FORM, WIDTH AND SYMMETRY OF THE SUPERIOR TEMPORAL GYRI IN MAN

A Thesis

Presented to

the Faculty of Graduate Studies

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Elizabeth Jane Akesson

May 1972

FORM, WIDTH AND SYMMETRY OF THE SUPERIOR TEMPORAL GYRI IN MAN

by

Elizabeth Jane Akesson

ABSTRACT

Fifty-four human brains were studied to compare form, width and symmetry at the right and left superior temporal gyri. The brains were divided into two groups--an I (infant) group of 12 brains and an A (adult) group of 42 brains.

Although not all of our observations and measurements were highly significant ($P < 0.01$) we did find definite non-symmetries in our right and left superior temporal gyri. There were straight vs sinuous gyri, right-angled upturned lateral sulci, and an interesting shift from symmetrical superior temporal gyri in infants to wider right superior temporal gyri in adults.

ABSTRACT

Fifty-four human brains were studied to compare form, width and symmetry at the right and left superior temporal gyri. The brains were divided into two groups--an I (infant) group of 12 brains and an A (adult) group of 42 brains.

Although not all of our observations and measurements were highly significant ($P < 0.01$) we did find definite non-symmetries in our right and left superior temporal gyri. There were straight vs sinuous gyri, right-angled upturned lateral sulci, and an interesting shift from symmetrical superior temporal gyri in infants to wider right superior temporal gyri in adults.

ACKNOWLEDGEMENTS

I would like to thank Dr. J. B. Hyde, my advisor and mentor, for his encouragement, support and direction throughout this investigation, and for his invaluable assistance in preparing this thesis. To Mrs. B. Bell, for her excellent photography, to the Computer Department, Health Services for the analysis of my statistics, and to Mr. Bernie Bressler and Mr. R. Rollwagen, who helped to organize the statistical programme, and to Mr. Andrew Cleaver who arranged the randomization of the brain transparencies, my sincere thanks.

This investigation was supported by the Anatomical Research Fund.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

In anticipation of the question--why have I chosen to study the superior temporal gyri?--I would like to outline my basic reasons. First, there is a constancy to this gyrus throughout primates. It appears as a primary fissure or sulcus in the human fetus of 16 weeks, and its position and form are quite constant throughout the primate series (Connolly, 1950). A second characteristic is the lateral surface of this gyrus which lends itself well to being photographed. It presents a clearly defined lateral surface which can be measured in the photographs. The superior temporal gyrus plays an important role in the receptive part of the verbal function (Penfield & Roberts, 1959) and this provides the third reason for investigation of this area. The brains to be used were divided into two groups--(1) Infants' brains, of which there were 12, and (2) adult size brains, 42 in number.

Before proceeding, I will define the words form, width and symmetry as they apply to this thesis. Form is used to describe the shape of the superior temporal gyrus. Is it sinuous or is it straight, i.e., does it fold and pleat upon itself or does it present a smooth uncomplicated lateral surface? It appears in the early primates as a straight gyrus as in Sub-order Anthropoidea Platyrrhini,--Family Hapalidae--Genus Hapale--Common Marmosets (Connolly, 1950). This straight gyrus is a constant feature in primates including the gorilla, orangutan and chimpanzee. This same straight superior temporal gyrus is seen in the young human fetus and is well documented in the photographs of Larroche (1962). As the fetus develops, the gyri become more sinuous or folded. But in this study of infant and adult-sized brains I did find straight gyri as defined above.

The widths measured were the distances between the lateral sulcus and the superior temporal sulcus as seen in the tracings of the brains.

In order to compare the symmetry of the hemispheres, right and left hemispheres of each brain were photographed, then traced. The pairs of hemispheres were assigned coded numbers so that the observer was not aware which hemisphere was the actual right or left. Their symmetry was judged by comparing their form--sinuous vs straight--and their width. Throughout this presentation I will refer to symmetry and non-symmetry. The term non-symmetry is used rather than asymmetry because I have found considerable confusion caused in the spoken usage of asymmetry. It is easily mistaken for "a symmetry." Geschwind and Levitsky (1968) reported finding marked right and left non-symmetries in their study of the planum temporale. They measured the superior surfaces of the right and left temporal lobes in 100 adult human brains, specifically the planum temporale from its anterior border (formed by the sulcus of Heschl) to its posterior margin. They found the planum temporale of the left hemisphere are larger in 65% and on the right in 11% with equality in 24% of their specimens. The length of the outer border of the planum temporale was also longer on the left than on the right, as other studies have indicated (Connolly, 1950; Von Bonin, 1962).

In contrast to their area of study I have chosen to examine the lateral aspect of the superior temporal gyrus, from a point 1 cm behind the anterior pole of the temporal lobe to the furthest point posteriorly at which I felt the gyrus was clearly defined. In the most posterior regions, the gyrus was not always definite and I felt it was not possible to clearly differentiate between the posterior part of the superior temporal gyrus and the parietal area. According to Penfield and Rasmussen (1950) "Ablation of cortical tissue on the dominant side must be limited to the anterior 5 cm of the temporal lobe as measured along the Sylvian fissure...in order to avoid aphasia."

Basically, two criteria were used to judge the symmetry or non-symmetry of the right and left gyri. One criterion was to compare the widths of one superior temporal gyrus with those in the opposite hemisphere, always remembering that it was not known which hemisphere was the actual right or left. The other basis of comparison was a visual examination of both transparencies and tracings for straight gyri as contrasted with sinuous gyri.

The measurements, therefore, were concerned with the anterior 6 - 8 cm of the superior temporal gyrus but not extending back into the parietal lobe. Measurements ceased at the point beyond which the superior temporal gyrus could not be clearly defined in the transparencies. Although a number of straight gyri were found I did not find that the left superior temporal gyrus was significantly greater than the right despite much evidence of its devotion to language function.

These references cited in the introduction are some of the few available concerned with form and symmetry of the human brain.

MATERIALS AND METHODS

In order to study the form and symmetry of superior temporal gyri, a collection of brains was assembled. These brains were all intact and were chosen only after a check of autopsy reports, eliminating those patients who showed neurological symptoms or those whose brains showed abnormalities at post-mortem. We originally started with 63 brains but some were eliminated because the skull cut had damaged one of the two hemispheres, others were not used because of poor fixation which led to distortion of the superior temporal gyrus, and finally a few had poor transparencies. These brains could not be re-photographed because they were subsequently sliced in Pathology. One group of 12 brains was from infants aged 2 to 18 months. The second group of 42 brains were of adult size from adults and from children 3 years of age and older (Spann and Dustmann, 1965). All of these brains were suspended by the basilar artery in a fixative of neutral formalin for approximately two weeks. Before the hemispheres were photographed, the pia mater was stripped from each temporal gyrus back to the end of the lateral sulcus (Sylvian fissure). A plexiglass stand was built with an adjustable back support and angled stage (See Fig. 1). By adjusting the back support each superior temporal gyrus could be photographed in the same plane. (Fig. 2). The autopsy number for each brain was included in both photographs.

A square of black card measuring 4 cm by 4 cm was placed at the frontal pole of the hemisphere in the same plane as the superior temporal gyrus. This square enabled one to adjust the projected image to

FIGURE 1

Brain, plexiglass stand and camera to illustrate relation of plane of lateral surface of brain to camera.

FIGURE 2

Lateral surface of brain, showing 4 cm x 4 cm black card and brain autopsy number.

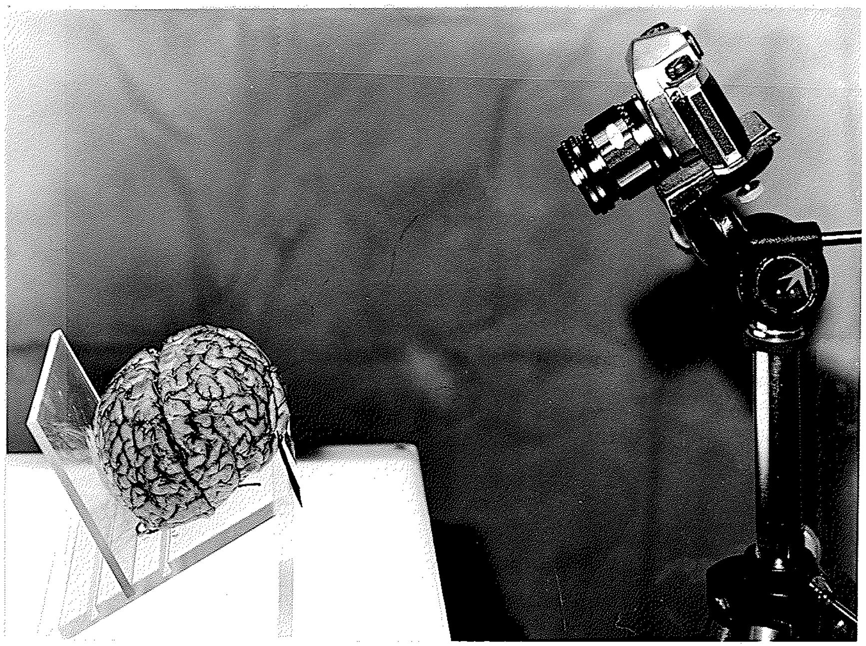


Fig. 1.

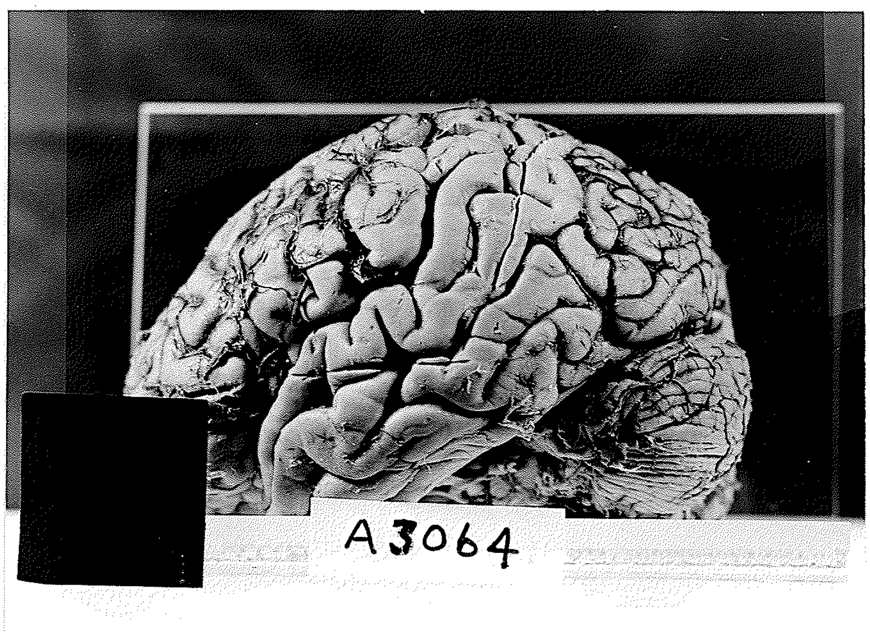


Fig. 2.

represent the actual size of the gyrus.

The pair of transparencies for each brain was numbered according to the autopsy number. Certain pairs of transparencies were reversed, selection being based on a series of random numbers. The viewer did not know which side was presenting--the actual right or the actual left. All of the numbers on the transparencies were covered and temporary numbers were assigned.

The slides were projected so that the image of the black square was 4 cm x 4 cm. The image of the outline of the hemisphere, the lateral sulcus (Sylvian fissure) and the superior temporal gyrus was traced onto tracing paper (Fig. 3). The projector was mounted on an adjustable stage. This permitted projection of the transparencies onto tracing paper in the same plane as the easel. It also facilitated adjustment of image size to bring the black card to its 4 cm by 4 cm size. White card was placed on the drawing board and the projected image of the superior temporal gyrus was actual size, but, because of the depth of each hemisphere, the outline of the hemispheres appeared somewhat smaller than life size. Once the tracings were completed they were mounted in pairs--a presumed right and left hemisphere--on white card, then measured as follows. First, a midline for the gyrus was drawn parallel to the lateral and superior temporal sulci. Starting at a point 1 cm behind the anterior temporal pole and at 5 mm intervals, lines were drawn across the gyrus perpendicular to its mid-line (Fig. 4). Measures were taken to the most posterior point of the superior temporal gyrus that could be clearly defined as determined by the lateral and superior

FIGURE 3

Projection of transparencies to actual size (guide is 4 cm x 4 cm black card) and tracing in progress.

FIGURE 4

Photocopy of actual tracing showing sinuosity of superior temporal gyrus, mid-gyral line, and lines intersecting at 5 mm intervals.

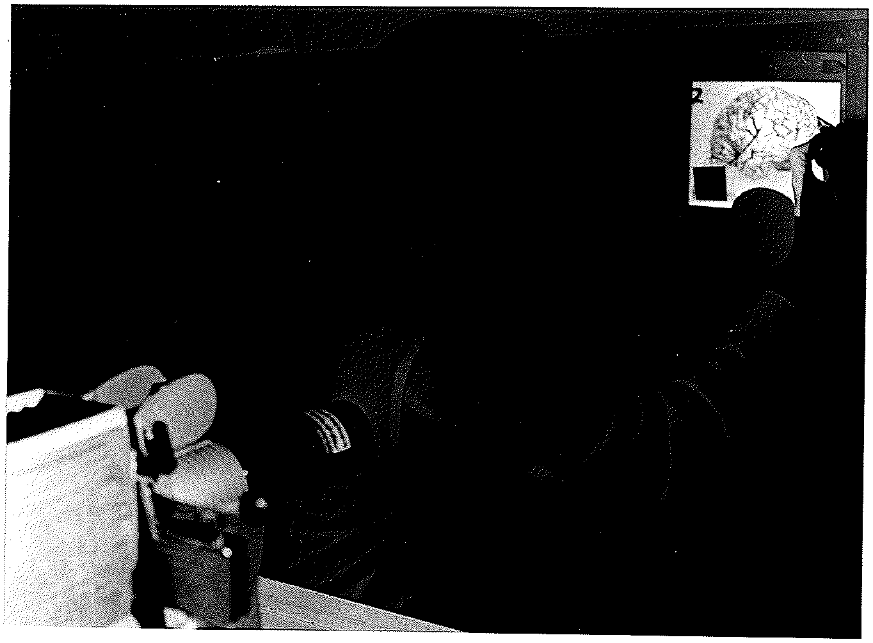


Fig. 3.

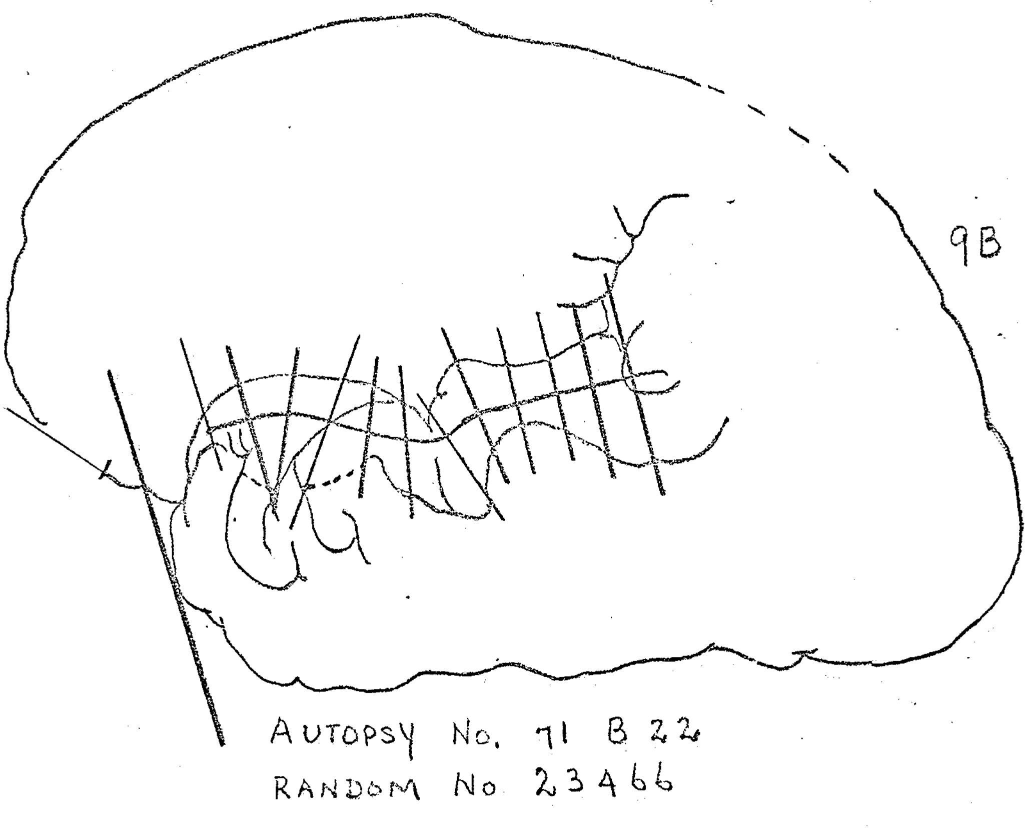


Fig. 4.

temporal sulci. At the most posterior end, the superior temporal sulcus tends to branch into several accessory branches--designated a^1, a^2, a^3 by Connolly (1950)--and a clear cut separation of superior temporal gyrus from the parietal area is not possible. A finely calibrated measure (Karvin Stainless, one-twentieth mm) was used to measure the widths of the gyri as indicated by these perpendiculars. In measuring each width the points of the calipers were placed at the points of intersection of the perpendiculars with the sulci, and the calipers were in such a position that the scale of measure could not be seen. This would protect the observer from the bias observed by Yule (1927)--"The long graduations and numerations at the units, the long graduations at the 5s that are usual on a decimally divided scale, seem to appeal to the reader with the force of personal suggestion." In his conclusions, Yule states that if the observer "could not see the scale until after he had adjusted the slide to what he estimated to be the best position, and then read, the errors should be trifling."

A comparison of "right" and "left" hemispheres was done using a non-parametric method of analysis--the "signed-ranks" test of Wilcoxon as described by Mainland (1963). The "signed-ranks" test was used for two reasons, the first reason being that it is easily done by hand: this enabled us to check the computer results very quickly. Some 12 analyses were done by hand to check this out. Because the number of measurements per gyrus were relatively few in number, there was not a sufficiently large number or N for a parametric test. It has been suggested by Freund (1967) that N should be 30 or greater for adequate normal distribution as defined by the Central Limit Theorem.

The widths of the entire length of the superior temporal gyrus from 1 cm from the anterior pole and at 5 mm intervals to the most posterior point of the gyrus were compared, and then a comparison was made of the more posterior aspects of the gyrus--Wernicke's area--where I felt there might be a wider gyrus because of the role of the left posterior superior temporal gyrus in auditory reception. The first five pairs of measurements of each brain were eliminated so that the first pair of measurements were used were 3.5 cm from the anterior pole of the temporal lobe.

In addition to the "signed-ranks" test of Wilcoxon, a study of the drawings and transparencies was done to ascertain the number of straight gyri. The observer scanned the tracings at three different sessions, each session one or two days apart. At each session the tracings were presented in an entirely different order to prevent the observer from recall of the previous findings. Each brain number was recorded and a plus sign given to those gyri which appeared straight. Only where the observations agreed in each of the three readings were the gyri designated straight gyri. From these data contingency tables were made; these were tested using the chi-squared test and Fisher's exact test.

As the observations were being made regarding straight and sinuous gyri, note was made of a tendency of the Sylvian fissure to turn upward sharply--almost at right angles to itself. These were counted by holding up a card with the drawings of the two hemispheres on it and noting which had right-angled lateral sulci. These results were put into a contingency table and tested with the chi-squared test and Fisher's exact test.

FINDINGS

Form. Illustration following this page. Fig. 5.

(a) Straight Gyri. Although 54 brains were examined and found to have some straight gyri (Table I), we did find straight gyri in brains other than those used for these data. These straight gyri are similar in appearance to those found in anthropoid primate brains (Connolly, 1950) and human fetal brains (Larroche, 1962). Mall (1909) also uses this parameter of straight (or fetal type = eurygyrencephalic) gyrus as compared with sinuous (or stenogyrencephalic) gyrus in grouping human brains. Mall does not report any specific gyri as being straight. The straight gyri were equally divided between right and left with 8 in each hemisphere.

TABLE I

	+	-	
Group I	4	20	24 hemispheres
Group A	12	72	84
	16	92	108

I = Infants A = Adults

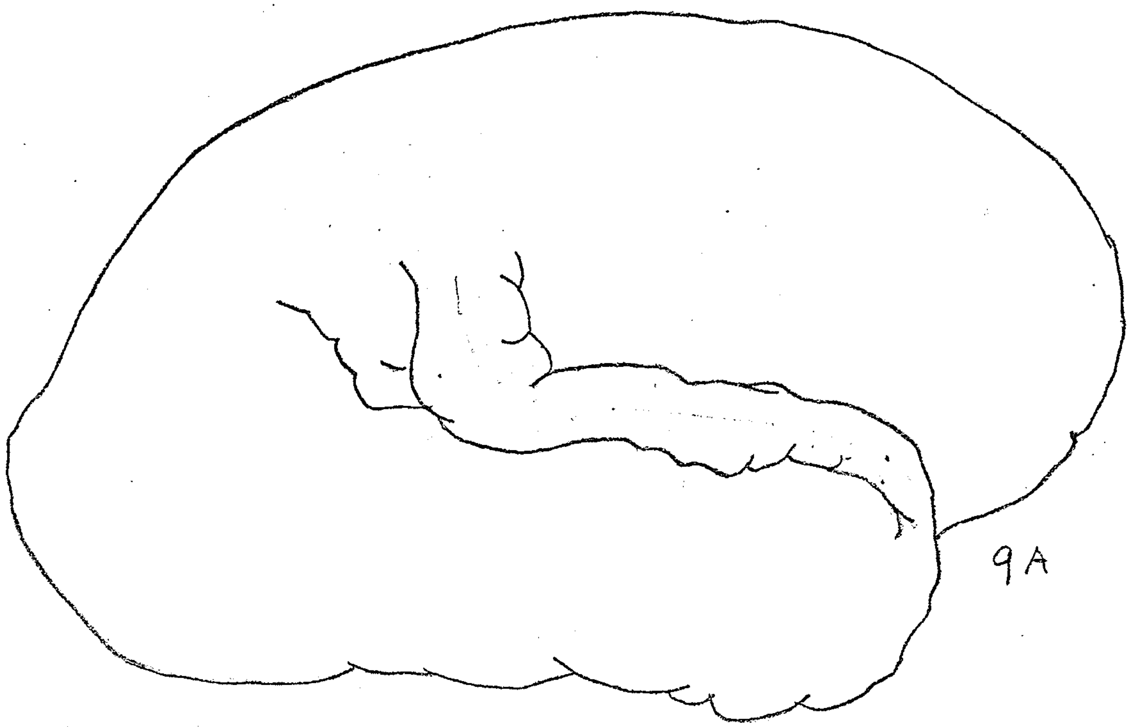
+ = Straight gyrus present

- = Straight gyrus absent

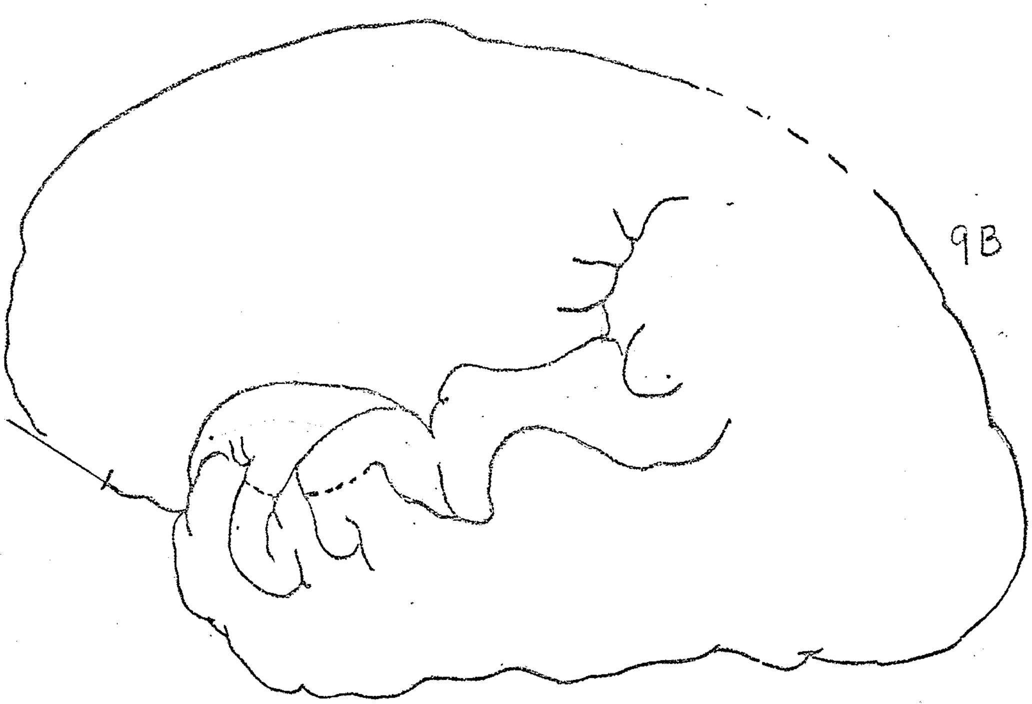
No statistical tests were done.

FIGURE 5

Photocopy of brain tracing to show straight vs sinuous gyri. Also note right-angled upturning of straight gyrus.



9A



9B

AUTOPSY No. 71 B 22
RANDOM No 23466

(b) Right angled Sylvian fissures (Nomina Anatomica: lateral sulci). In a visual examination of the tracings of each hemisphere, the Sylvian fissure turned upward at right angles. This occurred in 12 sulci on the right and 6 on the left.

TABLE II

	+	-	
Right	12	42	54
Left	6	48	54
	18	90	108

Chi-squared test showed no significant differences between Right and Left. Neither did Fisher's exact test.

Widths

Group I (Infants) and Group A (Adults)

TABLE III

	N	R	L
I	125	3.0 - 23.0 mm	3.0 - 24 mm
A	502	3.0 - 25.5 mm	3.5 - 27 mm

I= Infants A = Adults

N = No. of measurements of widths of gyri

R = Range of widths in right hemisphere

L = Range of widths in left hemisphere

TABLE IV - A

	N	Right $\bar{X}$	Right SD	Left $\bar{X}$	Left SD
Infant	125	11.8951 mm	±4.2783	11.3095 mm	±3.3725
Adult	502	13.1483 mm	±3.9767	12.5380 mm	±4.0982

N = Number of measurements of widths in mm

$\bar{X}$ = Arithmetic mean

SD = Standard deviation

TABLE IV - B

	N	Right $\bar{X}$	Right SDM	Left $\bar{X}$	Left SDM	t	p
Infant	125	11.8951	0.3827	11.3095	0.3016	1.4577	0.100
Adult	502	13.1483	0.1775	12.5380	0.1829	2.9107	0.005

N = Number of measurements in mm

$\bar{X}$ = Arithmetic means

SDM = Standard deviation of the means--
"standard error."

<u>Signed Ranks.</u>

(a) Entire length of gyrus.

TABLE V

	R larger		Pairs of Symmetrical Gyri	L larger	
	P<0.05	P<0.03		P<0.05	P<0.03
I	2	2	9	1	1
A	8	5	33	1	1
Totals:	10	7	42	2	2

Because there appeared to be no significant difference in the infant brains no statistical analysis was done on their data. Only the adult brains were analysed. In 5 of these the right superior temporal gyrus was significantly larger (P<0.03); in 1 the left gyrus was larger.

TABLE VI

		+	−	
ADULTS	Right	8	17	25
	Left	1	16	17
		9	33	42

Chi squared value = 4.10 $P<0.05$.

(b) Posterior measurement of gyrus.

TABLE VII

	Right Larger		Pairs of Symmetrical Gyri	Left Larger	
	$P<0.05$	$P<0.03$		$P<0.05$	$P<0.03$
Infant	2	0	9	1	1
Adult	8	6	29	5	2
Totals	10	6	38	6	3

TABLE VIII

		+	−	
Adult	Right	8	15	23
	Left	5	14	19
		13	29	42

Chi squared value = 0.35. Not significant.

Symmetry. Defining symmetry as the similarity or non-similarity of the right and left superior temporal gyrus, I will review the data of form and width, as they both contribute to the symmetry or non-symmetry of the gyri. In both infant and adult brains straight gyri were found and were distributed equally; there were 16 straight gyri observed, 8 in the right hemisphere and 8 in the left hemisphere. These were divided proportionately among infant brains (ratio of 1:6) and adult brains (ratio of 1:7). As there was no obvious difference in distribution between the two groups no statistical tests were done. In regard to the appearance of the right and left superior temporal gyri, as well as difference in complexity or sinuousness, we found that the posterior part of the Sylvian fissure turned up at right angles to the anterior part of the fissure. This was found in both right and left Sylvian fissures but of the 108 hemispheres studied 18 right-angled lateral sulci were found, 12 of them on the right and 6 on the left.

In a comparison of the widths of the superior temporal gyrus of the infants and adults, the range of widths was very similar with the adult group showing slightly wider gyri as was to be expected. In contrast when the means of the right and left superior temporal gyri of infants and adults were compared in a paired t-test, the adult brains showed the right superior temporal gyrus to be wider than the left ($P<0.005$). The infant brains however showed the right superior temporal gyri to be somewhat wider, at a level of less than 10% probability. A signed-ranks analysis was also done to compare all of the widths of right vs left superior temporal gyri in each individual brain. The infant brains showed no significant non-symmetry so no further analysis was done. In the adult brains the apparent non-symmetry was less than the 5% level of probability when tested with the chi-squared test, and showed at this level the right superior temporal gyrus to be wider than the left. The further study done on the posterior aspects of the gyrus also showed a non-symmetry between right and left superior temporal gyri at the 10% level of probability, with the right larger than the left.

When the widths of the gyri of the adult brains were converted to logarithms and the paired t-test repeated, the value was 3.4866 which is significant at the $P < 0.001$ level. The same procedure was followed on the infant brains but they showed no significant difference between right and left superior temporal gyri.

DISCUSSION

When this study was begun, it was with the idea that I would find, overall, no great differences between the widths of the right and left superior temporal gyri of each brain. If I did find a difference I felt it would be that the left superior temporal gyrus would be larger because of its acknowledged role in speech function. "Since, however, about 93% are left-brained for speech,...." (Geschwind and Levitsky, 1968).

Before any observations or measurements were made, great care was taken to insure that a blind study of the gyri would be done. Because I felt that there might be a predisposition to seeing left superior temporal gyri larger than the right, the brain autopsy numbers, which appeared in each transparency of each hemisphere, were covered, and a random number was assigned to each pair of transparencies. Some pairs of transparencies were reversed in the slide mounts according to this series of random numbers, and then temporary numbers were assigned. At no time during the observations and measurements did I know which hemisphere was shown--right or left. The earliest reference I found to this method of blind study of human brains was by Mall (1909). Precautions were taken to ensure that neither he nor his colleagues knew whether the brains to be studied were from white or negro individuals. None of the other studies I shall mention have chosen this approach, but I feel it can make a difference in judgment.

Form. As the title outlines a study of form, width and symmetry of the superior temporal gyrus, the discussion will continue in the same order.

I mentioned in the introduction that the superior temporal gyrus is a constant feature of the brain throughout the primate series, always presenting as a straight uncomplicated gyrus. Its appearance is the same in the human fetal brain in its earlier stages of development. After the fifth month, the brain of the fetus becomes more complicated. The gyri start to fold and pleat, appearing more sinuous (Larroche, 1962). In this population I had brains from babies of two months of age and from adults. These were subdivided into Group I, babies' brains, and Group A, adult-sized brains, the criterion used for the dividing point being that set up by Spann and Dustmann (1965). They found that the majority of brains weighed in their studies were of adult size and weight by the fourth year. In my adult sampling there was only one brain which was less than four years of age (a three-year-old) and this was included with the adult-sized brains because it was large in size. This gave me an adult-sized population of 42 brains and 12 babies' brains, and in these two groups I did find simple, straight gyri. Mall (1909) describes studies done on the human brain where the brains were sorted according to the "richness of the gyri and sulci." Where the configuration was complex he assigned the term stenogyrencephalic; in the simple fetal type it was called eurygyrencephalic. Tilney (1928) also shows the increase in the complexity of "convolutional richness and intricacy of fissural pattern" in the human brain, as contrasted with the ape. The general appearance of straight gyri vs. sinuous gyri, therefore, became one measure of form.

We also found that both superior temporal gyri--right and left--exhibited a sharp upturn or right-angled turn at the posterior end of the lateral sulcus in some of the brains. This was more predominant on the right side in a ratio of 2:1 for the sample of 54 brains we examined, but when analyzed with the chi-squared test they did not show any significant differences. Geschwind and Levitsky (1968) found the planum temporale of the superior temporal gyrus to be larger on the left than on the right. After seeing the brains in our sample and this right-angled upturning of the Sylvian fissure, I wonder if their plane of cut to expose the posterior part of the superior surface of the gyrus might have cut through or cut off some of the superior temporal gyrus and hence the planum temporale. Connolly, Von Bonin, and Geschwind and Levitsky all speak of the Sylvian fissure as longer on the left than on the right. This I did not measure as I felt it impossible to ascertain the posterior end of the Sylvian fissure from the photographs.

Width. Although a careful search of the literature was made, it failed to reveal any studies of the widths of gyri in the human brain. Another student working in this department, Mr. Ed. Berinstein, did a similar study of widths of the superior temporal gyri in the brains of very young children ranging in ages from a few days to 9 months of age. He found no innate anatomical non-symmetry in the brains of children who died a few days after birth up to an age of 2 months. From 3 months to 9 months of age he found a tendency towards non-symmetry. In my own investigation, Group I, or the babies, ranged in age from 2 months to 18 months and Group A or the adult-sized, ranged in age from 3 years to more than 80 years. In the I group there were 12 babies' brains and in A group 42 adult-sized brains.

The infant brains did not appear non-symmetric but the adult-sized brains had wider superior temporal gyri on the right. These differences were highly significant with $P < 0.005$. This trend was completely unexpected. With maturation of cortical tissue and development of speech function I had expected progressive non-symmetry to develop with the left superior temporal gyrus being wider than the right. But this was not the case.

Since 1960, there has been more interest shown in trying to assess the role of the right hemisphere. The left hemisphere met with extensive investigation from the time of Marc Dax who first described speech as being centred in the left hemisphere, and Paul Broca. Von Bonin (1962) referred to handedness in the Bible, Judges 20:16 as the oldest reference, being about 1400 B.C. There was a very sound reason for this interest since dysphasia, evidenced as a loss or distortion of language function, is a very distressing affliction. In the 20th century there has been a reaction against the strictly anatomical approach (e.g., Broca,(1861) who attempted to relate a type of language disorder with a particular part of the brain), as evidenced by Brain (1961) who stated that dysphasia should be regarded as a "particular manifestation of a loss of some aspect of general intellectual ability." The work of Piercy (1960) showed highly significant (P 0.01) constructional apraxia in right hemisphere lesions over left. I would like to quote one of his conclusions: "The right cerebral hemisphere in right-handed people has a special non-subordinate role in the cognitive functions involved in normal constructional performance." Milner (1971) found that the right hemisphere plays a major role in many non-verbal cognitive functions such as spatial and perceptual understanding. She also found a consistent right ear advantage for verbal material. Perhaps some of these right hemisphere roles or functions can explain a greater width in the right superior temporal gyrus over the left as the brain matures.

With these same data, widths of right and left superior temporal gyri, a signed-ranks test was also done. The signed-ranks test was first done to compared all the measurements of each right superior temporal gyrus against its corresponding left partner. In the I (infant) group 2 right and 1 left ($P<0.03$) non-symmetrical superior temporal gyri were seen while 9 were symmetrical. There appeared to be no difference between the right and left gyri and no further analysis was done. But in the A (adult) group there was considerable non-symmetry shown in that 8 of the right gyri were significantly larger than the left where $P<0.05$ and 5 of these were significant at the $P<0.03$ level (Table V). The left gyri showed only 1 gyrus larger than the right and this was significant at the $P<0.03$ level. These results were analyzed using the chi-squared test and the results approached the $P<0.05$ level (Table VI). The same results were obtained with Fisher's exact test. This trend to non-symmetry would appear to support the findings of Milner (1970) and Piercy (1960) that the right hemisphere has a non-subordinate role in many non-verbal cognitive functions. Again the posterior measurements of the gyri showed no significant difference in the brains of the infants and no further analysis was done on those figures. But in the A (adult) group there were 6 right gyri significant at the $P<0.03$ level as compared with 2 left gyri at the $P<0.03$ level (Table VII). A contingency table was prepared and these data also analyzed using the chi-squared test and Fisher's exact test with results approaching the 10% level of probability. Again there is a noticeable non-symmetry in the more mature brains.

Symmetry. As I have stated earlier, symmetry or non-symmetry is the summation of the similarities and/or differences in the form of the right and left superior temporal gyri and their widths. Smith (1907) did a study of asymmetry of the caudal poles of the cerebral hemispheres and its influence on the occipital bone, particularly comparing white and negroid brains. He found the white crania more asymmetrical and concluded that "the symmetry of the negro cranium is thus a sign of inferiority." Two years later Mall (1909) published a paper "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." He did the first unbiased blind study I have found--not knowing which brains were "white" and which were "negro." He studied the brains as to sex differences with the same blind method. Although he found definite differences such as stenogyrencephalic (complex) gyri as opposed to eurygyrencephalic (simple or fetal) gyri, he felt that any differences observed were not due to sex or race. We also observed these straight vs sinuous gyri (Table I). Von Bonin (1962) made a study of interhemispheric relations and cerebral dominance, in particular, looking at anatomical non-symmetries of the cerebral hemispheres. One point he emphasizes is that asymmetry or non-symmetry of paired organs in the human is the rule rather than the exception. In his studies, he found that measured weighings of right and left hemispheres had ambiguous and conflicting results. He did find the left Sylvian fissure to be longer than that of the right hemisphere but concluded that the morphological differences were very small and he was unable to equate them with "the astonishing differences in function." Frederick Tilney (1928) in his very detailed study The Brain From Ape to Man, describes the surface appearance of the brain in man as compared with the apes and comments on the "great complexity of convolutional richness and intricacy of fissural pattern." He feels that the significance of this convolutional complexity in the human brain emphasizes the "chief superiority of the human brain which lies in its intricate complexity of convolutional arrangement." Although overshadowed by the greater increase in frontal and occipital lobes, the temporal lobes still have progressed in size and complexity. Tilney does not compare symmetry of the hemispheres but I felt his descriptions of the increased size and complexity of the human brain helped to give a clearer background which has been added to by more recent investigations. Connolly (1950), in his morphological study of the primate brain, did look at some specific symmetries or non-symmetries. He found that the lateral sulcus, which he defined as extending from the plane of the frontal pole to the point of bifurcation of the lateral fissure, was usually longer on the left than on the right. The superior temporal sulcus is described as usually a continuous fissure but if it was broken or discontinuous, this occurred more often on the left than on the right. The brains examined ranged from infants to adult brains and Connolly felt there was an evident non-symmetry in infant brains with the superior temporal sulcus longer on the left than on the right. He also describes all primary, secondary and some tertiary sulci as being present at birth, and that the positions of the sulci were quite constant, as he found throughout the primate series. Therefore he felt the origin of the sulci must be due to intrinsic factors. Connolly also mentions the functional superiority of the left hemisphere in regard to speech in about 95% of the cases examined. He therefore expected to find an excess of size on the left as compared with the right. But this he did not find. In none of these preceeding reports was any mention made of a possible role for the right hemisphere and more specifically the right superior temporal gyrus which might account for its increase in growth and development at a proportional rate with the left superior temporal gyrus. In fact, in my results I found the right superior temporal gyrus to be wider than the left at $P < 0.05$. J.C. Lilly (1963) in a paper "critical brain size and language" describes the motor cortex as being of the same relative size whether in small or large vertebrate animals, but the great increase in cortical brain size in the human is due to learning, language, etc. Where earlier studies tried to equate laterality of handedness with that of speech, Goodglass and Quadfasel (1954) described the independence of distribution of language from that of handedness. In other words, laterality for language is not identical with laterality for handedness. Geschwind and

Levitsky (1968) reported finding marked anatomical asymmetries between the upper surfaces of the human right and left temporal lobes, finding the left planum temporale to be larger. Although I did not examine the superior surface of the temporal lobe I did measure carefully the widths of the superior temporal gyri and found non-symmetry present but with right gyri wider than the left in the adults. Geschwind and Levitsky regard their findings of a significantly larger area on the left side as compatible with the known functional asymmetries. Geschwind (1970) in another paper, "the organization of language and the brain," reviews the work he did with Levitsky in 1968 as a reinvestigation into the widely stated conclusions in the literature that the human brain is symmetrical. According to their reports this was not the case. They cited a paper read by Wada at the 9th International Congress of Neurology, New York, 1969, as confirming their results. Wada also studied these same areas in infants' brains and found these differences present at birth. Geschwind further points out that the phenomenon of cerebral dominance occurs, as far as is known, in no mammal other than man, and that it is reasonable to assume that there are other anatomical asymmetries in the hemispheres of the human brain, reflecting aspects of dominance other than that of the left temporal speech. Very little work has been done regarding these other non-symmetries but the work of Piercy, Hecaen & de Ajuriaguerra (1960) and Milner (1971) is shedding some light on the role the right hemisphere plays in non-verbal cognitive functions. This may be a partial answer or explanation to our results which showed some larger right gyri in infants and more significantly larger right gyri in adults.

SUMMARY

SUMMARY

Fifty-four human brains were studied to compare form, width and symmetry at the right and left superior temporal gyri. The brains were divided into two groups--an I (infant) group of 12 brains and an A (adult) group of 42 brains.

1. Gyri were found which were not of the typical sinuous form. These are called straight gyri. These were equally distributed; 8 on the right and 8 on the left. In Group I there were 4 straight and in Group A there were 12. These differences were not significant.

2. Some Sylvian fissures were found to turn up almost at right angles. This was found 12 times on the right and 6 times on the left. This difference was not significant.

3. All of the widths of the right and left gyri of Group I and Group A were averaged and a histogram drawn by the computer. The means were converted to logarithms and a paired t-test done on each group. The means showed Group I with 125 pairs of measurements to have a wider right superior temporal gyrus with $P<0.10$. The means of Group A with 502 pairs of measurements pointed to a wider right superior temporal gyrus with $P<0.005$.

4. The widths of the entire right and left gyri of Group I and Group A were compared with signed-ranks analysis. In Group I,

the left gyrus was wider in 1 brain (P 0.03) and right gyrus wider in 2 brains (P 0.03). Group A showed right gyrus wider in 5 brains (P 0.03) and left gyrus wider in 1 brain (P 0.03). Group I showed no obvious differences; the differences in Group A approached P 0.05.

5. The widths of the posterior parts of the right and left gyri of Group I and Group A were compared with the signed-ranks test. Group I showed no obvious differences with 1 left gyrus wider; no right gyrus was wider. Group A showed 6 gyri wider on the right and 2 gyri wider on the left, all at P 0.03. The difference in Group A approached P 0.10.

Although not all of our observations and measurements were highly significant (P 0.01) we did find definite non-symmetries in our right and left superior temporal gyri. There were straight vs sinuous gyri, right-angled upturned lateral sulci, and an interesting shift from symmetrical superior temporal gyri in infants to wider right superior tempral gyri in adults.

BIBLIOGRAPHY

Brain, Lord (1965). Speech Disorders. London: Butterworths.

Connolly, C.J. (1950). External Morphology of Primate Brain. Springfield: Charles C. Thomas.

Freund, J.E. (1967). 3rd edition, p.211. Modern Elementary Statistics. Englewood Cliffs: Prentice-Hall.

Geschwind, N. (1970). Organization of language and the brain. Science, 170, 940-944.

Geschwind, N. & Levitsky, W. (1968). Human brain; left-right asymmetries in temporal speech region. Science, 161, 180-187.

Goodglass, H. & Quadfasel, F.A. (1954). Language Laterality in Left-Handed Aphasics. Brain 77, 521-542.

Larroche, J.C. (1962). Quelques aspects anatomiques du développment cérébral. Biologia Neonatorum 4, 126-153.

Lilly, J.C. (1963). Critical brain size and language. Perspectives in Biology and Medicine, 6, 246-55.

Mainland, D. (1963). Elementary Medical Statics. Philadelphia: Saunders.

Mall, F.P. (1909). On several anatomical characters of the human brain. American Journal of Anatomy, 9, 6-20.

Milner, B. (1971). Interhemispheric differences in localization of psychological processes in man. British Medical Bulletin, 27, 273-277.

Penfield, W. & Rasmussen, T. (1950). The Cerebral Cortex of Man. New York: MacMillan.

Penfield, W. & Roberts, L. (1959). Speech and Brain Mechanisms. Princeton University Press.

Piercy, M., Hecaen, H., & de Ajuriaguerra, J. (1960). Constructional apraxia associated with unilateral cerebral lesions--left and right sided cases compared. Brain 83, 225-242.

Smith, G.E. (1907). On the asymmetry of the caudal poles of the cerebral hemispheres and its influence on the occipital bone. Anatomische Anzeiger 30, 574-578.

Spann, W. & Dustmann, H.O. (1965). Das Menschliche Hirngewicht und Seine Abhangigkeit von Lebensalter, Korperlange, Todesurache und Beruf. Deutsche Zeitschrift fur gerichtliche Medizin 56, 299-317.

Tilney, F. (1928). The Brain from Ape to Man. Paul B. Hoeber Inc., Vol II, 778, 789-790.

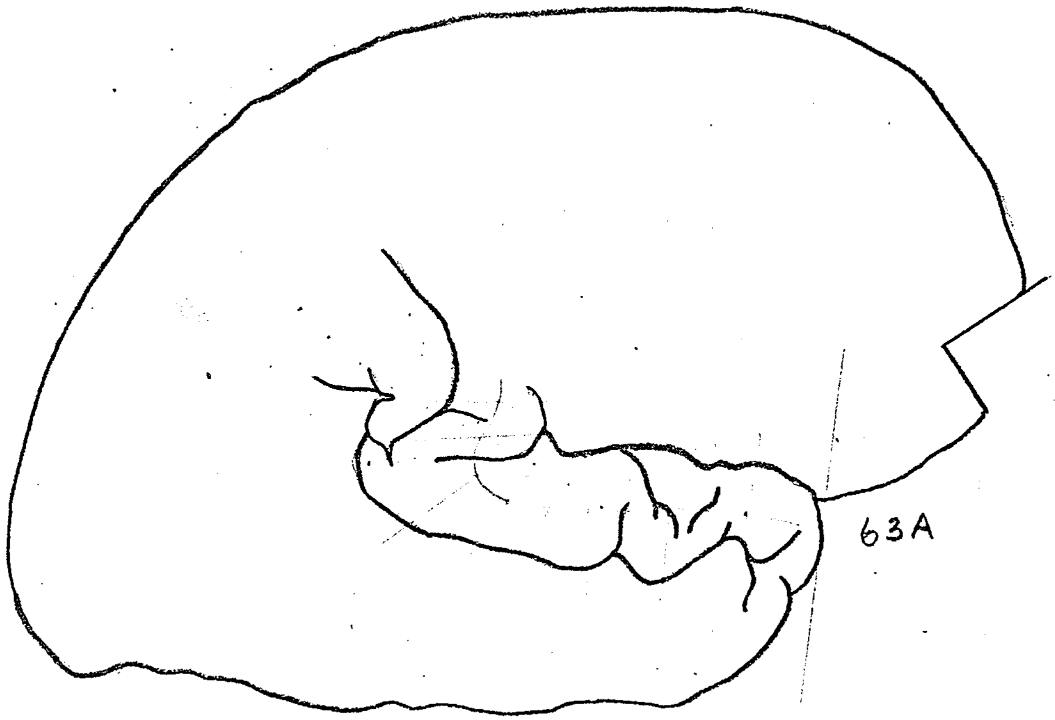
Von Bonin, G. (1962). Anatomical asymmetries of the cerebral hemispheres. In Interhemispheric Relations and Cerebral Dominance (Ed. V.B. Mountcastle), pp. 1-6, Baltimore: Johns Hopkins.

Wada, J. (1969). Paper presented at 9th International Congress of Neurology, New York. Cited by Geschwind (1970).

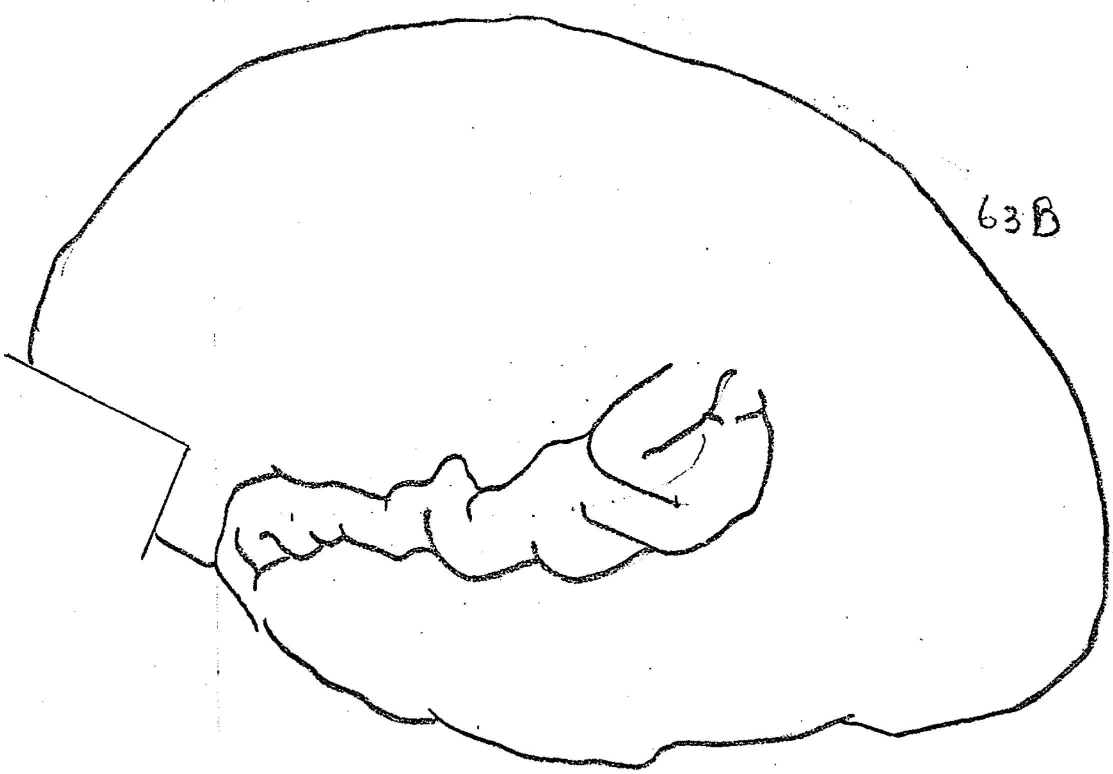
Wyke, M. (1971). Dysphasia, a review of recent progress. British Medical Bulletin 27, 211-217.

Yule, G.U. (1927). On reading a scale. Journal of the Royal Statistical Society 90, 570-583.

APPENDIX

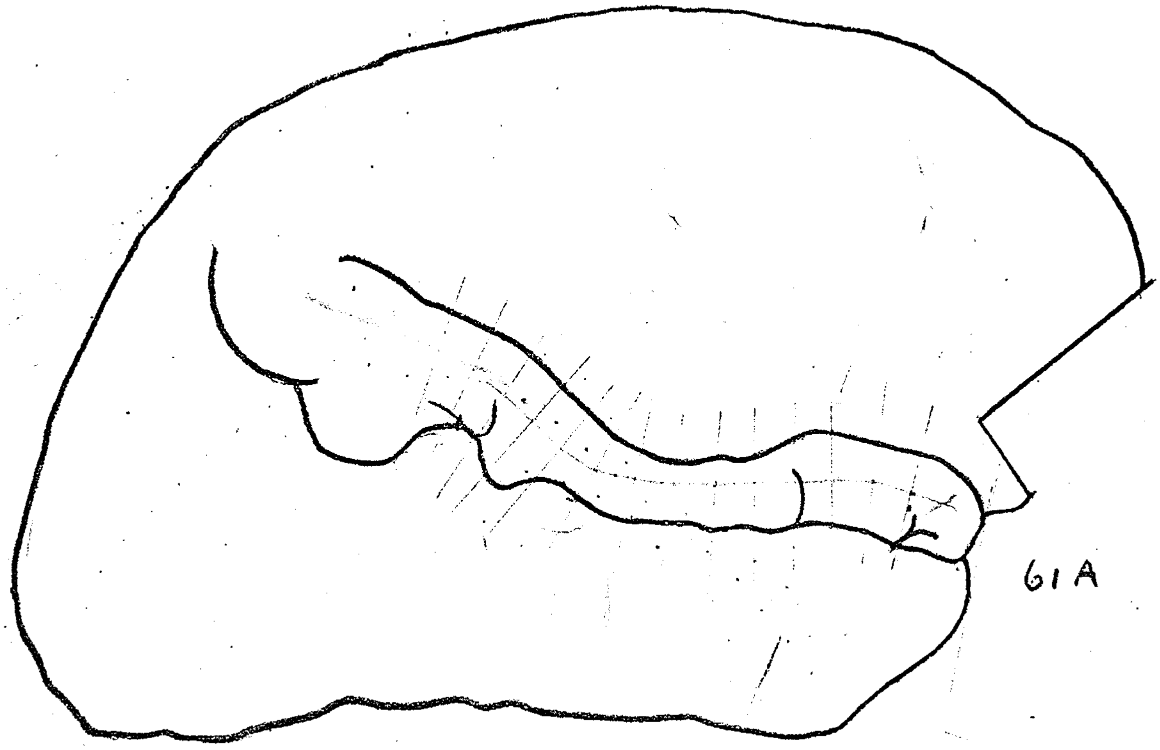


63A

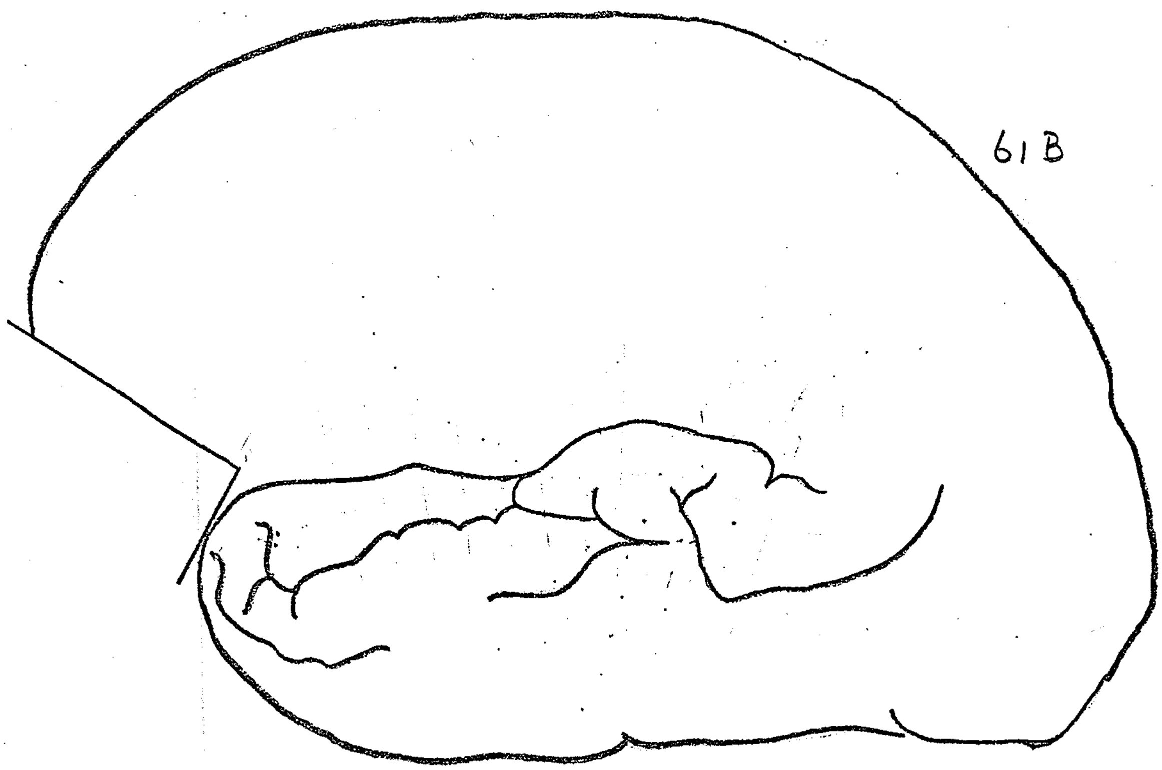


63B

AUTOPSY No. 71 B 69
RANDOM No. 97720

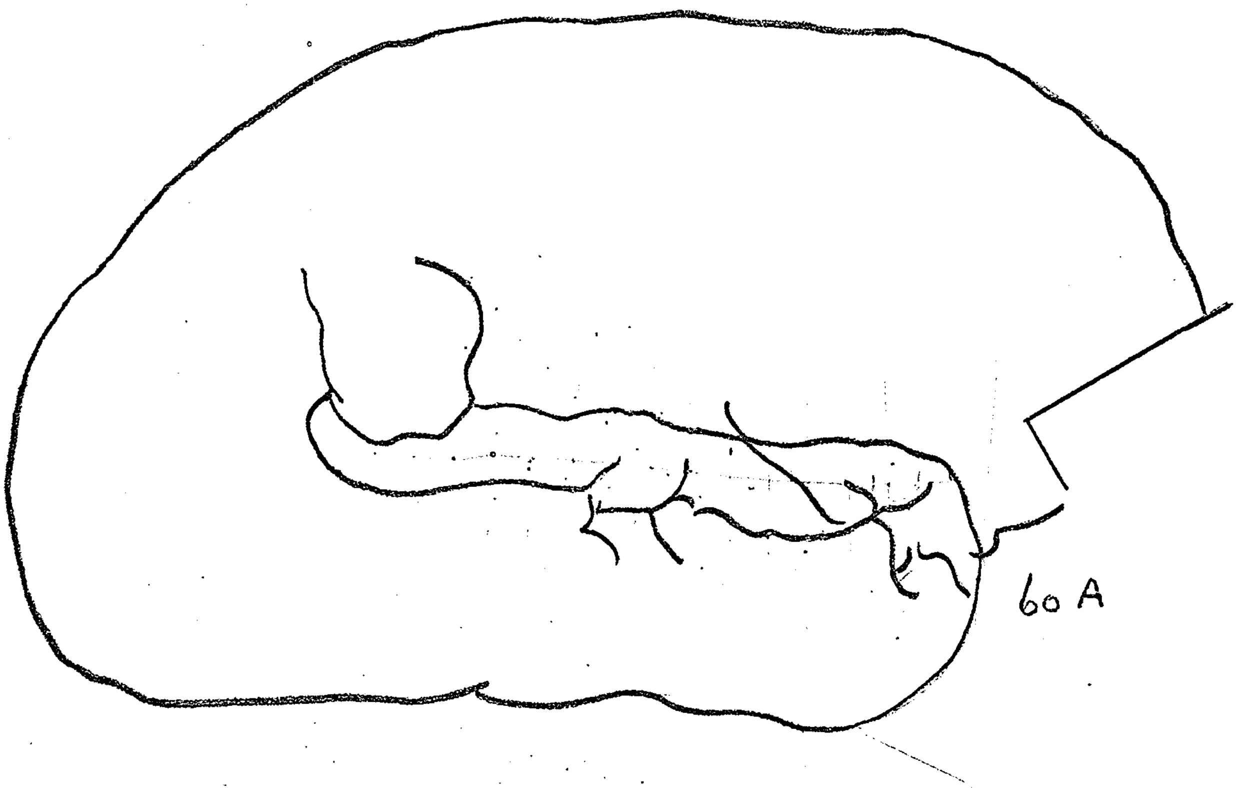


61A



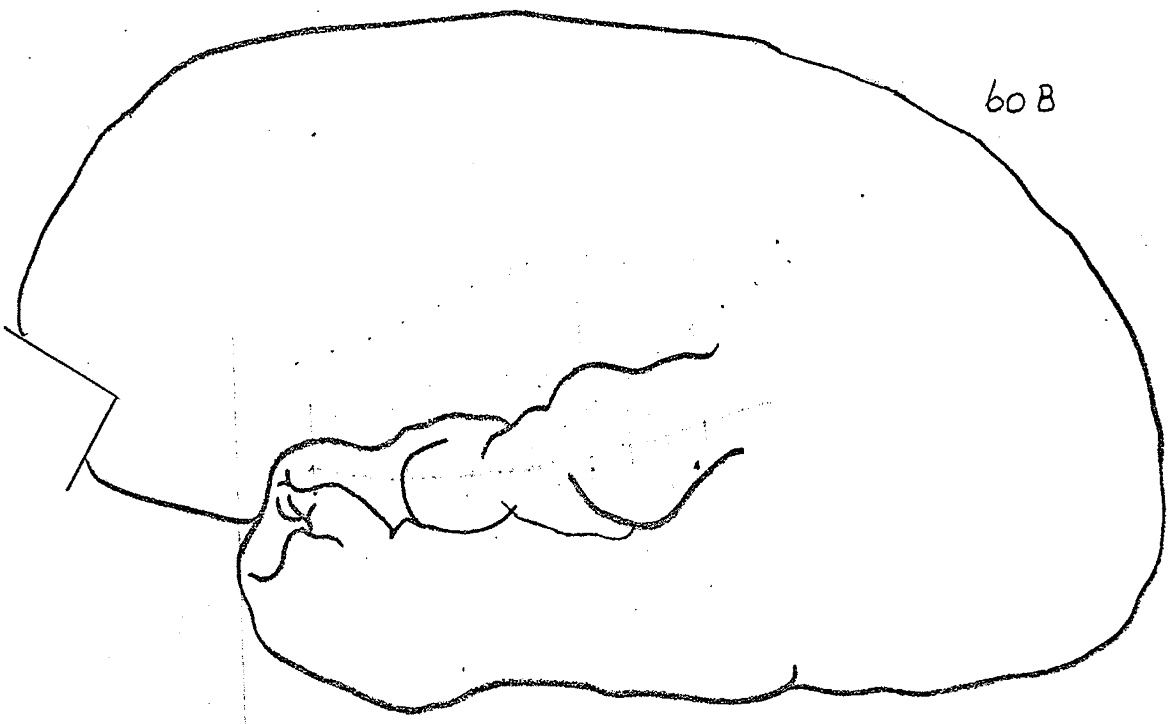
61B

AUTOPSY No. 71B60
RANDOM No. 71628

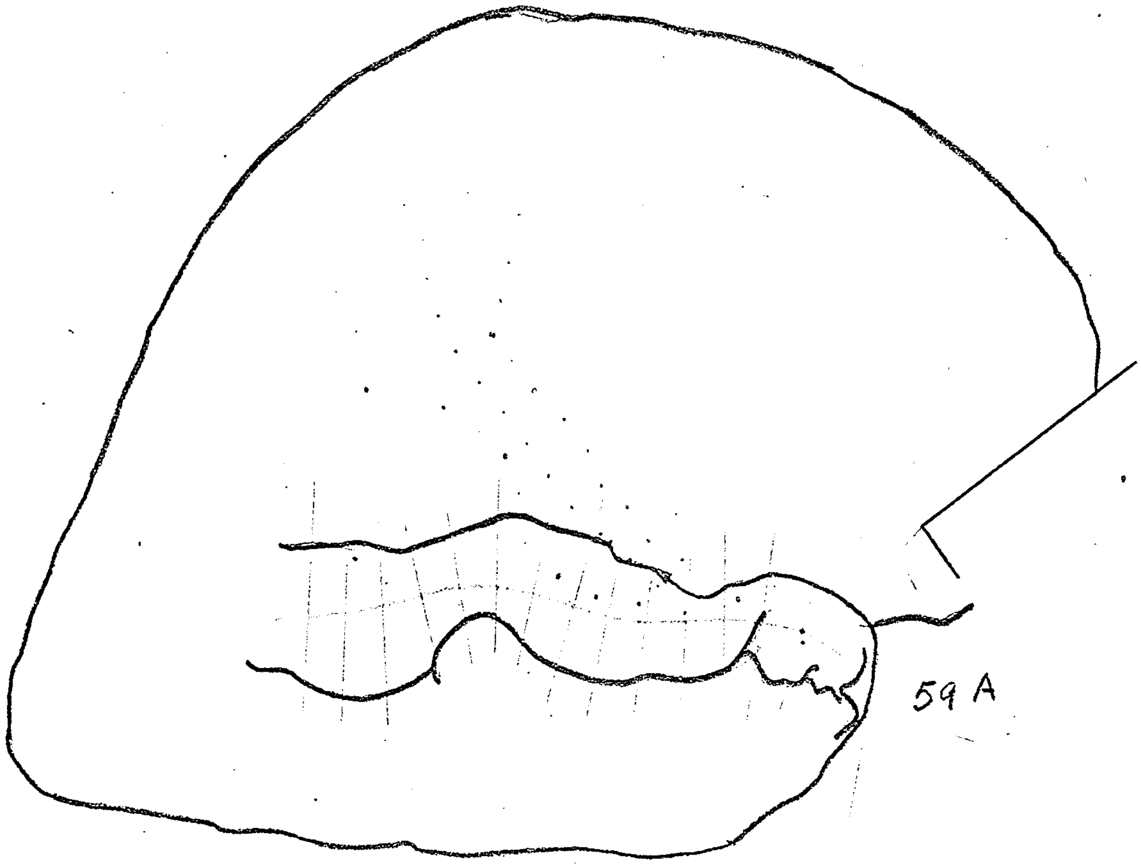


60 A

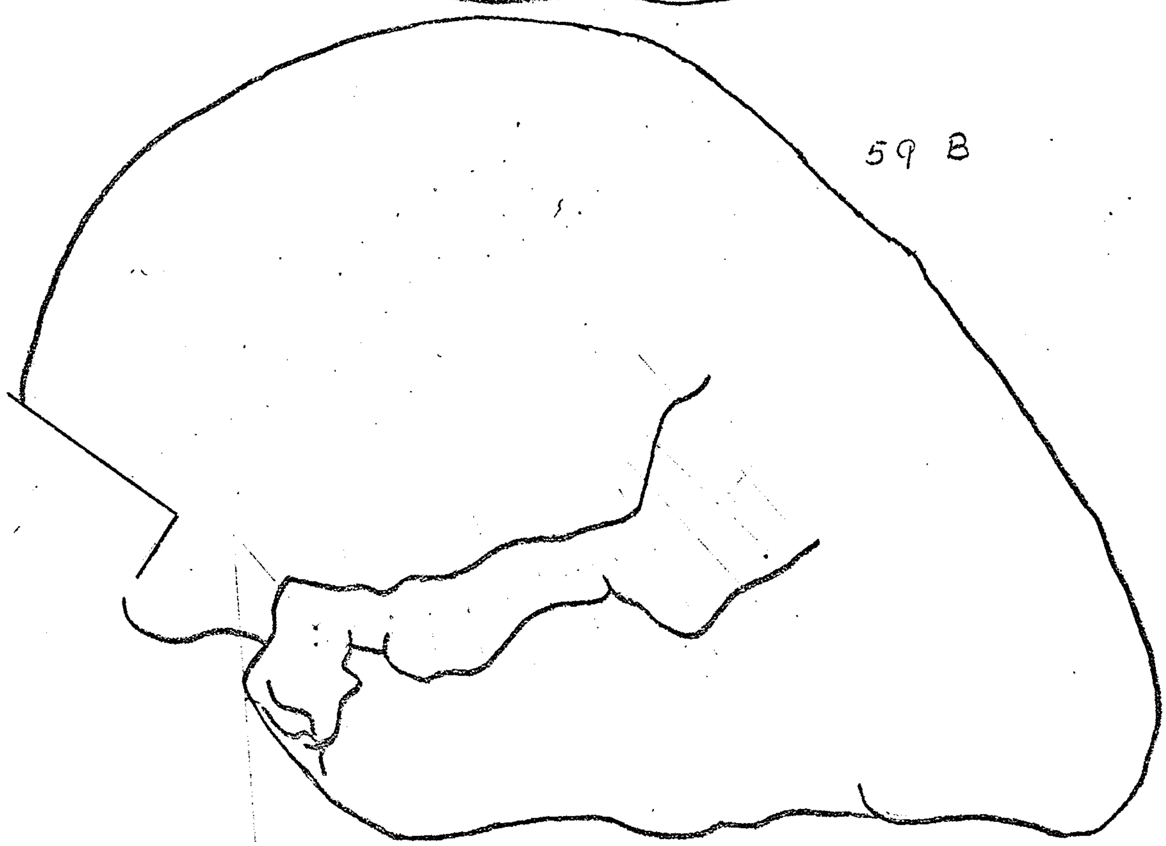
60 B



AUTOPSY NO. 71 B 67
RANDOM NO. 40501

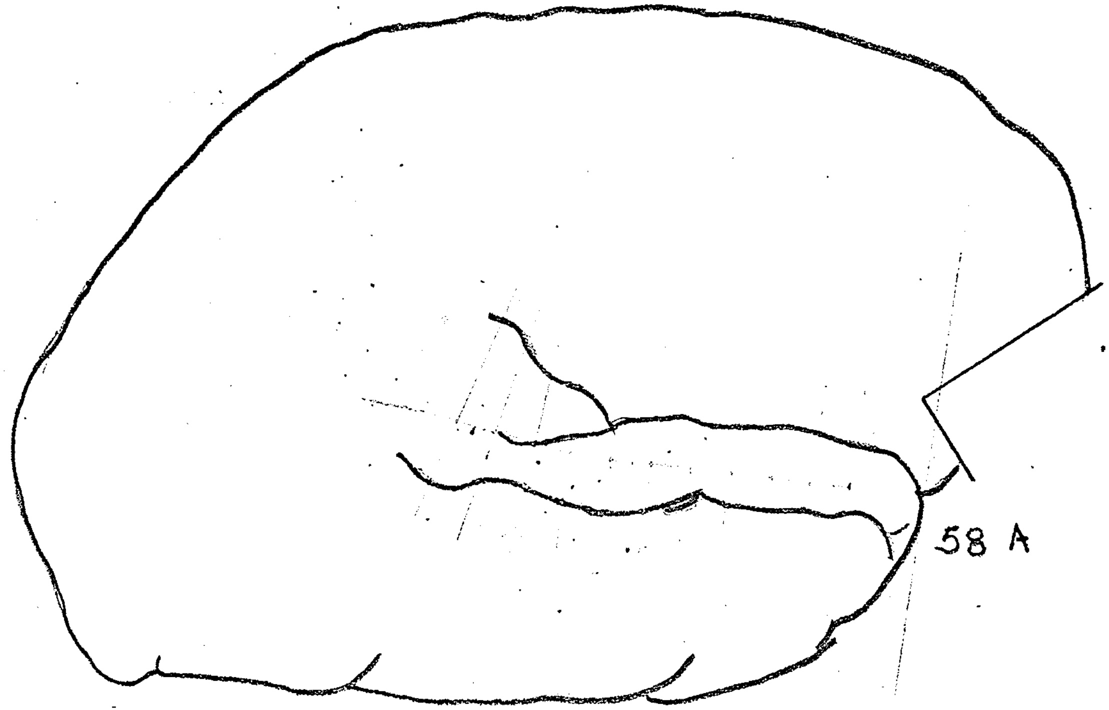


59 A

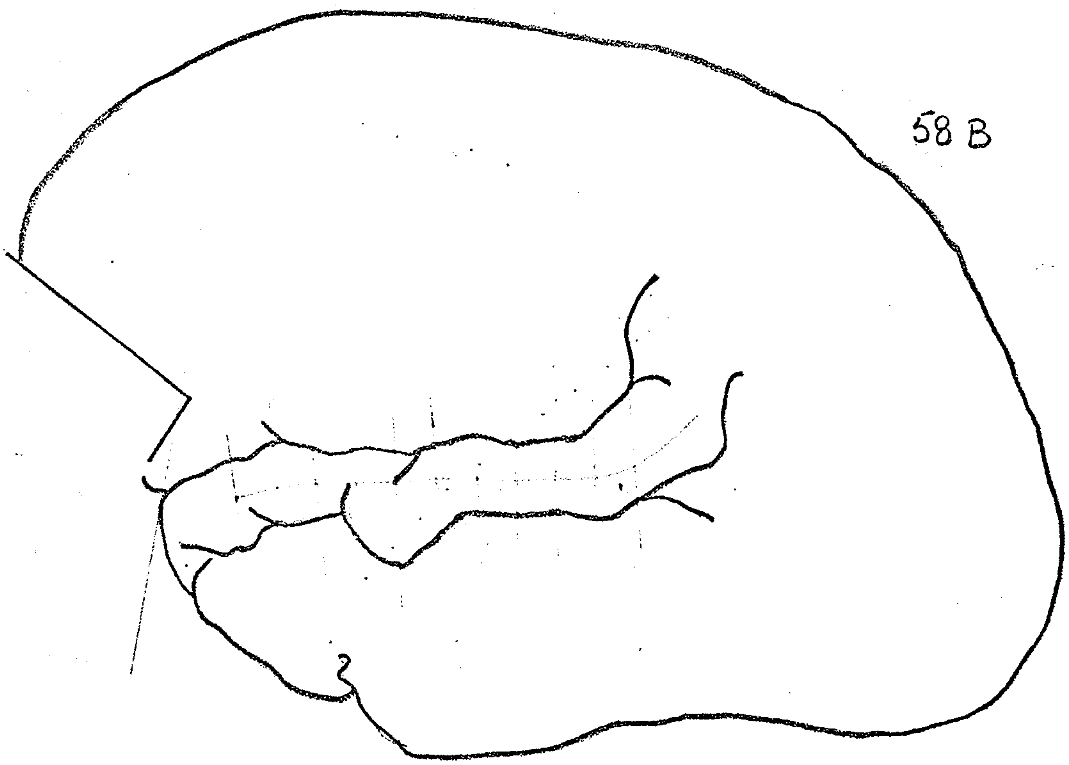


59 B

AUTOPSY NO. A 71-34
RANDOM NO. 22518

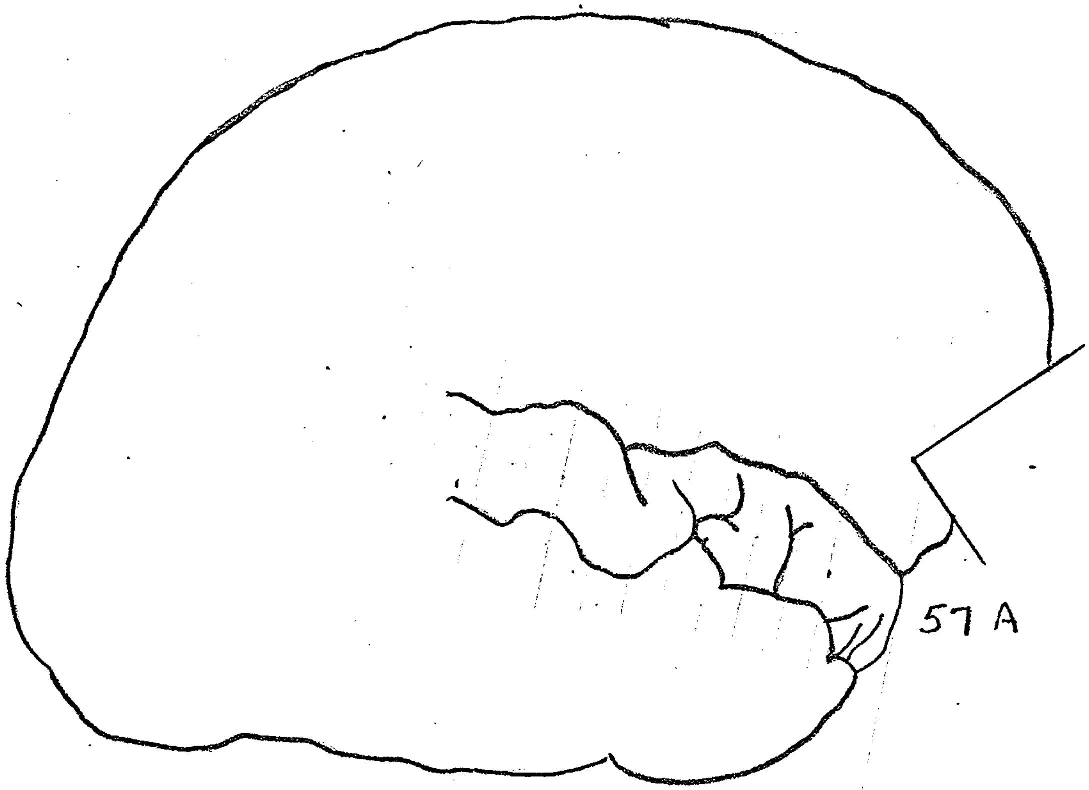


58 A

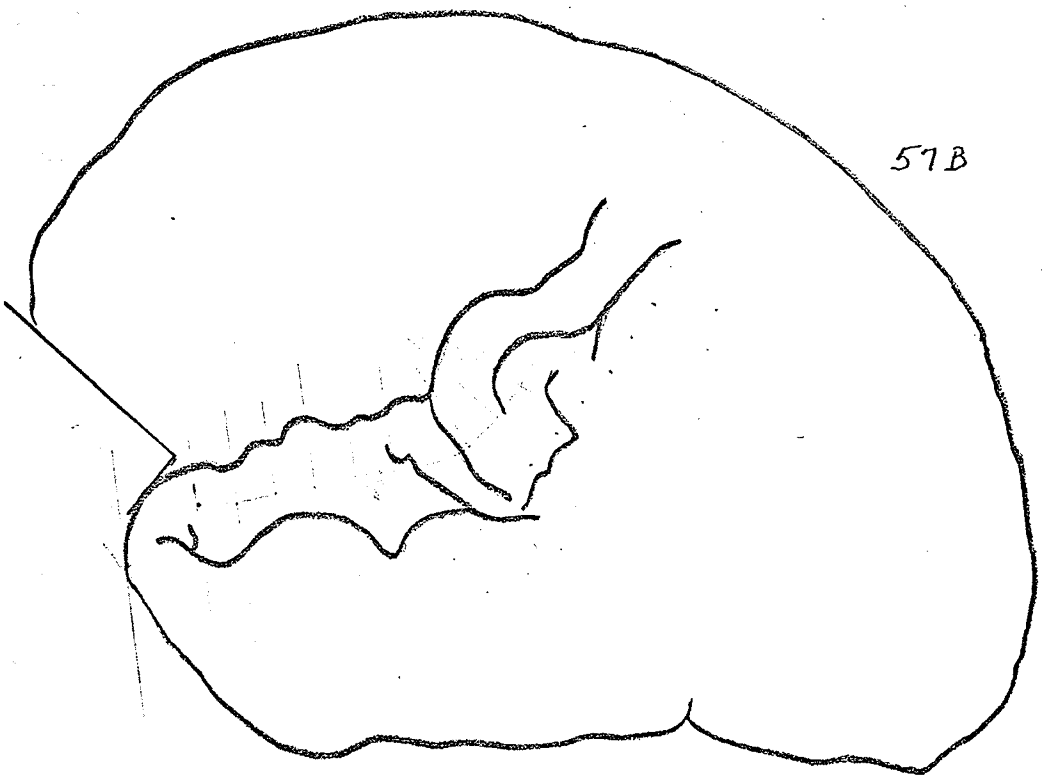


58 B

AUTOPSY No. 71 B 68
RANDOM No. 75112

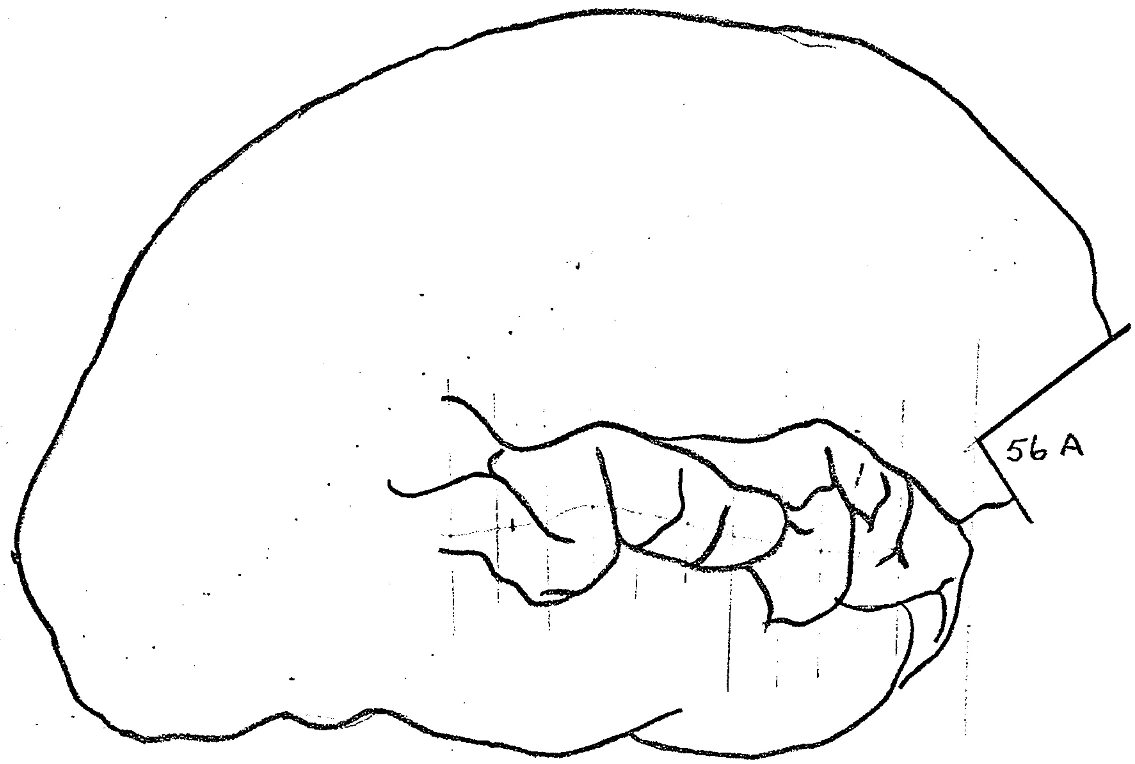


57 A

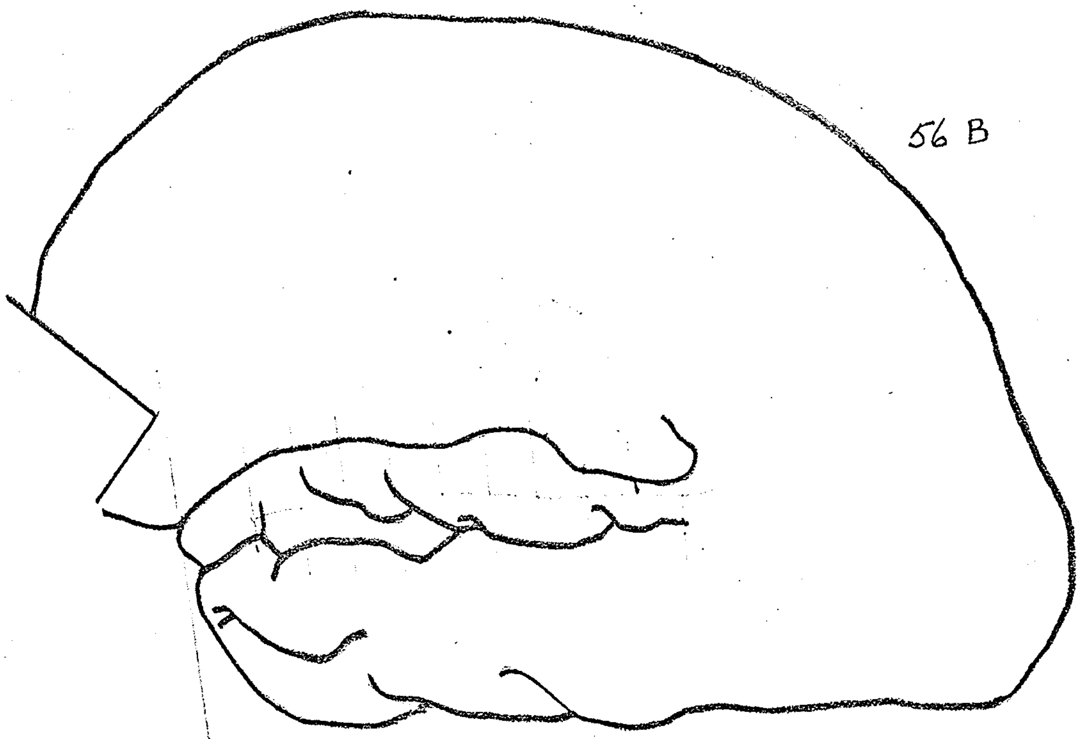


57B

AUTOPSY No. 71 B 73
RANDOM No. 80327

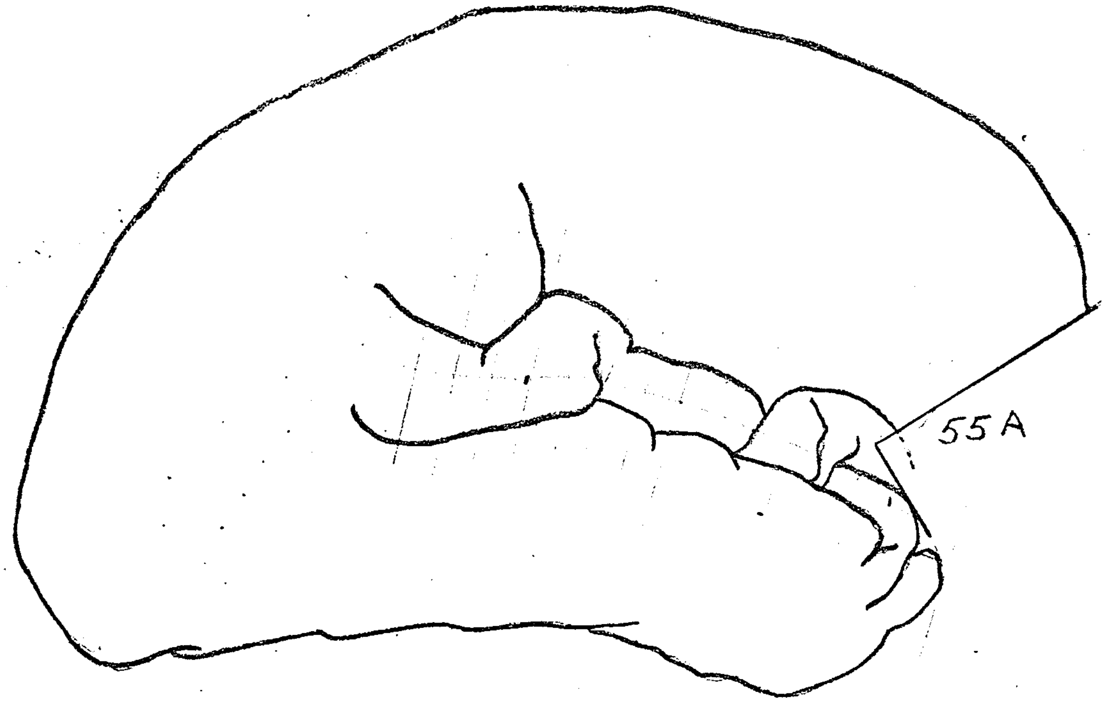


56 A

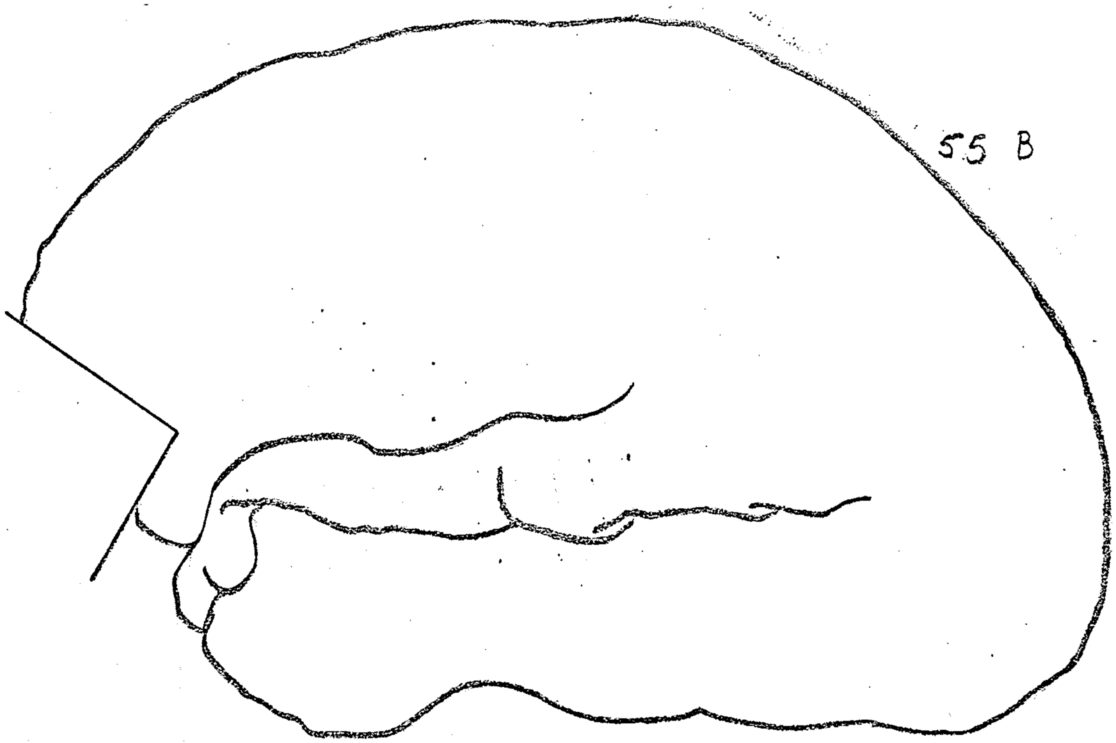


56 B

AUTOPSY NO. 71 B 72
RANDOM NO. 60251

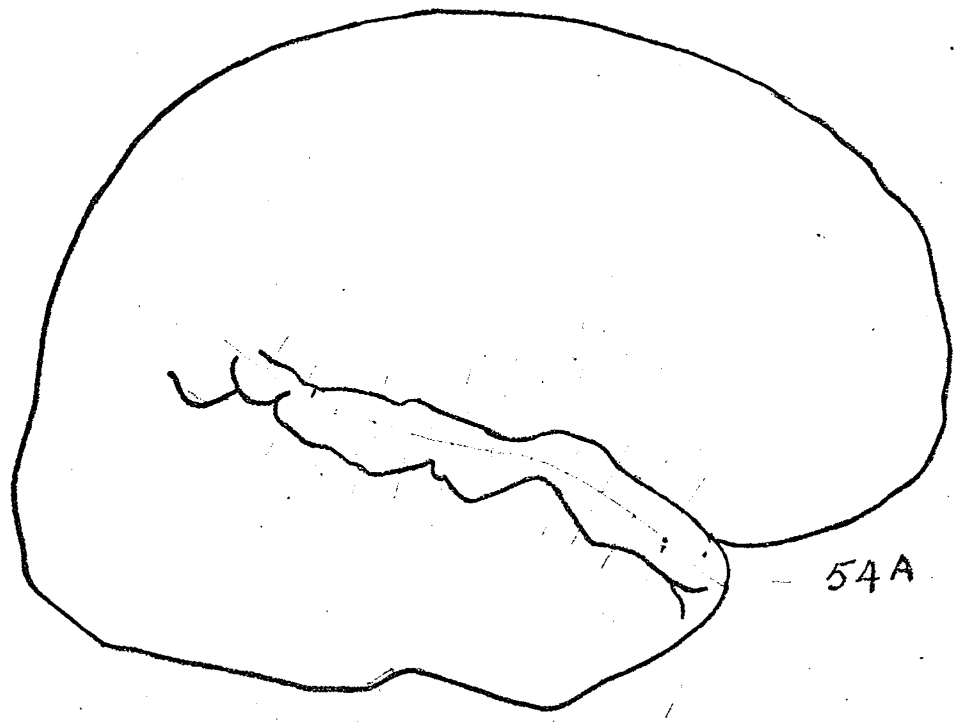


55 A

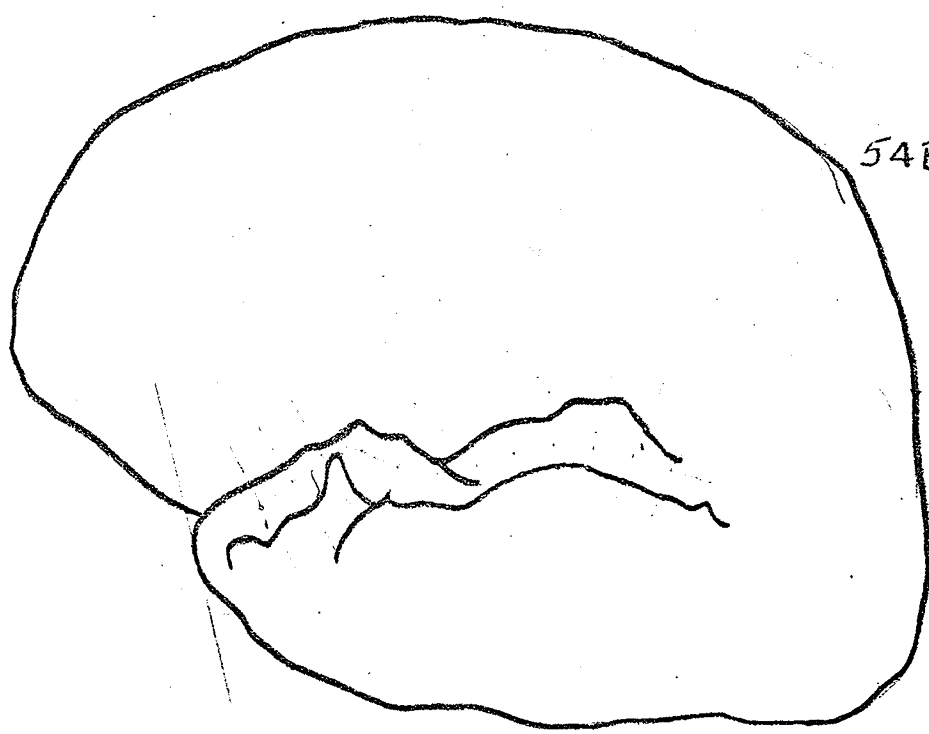


55 B

AUTOPSY No. 71 B 65
RANDOM No. 57430

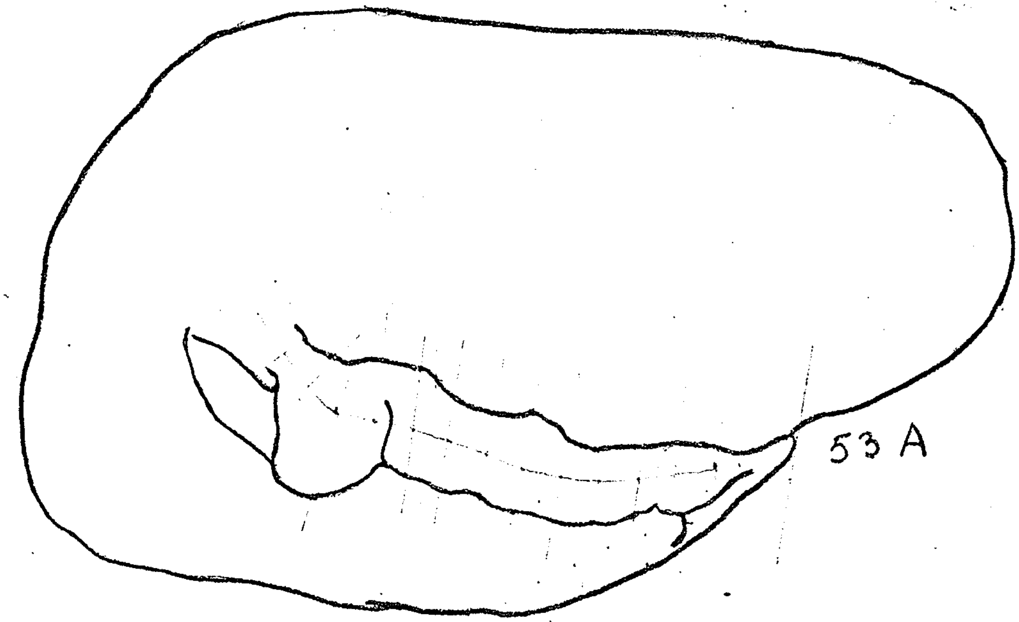


54A



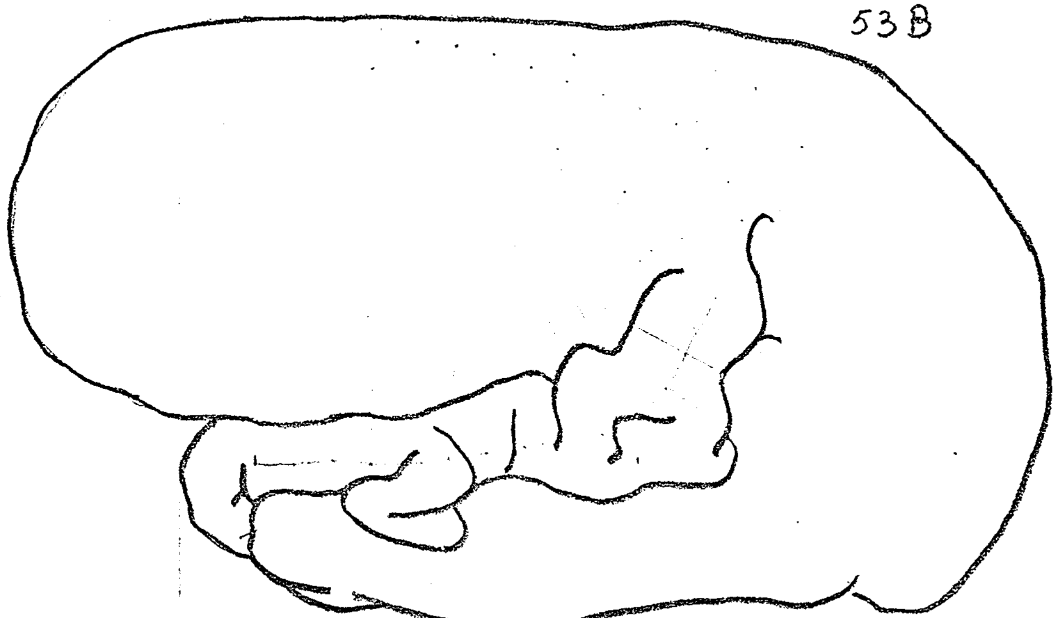
54B

Autopsy No. A70-12
Random No. 76229

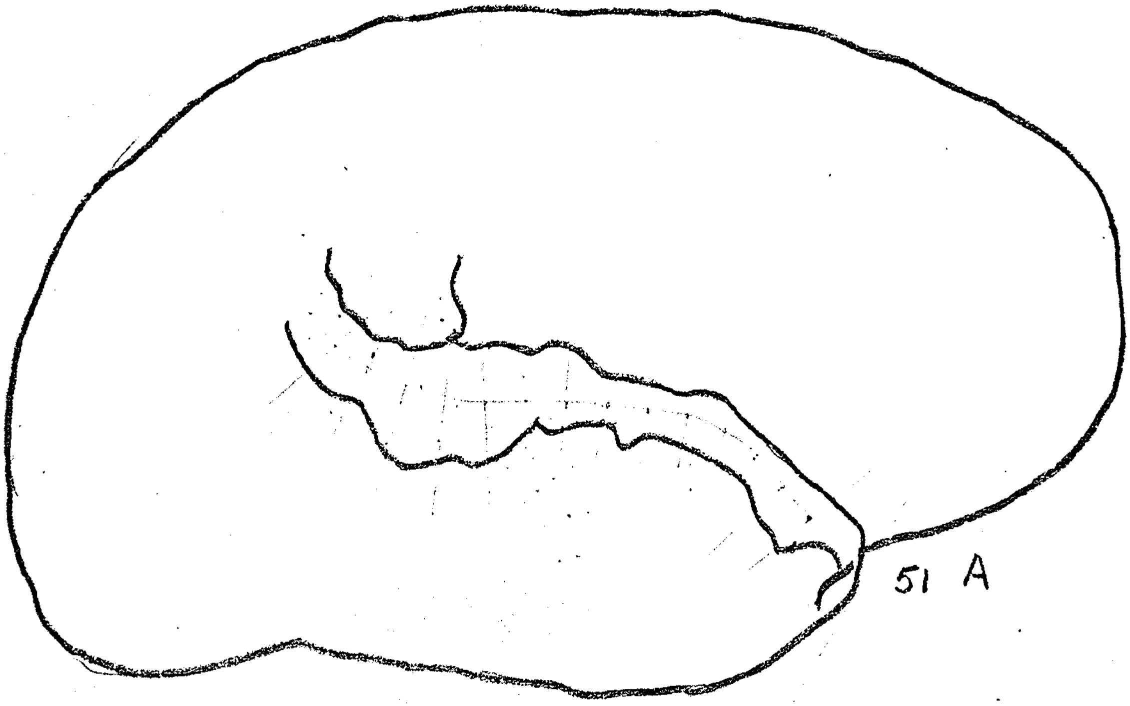


53 A

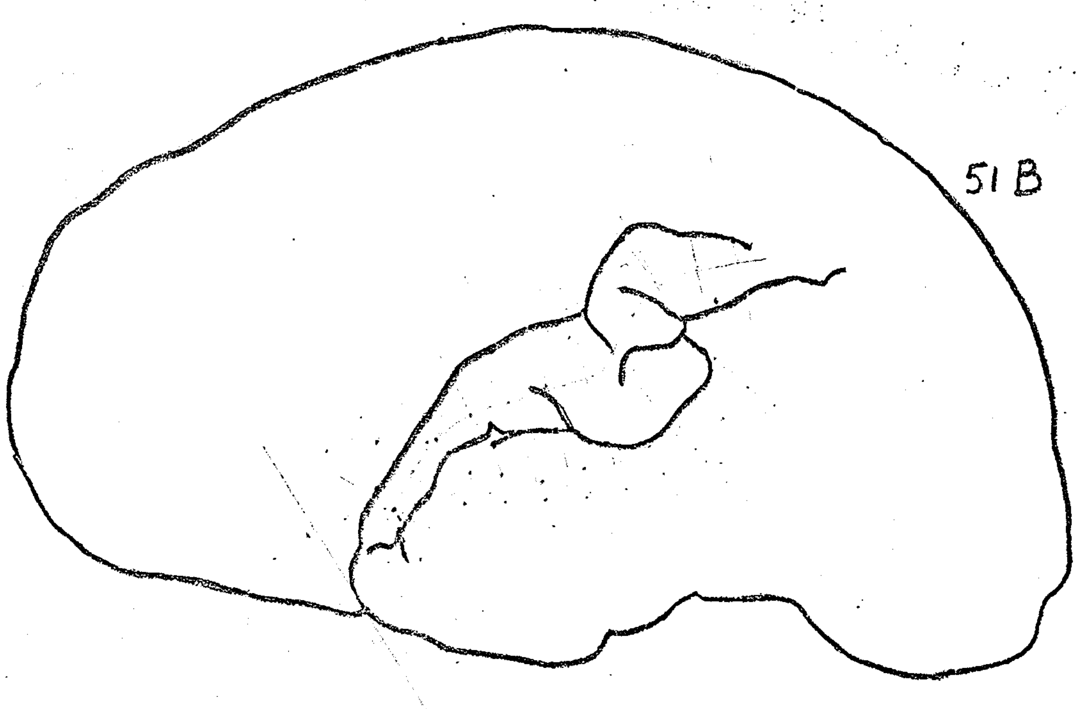
53 B



AUTOPSY No.
RANDOM No.

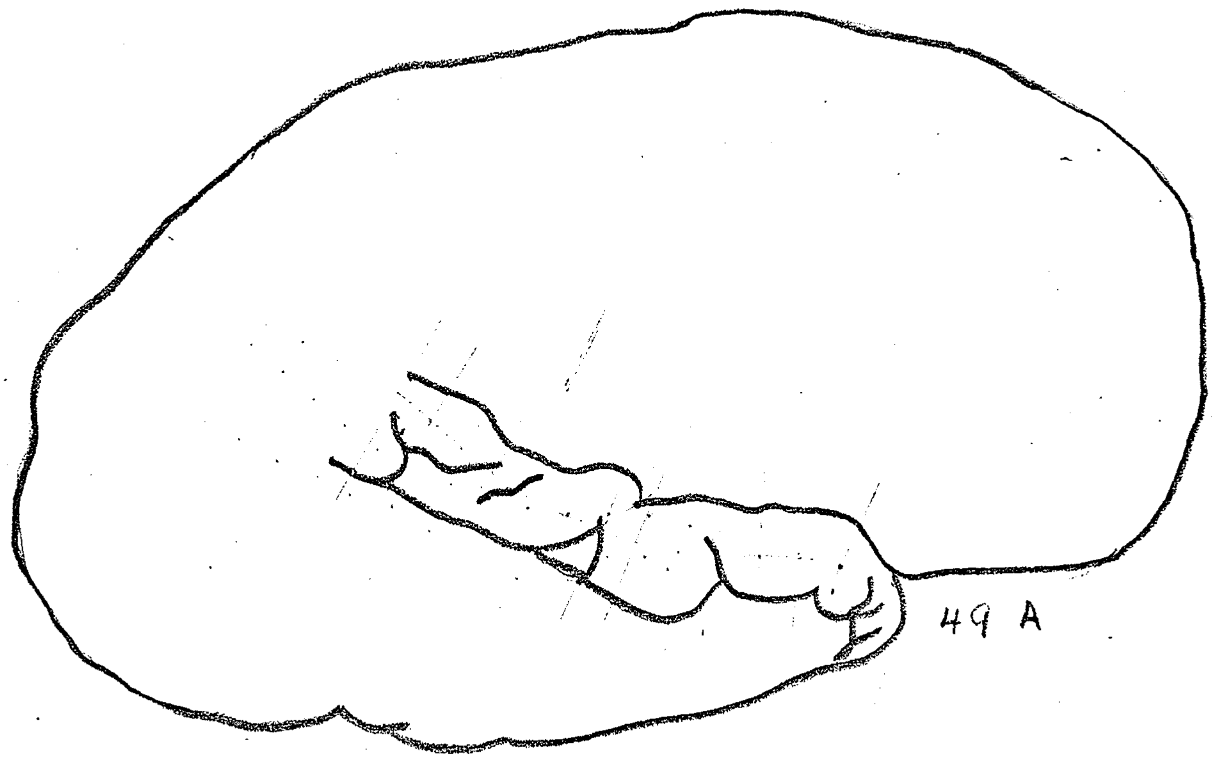


51 A

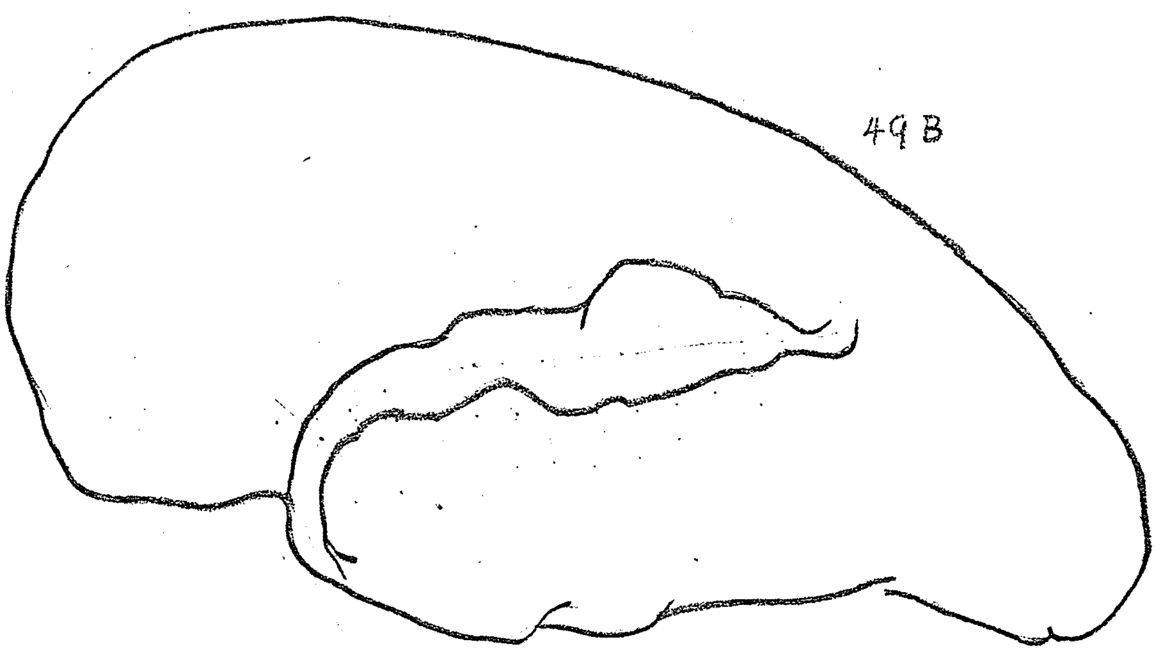


51 B

AUTOPSY No. A 70-40
RANDOM No. 91853

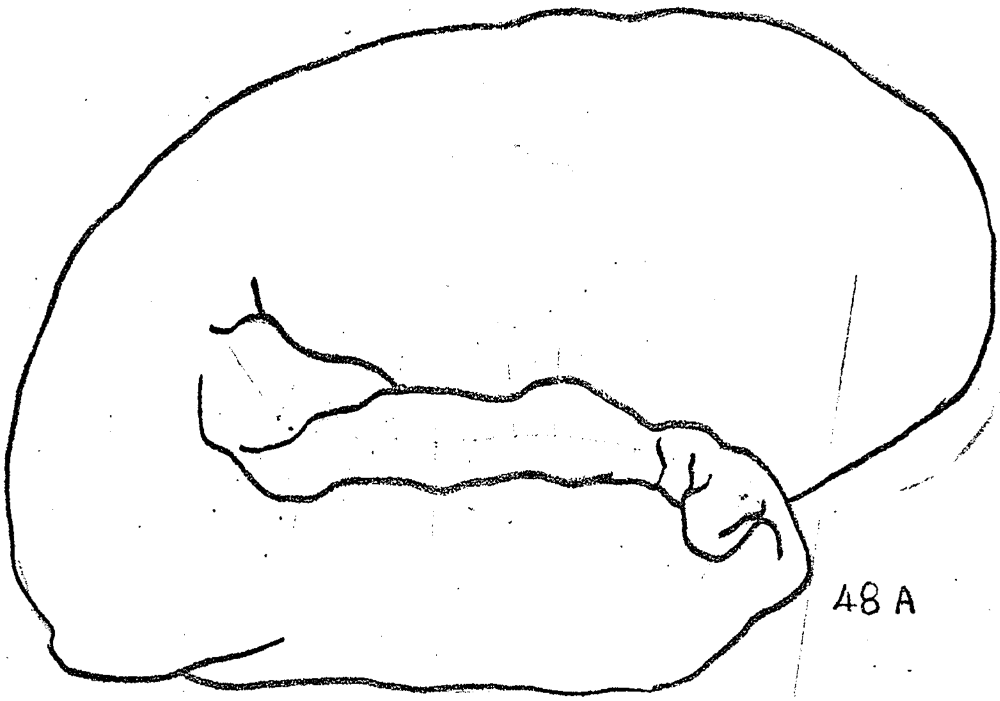


49 A

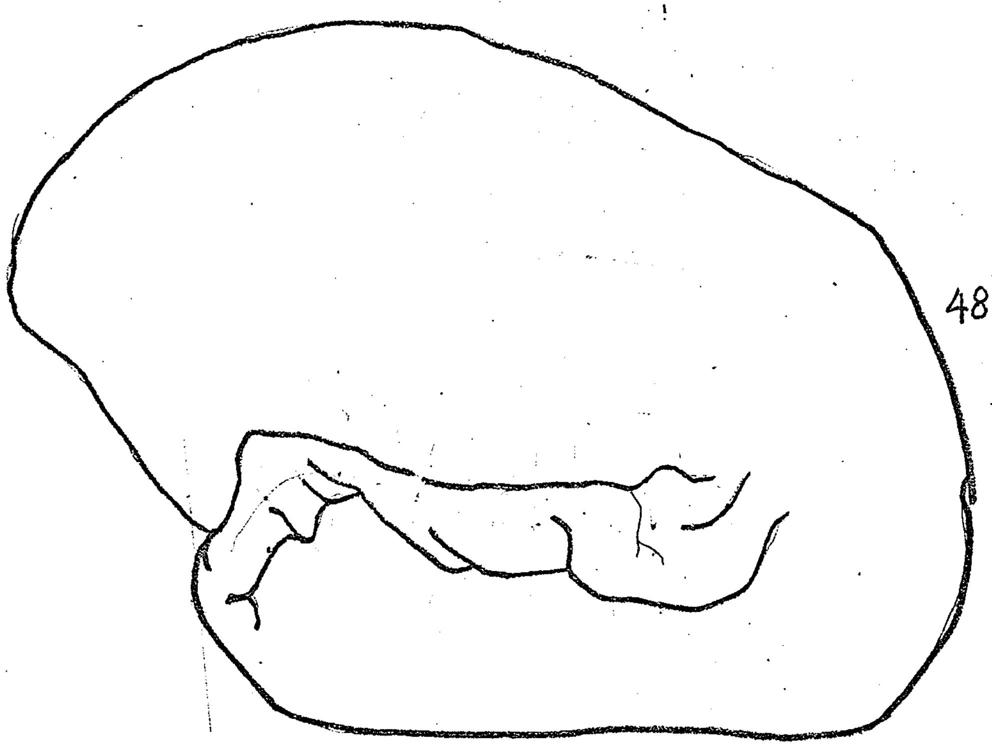


49 B

AUTOPSY No. A70-64
RANDOM No. 77642

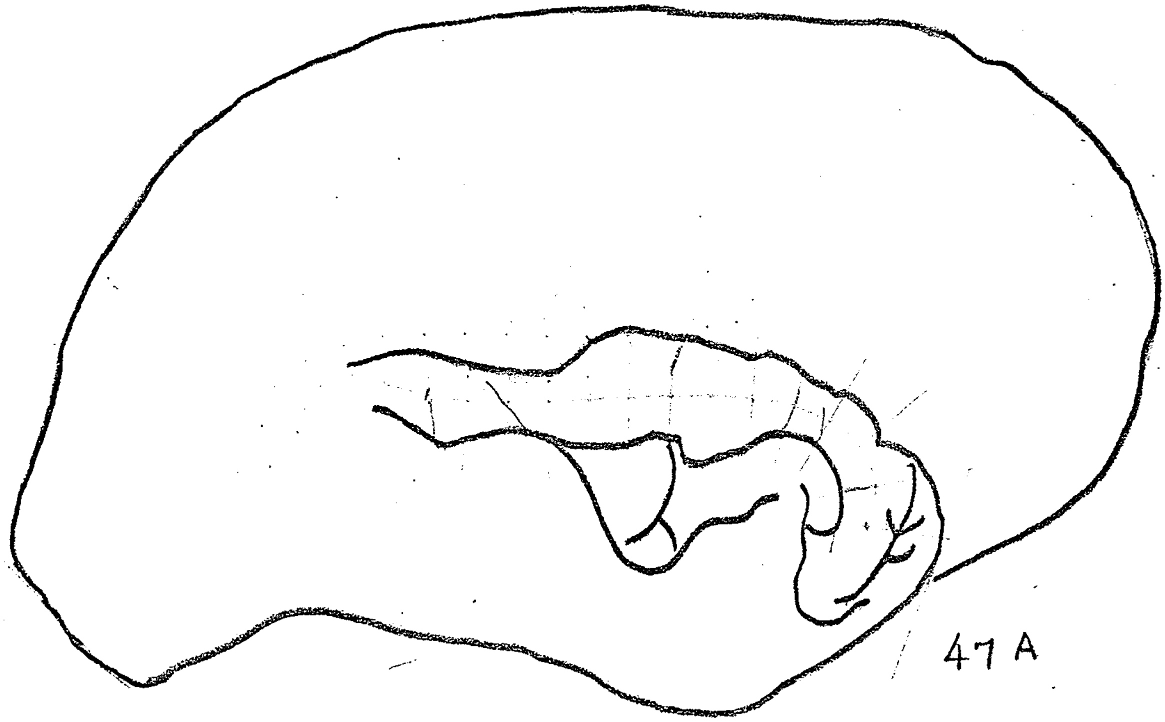


48 A



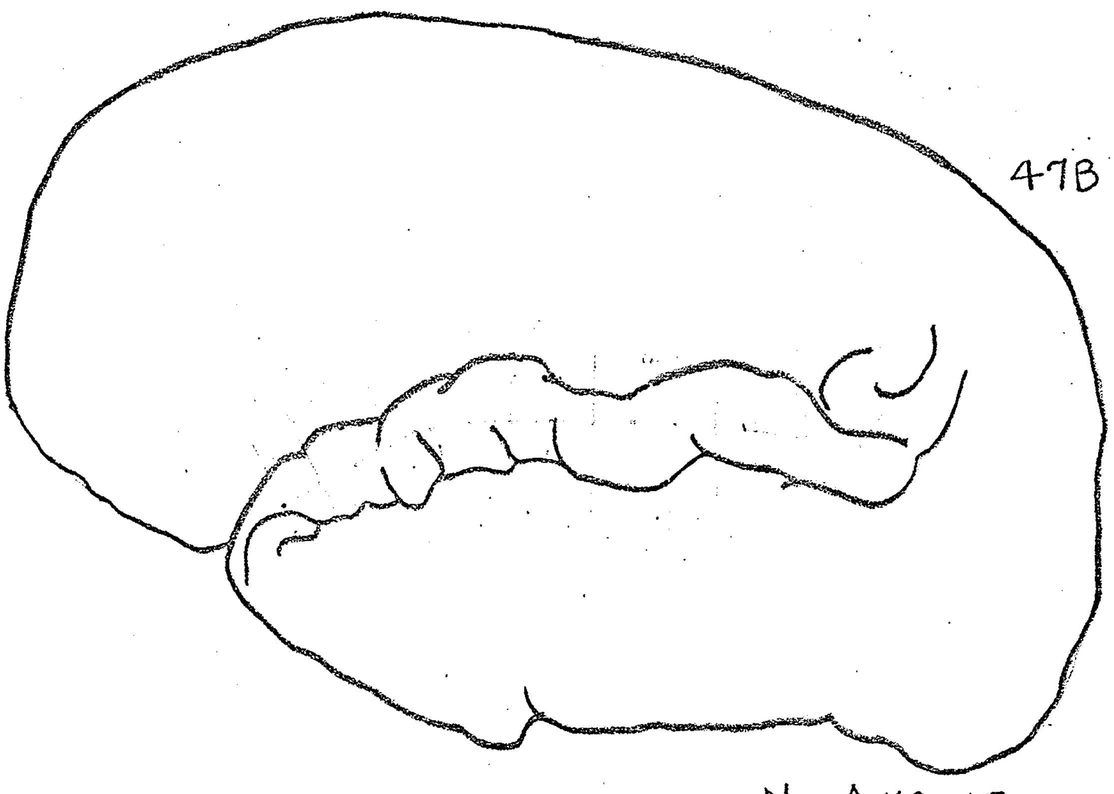
48 B

AUTOPSY No. A70-69
RANDOM No. 95398

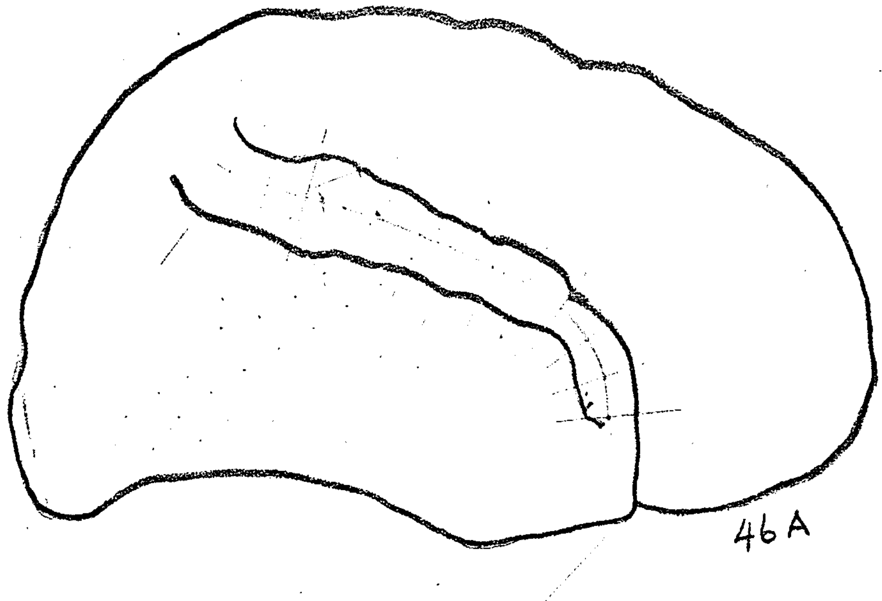


47 A

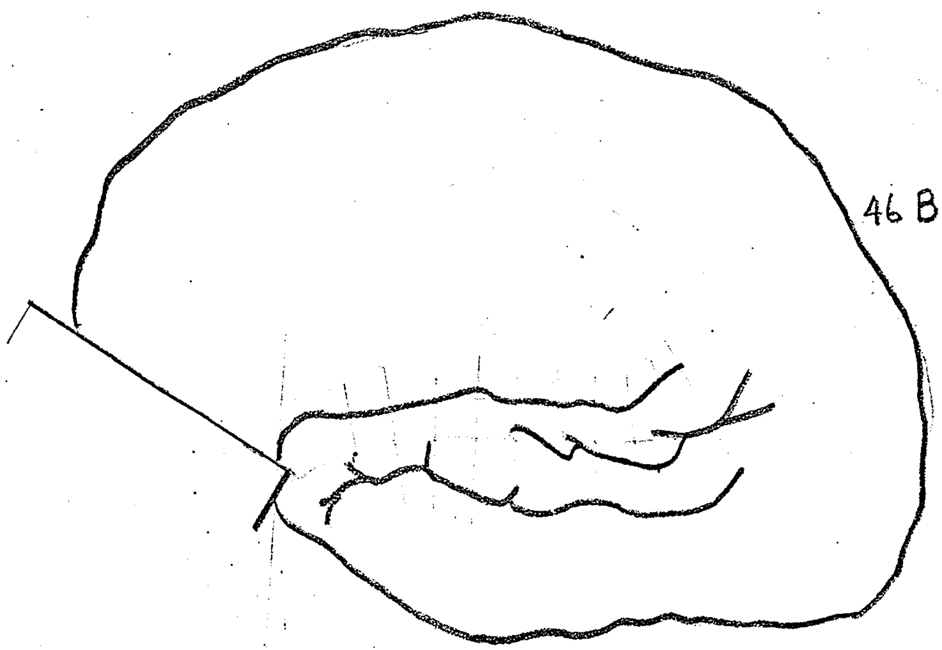
47B



AUTOPSY NO. A 70-75
RANDOM NO. 67799

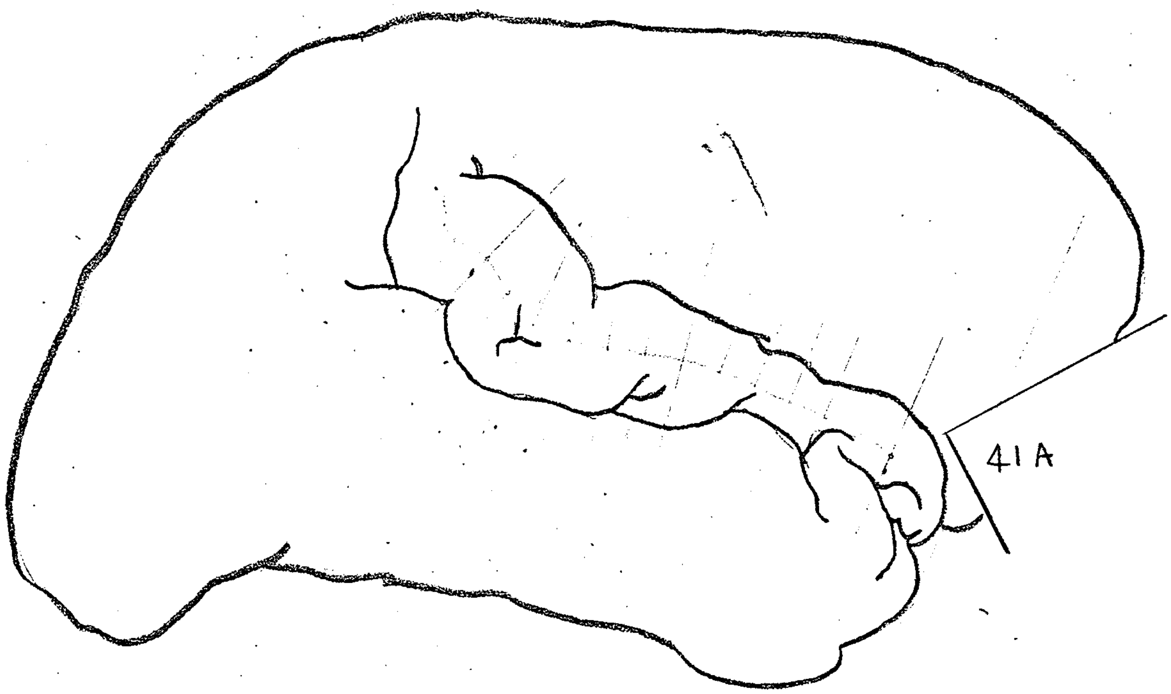


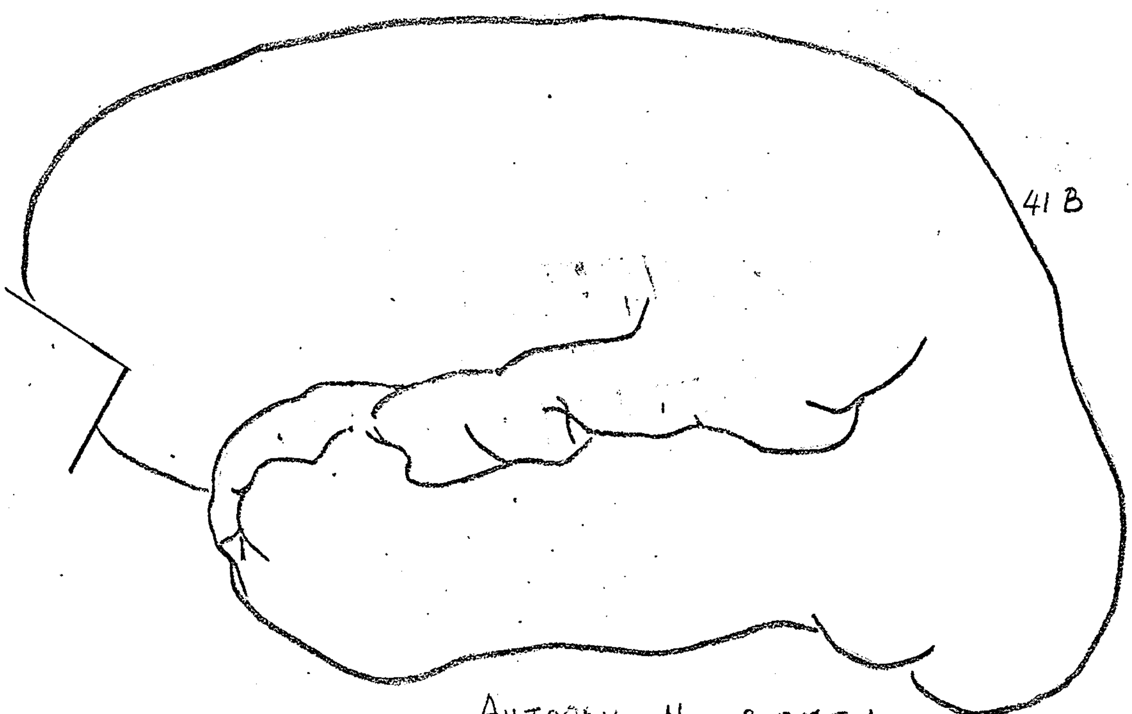
46A



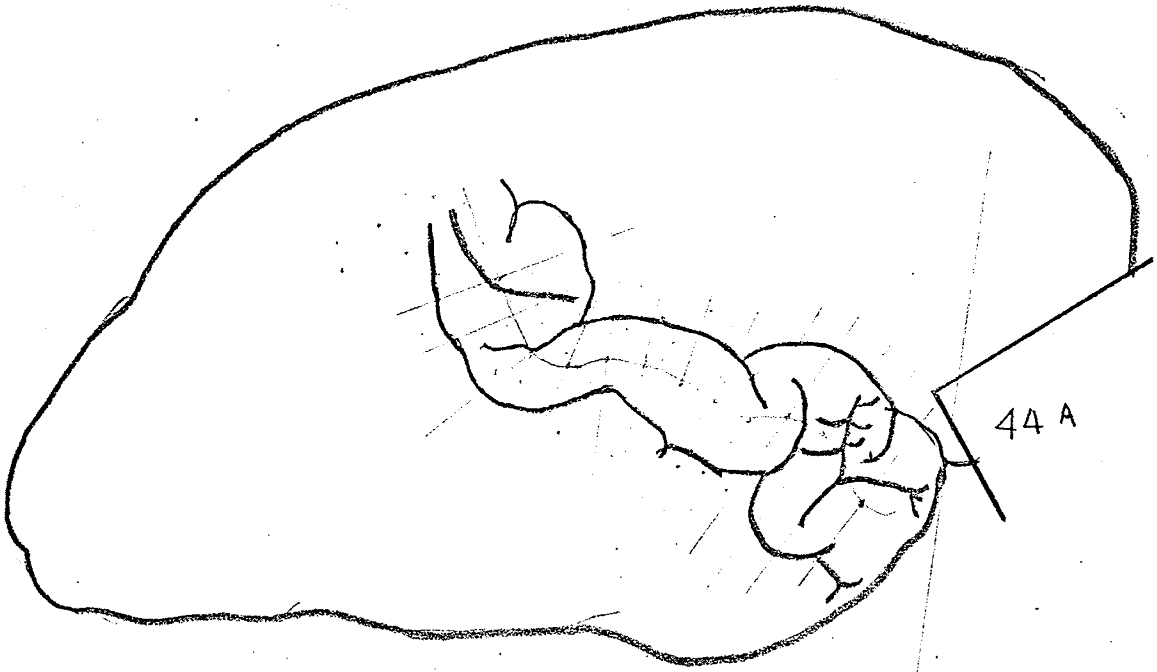
46B

AUTOPSY NO. A 70-108
RANDOM NO. 56492

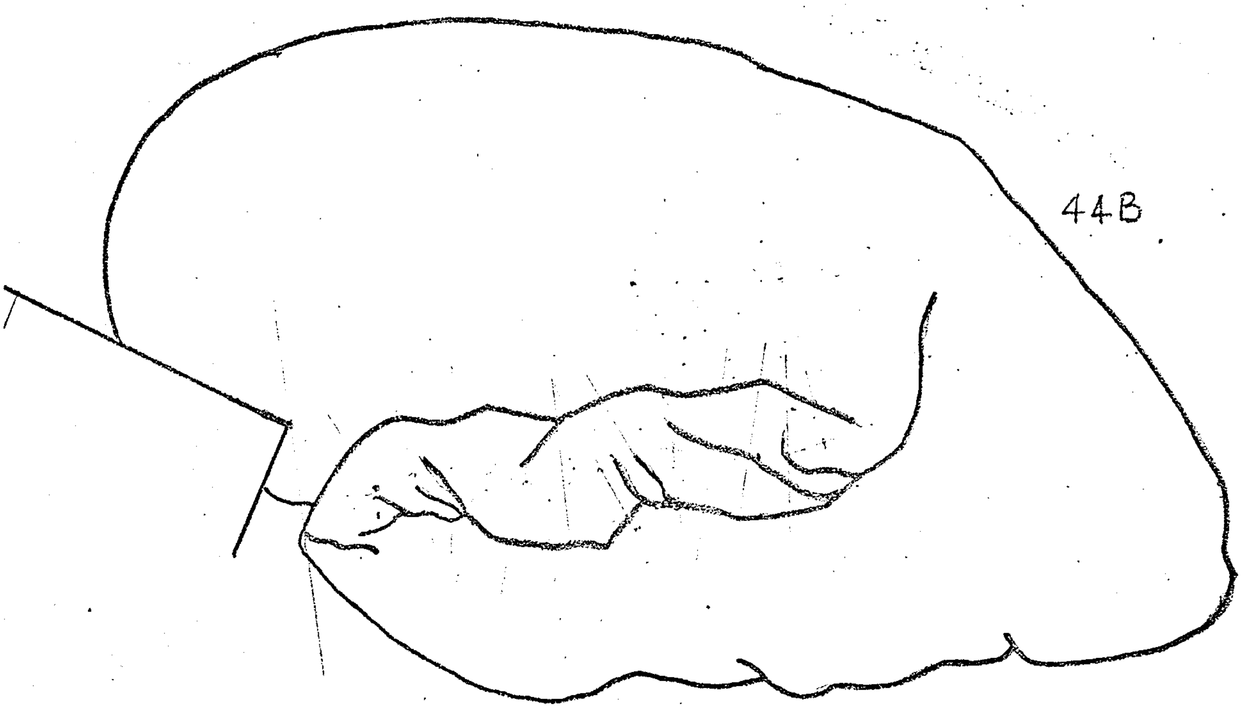




AUTOPSY No. 25754
RANDOM No. 42626

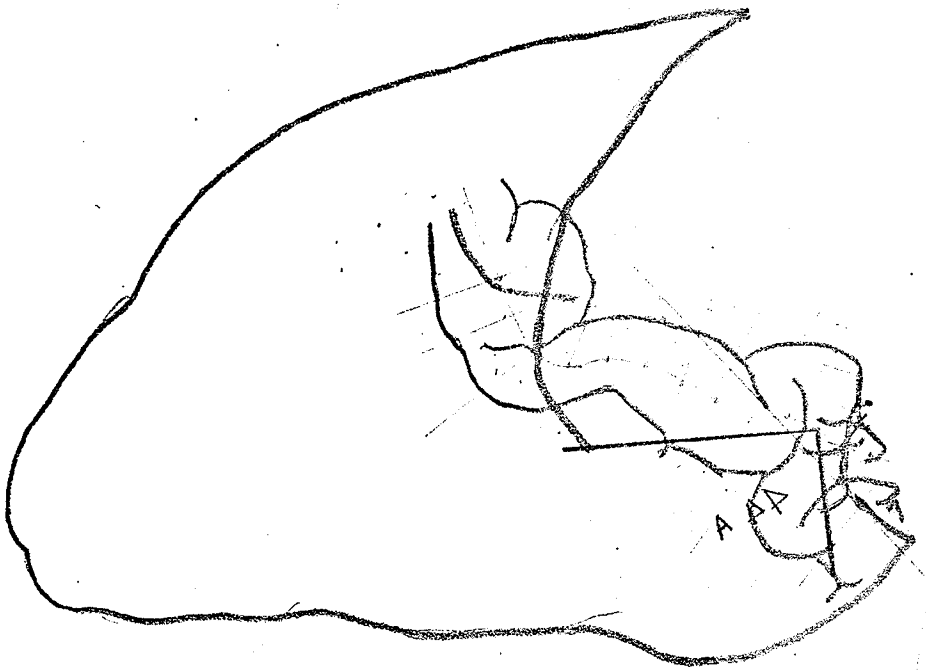


44 A

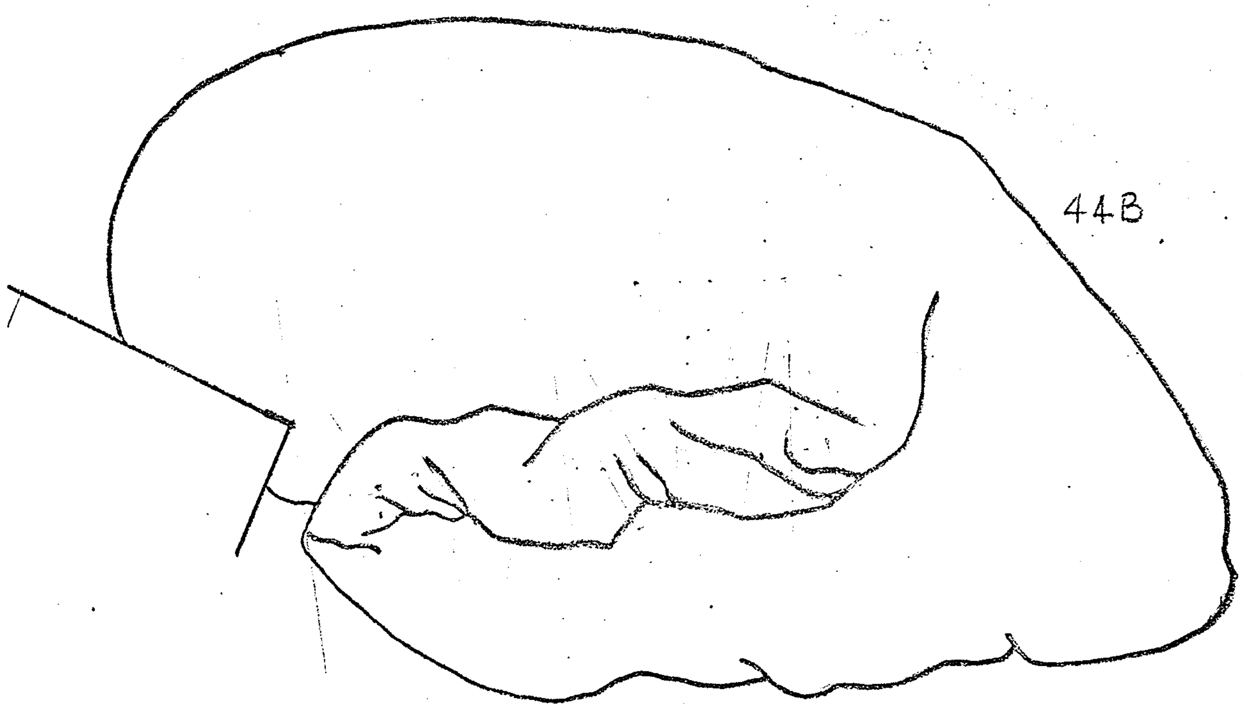


44B

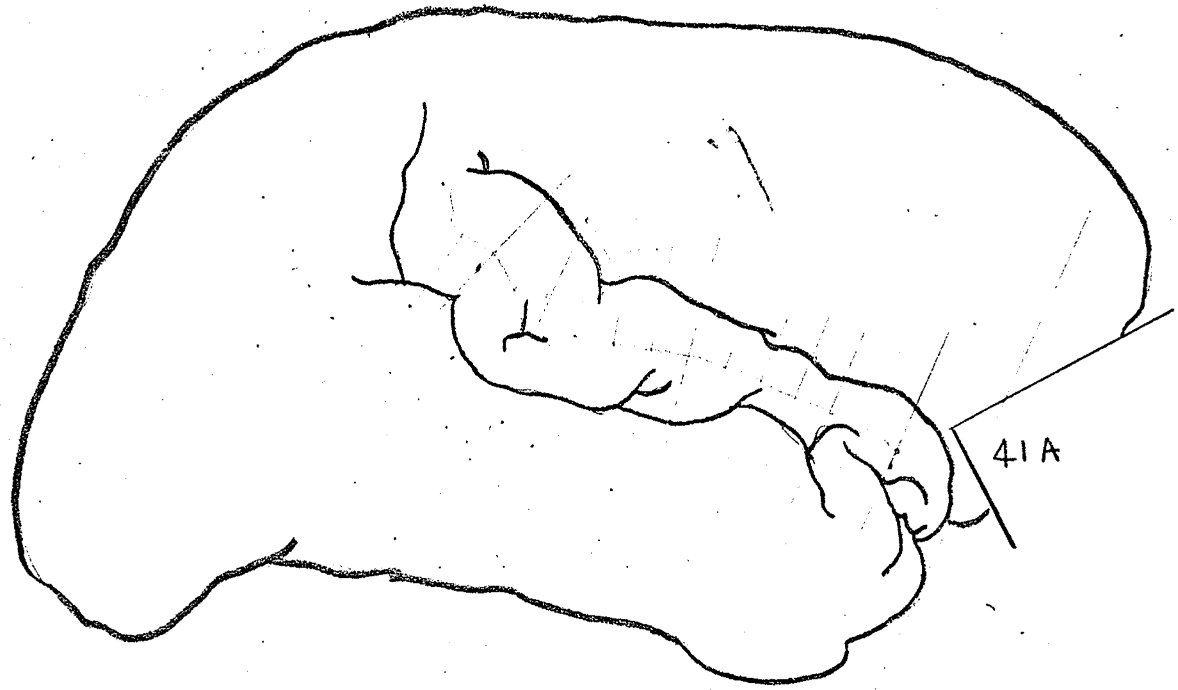
AUTOPSY No. 71 B 56
RANDOM No. 92294

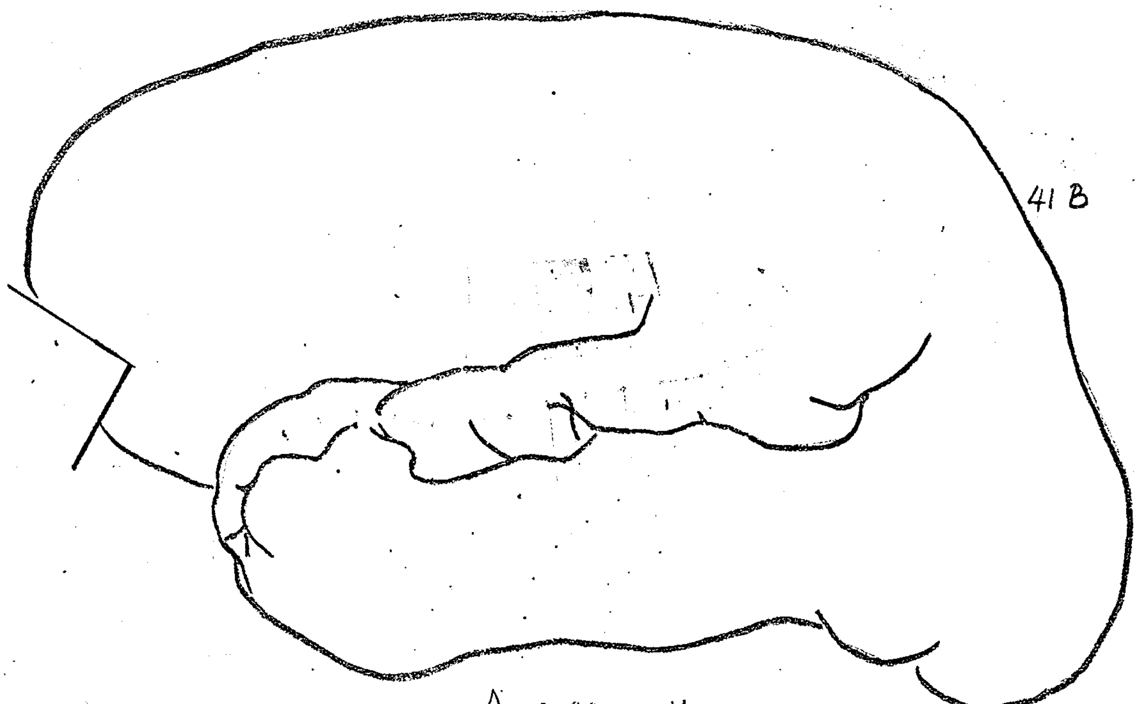


44B

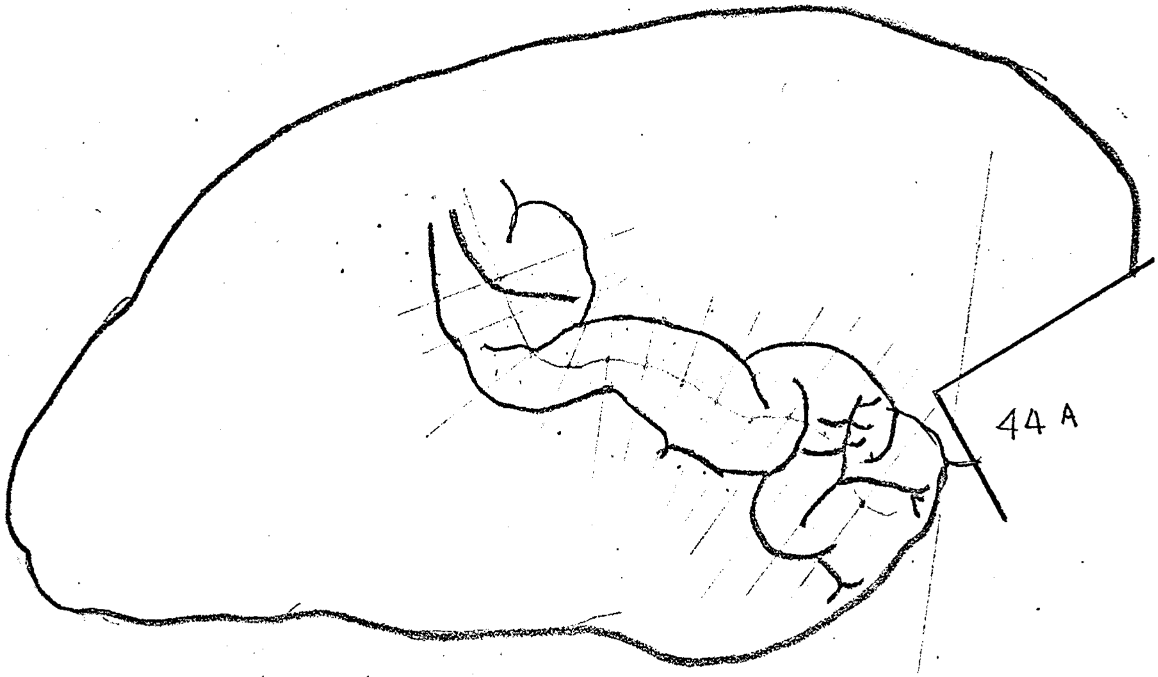


AUTOPSY No. 71 B 56
RANDOM No. 92294

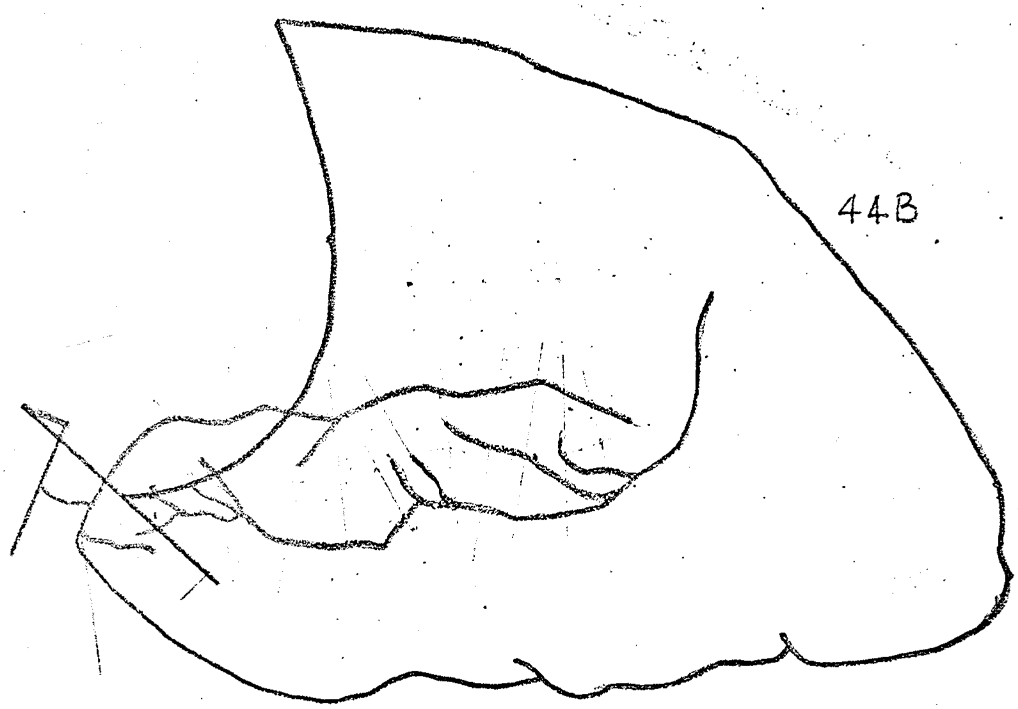




AUTOPSY No. 25754
RANDOM No. 42626

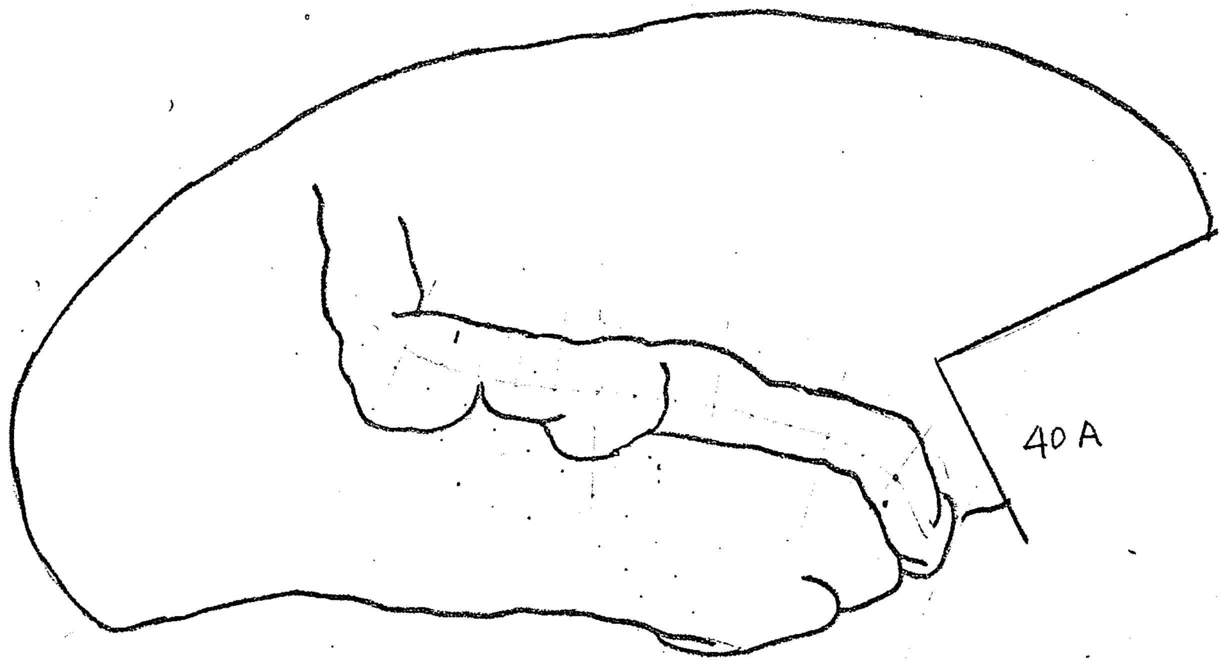


44 A



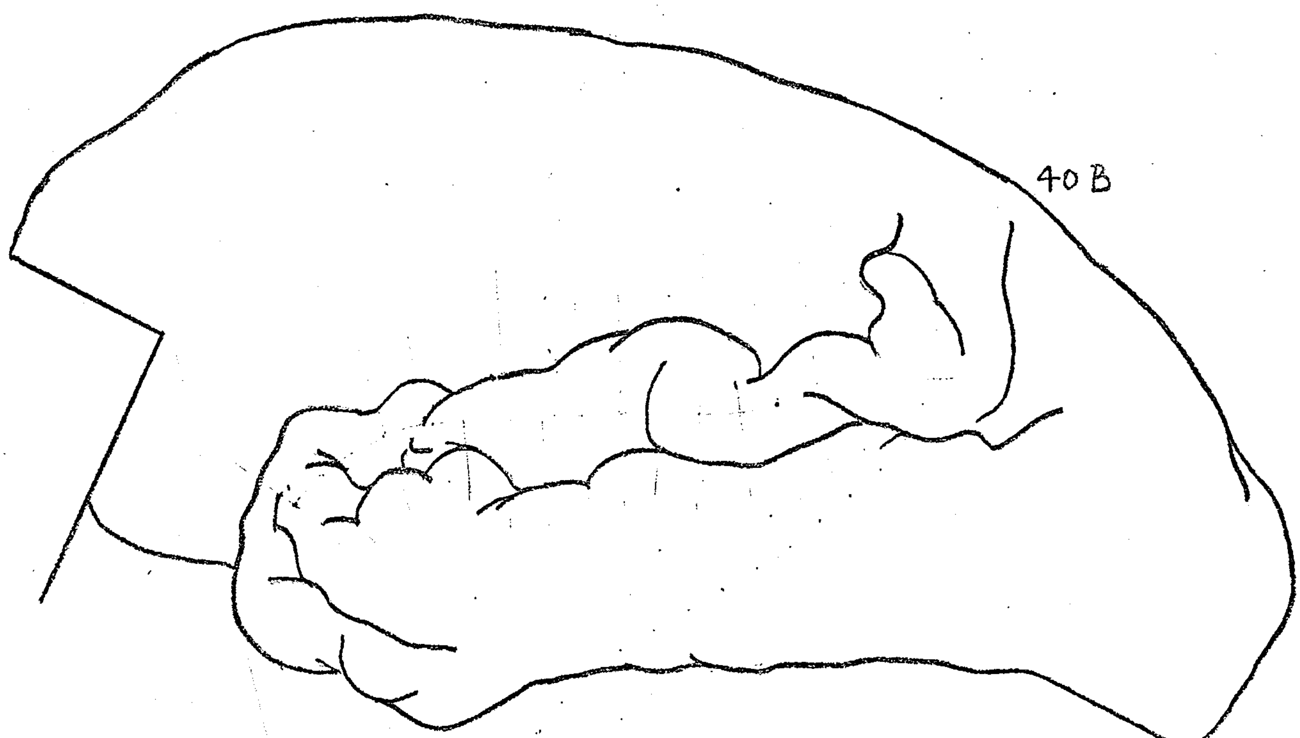
44B

AUTOPSY No. 71 B 56
RANDOM No. 92294

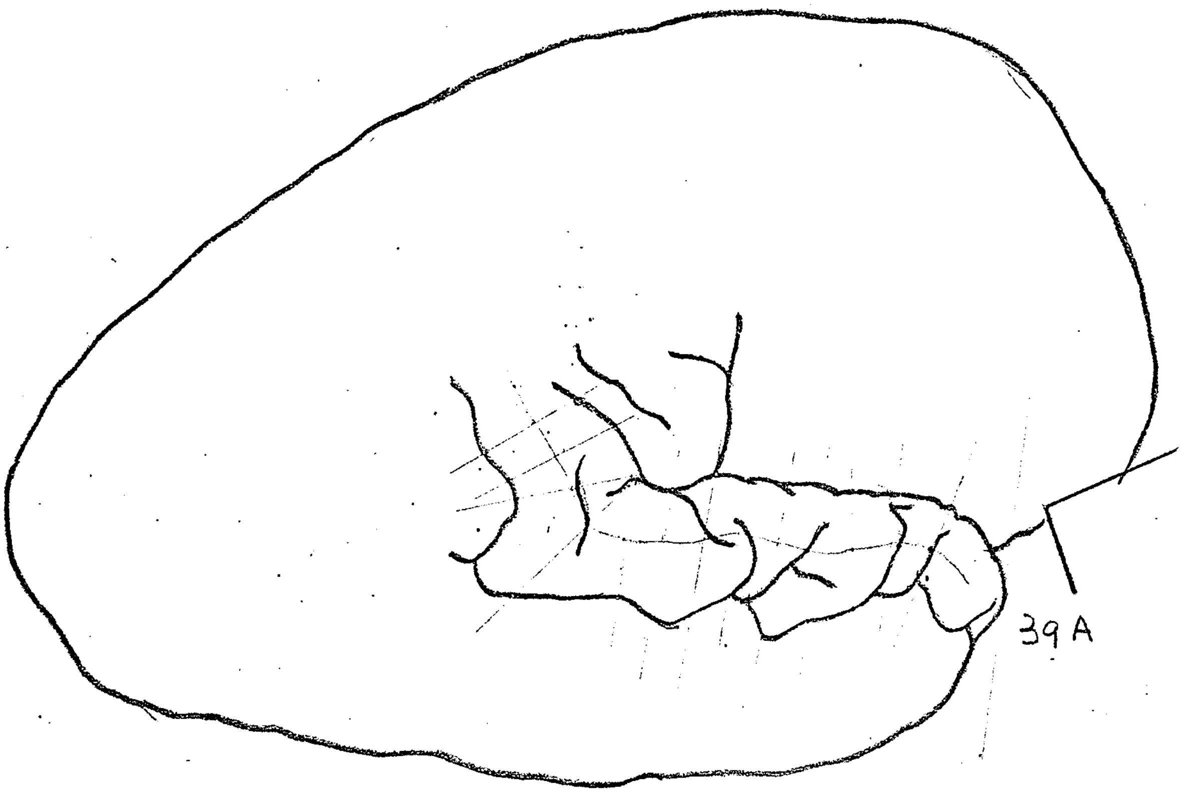


40 A

40 B

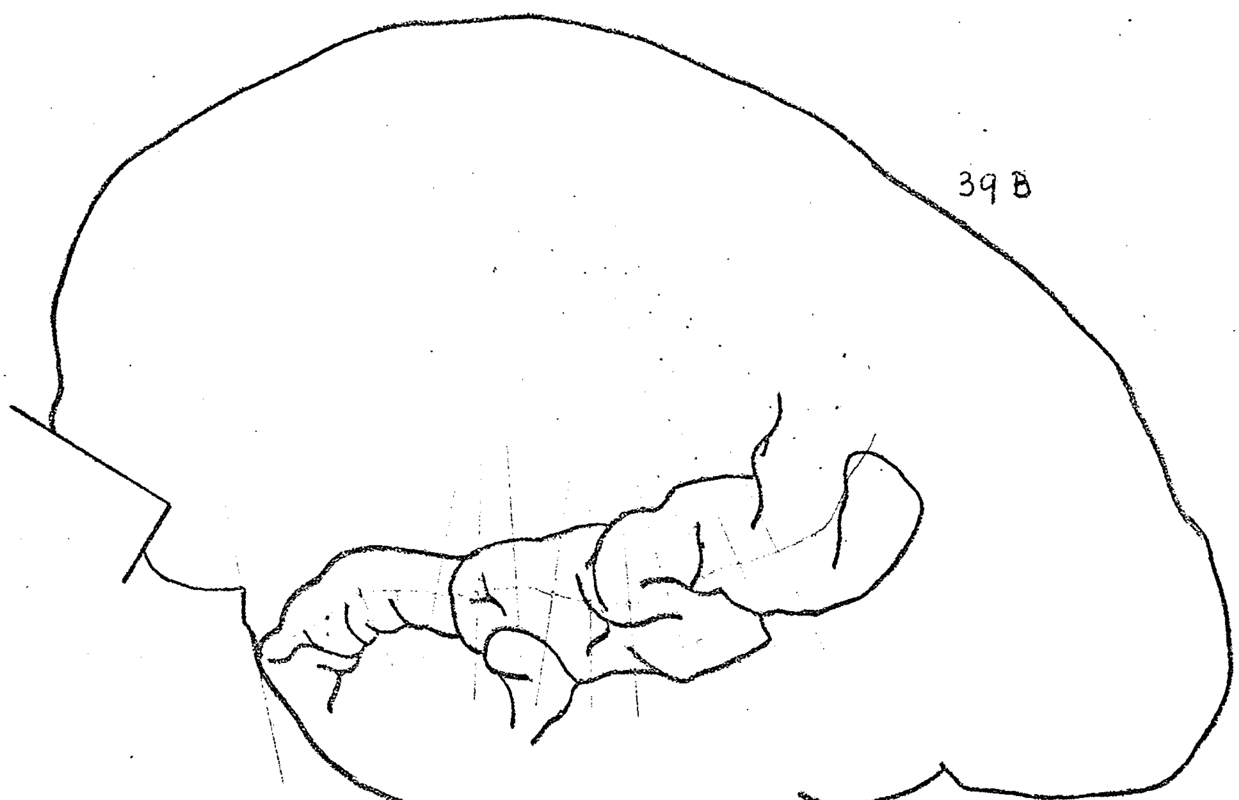


AUTOPSY No. 25718
RANDOM No 42054

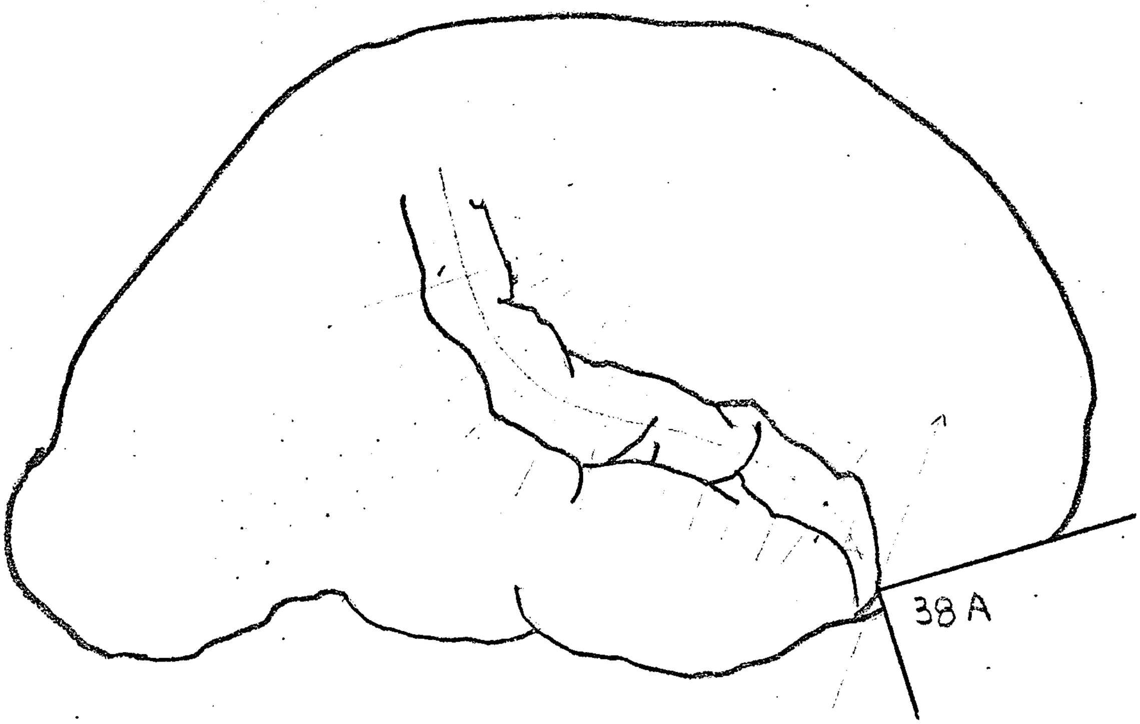


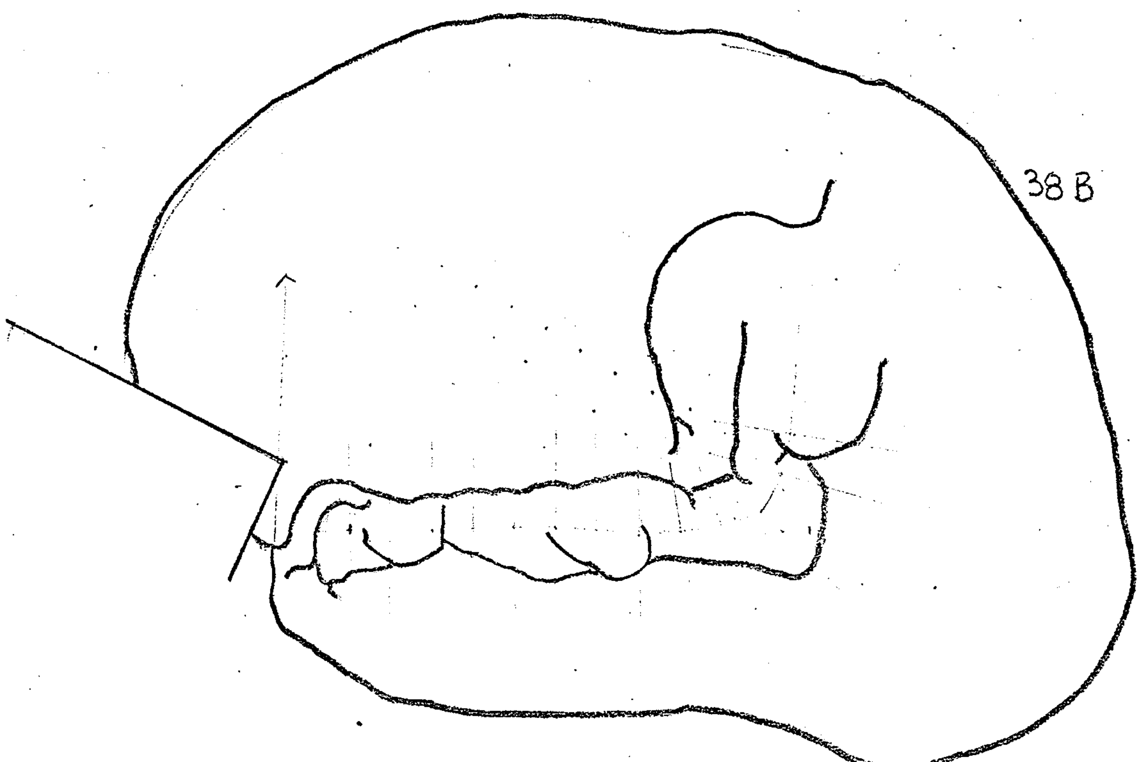
39 A

39 B

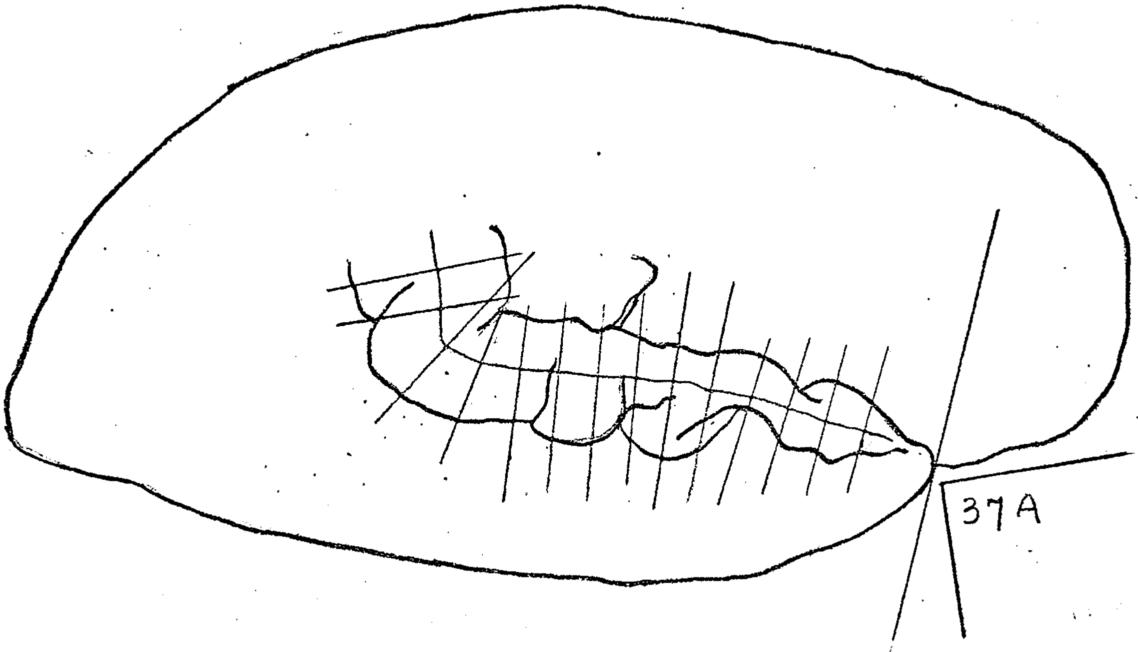


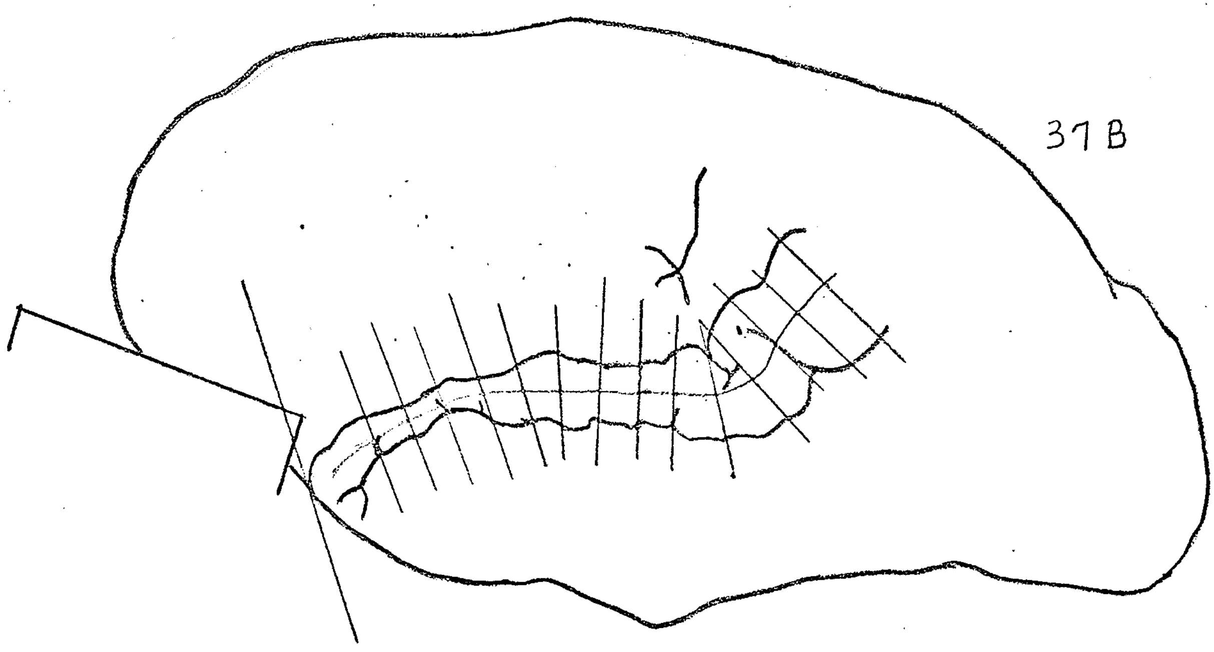
AUTOPSY No. 70-13-16
RANDOM No. 58680



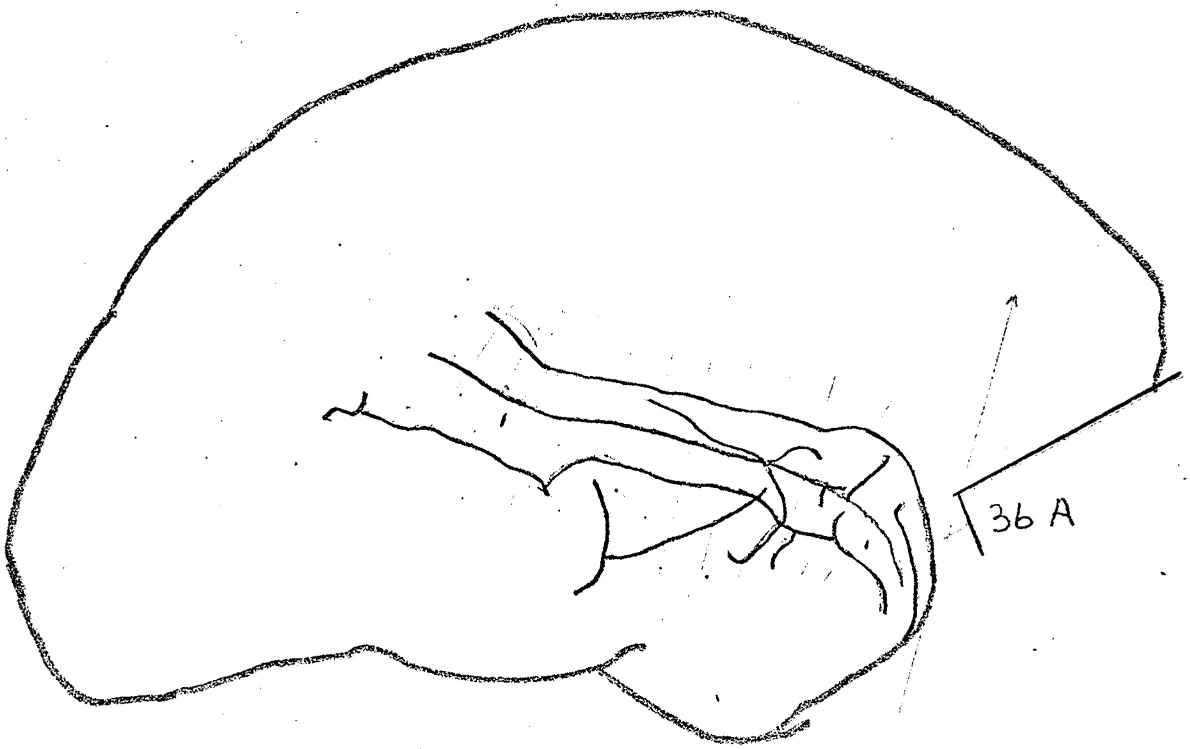


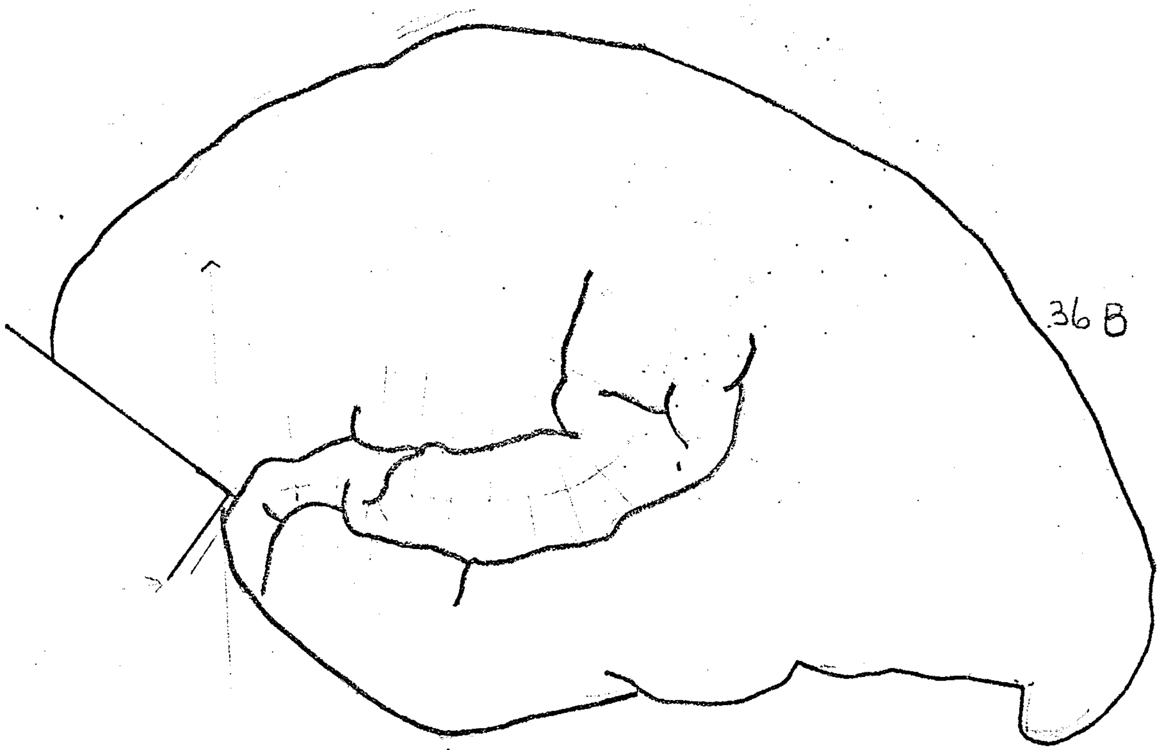
AUTOPSY No. A 4859
RANDOM No. 23474



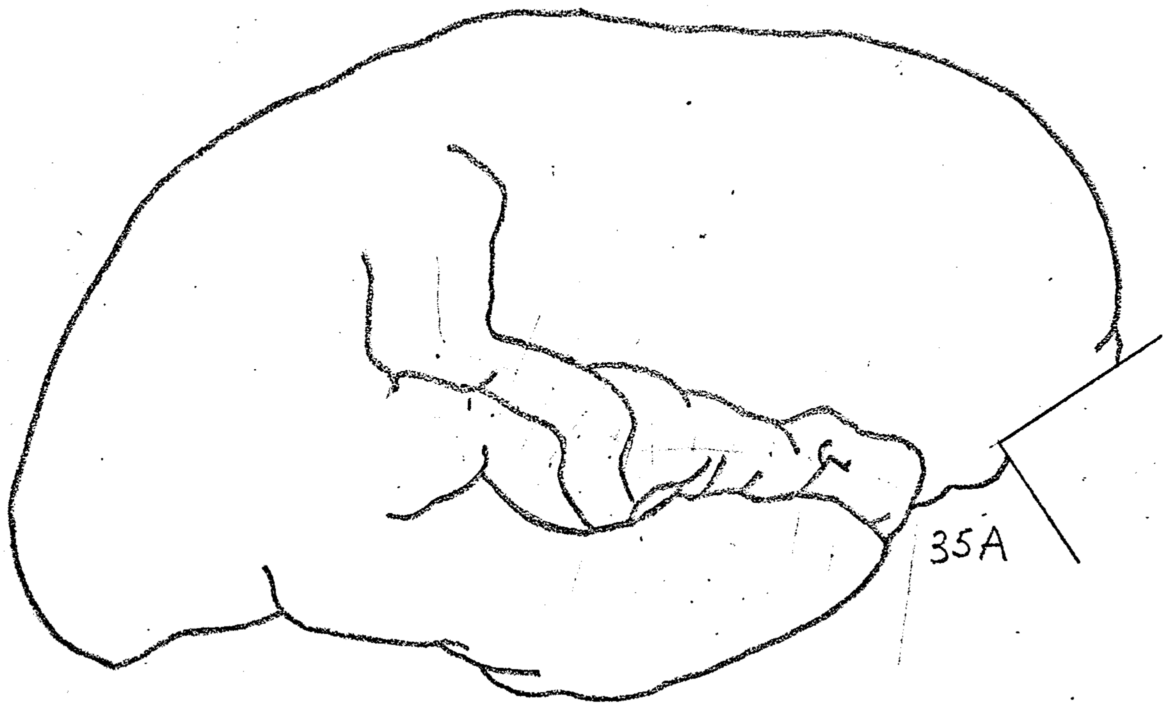


AUTOPSY No. A 4864
RANDOM No. 21460

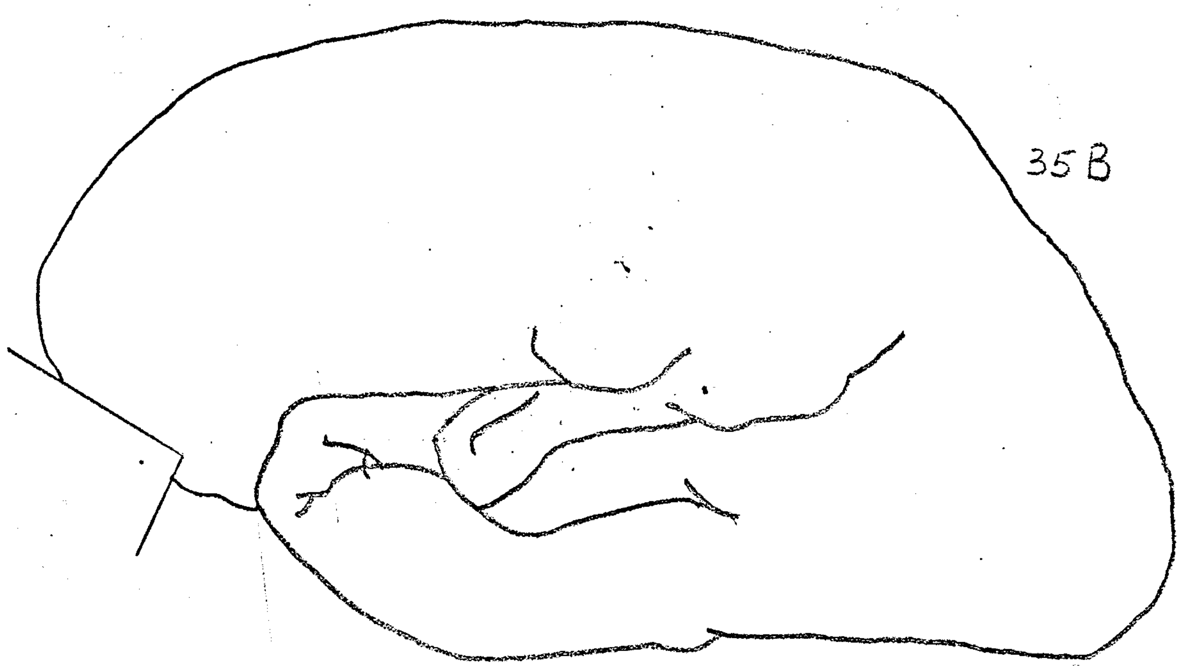




AUTOPSY No. A 4865
RANDOM No. 74261

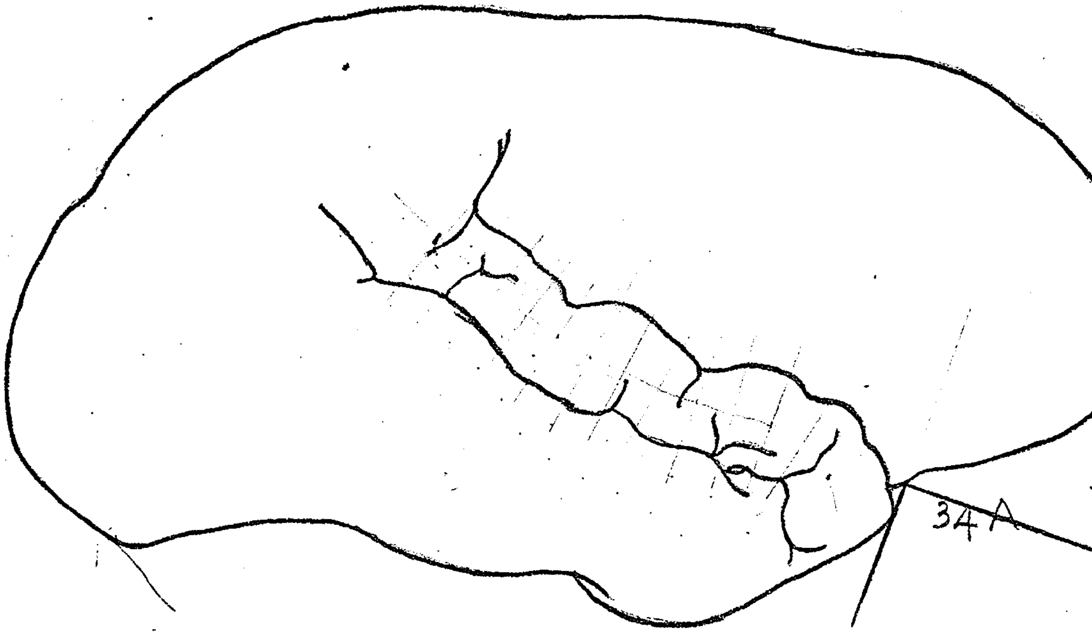


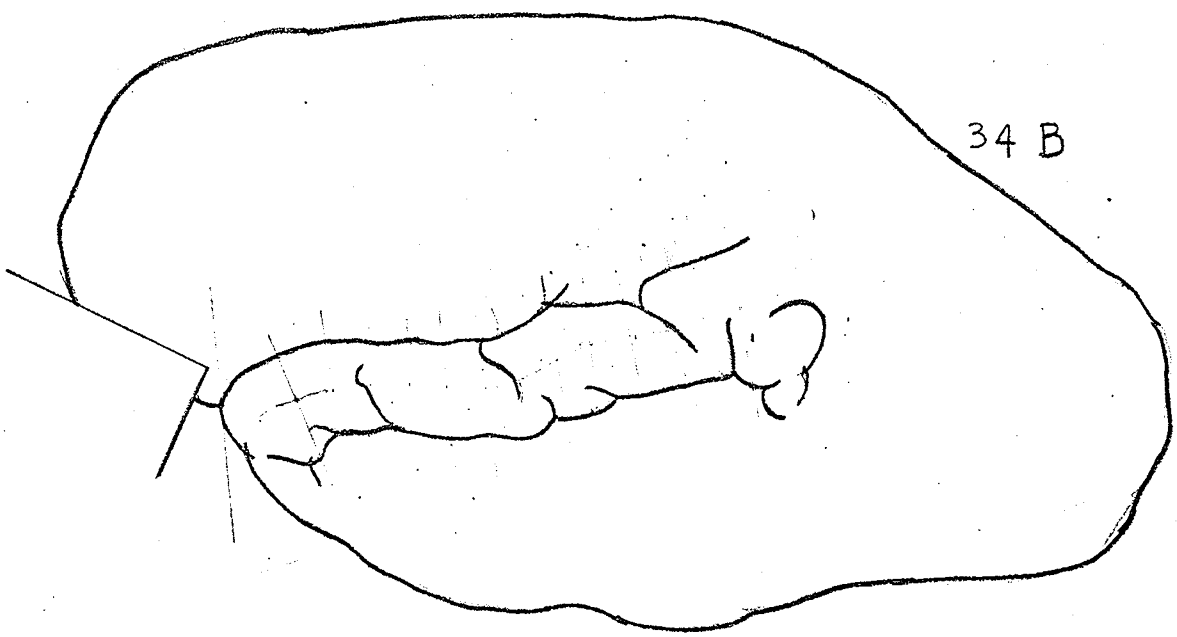
35A



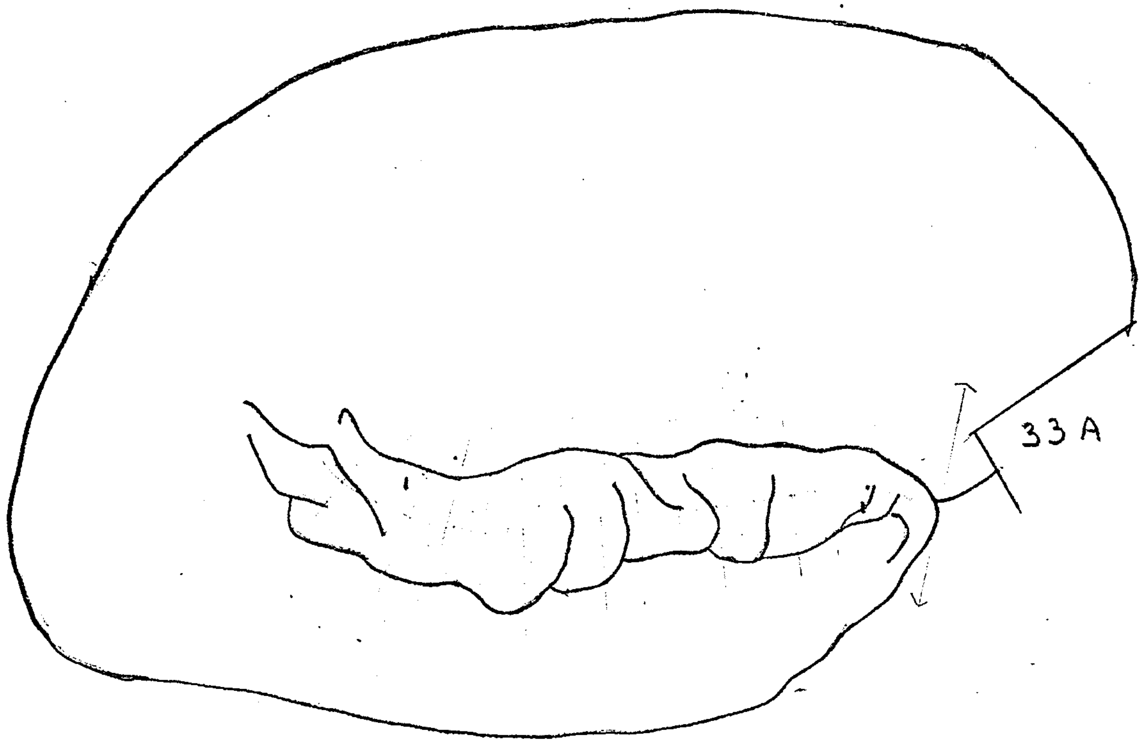
35B

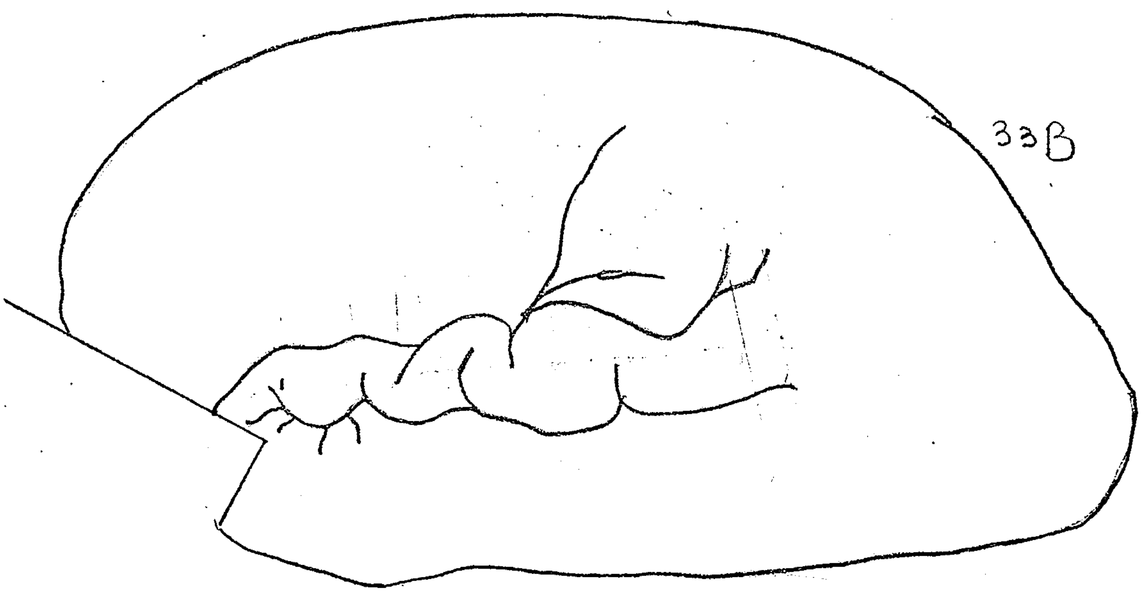
AUTOPSY No. A4870
RANDOM No. 15718



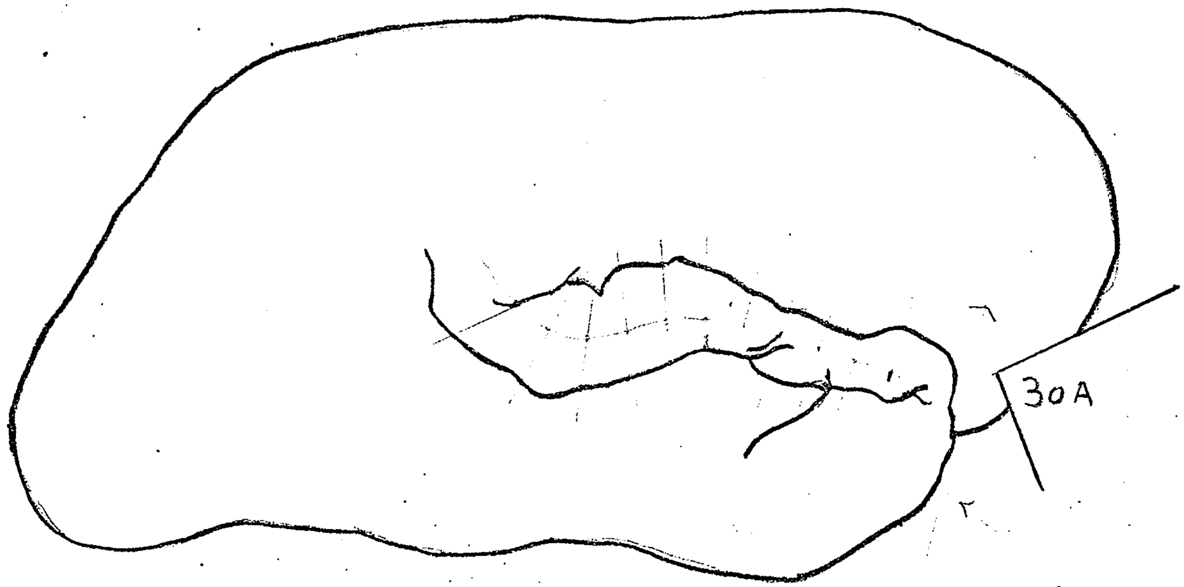


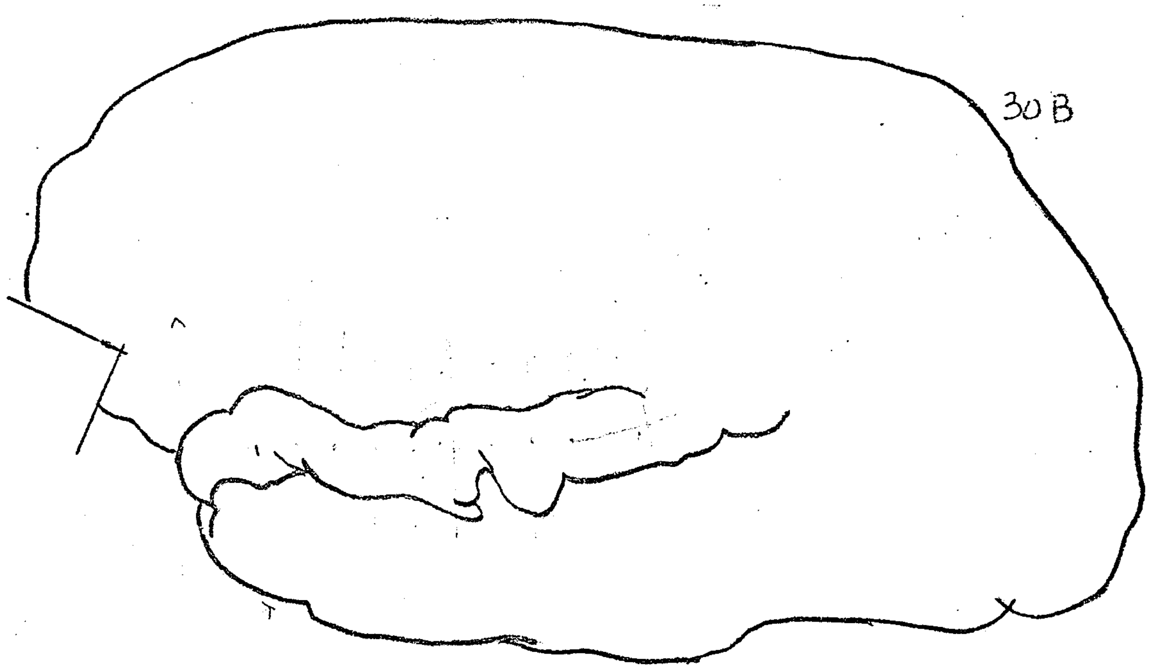
AUTOPSY NO. A 4868
RANDOM NO. 00333



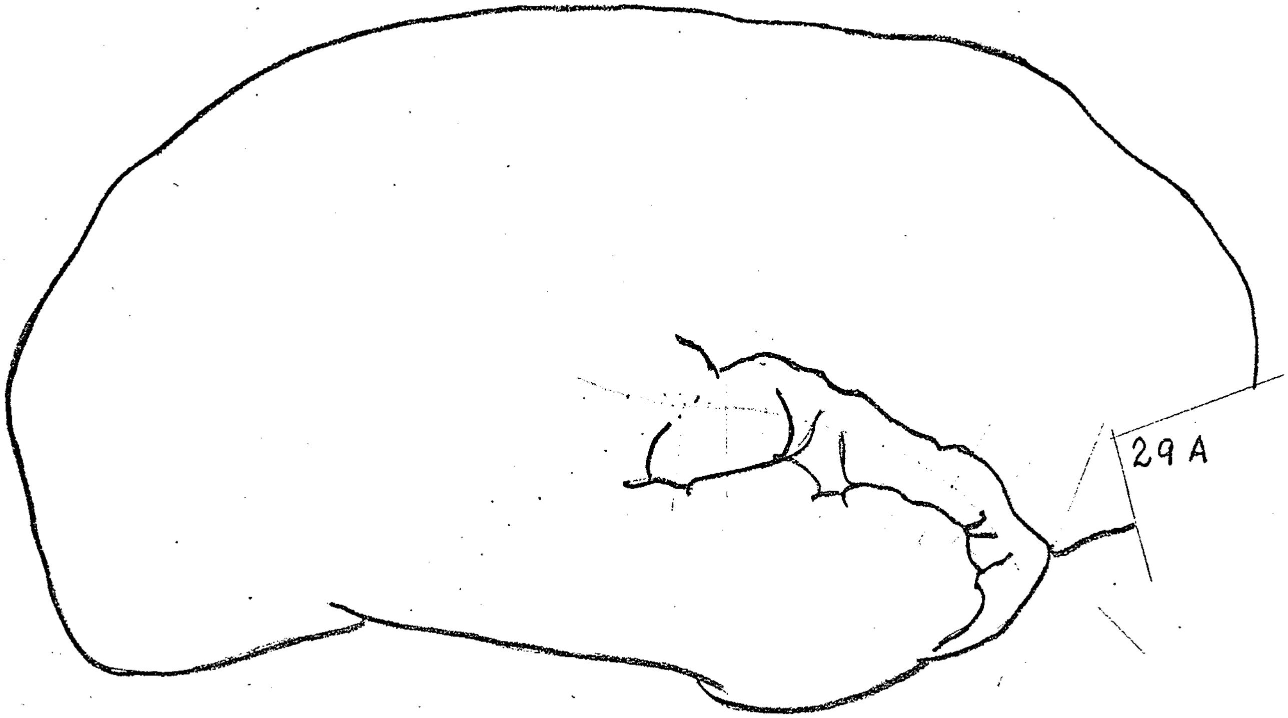


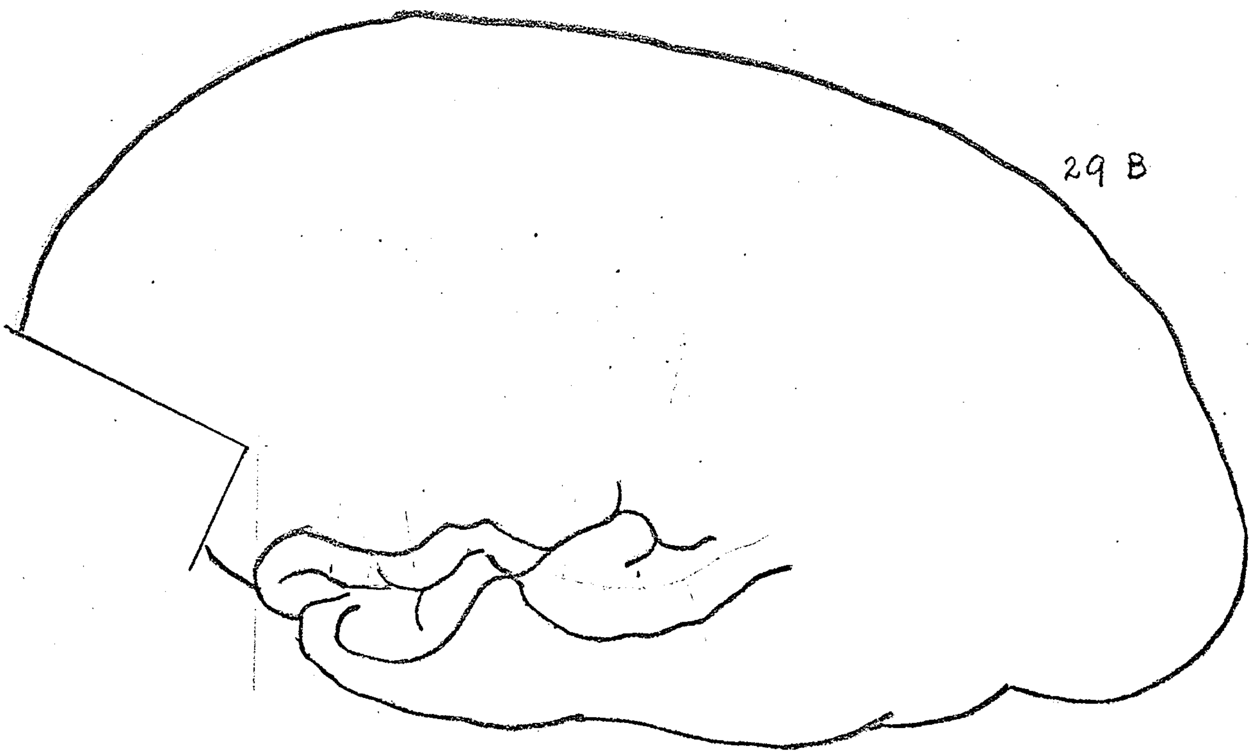
AUTOPSY No. A 4872
RANDOM No. 96199



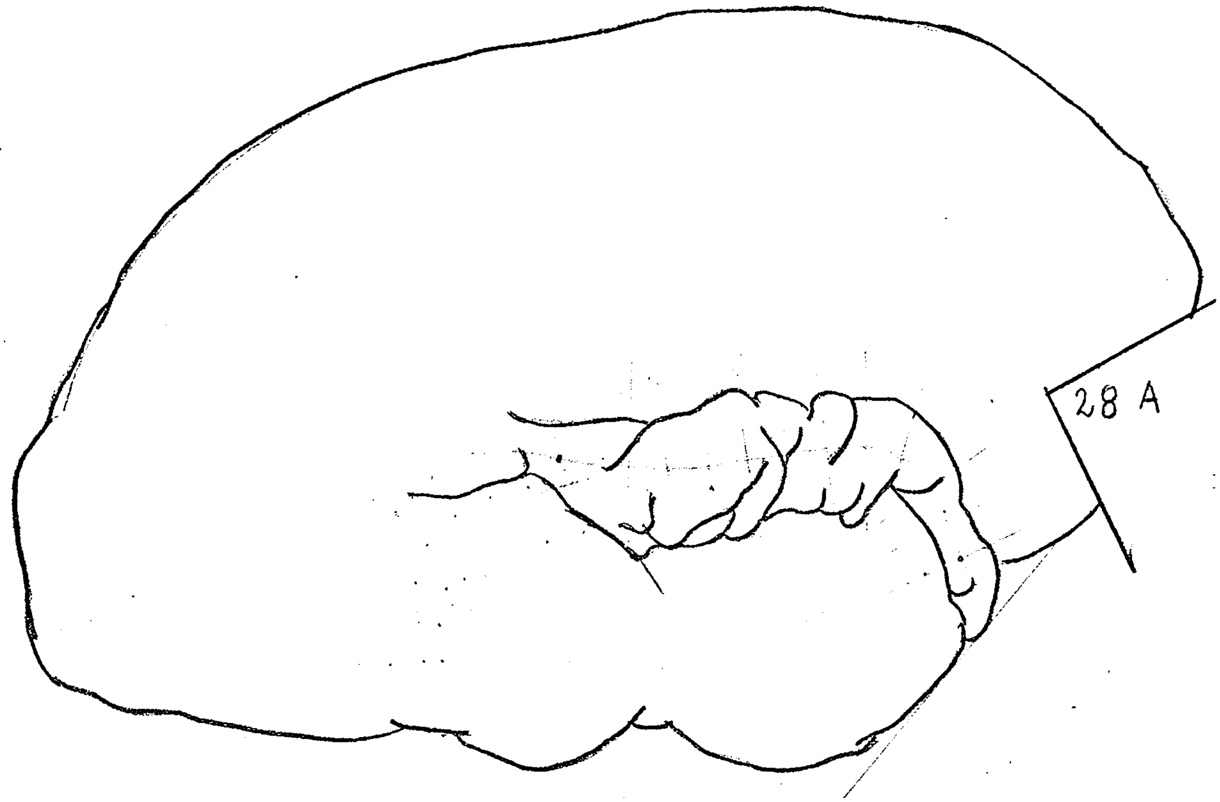


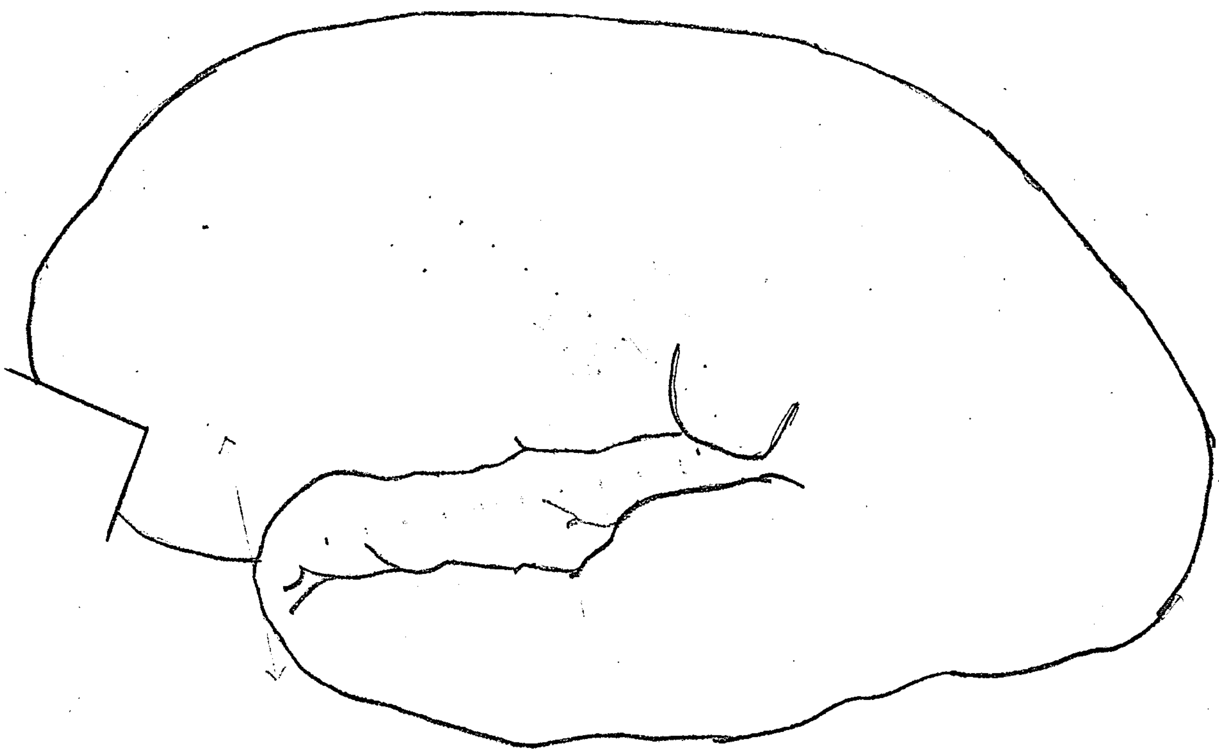
AUTOPSY No 71B79
RANDOM No. 34770



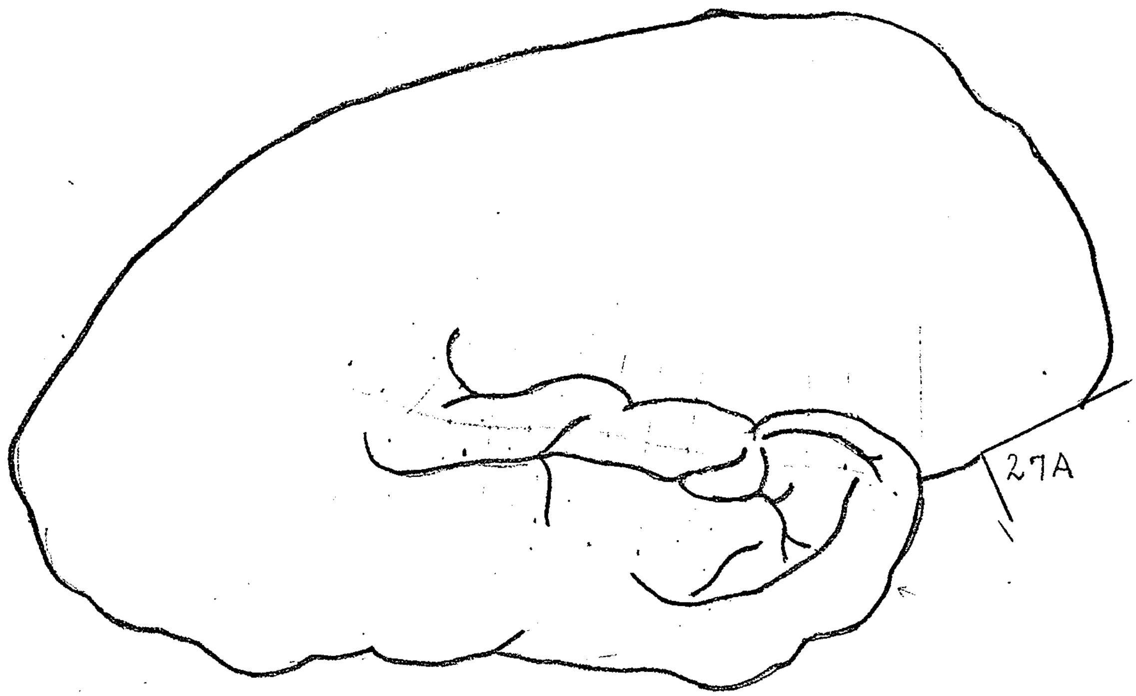


AUTOPSY No. 71 B 83
RANDOM No. 10154

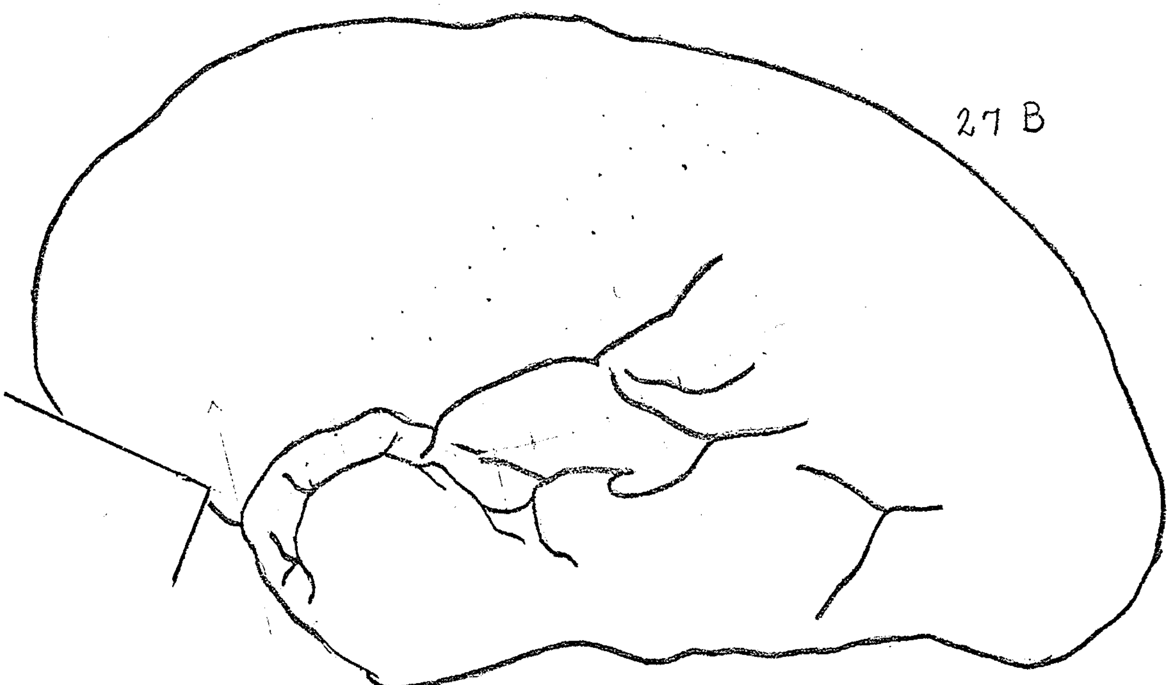




AUTOPSY No. 71 B 84
RANDOM No. 88877

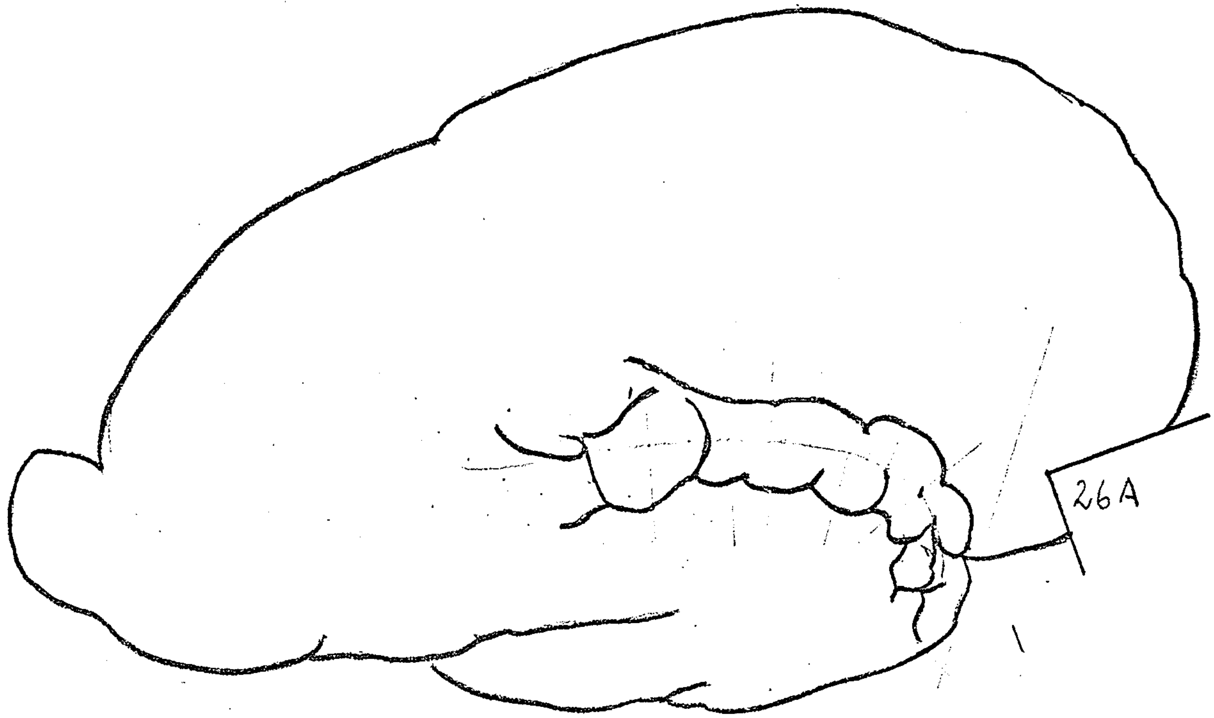


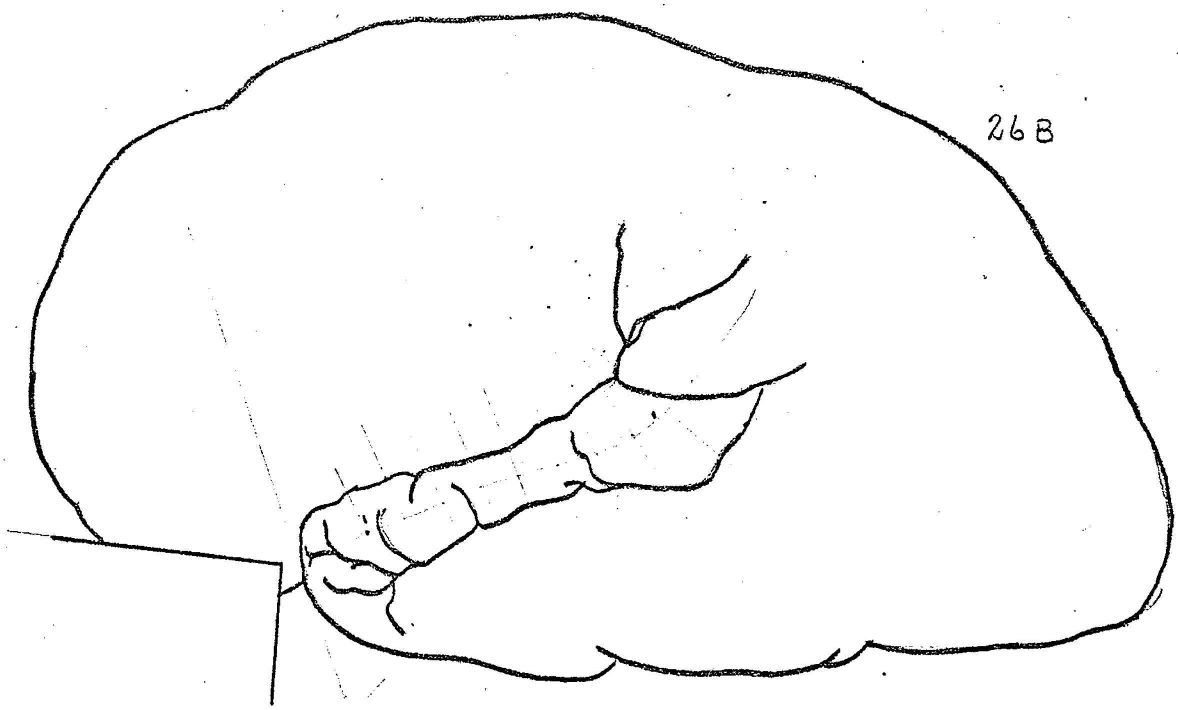
27A



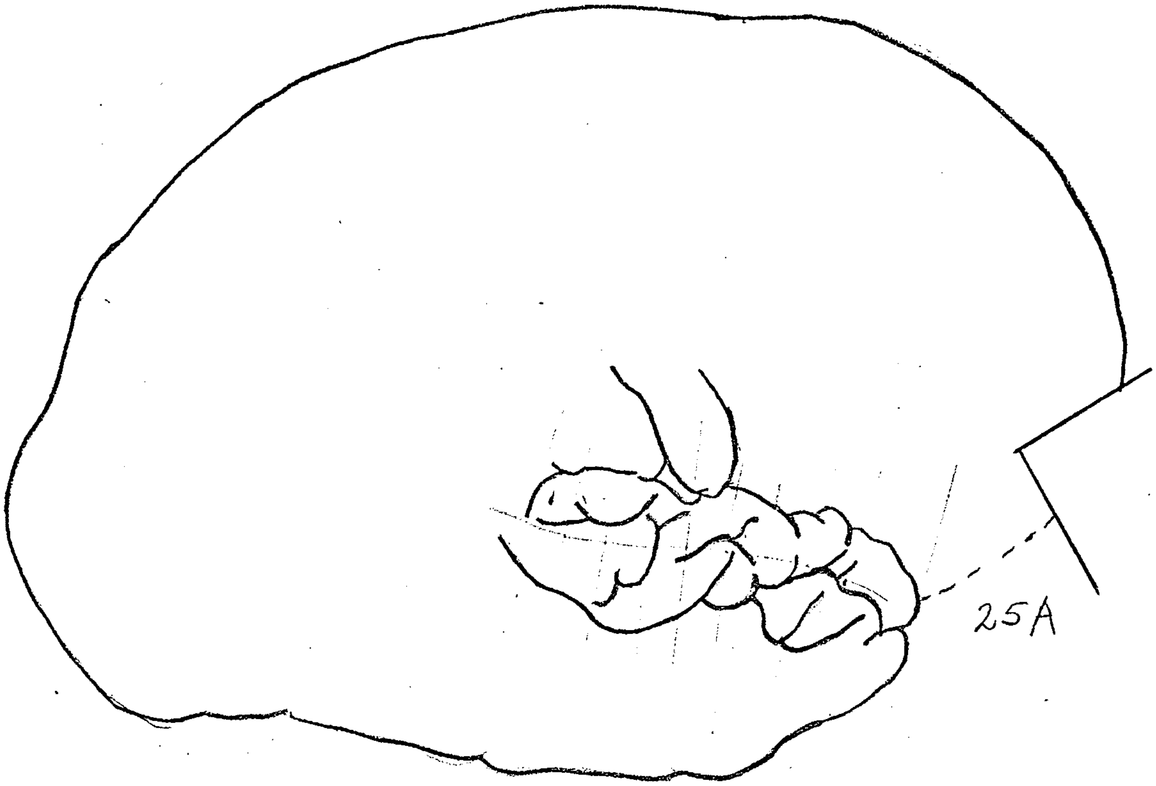
27 B

AUTOPSY No. 70 B20
RANDOM No. 76766



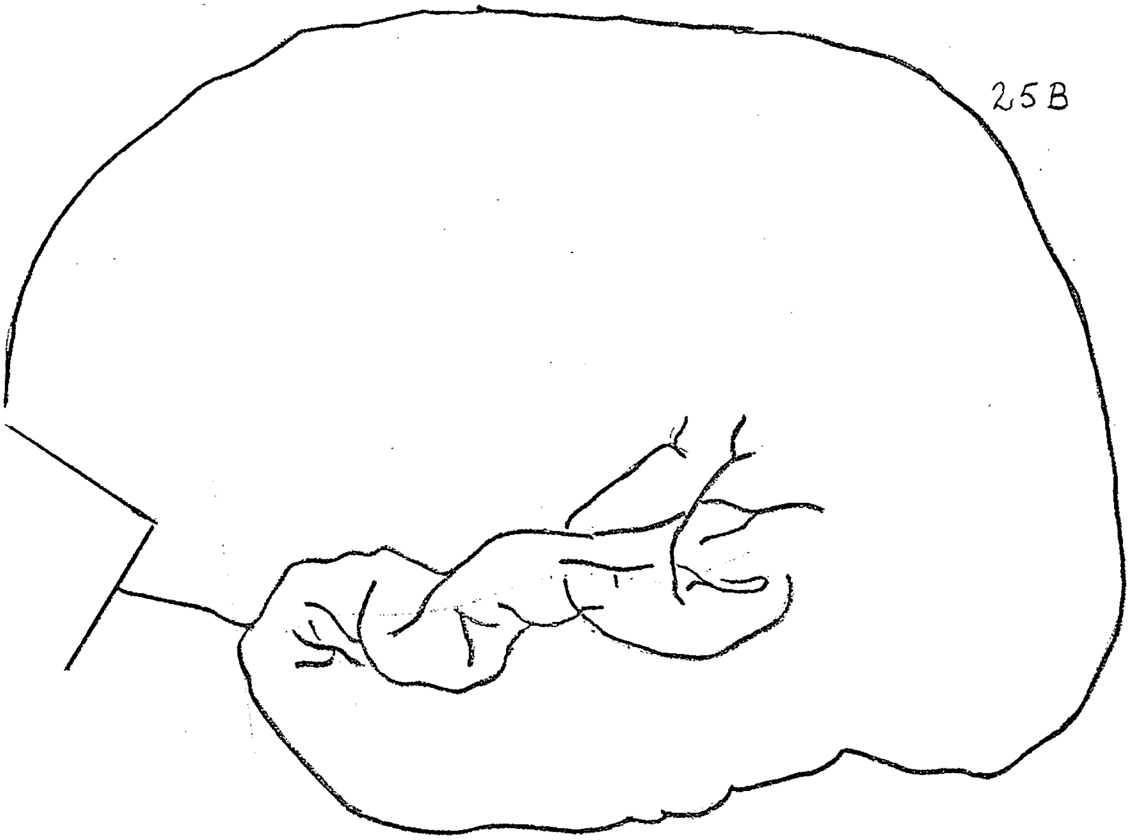


AUTOPSY No. A70-46
RANDOM No. 30329

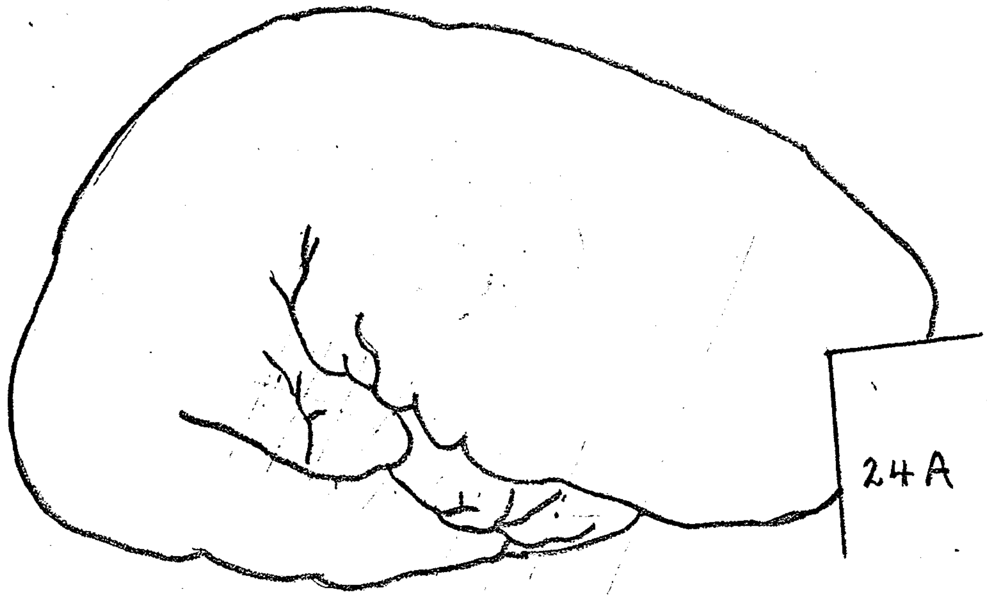


25A

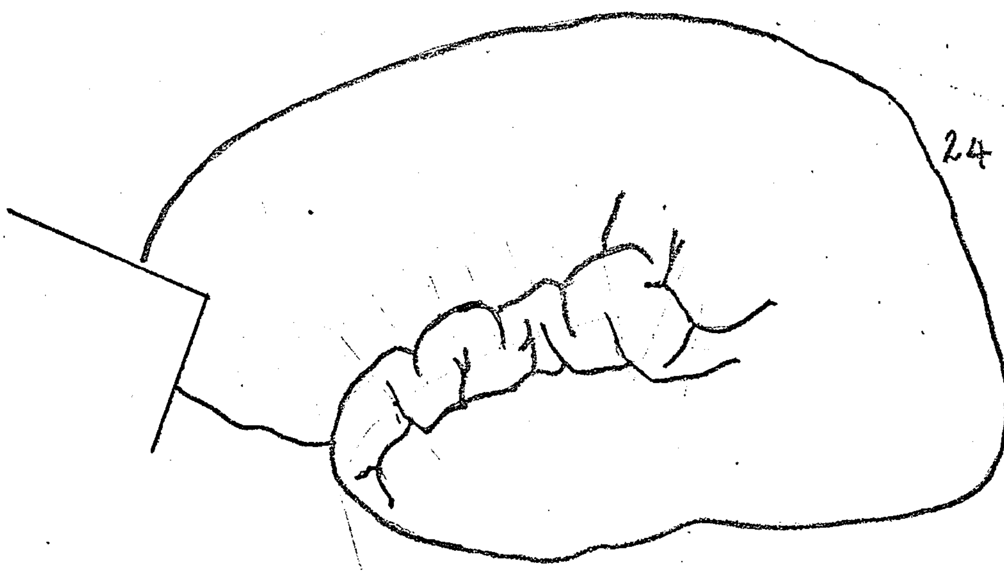
25B



AUTOPSY No. A 70-84
RANDOM No. 62880

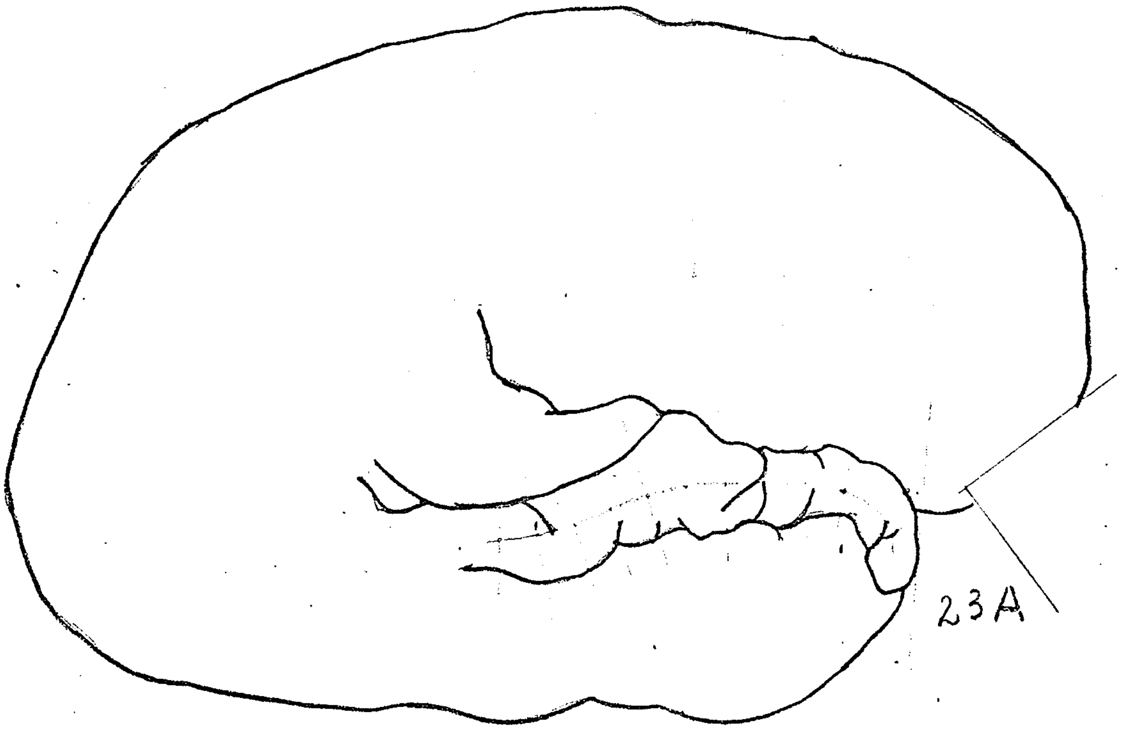


24 A

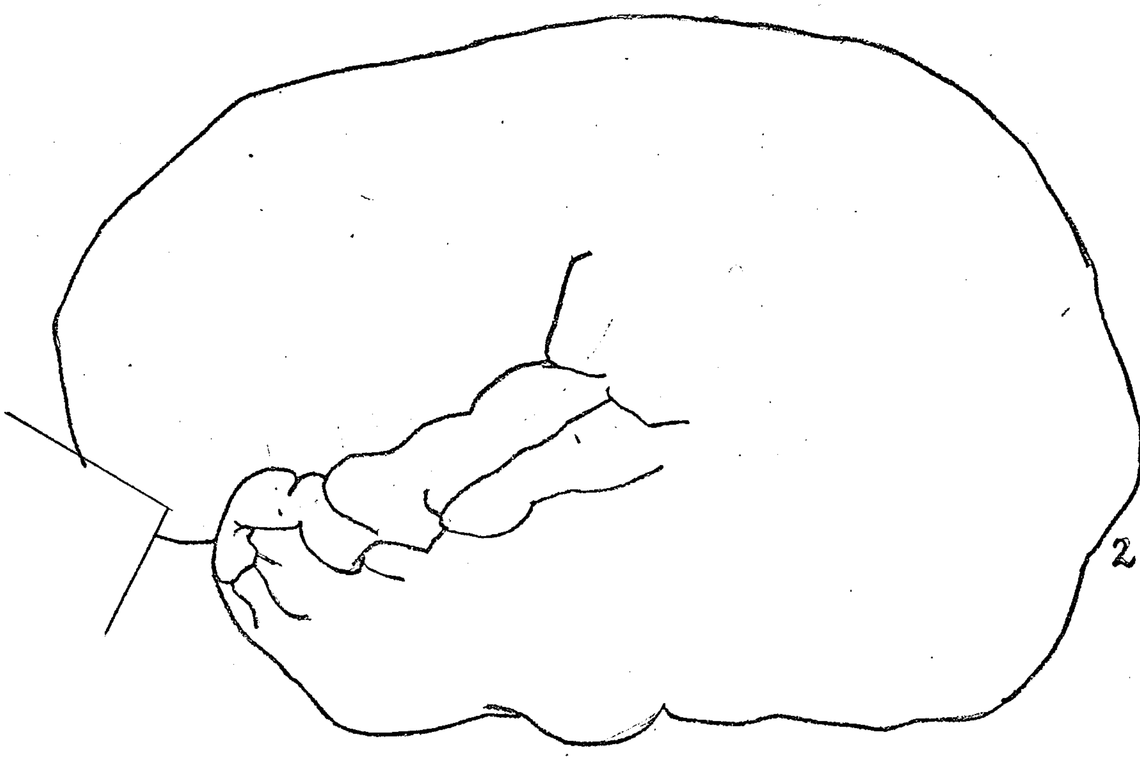


24 B

AUTOPSY No. A70-88
RANDOM No. 16944

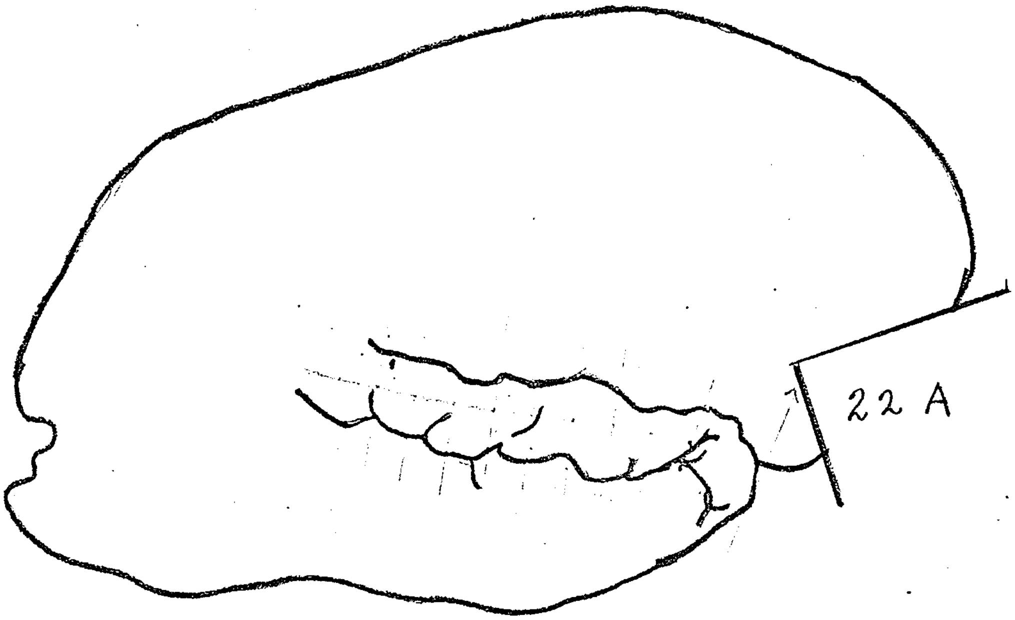


23A

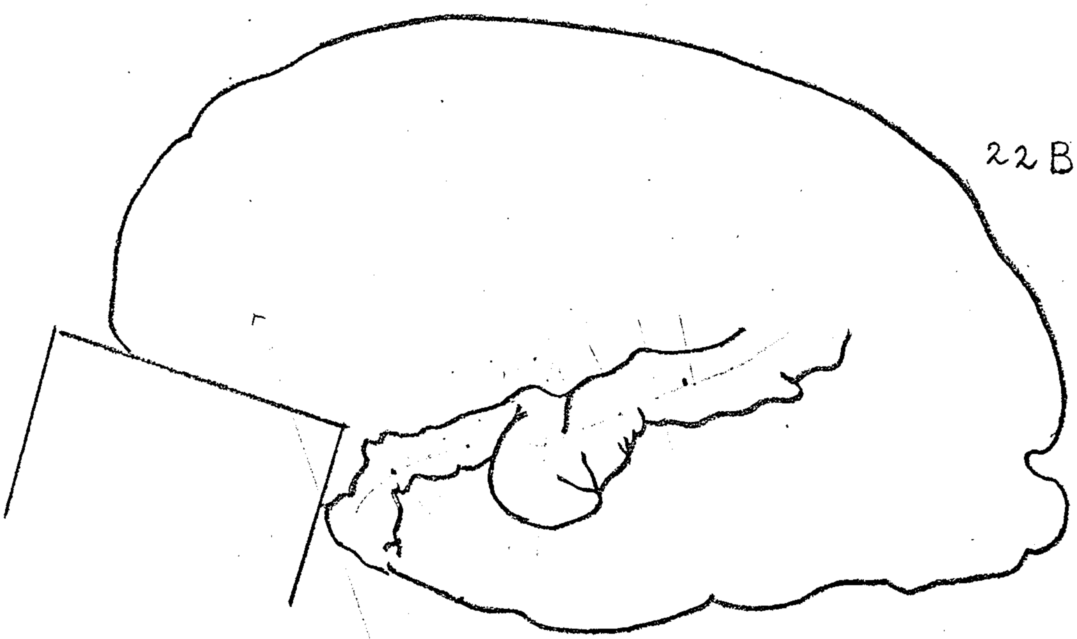


23 B

AUTOPSY NO. A 70-89
RANDOM NO. 11859

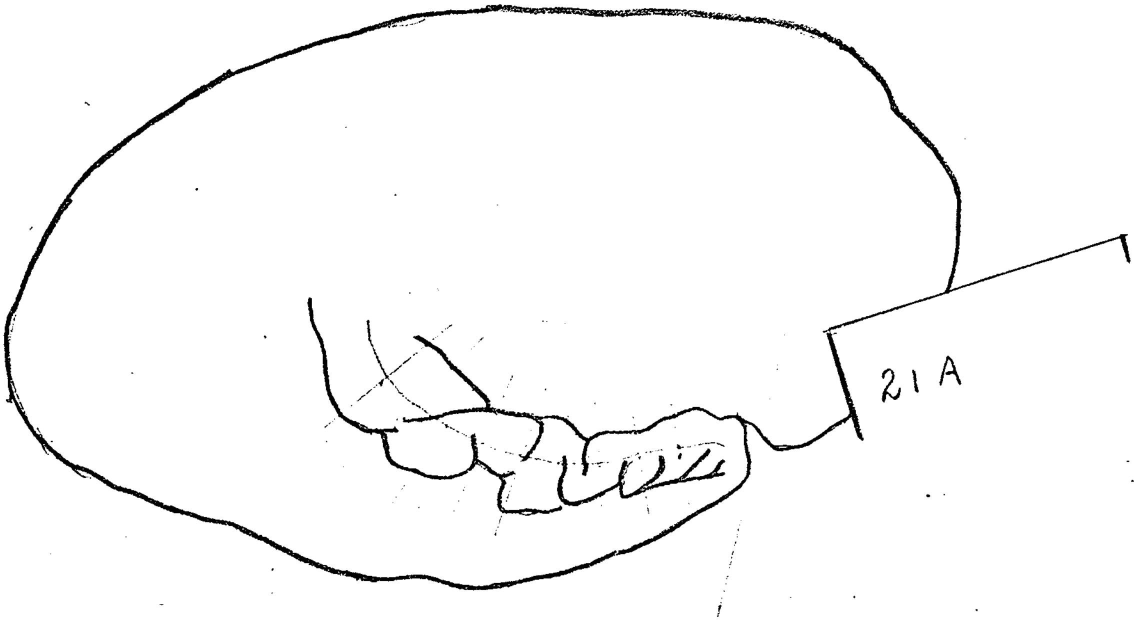


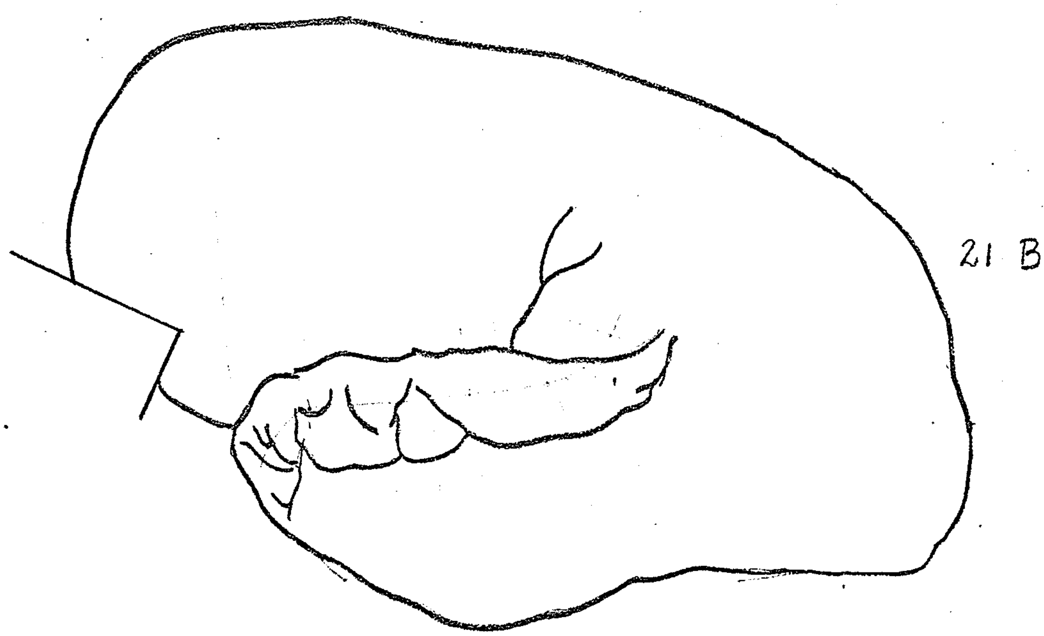
22 A



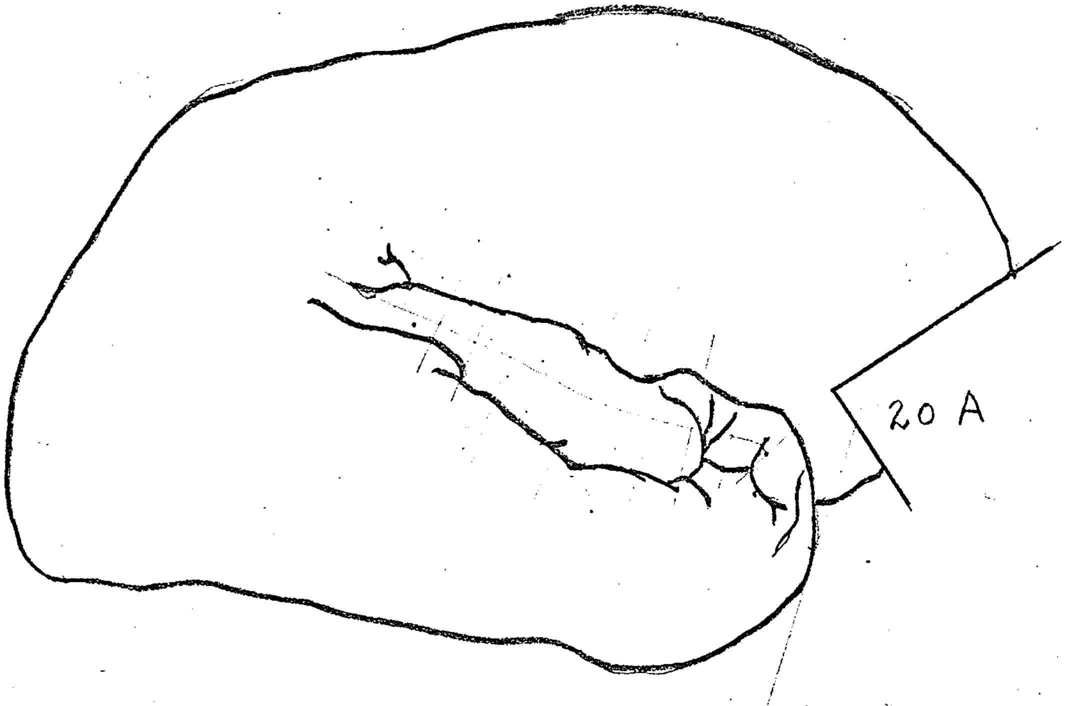
22 B

AUTOPSY NO. A70-106
RANDOM NO. 89964

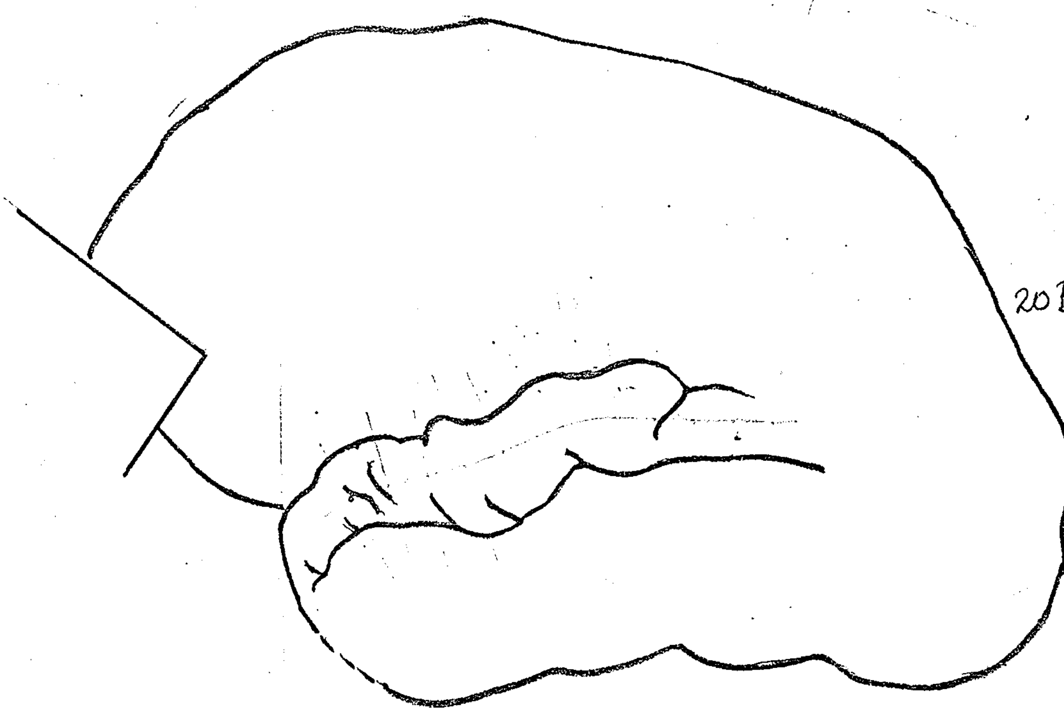




AUTOPSY No. A 70-108
RANDOM No. 65109

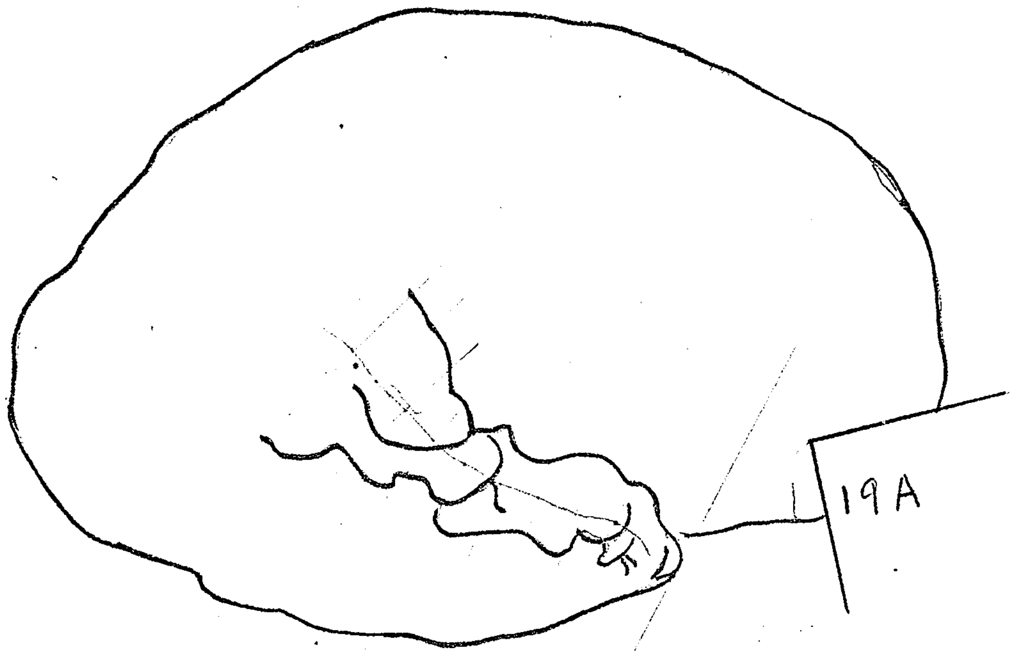


20 A

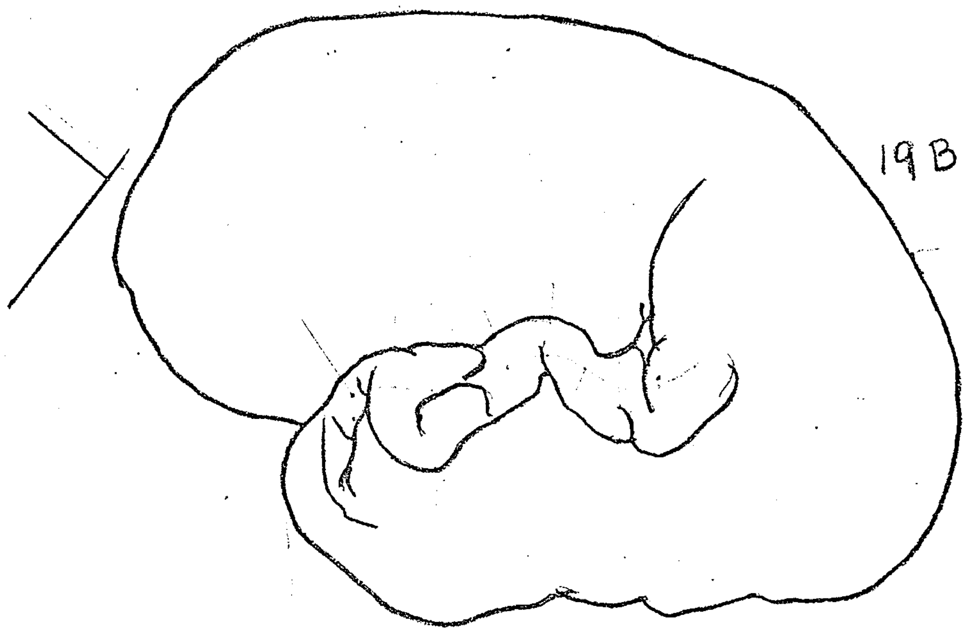


20B

AUTOPSY No. A70-122
RANDOM No. 94771

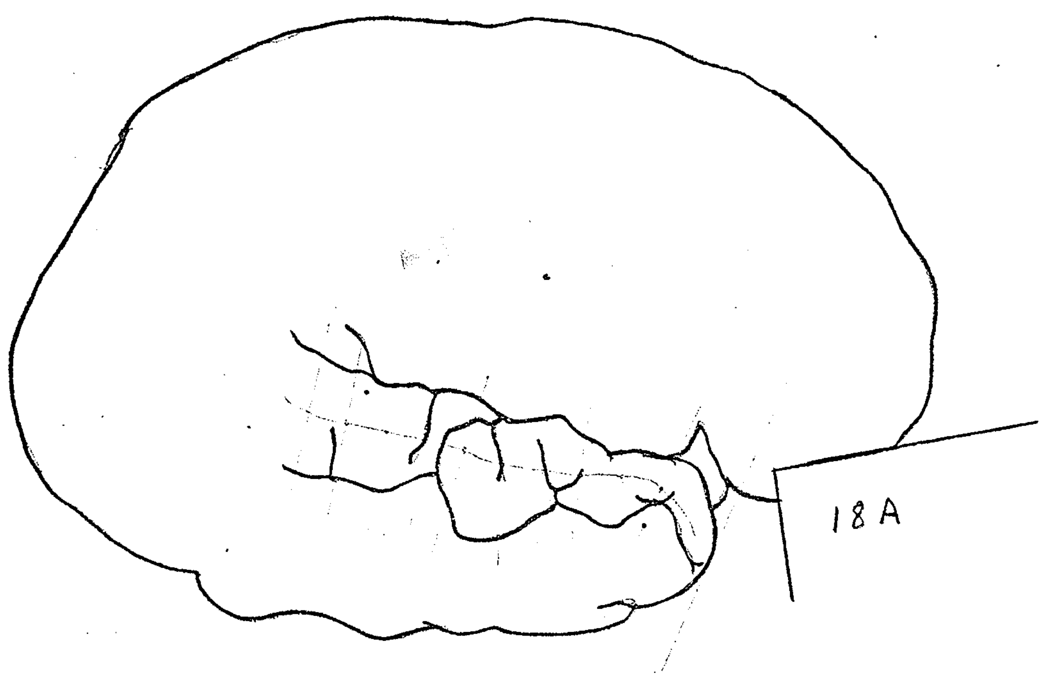


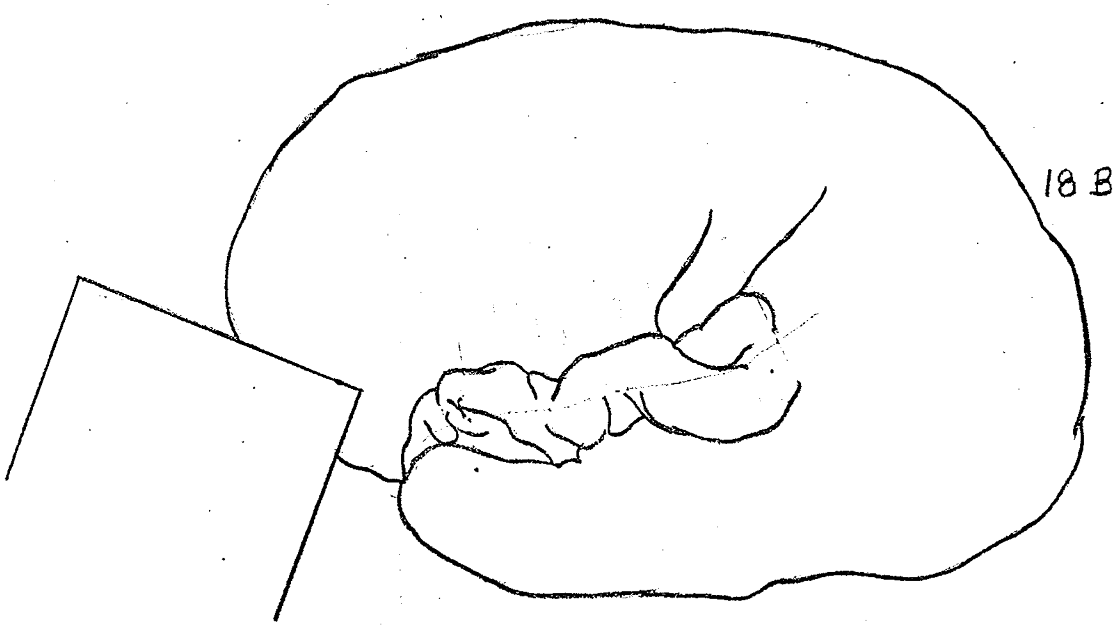
19A



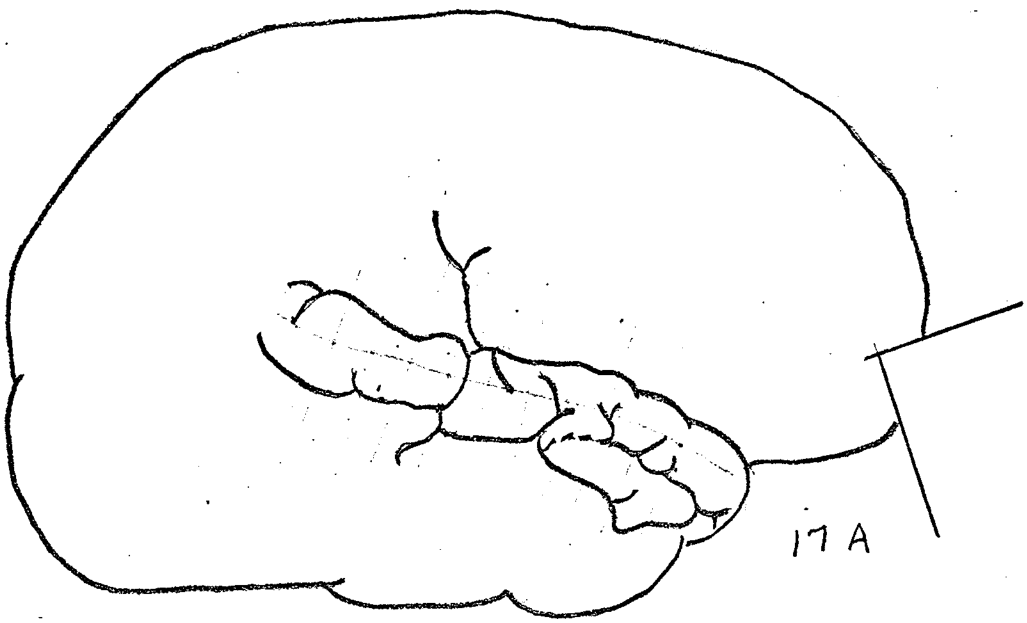
19B

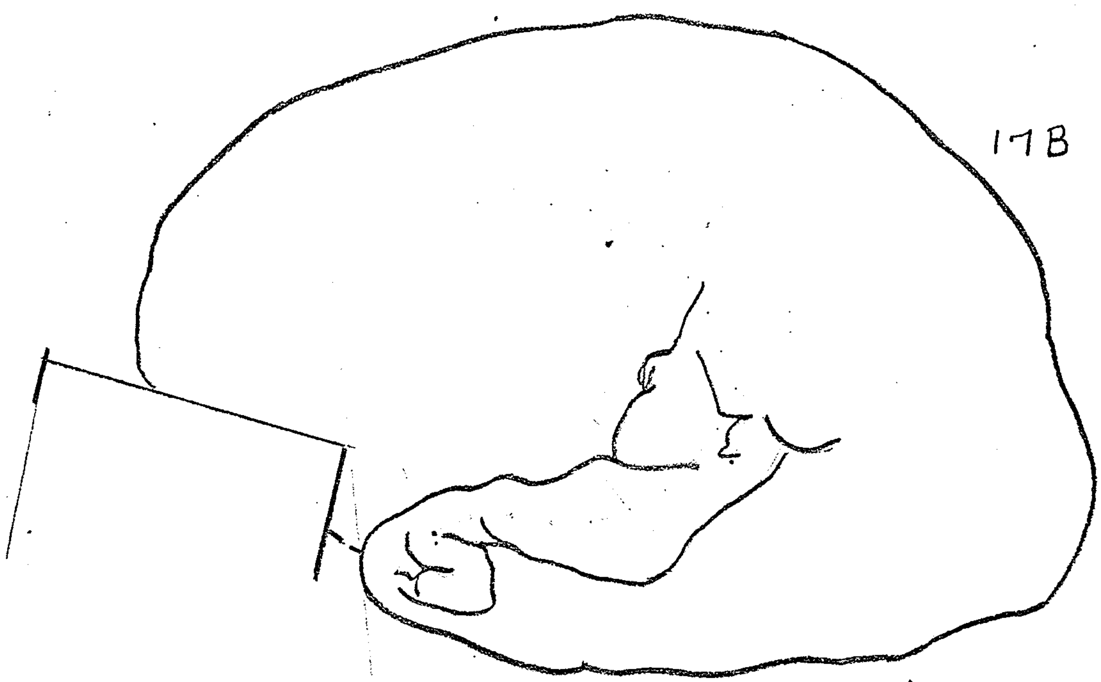
AUTOPSY No. A70-125
RANDOM NO 01412



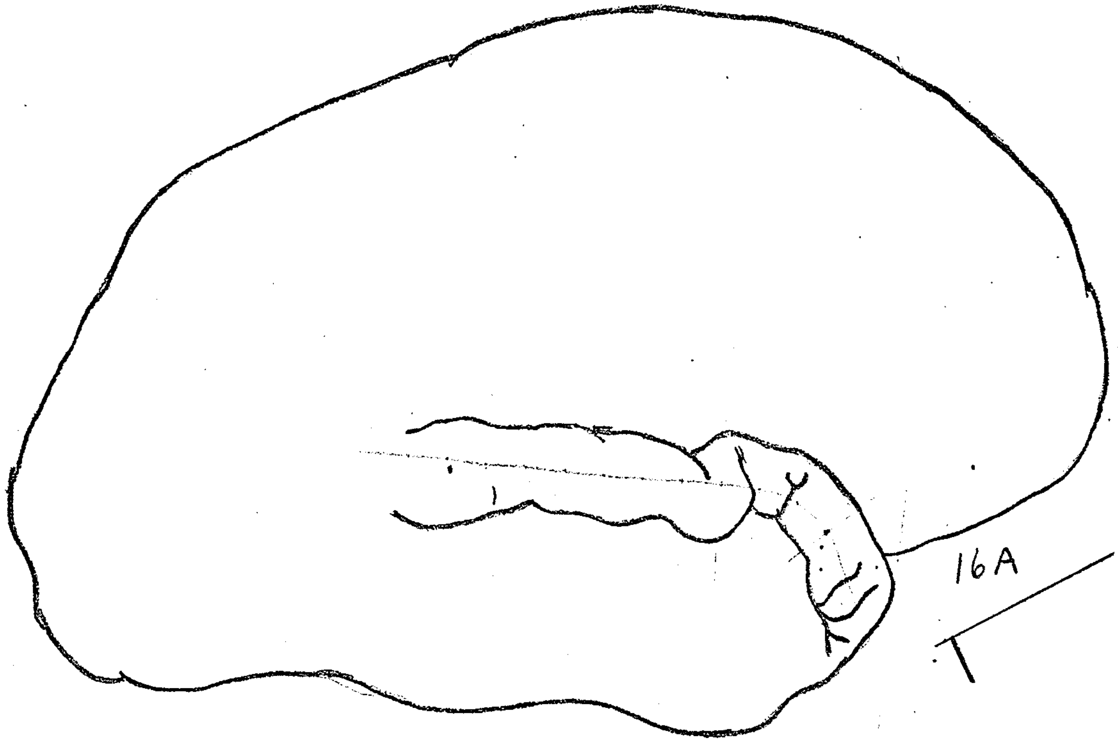


AUTOPSY No. A 70-130
RANDOM No. 51211

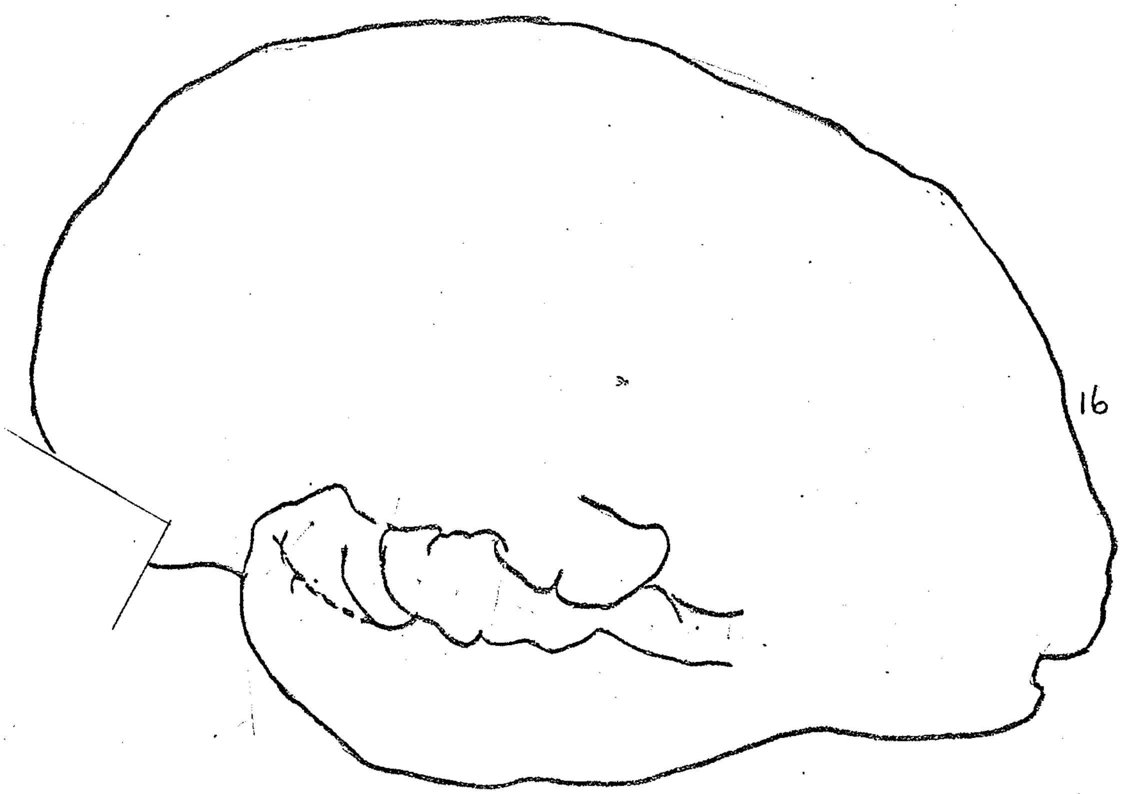




AUTOPOSY No. A70-131
RANDOM No. 53829

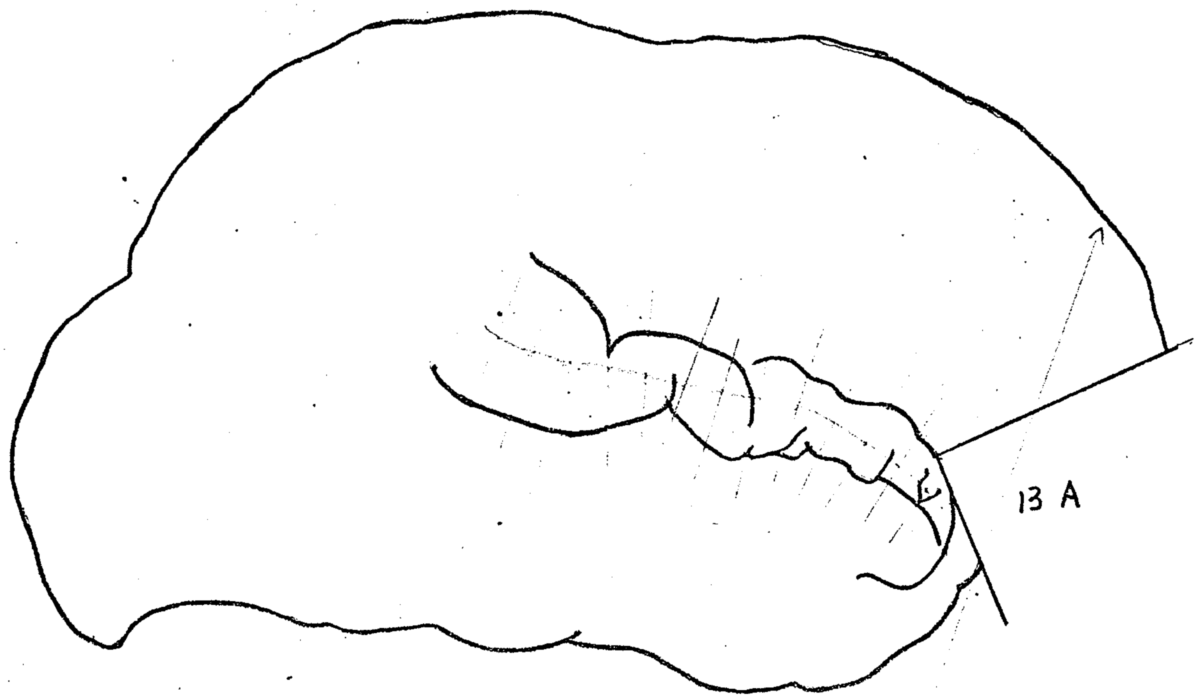


16A



16B

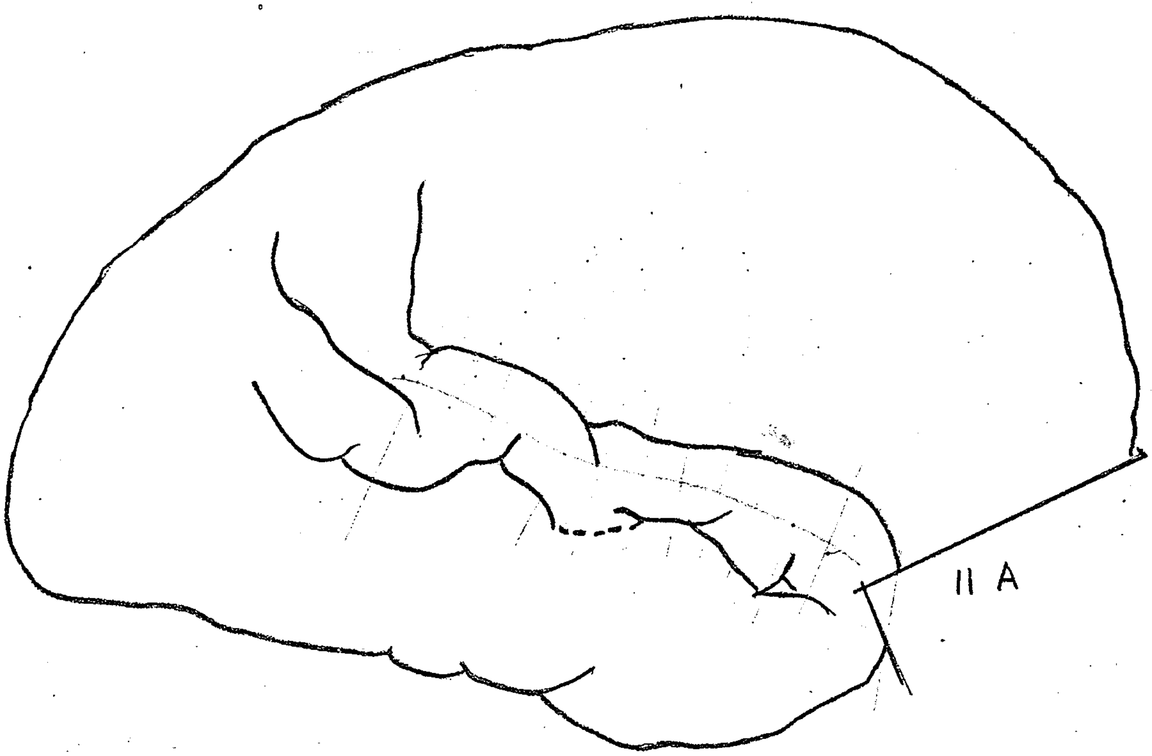
AUTOPSY NO A 70-133
RANDOM NO. 13163

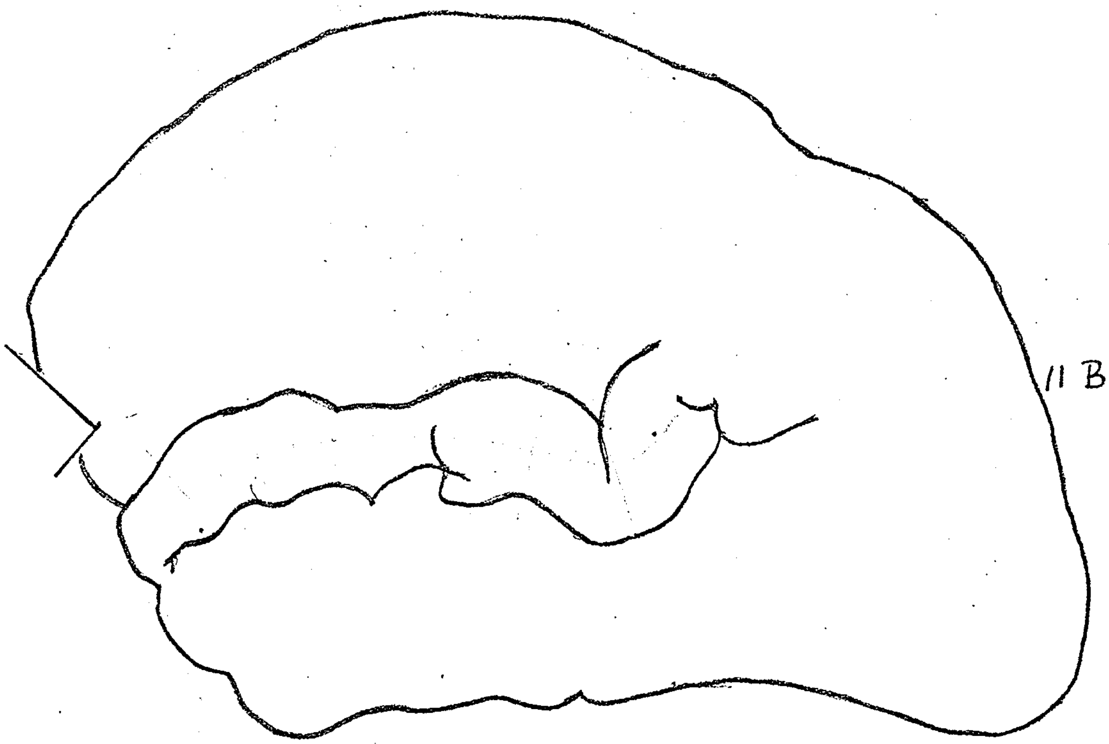


13 A

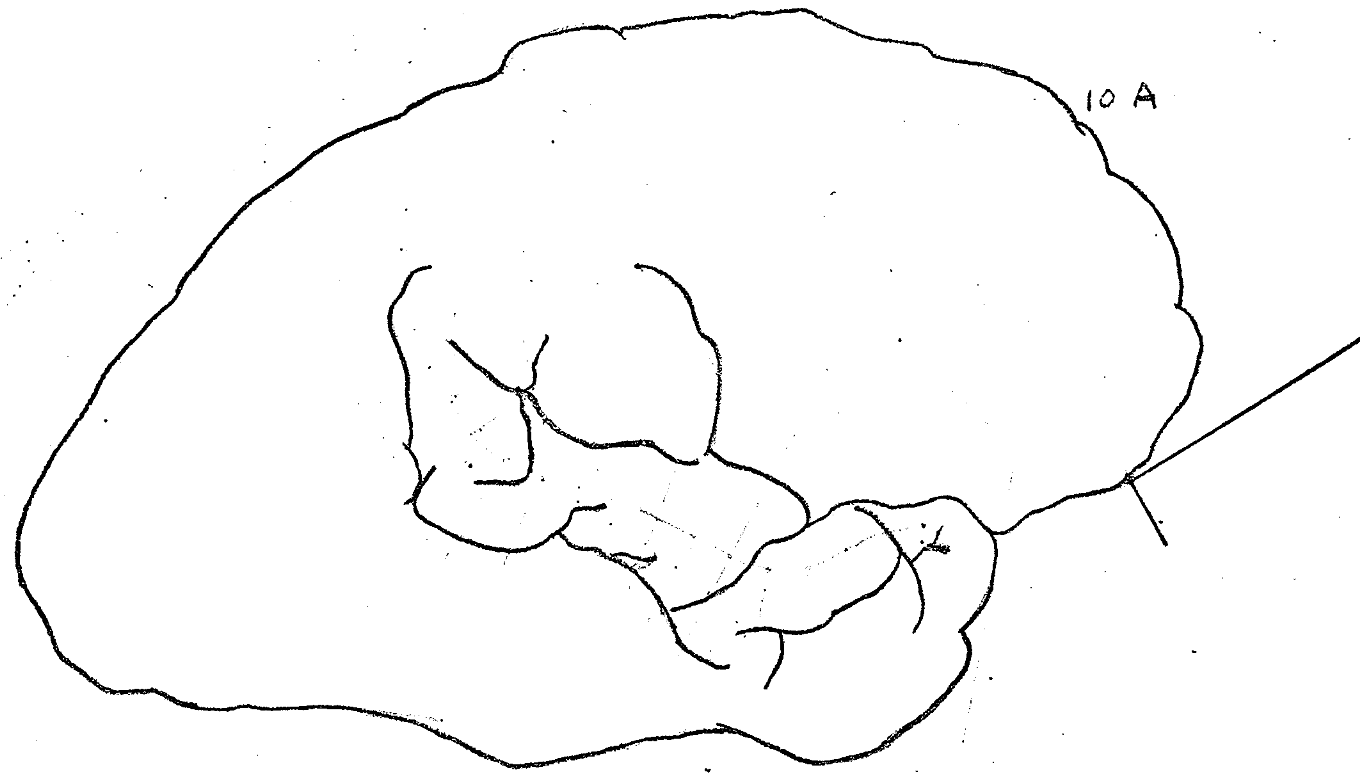
13 B

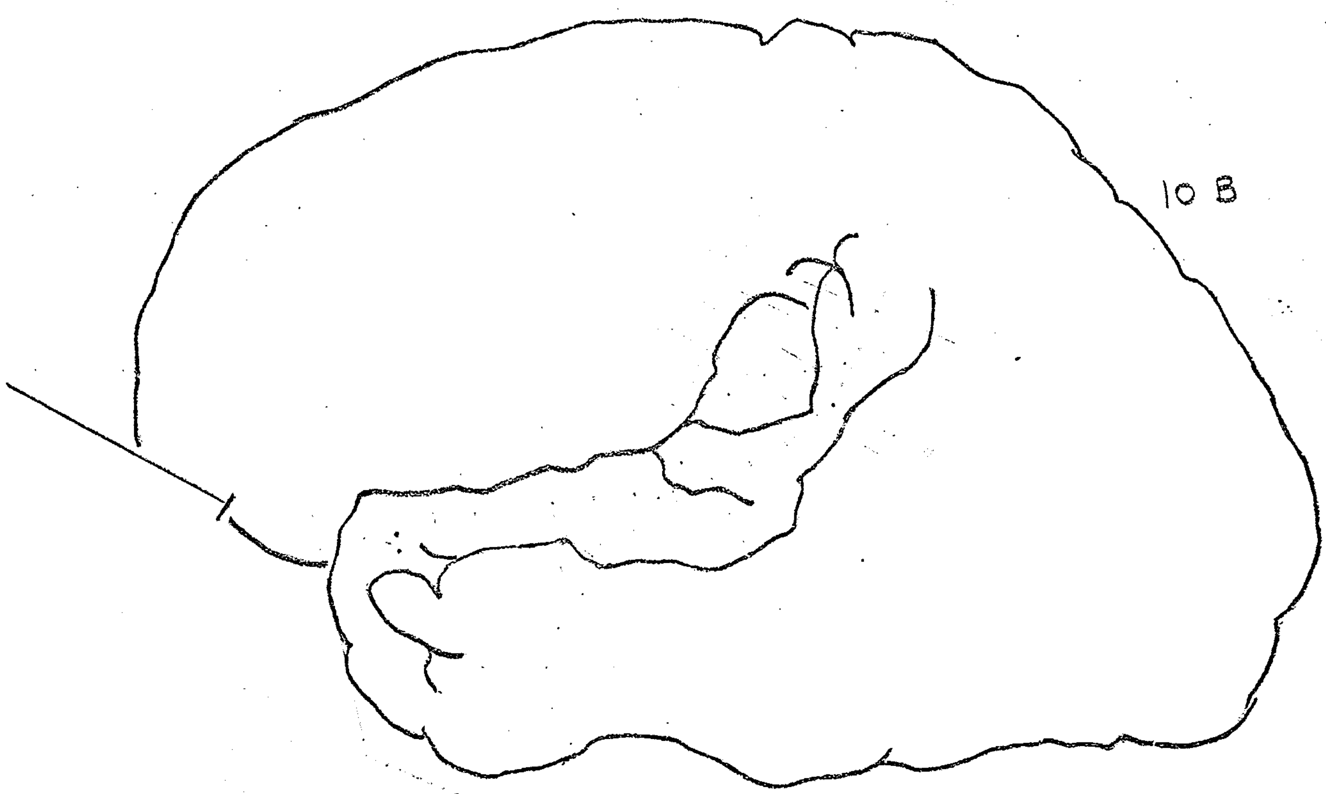
AUTOPSY No. 70 B 36
RANDOM No. 91621



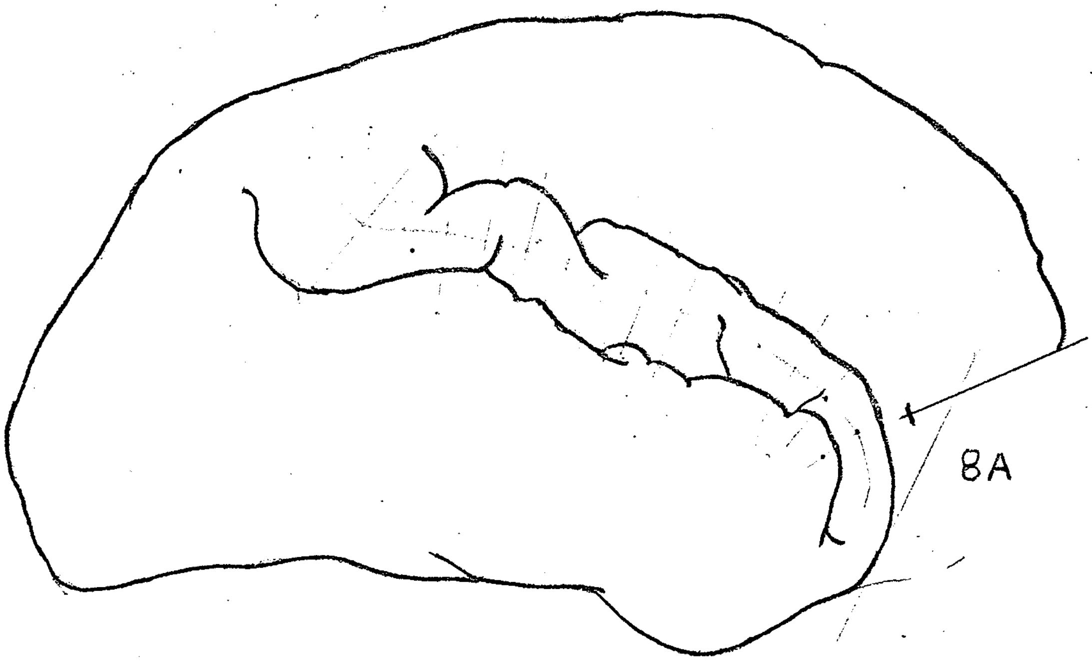


AUTOPSY No. 71 B 14
RANDOM No. 17852

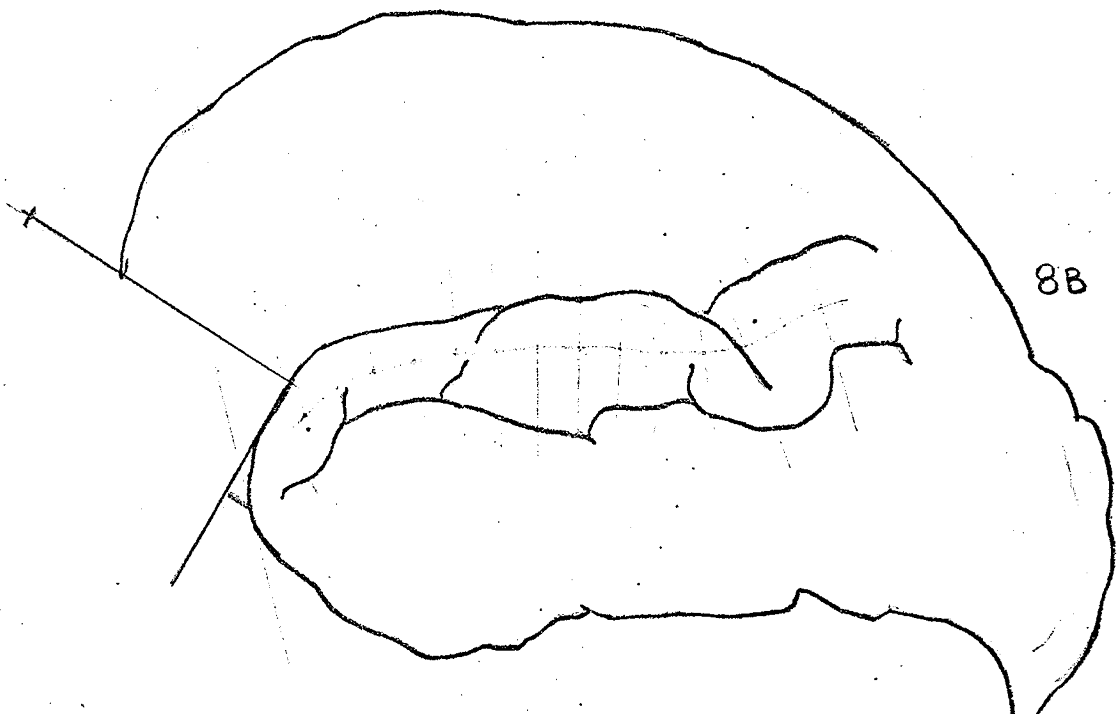




AUTOPSY No. 71 B 19
RANDOM No. 27491



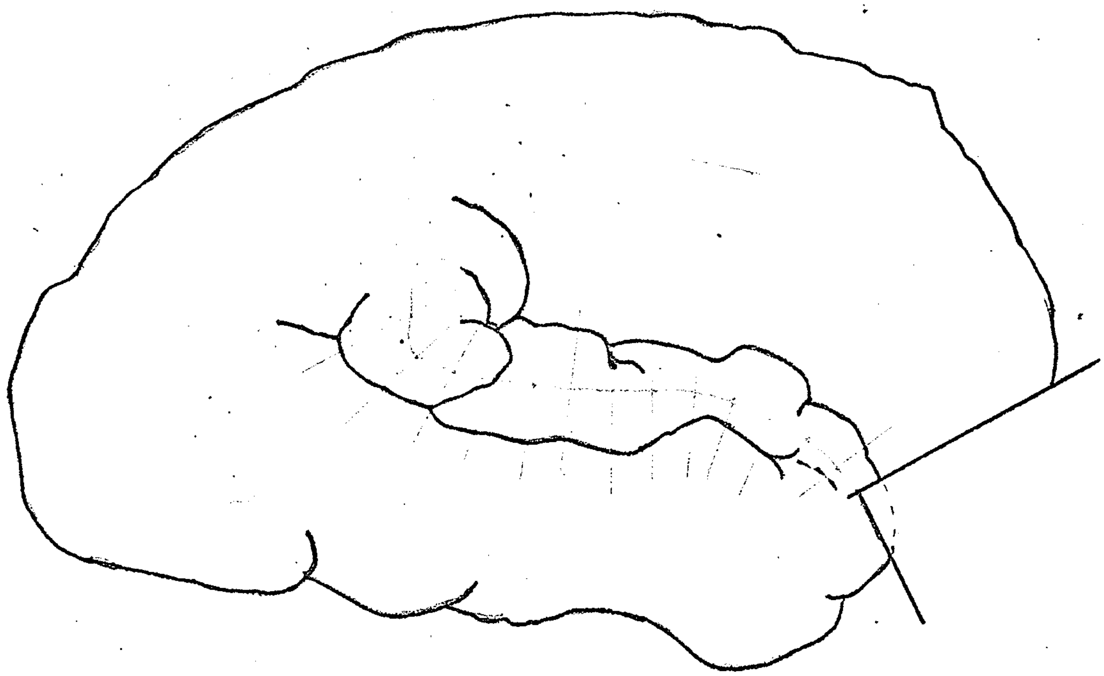
8A



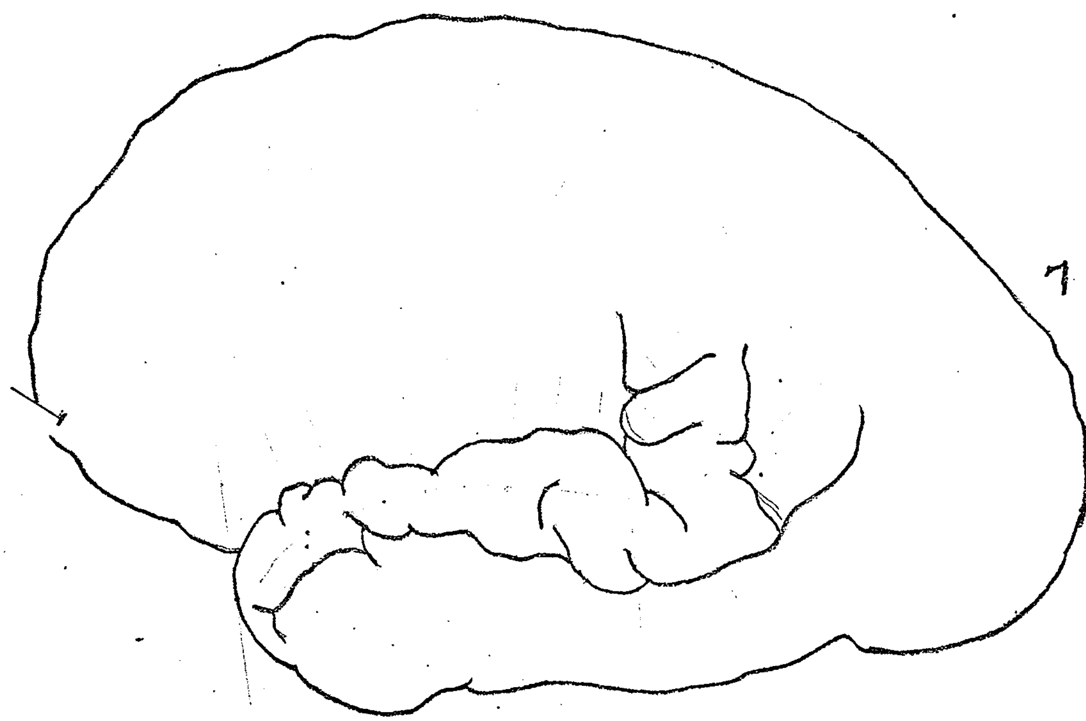
8B

AUTOPSY NO. 71 B 23
RANDOM NO. 03887

7A

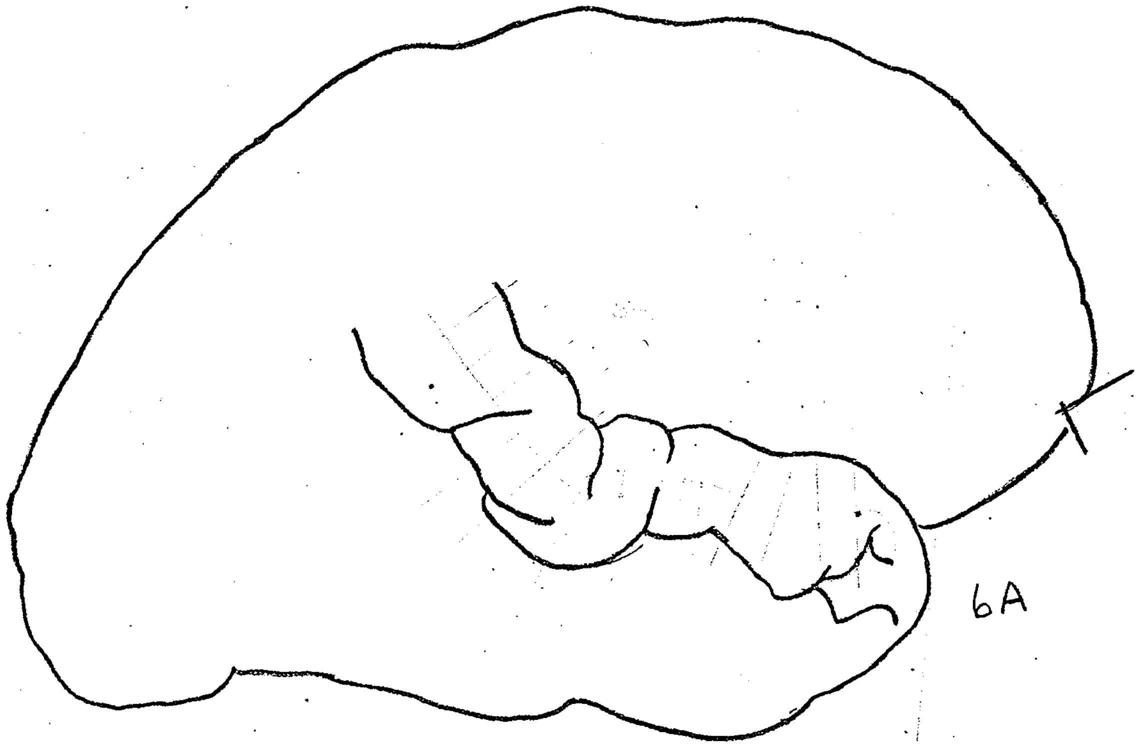


7 B



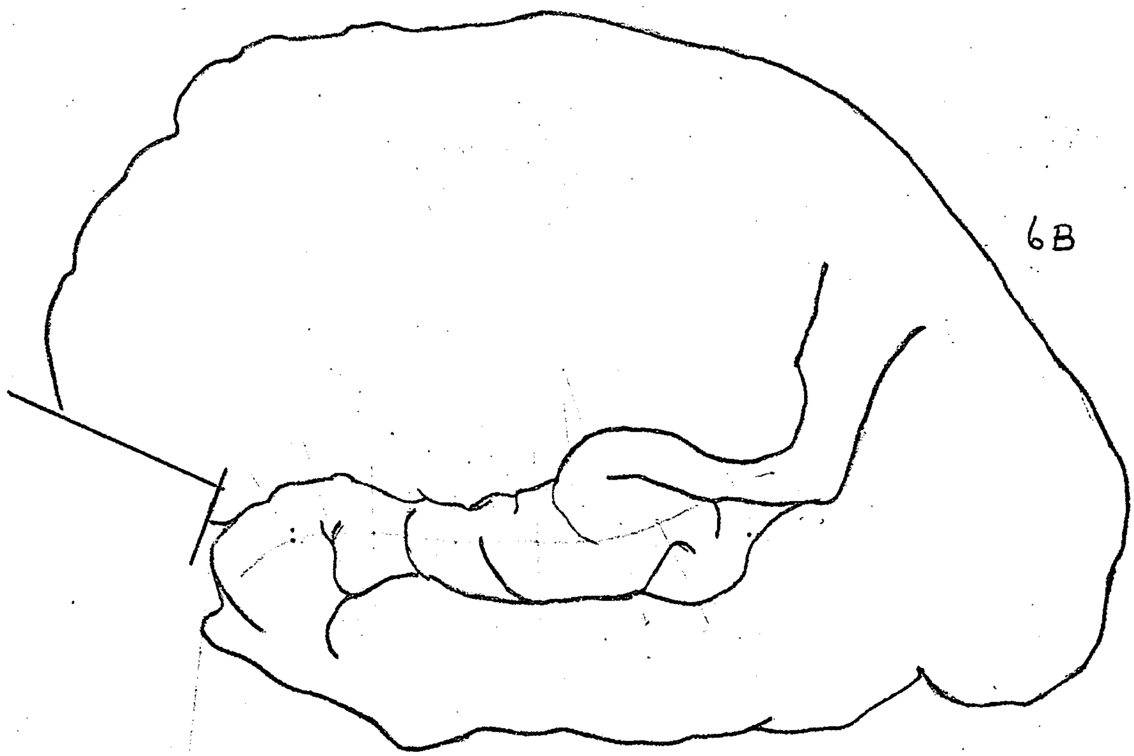
AUTOPSY NO. 71 B 28

RANDOM NO. 55349



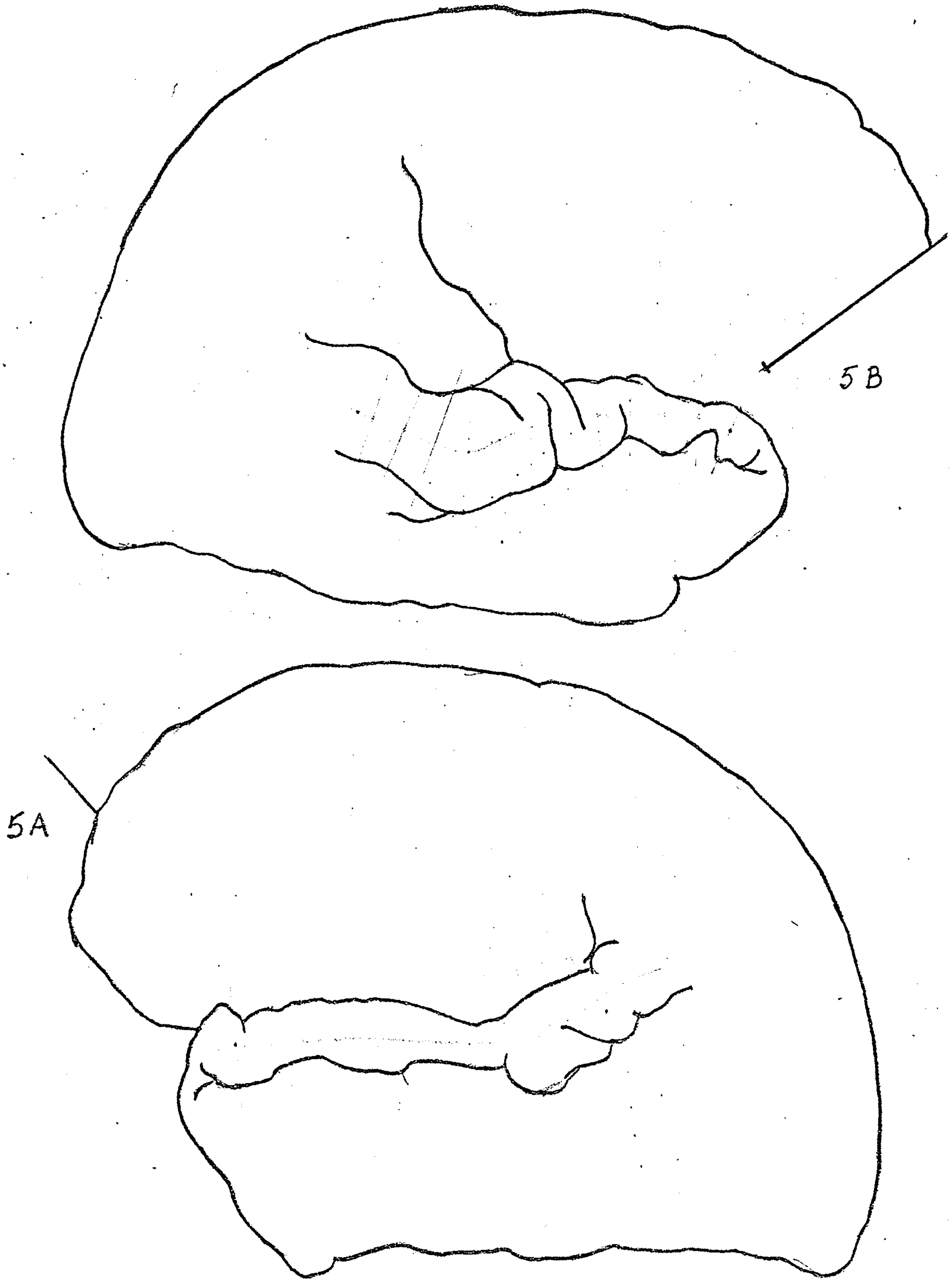
6A

6B

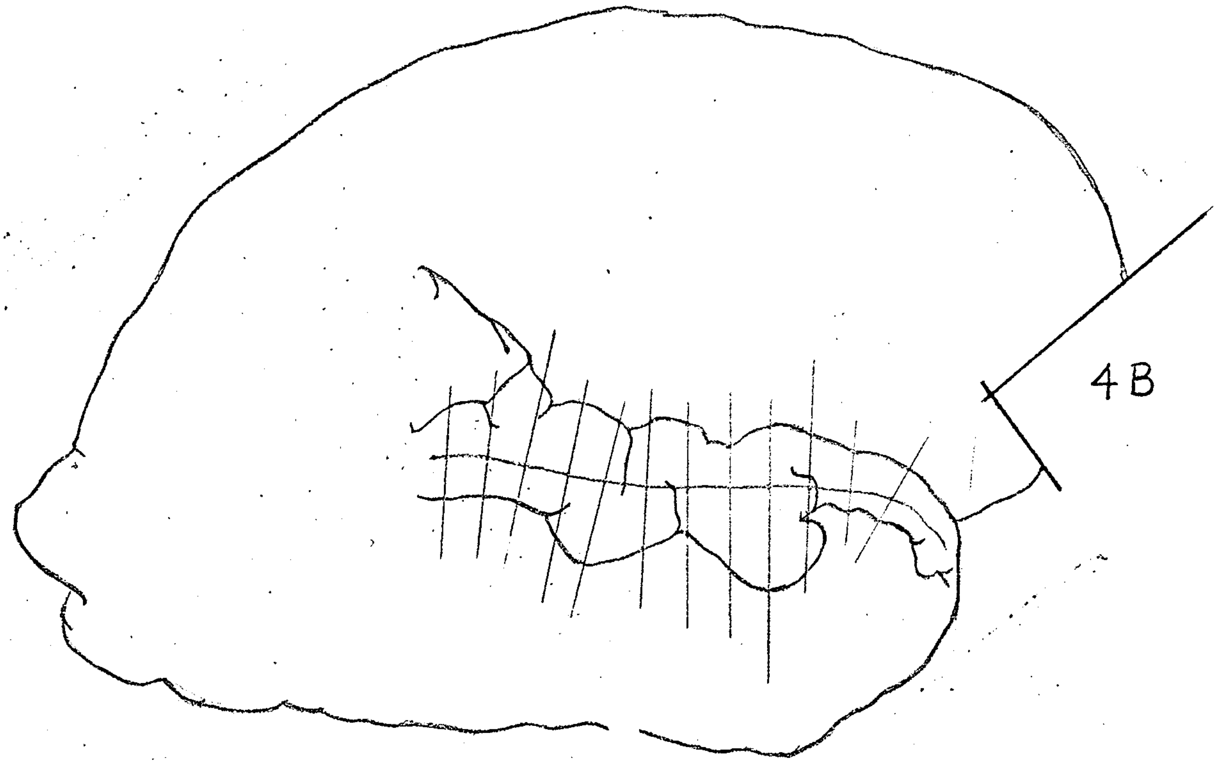


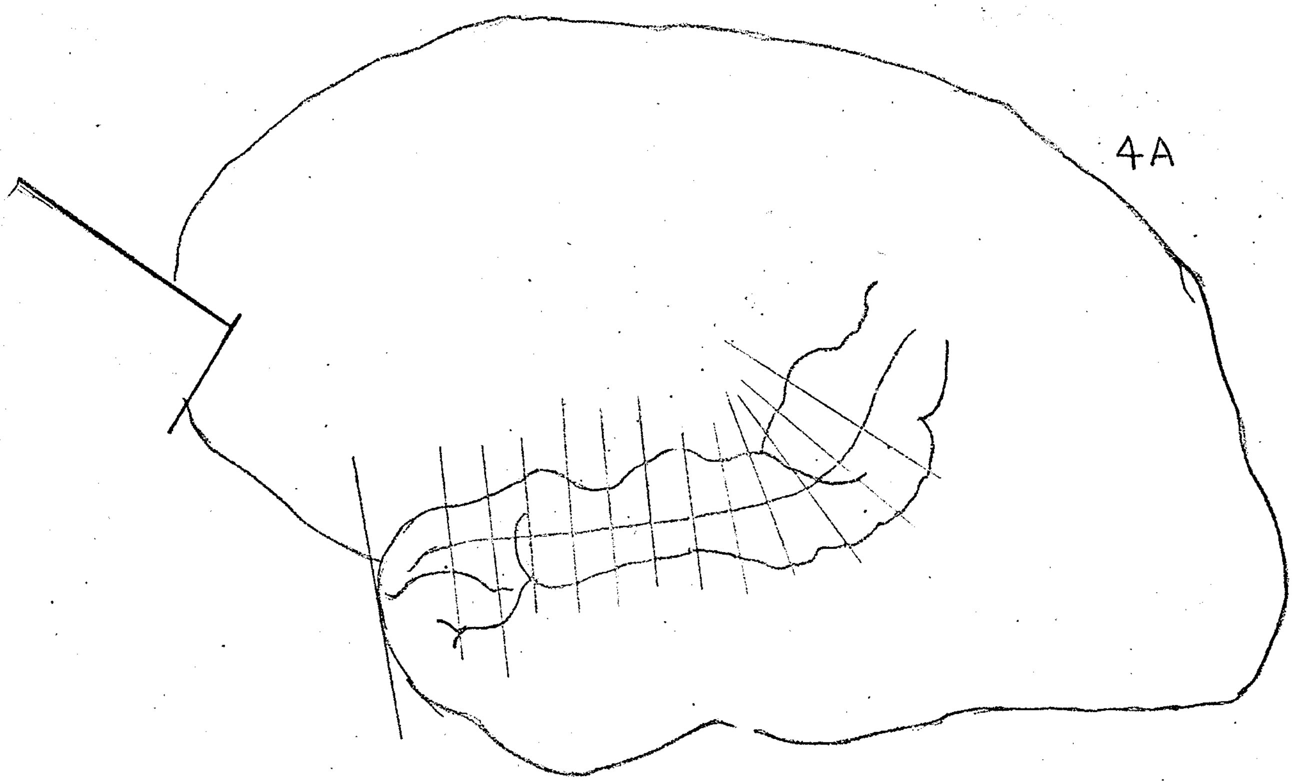
AUTOPSY NO. 71 B 36

RANDOM NO. 83942



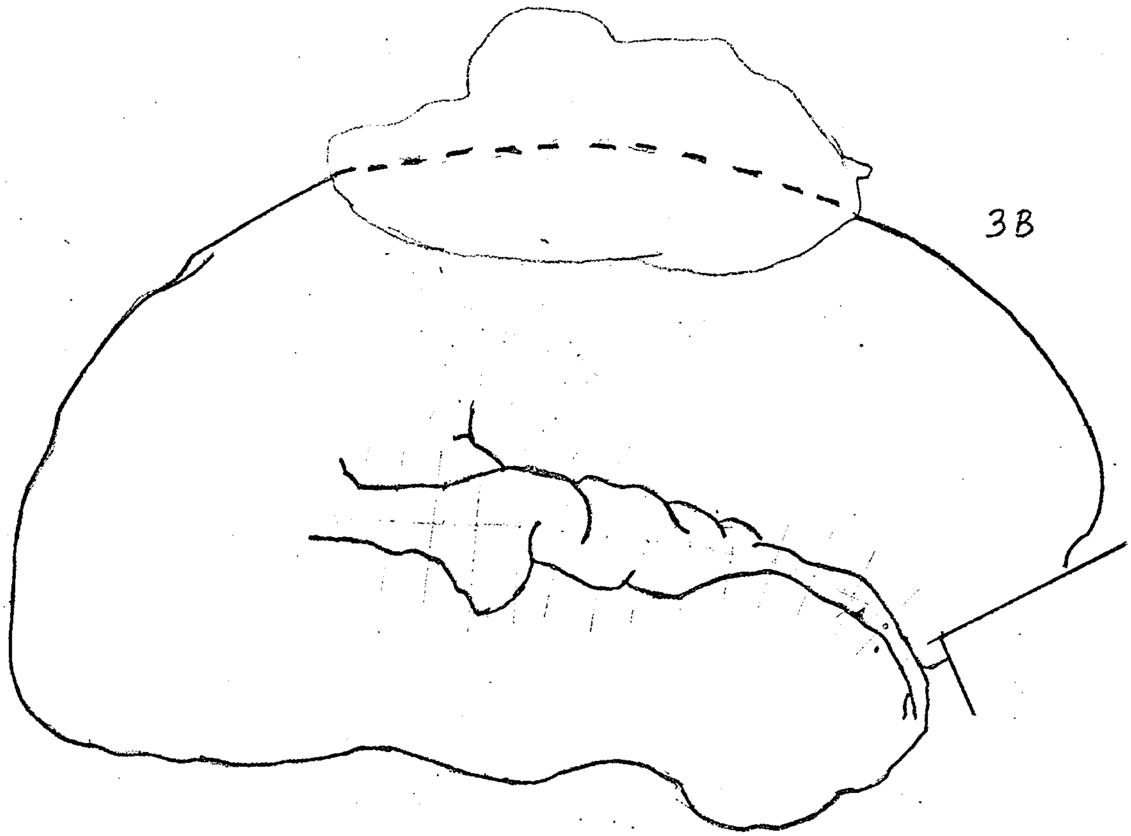
AUTOPSY NO. 71 B 37
RANDOM NO. 39435



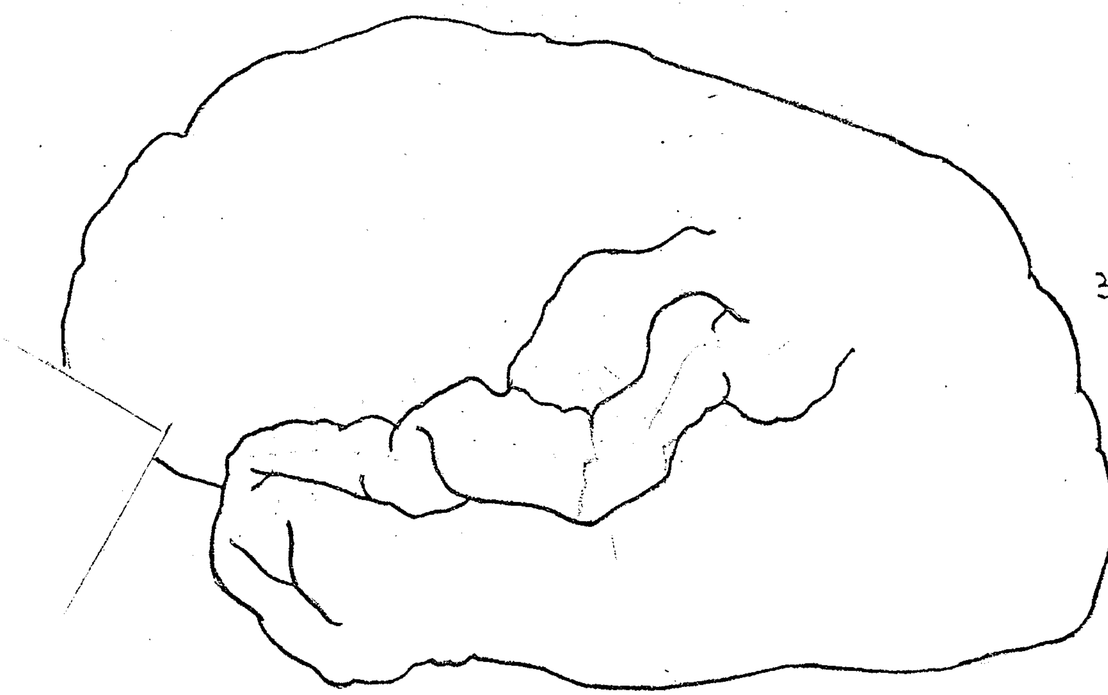


AUTOTOPSY No. 71 B 41
RANDOM No. 60609

3B



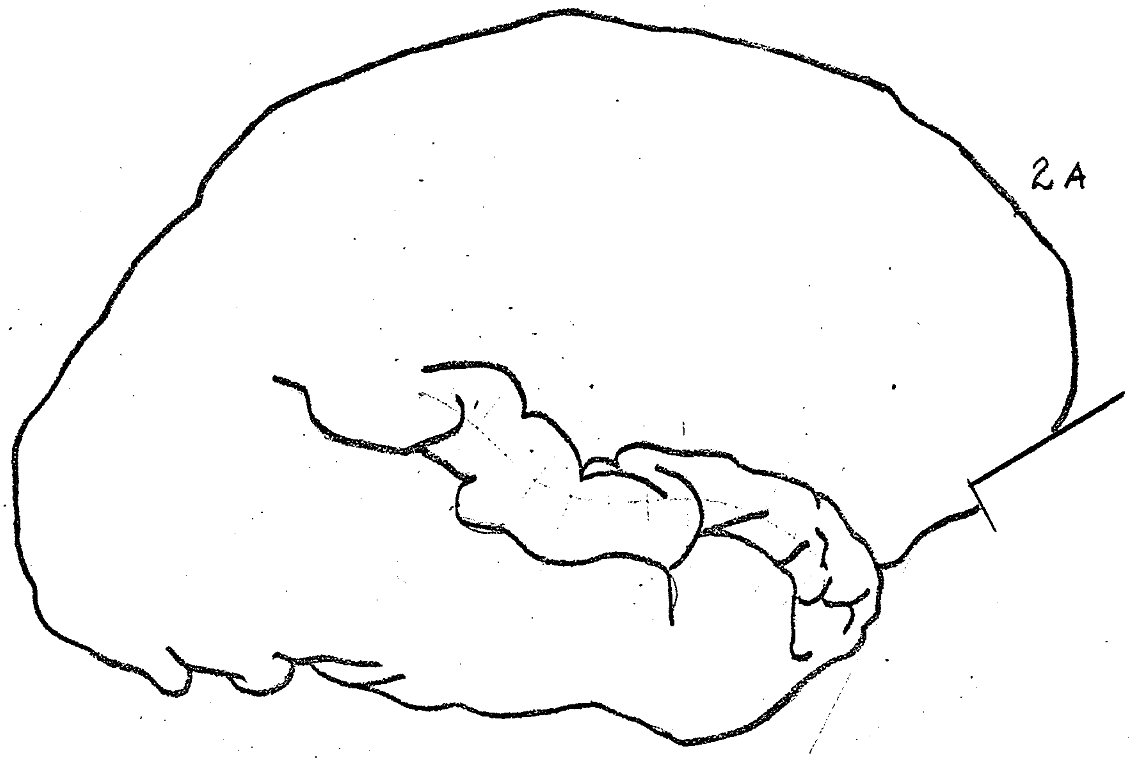
3A



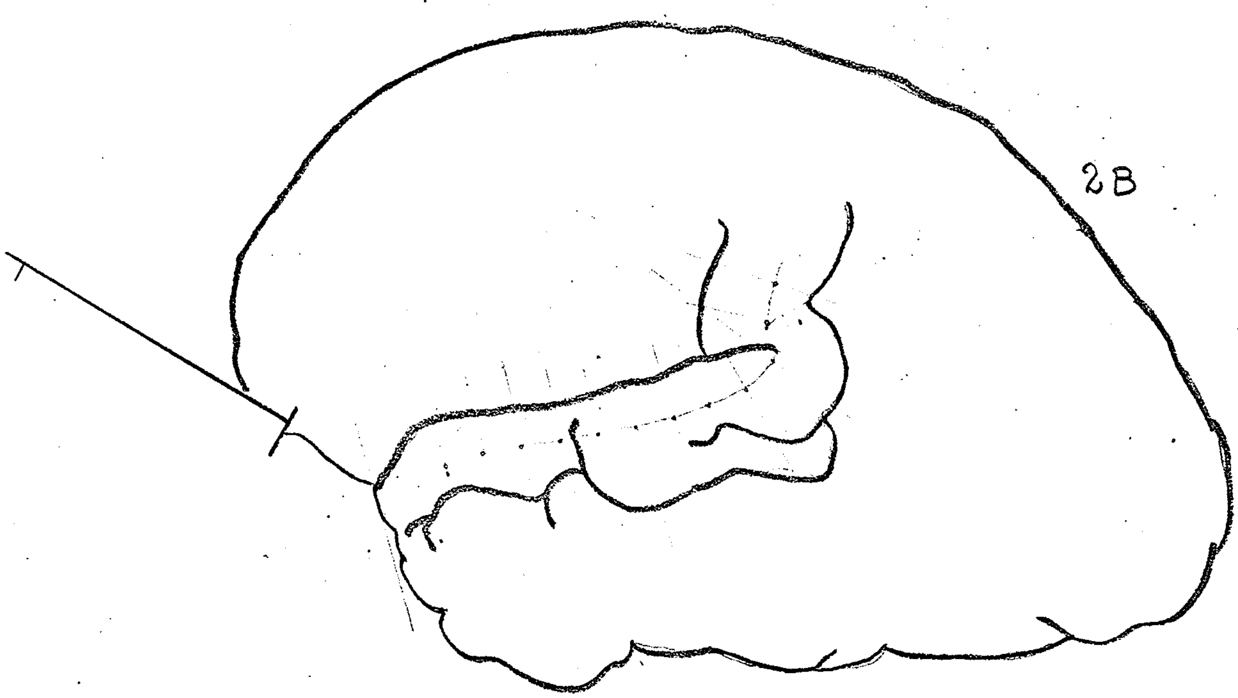
AUTOPSY No 71 B 43

RANDOM NO. 45375

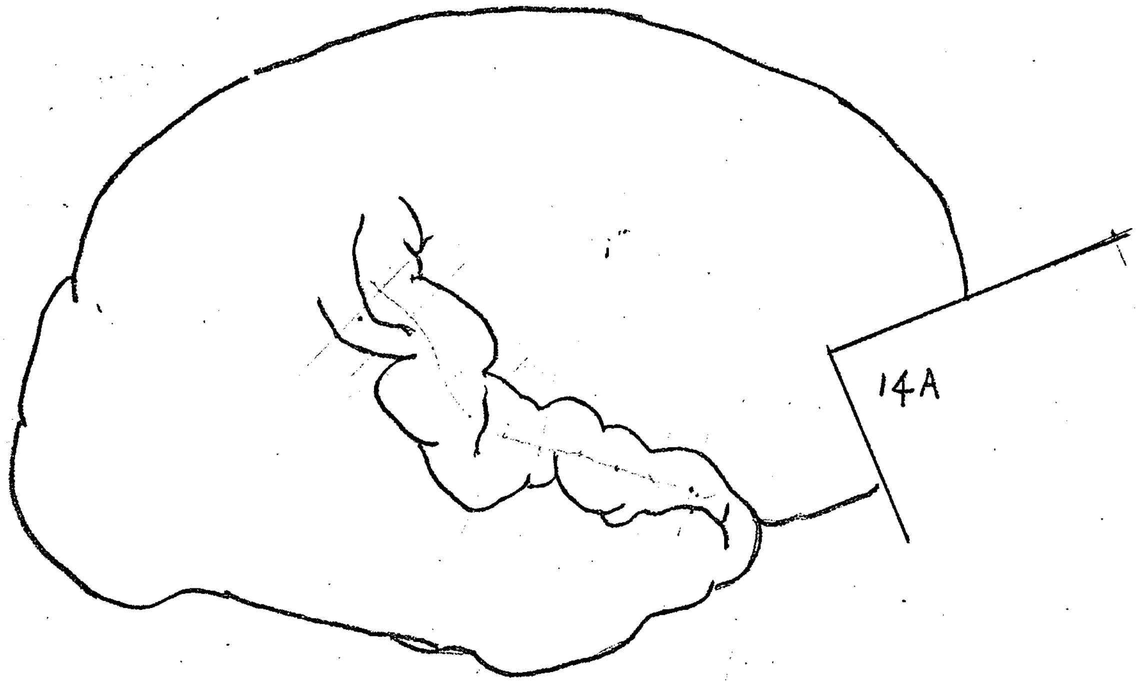
2A

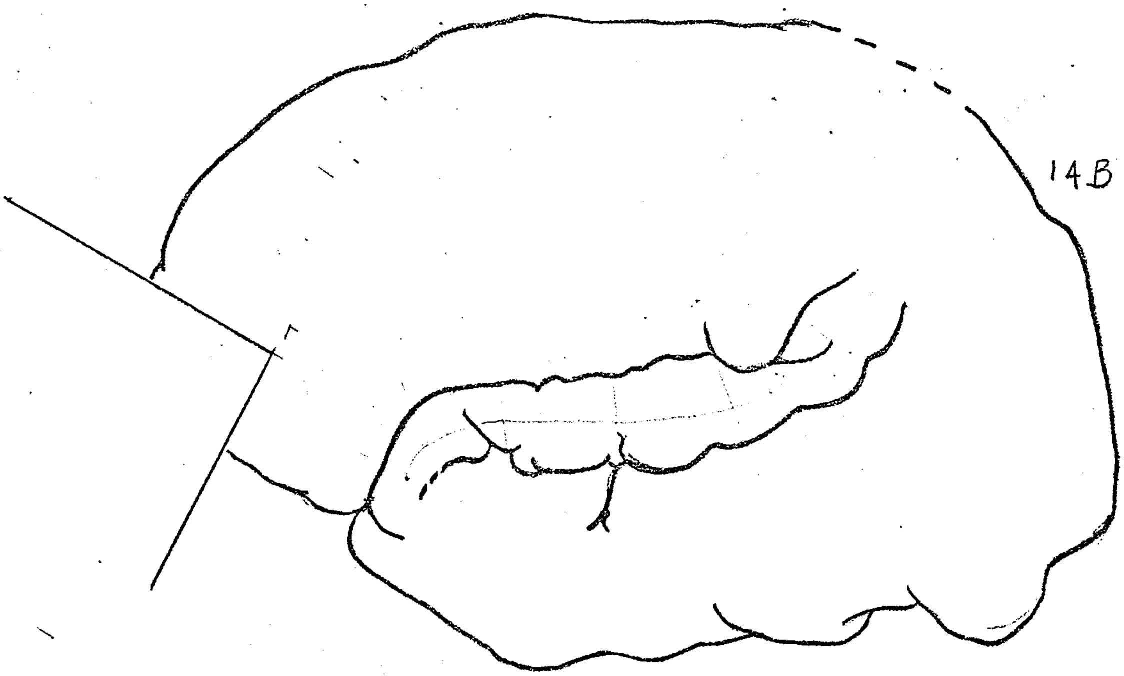


2B



AUTOPSY NO. 71 B 46
RANDOM NO. 86679



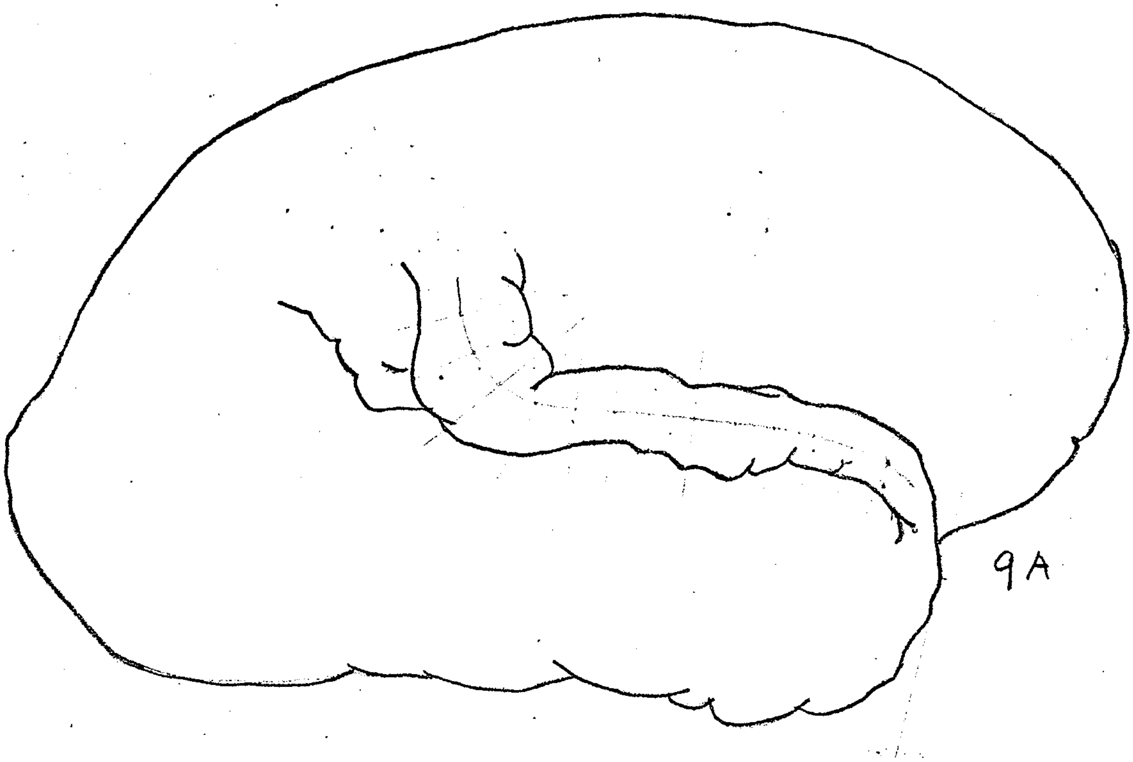


AUTOPSY No.
RANDOM No.

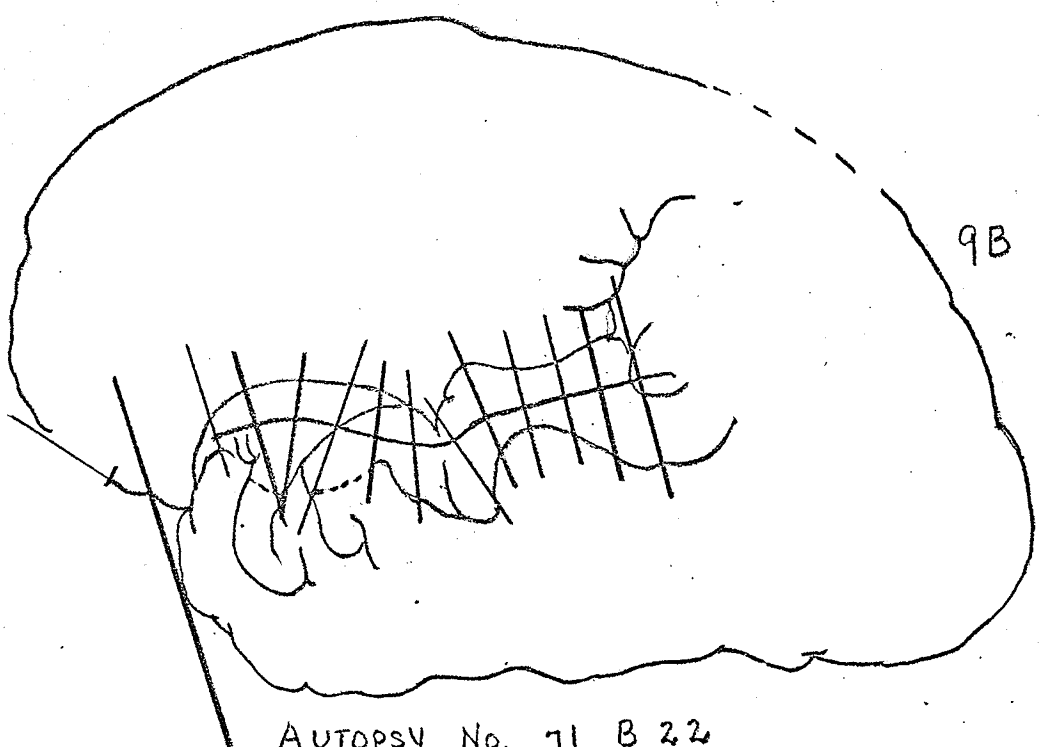
12 A

12 B

AUTOPSY No. 71 B 8
RANDOM No. 30506

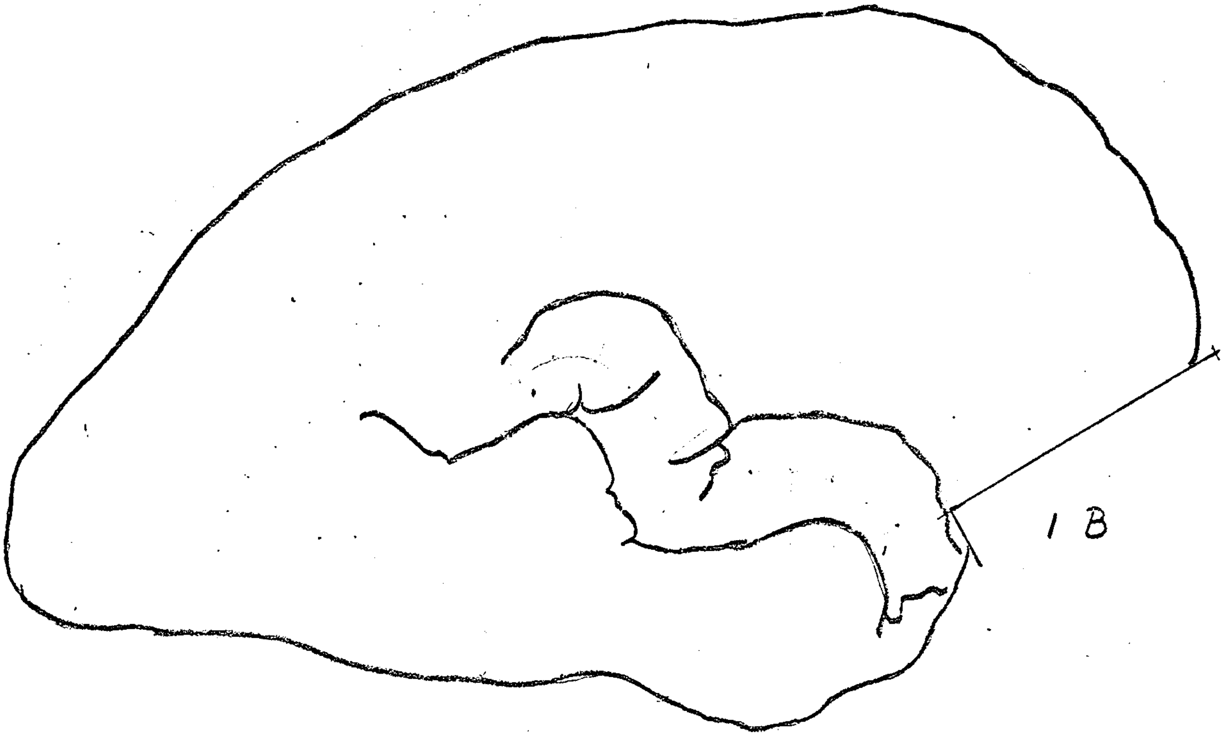


9A

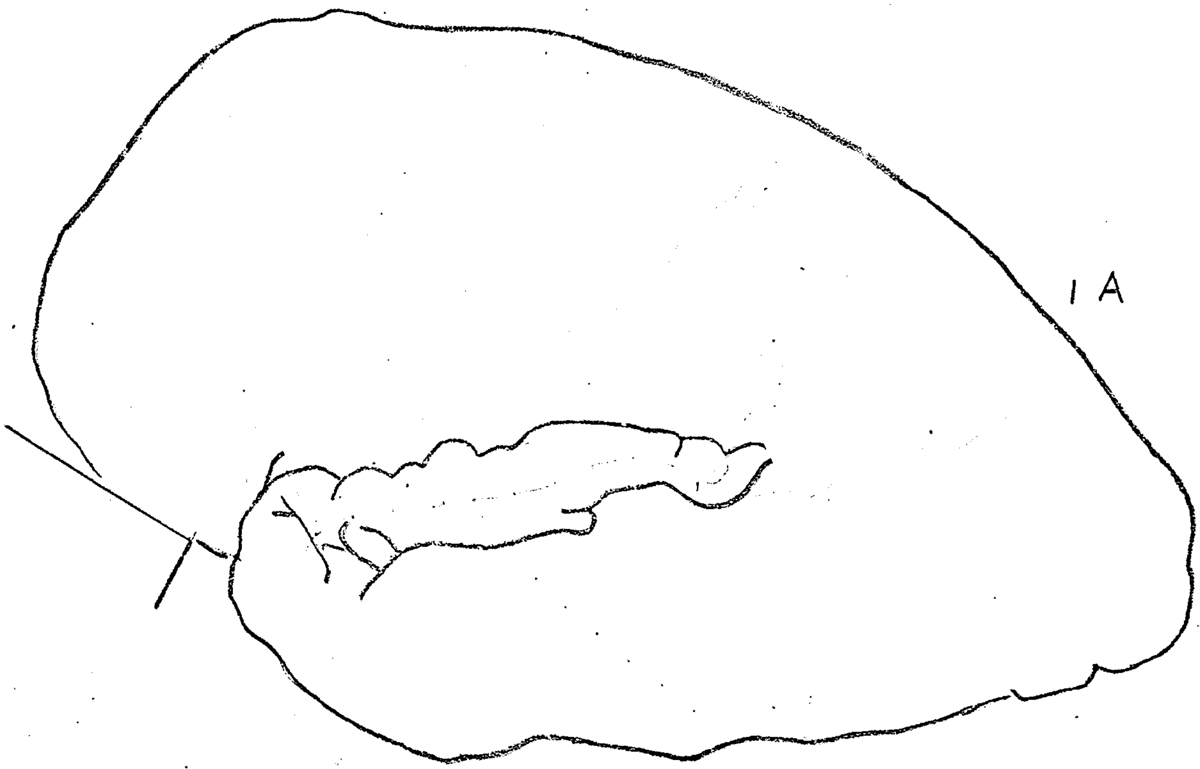


9B

AUTOPSY No. 71 B 22
RANDOM No. 23466

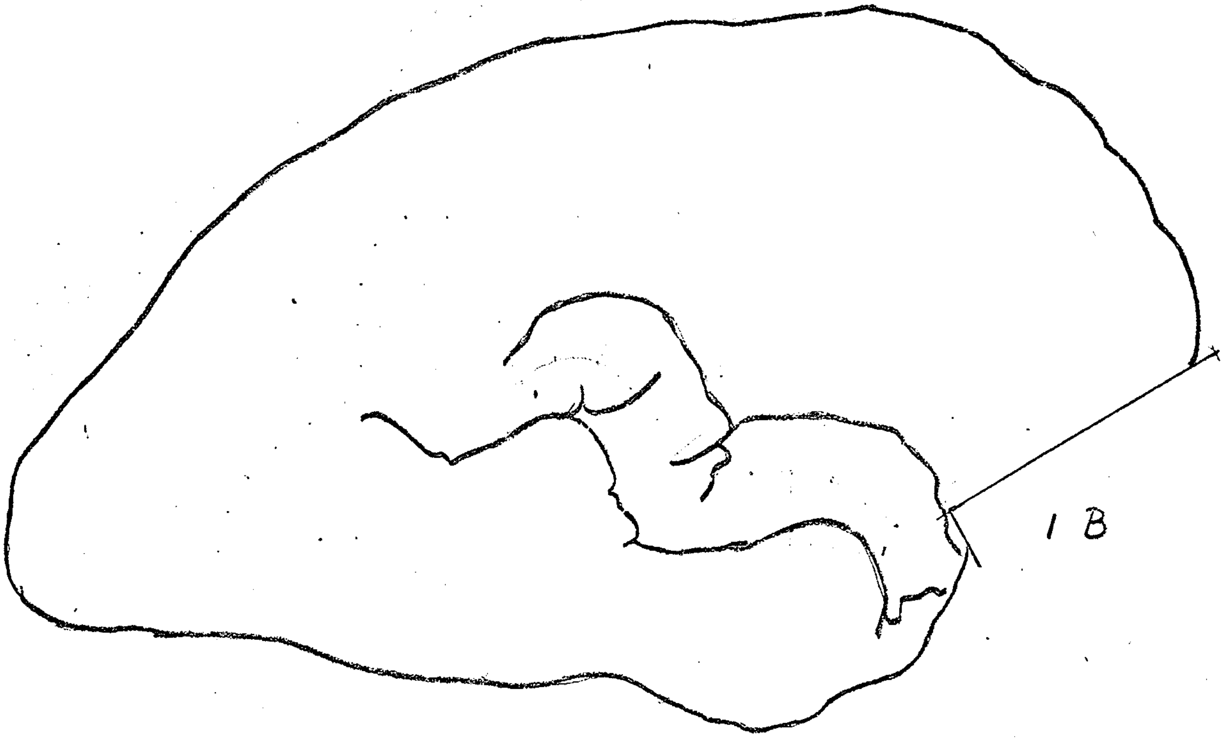


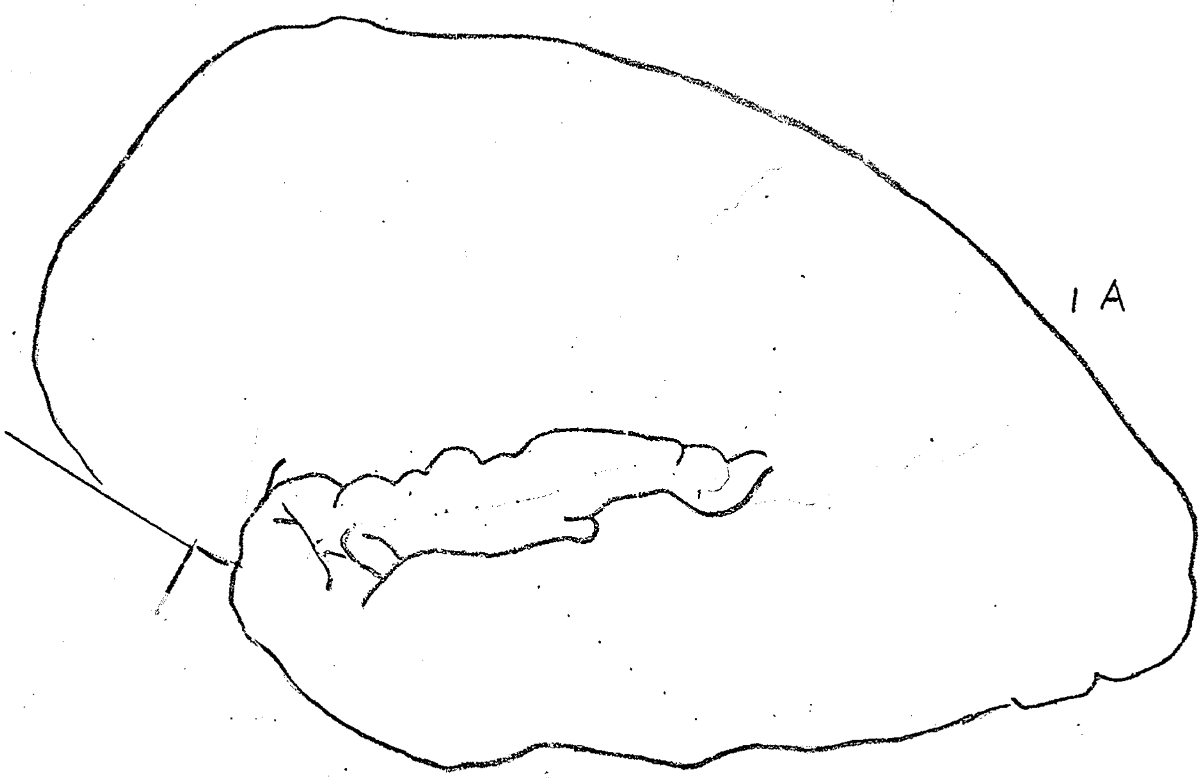
1 B



1 A

AUTOPSY No. 71 B 47
RANDOM No. 46614





AUTOPSY No. 71 B 47
RANDOM No. 46614