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THE ANATOMY OF THE BRAIN OF THE TUFTED CAPUCHIN (*Cebus apella* LINNAEUS, 1758).

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ABSTRACT: Macroscopical and microscopical observations of the Cebus apella *encephalon were carried out. Ten encephalons of adult specimens of both sexes were used. The brain of the* Cebus apella *is primitive when it is compared to the man's one; but it presents itself more evoluted than that of* Callithrix jacchus. *The brain of the* Callithrix *has a smooth cortex and in the* Cebus *convolutions may be seen in the frontal, parietal, temporal, and occipital lobes, and in the insula. Evident sulci (lateralis, centralis, calcarinus and parieto-occipitalis medialis and lateralis) are well defined and the localization of the precentralis, postcentralis, temporalis superior and inferior, frontalis, parietalis, and occipitalis gyri is well characterized. In the brain of* Cebus *the formation of white matter (corpus callosum, capsula interna, capsula externa, capsula extrema, comissura rostralis, comissura epithalamic and fornix) is evident and is more evoluted than that of* Callithrix. *The same structures are equivalent in man. The three nuclear masses, nucleus caudatus, nucleus lenticularis (with the putamen and globus pallidus), and claustrum are more evident and better delimited than those of* Callithrix, *but they concern mainly the nucleus lenticularis. In the diencephalon, the thalamus is also more evolved in the* Cebus *and there is evidence of anterior, medial, lateral, and posterior cellular groupings. The hypothalamic structures (nucleus mamilaris, tractus and chiasma opticus and tuber cinereus), the epithalamic structures (corpus pinealis and trigomus habenularis), and the metathalamic structures (corpus geniculatum medialis and lateralis) are also more evoluted, when compared to the* Callithrix jacchus. *All these structures are equivalent, although better delimited, in man.*

KEY-WORDS: Central nervous system; Cebus apella; comparative anatomy.

Primates encephalons (brains) have been described by several authors, but there are few and incomplete references concerning the encephalon of the *Cebus apella*, a monkey that can be found in many forests of Brazil.

A few data on gyri and sulci of the *Cebus* and the comparison with equivalent structures from other primates are given by CONNOLOY (1936).

BONIN (1938) refers to the fact that the cerebral cortex of the *Cebus* is more differentiated in the occipital lobe, close to the calcarine sulcus.

CLARK (1959) reports that in the *Cebus* brain, among other known sulci there is an intraparietal sulcus which separates the parietal cortex from the preparietal cortex and a well marked temporal sulcus which runs parallel to the lateral sulcus.

HILL (1964) presents a description of the *Cebus* brain surface in which he refers to the main sulci bordering lobes and gyri.

Since *Cebus apella* is a primate much used in experimental investigations, the researchers need more and more information on its anatomy. This paper deals with a macroscopic and microscopic description of the

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Cebus encephalon. The observations will be compared to those which have been described by REIS (1975) in the *Callithrix jacchus* and to what is known in man.

MATERIAL AND METHOD

Ten adult plathyrrine *Cebus apella*, males and females, captured in São Paulo State, Brazil, were used for this study.

The animals were anesthetised and sacrificed with an over inhalation of ether. The carotid artery was dissected and 60 ml of a 10% formalin solution was injected in each animal, through the artery, as perfusion. After removing the calvaria and part of the dura-mater, the decapitated heads were fixed in a 10% formalin solution in order to complete the fixation of the encephalon, in situ. When well fixed, each brain was removed from the remaining bony holster and the pia-mater was carefully stripped off from the cortex, in order to facilitate the observation of the whole encephalon.

Three of the ten brains were sectioned in successive and parallel slices, 2 to 3 mm thick each. One encephalon was sectioned horizontally, the other at the frontal plane and the third at the sagittal plane.

Four brains were embedded in celloidin and serial sections 40 μ thick were cut for histological studies. From these, one of every five sections of each encephalon was stained by Pal-Weigert method for myelin sheaths, modified by ERHART (1951). For counterstain, Grenacher's carmin was used to demonstrate nerve-cell bodies and nuclei.

The three remainder brains were kept intact for further studies and rechecked of macroscopic observations.

RESULTS

The telencephalon of the *Cebus apella* is represented by two well developed hemispheres in which the frontal, parietal, temporal, and occipital lobes are evident (Figs. 1 and 2).

The sulcus centralis and the sulcus lateralis (Figs. 1 and 3) are identified on the dorsolateral aspect of each hemisphere. The sulcus centralis, which lies between the frontal and parietal lobes, begins near the fissura longitudinalis about midway between the frontal and occipital poles. It does not extend on the medial surface; its ventral extremity does not reach the sulcus lateralis. The sulcus lateralis (Fig. 3), which separates the frontal and temporal lobes, extends backwards into the parietal lobe.

In the specimen from which these photos were taken, the posterior end of the sulcus lateralis joins the parallel sulcus.

The frontal sulcus, short and shallow, between the gyrus frontalis superior and the gyrus frontalis medius, and the sulcus precentralis inferior, between the gyri frontalis medius and inferior (Fig. 3), were identified in the frontal lobe. The sulcus precentralis superior is simply outlined.

The temporal lobe, situated in the lateral inferior part of the brain, shows the gyrus temporalis superior and the gyrus temporalis inferior (Fig. 3). The parallel sulcus lies between these two gyri.

In the parietal lobe the gyrus centralis posterior and the gyrus post-parietalis may be seen. The gyrus centralis posterior lies between the sulcus centralis and the sulcus intraparietalis. The gyrus parietalis posterior remains between the posterior part of the parallel sulcus and the sulcus parieto-occipitalis lateralis.

The parieto-occipitalis sulcus is relatively deep and it separates the parietal from the occipital lobe on the lateral and medial surfaces (Figs. 3 and 4). On the lateral surface this sulcus is known as the sulcus parieto-occipitalis lateralis and on the medial surface as parieto-occipitalis medialis.

The occipital lobe on the superolateral view of the brain is smooth and presents no definite convolutions (Figs. 1 and 3).

The insula lies concealed in the depth of the sulcus lateralis. It has a smooth surface.

On the basal surface of the brain (Fig. 2) the following structures may be identified: the gyrus rectus and the gyrus orbitalis, in the frontal lobe; the bulbus, tractus, trigonus, tuberculus, and striae olfactoriae lateralis and medialis (Fig. 2). In the *Cebus*, the bulbus olfactorius extends to the anterior part of the gyrus rectus.

In the median surface of the brain (Fig. 4), the sulcus corporis callosi, the gyrus frontalis superior, the sulcus gyri cinguli and the gyrus cingulus may be identified in the frontal lobe. The extreme posterior end of the gyrus cingulus does not show the gyrus precuneus and the paracentralis lobe. The sulcus calcarinus is evident.

The corpus callosum is very developed (Fig. 4), its portions called splenium, truncus, radiations, genu, rostrum, as well as the lamina rostralis, are easily identified. The lamina terminalis in the *Cebus* is very delicate.

In the horizontal, frontal and sagittal sections of the brain, the following structures were also identified: the nucleus caudatus, the nucleus lentiformis with its putamen and globus pallidus medialis and lateralis, the claustrum and the corpus amigdaloideum. The ventriculus lateralis is small and all its parts are evident: pars centrale and the frontal, occipital, and temporal cornua.

A horizontal section of the brain, passing through the rostral portion of the corpus callosum, discovered the following structures: the nucleus caudatus, the putamen and the thalamus with anterior, medial, lateral and posterior cellular grouping. It may also be seen at this level, the capsula interna with its anterior and posterior parts, capsulae externa and capsulae extrema, the claustrum, and the cortex of the insula. The lamina of the septum pellucidum and the fornix are also observed (Fig. 5).

The commissure is very large and crosses the median plane, ventrally to the fornix. The putamen and the globus pallidus are better delimited.

In the thalamus, the medialis and posterior cellular groupings are noted. The acqueductus mesencephali is perfectly delimited.

The structure of the stratified layer and commissural fibers are observed (Fig. 6) in the colliculus cranialis.

A frontal section through the frontal lobes and the anterior part of the temporal lobes, just caudal to the genus corporis callosi and the nervus opticus is shown in Fig. 7. Here, the sulcus lateralis and the fissura longitudinalis are clearly outlined. The three nuclear masses: nucleus caudatus, nucleus lentiformis and claustrum are well defined, as well as the capsulae interna, externa and extrema and the overlying cortex of the insula.

The columna fornicis has replaced the septum pellucidum and the cavity of the ventriculus lateralis may be identified (Fig. 8).

This section shows, furthermore, the tractus opticus and the III ventriculus, localized in the sagittal plane. At the time of the removal of this brain, the hypophysis remained in its bony holster; consequently, it did not appear in this illustration.

In Fig. 9 three nuclear masses (nucleus caudatus, nucleus lentiformis and claustrum) and the capsulae interna, externa, and extrema may be seen. The division of the globus pallidus into its two parts is now well evident.

The parietal and temporal lobes in the region of par ventralis pontis and pedunculus cerebralis and an increasing size of the nuclei medialis and lateralis thalami are noted in Fig. 10. The nuclei caudatus and lentiformis are becoming smaller and are moving farther laterally in this section.

Ventral to the tegmentum of the mesencephalon are the substantia nigra and the basis pedunculi. The latter in this section is seen in continuity with the fibers of the capsula interna. The capsula interna in the *Cebus apella* is very large (Fig. 10). The tractus opticus and the gyrus hippocampi may be found inferior-medially to the temporal lobe. The region of the splenium of the corpus

callosum and corpus pineale are well observed in Fig. 11. It also shows the ventriculus lateralis with the plexus choroideus, the reduced nuclear masses, the nucleus caudatus displaced laterally, and the gyrus dentatus of the hippocampi (Fig. 11).

In the posterior part of the truncus ventriculus lateralis and abundant plexus choroideus is distinguished (Fig. 12).

A sagittal section through the cerebral hemispheres of the *Cebus apella* shows the large gyrus cinguli immediately above the corpus callosum and the anterior, medial and posterior cellular groupings of the thalamus. Ventrally, the commissura rostralis and the chiasma opticum are observed. It is also evident the nucleus caudatus and part of ventriculus lateralis. This section includes the cerebellar hemisphere and the brain stem with the following parts: mesencephalon, pons, and medulla oblongata.

Fig. 13 ilustrates a sagittal section through the cerebral hemisphere, parallel to the anterior section.

The different groups of nuclei of the thalamus continued evident, as well as the corpus callosum and the nuclei caudatus. The nucleus ruber, the nucleus olivaris, the tractus opticus and the commissura anterior are well evident (Fig. 14).

In the sagittal section (Fig. 15) it was observed the capsula interna passing ventrally to the nucleus anterior thalami. In this section, the continuity of the fiber bundles through the basis pedunculi and capsula interna is seen. The tractus opticus, the commissura anterior, the nucleus caudatus, the thalamus, the corpus callosum and part of the white matter are also seen.

The cerebellar hemisphere is clear enough and presents the nucleus dentatus (Fig. 15).

The subdivision of the nucleus lentiformis, the corpus geniculatum mediale, and tractus opticus is well developed in *Cebus apella*.

The lateral part of the thalamus is evident, as well as the gyrus hippocampi and gyrus occipito-temporalis medialis (Fig. 16).

DISCUSSION

The brain of *Cebus apella* is primitive when compared to that of man; but it is more evoluted in comparison to the *Callithrix jacchus* brain as described by REIS (1975). The brain of the *Callithrix* has a smooth cortex; in the *Cebus*, convolutions may be seen in the frontal, parietal, temporal, and occipital lobes, and in the insula. Evident sulci (lateralis, centralis, calcarinus, and parieto-occipitalis medialis and lateralis) are well defined and the localization of the gyri precentralis, postcentralis, temporalis superior and inferior, frontalis, parietalis, and occipitalis, as observed in man is well characterized.

The main sulci of the *Cebus* are similar to that reported by GEIST (1930), CONNOLOY (1936), BONIN (1938), CLARK (1959) and HILL (1964), in other monkeys.

The white substance in the *Cebus apella* brain (corpus callosum, capsula interna, externa, extrema commissura rostralis, commissura epithalamic, and fornix) is much more evoluted than in the *Callithrix jacchus* and is similar to what may be seen in man.

The basal nuclei (nucleus caudatus, lenticularis with putamen and globus pallidus, claustrum, and amigdalis complex) are more evident and better delimited than in the *Callithrix*.

In the diencephalon, the thalamus is more developed than the one of the *Callithrix*; the anterior, medial, lateral, and posterior cellular groupings are very well marked.

The hypothalamic structures (nuclei mammilares, tractus and chiasma opticum, and tuber cinereus) as well as the epithalamic (corpus pinealis and trigonus habenularis) and metathalamic (corpus geniculatum medialis and lateralis) ones are more evoluted, when compared to the equivalent structures of the *Callithrix jacchus.*

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*RESUMO: Observações macro e microscópicas do telencéfalo do macaco-prego (*Cebus apella*), foram realizadas em 10 encéfalos de animais adultos, de ambos os sexos. Após a remoção total da pia-mater procedeu-se ao estudo da morfologia em geral em três encéfalos. Em três outros foram feitos cortes paralelos e sucessivos com cerca de 2 a 3 mm de espessura, orientados segundo os planos frontal, transversal e sagital. As fatias assim obtidas foram confrontadas com as obtidas do homem e do sagüi (*Callithrix jacchus*), em planos similares. Os outros três encéfalos, conservados intactos, serviram para o estudo macroscópico da morfologia externa. As quatro peças, após a remoção das meninges, foram submetidas a desidratação e inclusão em Celoidina. Foram efetuados cortes seriados de 40 micrômetros de espessura. Um em cada cinco cortes foi corado pela técnica de Pal-Weigert modificada por Erhart (1951) para as bainhas de mielina e com coloração de fundo pelo Carmin de Grenacher. Esses cortes foram estudados em um microscópio e estéreo microscópio Zeiss e comparados com cortes seriados equivalentes de encéfalos humanos e de sagüi. Os resultados mostram que, morfologicamente, o encéfalo do* Cebus apella, *embora primitivo quando comparado ao do homem, é mais evoluído que o do* Callithrix jacchus, *visto que este tem córtex liso e o* Cebus *apresenta os lobos frontal, parietal, occipital temporal e a ínsula, bem delimitados por evidentes sulcos (lateral, central, calcarino e parieto-occipital medial e lateral) que também caracterizam a localização dos giros pré-central, pós-central, temporais superior e inferior, frontais, parietais e occipitais. No cérebro do* Cebus *são evidentes as formações de substância branca (corpo caloso, cápsula interna, cápsula externa, cápsula extrema, comissura rostral, comissura epitalâmica e fórnix) mais evoluídas que as do sagüi e muito semelhantes às formações correspondentes encontradas na espécie humana. Os núcleos da base — caudado, lentiforme (com as partes putamen e globo pálido) e claustrum — são mais evidentes e melhor delimitados que os do sagüi, principalmente o núcleo lentiforme. Os núcleos da base do* Cebus *apresentam características morfológicas semelhantes às do homem. No diencéfalo, o tálamo é mais evoluído que o do sagüi e evidencia os grupamentos nucleares anterior, medial, lateral e posterior; estes equivalem-se aos que se conhece na espécie humana. As estruturas hipotalâmicas (núcleos mamilar, tracto e quiasma ópticos e túber cinério), as epitalâmicas (o corpo pineal e trígonos habenulares) e as metatalâmicas (corpos geniculados medial e lateral) são equivalentes àquelas da espécie humana.*

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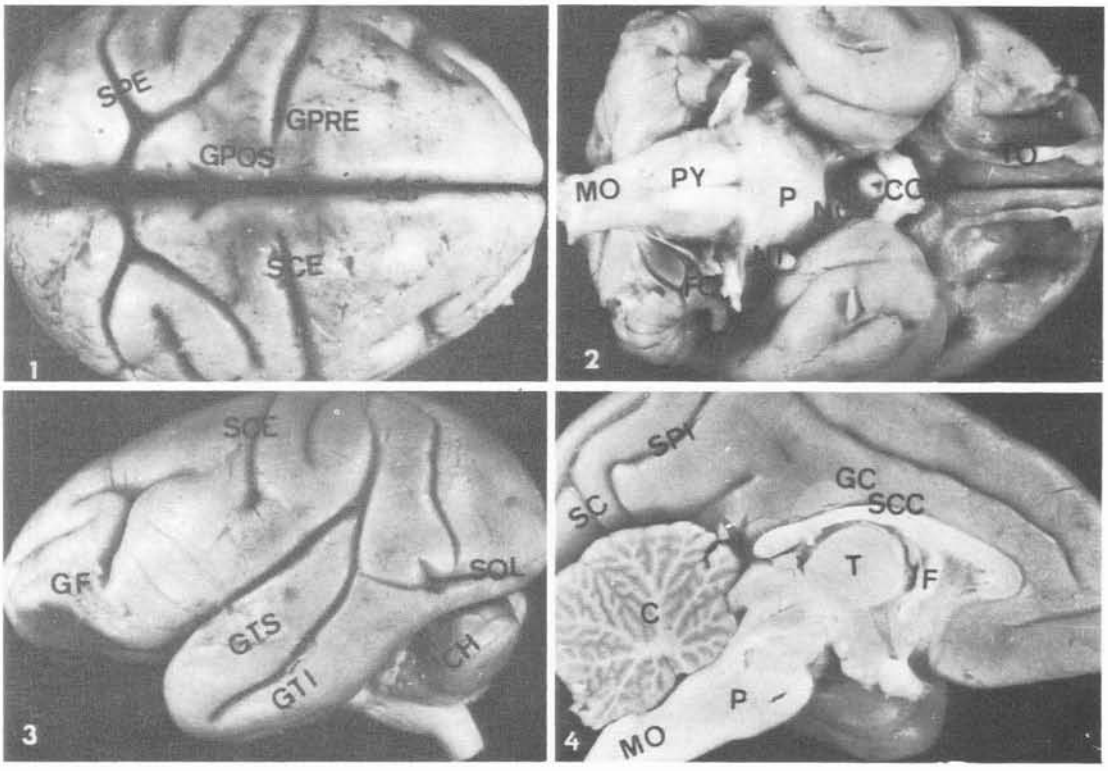

FIG. 1 — Photograph of the superior view of the *Cebus apella* brain showing the longitudinalis cerebral fissure (LCF), gyrus precentralis (GPRE), gyrus postcentralis (GPOS), sulcus parieto-occipitalis externus (SPE) and sulcus centralis (SCE).

FIG. 2 — Photograf of the central view of the brain showing the tractus olfactorius (TO), chiasma opticum (CO), nervi oculomotorius (NO), pons (P), nervi trigemini (NT), flocculus cerebellum (FC), pyramis (PY), and medulla oblongata (MO).

FIG. 3 — Photograph of the lateral view of the cerebral hemisphere showing the gyrus frontalis (GF), sulcus centralis (SCE), sulcus occipitalis lateralis (SOL), gyrus temporalis superior (GTS), gyrus temporalis inferior (GTI) and cerebellar hemispheres (CH).

FIG. 4 — Photograph of the medial view indicating the gyrus cinguli (GC), sulcus corpus callosum (SCC), fornix (F), thalamus (T), sulcus calcarinus (SC), sulcus parieto-occipitalis internus (SPI), cerebellum (C), pons (P) and medulla oblongata (MO).

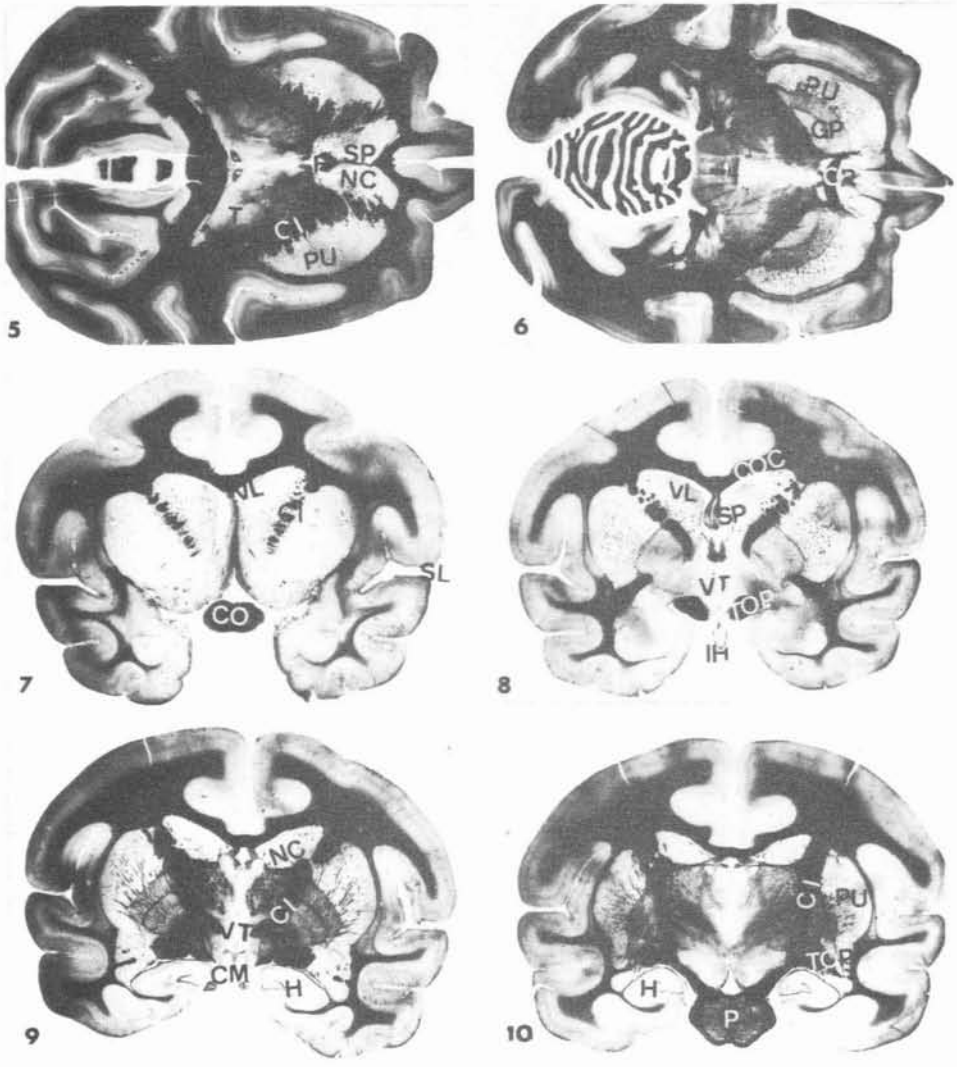

FIG. 5 — Transversal section of the brain showing the nucleus caudatus (NC), septum pellucidum (SP), fornix (F), thalamus (T), capsula interna (CI), and putamen (PU).

FIG. 6 — Transversal section of the brain showing the division of nucleus lentiformis in globus pallidus (GP), and putamen (PU), and comissura rostralis (CR).

FIG. 7 — Frontal section of anterior part of the brain showing the chiasma opticum (CO), ventriculus lateralis (VL), capsula interna (CI), and sulcus lateralis (SL).

FIG. 8 — Frontal section of the brain showing the septum pellucidum (SP), ventriculus tertius (VT), infundibulum (IH), tractus opticus (TOP), corpus callosum (COC), and ventriculus lateralis (VL).

FIG. 9 — Frontal section of the brain showing the corpus mammilaris (CM), ventriculus tertius (VT), capsula interna (CI), nucleus caudatus (NC), and hippocampi (H).

FIG. 10 — Frontal section of the brain showing the capsula interna (CI), putamen (PU), tractus opticus (TOP), hippocampi (H), and pons (P).

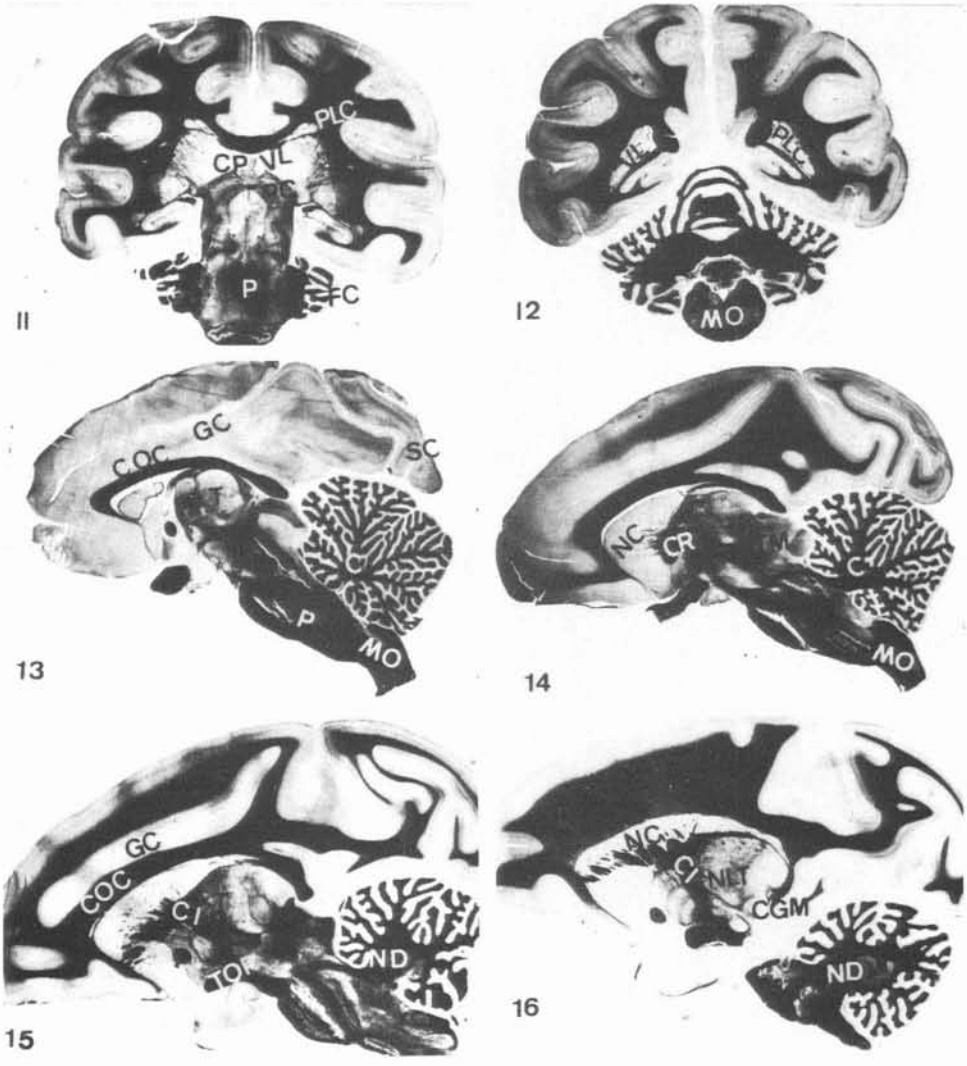

FIG. 11 — Frontal section of the brain showing the ventriculus lateralis (VL), plexus choroideus (PLC), corpus pineali (CP), pedunculus cerebri (PC), pons (P), and flocculus cerebellum (FC).

FIG. 12 — Frontal section of the posterior part of the brain showing the white and gray matter. Also, it is observed the ventriculus lateralis (VL), plexus choroideus (PLC), cerebellum and medulla oblongata (MO).

FIG. 13 — Sagittal section indicating the medulla oblongatta (MO), pons (P), thalamus (T), cerebellum (C), sulcus calcarinus (SC), corpus callosum (COC), and gyrus cinguli (GC).

FIG. 14 — Sagital section of the brain showing the nucleus caudatus (NC), commissura rostralis (CR), tectum mesencephali (TM), cerebellum (C), and medulla oblongata (MO).

FIG. 15 — Sagittal section of the brain indicating the corpus callosum (COC), capsula interna (CI), tractus opticus (TOP), gyrus cinguli (GC), nucleus dentatus (ND), and thalamus (T).

FIG. 16 — Sagittal section of the brain showing the nucleus lateralis thalami (NLT), corpus geniculatum mediale (CGM), capsula interna (CI), nucleus caudatus (NC), and nucleus dentatus (ND).