scans of American Indians. However, analysis of frontal and occipital petalias in more than 200 Indian, and some Eskimo, skulls showed statistically less asymmetry, and more reverse asymmetries in skulls from the southwestern parts of the United States than in skulls from the Midwest and East (Table 2). These 200 skulls represented American Indians who died before, or during, the early invasion of Europeans into North America. McShane and his colleagues have pointed out that some of the differences in cerebral asymmetries between Indians and whites may be based on genetics. However, they question whether alcohol intake may artifactually influence the data. Indians with a positive alcohol history showed the lowest incidence of left occipital petalia of any of the ethnic groups (50). Since cerebral asymmetries are mostly programmed in early life, one must consider that at least some of the reverse asymmetries seen in American Indians may be the result of exposure to alcohol, and/or other toxins, before birth, as well as to a different genetic heritage.

Finally, reading CT scans at a cancer hospital, I discovered that patients with breast cancer have fewer cerebral asymmetries than do normal white individuals, and that these asymmetries are often reversed in type (Table 3). There is evidence that exogenous estrogens, particularly taken at the time of menopause, increase the risk of breast cancer. Trichopolos (52) has suggested that increased concentration of estrogens in pregnancy may increase the risk of breast cancer in daughters, which is one possibility for these findings.

We are just at the dawning of true analysis of anatomic and functional cerebral asymmetry. Much remains to be discovered. What we already know offers intriguing glimpses into how detection of asymmetry may help to determine past medical history, present diagnosis, and prognosis.

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