MORPHOLOGIC AND CYTOARCHITECTURAL STUDIES ON THE BRAINSTEM OF THE ONE HUMPED CAMEL (Camelus dromedarius)

BY

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CERTIFICATION

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DECLARATION

This is to certify that this study was carried out in the Department of Veterinary Anatomy, Ahmadu Bello University and that no part of this thesis has been submitted elsewhere for the award of a degree or diploma.

A. O. Adogwa

March, 1985.

DEDICATION

This work is dedicated to my late brother, Augustine Igaluwa Adogwa.

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ABSTRACT

The morphology and cytoarchitecture of the brainstem of the one humped camel was studied, and the observations were reported and discussed in this work.

Forty camel brainstems obtained from the abattoir were used for the morphologic and morphometric studies. The following salient observations were reported and discussed.

a. The pyramids are small in the camel.

b. There is no inferior olivary prominence in the camel.

c. The gracile tubercle is inconspicuous.

d. The corpus trapezoideum is small.

e. The medial eminence and the facial colliculus are not prominent.

f. Stria medullares of the fourth ventricle is not found in the camel.

g. The pons is small and all of it is pretrigeminal.

h. The trigeminal nerves are very thick.

i. The cerebral peduncles are not highly developed in evolutionary terms as its length is more than its width.

j. Transverse crural tract is poorly developed.

k. The rostral colliculi are large and prominent.

l. The lateral geniculate bodies are very large but the medial geniculate bodies are small.

m. The pineal gland is large, lobulated externally and saccular.

n. The thalami are small.

o. The hypophysis is very large.

p. The mammillary body is one solid mass and it is small.

For the cytoarchitectural studies, the brainstem were cut into three parts viz, the diencephalon, the mesencephalon and the remaining portion which is made up of the pons and the medulla oblongata. The brainstems were divided up into three parts to facilitate processing. Each of

the parts was processed by double embedding method using paraffin and celloidin. Transverse, horizontal and sagittal sections were cut from each of the three parts. Each section was 24um thick and the sections were stained with toluidine blue.

The red nucleus was studied into more detail than any of the other nuclei in the brainstem. A model of the red nucleus was also made using bristol board and paraffin. The red nucleus was studied into more detail because of its prominence in the mesencephalon.

The following important observations were made on the cytoarchitectural studies.

The red nucleus was reconstructed using Leitz drawing device and bristol board. The following observations were made and discussed.

a. The medulla oblongata of the camel in general resembles that of other domestic animals. However, the nucleus gracilis is unusually small; the principal olivary nucleus is poorly developed and the superior olive and the trapezoid bodies are small.

b. The rostral colliculi have prominent lamination and four laminae were identified.

c. The red nucleus is very large and is made up of parvocellular and magnocellular parts. The giant neurons of the magnocellular part are much larger than any such neurons reported in literature.

d. The oculomotor nucleus is well developed.

e. The trochlear nucleus is small and is well separated from the oculomotor nucleus, and an accessory trochlear nucleus is present.

f. The lateral geniculate nucleus is large and is made up of prominent neurons but it is poorly laminated.

g. The substantia nigra is well developed.

h. The lateral group of thalamic nuclei are well developed especially the nucleus lateralis pars posterior..

i. The nucleus ventralis posteromedialis is well developed.

j. The paraventricular and supraoptic nuclei of the hypothalamus are very large and prominent.

k. The pretectal area is fairly large and nuclei were identified in this area.

INTRODUCTION

In the desert and semi-desert environments the camel milk serves as an important source of animal protein and more importantly as a source of vitamin C and because of this fact camel milk is consumed in large quantities in these areas. The value of milk rich in vitamin C in arid or semi-arid areas, where there are no vegetables, cannot be overemphasized. Camel meat, as a source of animal protein, is consumed in large quantities in Nigeria as the slaughter figures show (Table 1). Much work has been done to improve camel production with the intention of making its meat and milk adequate for the protein requirements of the people living in these areas (Burgemeister, 1978; Leopold, 1968 and Nanda, 1957).

The camel has made its greatest contribution in the area of transport with which it has been widely associated. The camel played a very important role as a source of transport in the history of the people of North Africa and of those living in arid or semi-arid areas and especially of the famous trans-Saharan trade. The use of the camel for transport for long and short distances and the possible role of the camel for transport by the army

attracted much interest (Gillepsie, 1962 and Bulliet, 1975).

The camel is also used as a draught animal (Mcnight, 1969; Knoess, 1977).

Apart from the socio-economic uses of the camel, interest in the camel was evoked by its unique qualities of adaptation to a dry environment. The camel is known to survive without water for some days in a dry and hot environment. It can live in areas where there is little food and where other animals can hardly survive (Burgemeister, 1978). Envornmental physiologists and anatomists became interested in the camel for these reasons.

Many areas of the anatomy of the camel have been studied (Dagg, 1974; Taher et al., 1975; Pousty, 1977 and El-Shaieb, 1978). Although a good volume of literature has accumulated on the anatomy of the camel, there is dearth of information on the central nervous system even though the study of the central nervous system could contribute to the understanding of some of the unique behaviour of the camel. The study of the hypothalamus, for example, could provide information that might be useful to the understanding of homeostasis in the camel. The

camel can survive in desert conditions without water for several days. Also the gait of camel is characteristic and suited to the sandy soil. The motor tracts of the spinal cord as well as other parts of the central nervous system need to be studied in greater detail to explain these characteristic traits of camel. Most of the literature on the central nervous system of the camel is on the cerebral cortex (Reperant, 1971; Abdulhamid, 1973; Barone, 1973; Lauer, 1982; Ghaji, 1983). Literature on the brainstem of the camel is scanty (Slimane et al., 1969; Kanagasuntheram et al., 1970; Taher et al., 1975;and Flieger, 1981). Apart from the work of Kanagasuntheram et al. (1980) which covered the nuclei of the diencephalon, all the other studies were confined to a few nuclei only. A comprehensive work on the brainstem of the camel has not been done. In the present study the author intends to make a comprehensive study of the morphology and cytoarchitecture of the brainstem of the one humped camel (Camelus dromedarius).

The objectives of this study are: a) to make a comprehensive study of the morphology and cytoarchitecture of the brainstem in the one humped camel, b) to reconstruct the red nucleus and c) to

compare the findings with those of other animals especially the ungulates.

REVIEW OF LITERATURE

Medulla Oblongata

While the general descriptive information given by textbooks is the same for all mammals, the artiodactyla have no inferior olivary prominence, and the pyramids are poorly developed in these animals (Marsden and Rowland, 1965).

Pons

According to Harper and Maser (1975) the pons increases in size progressively from lower animals in which there are prominent pre and post pontine sulci, to primates in which the pre and post pontine sulci are obliterated.

Mesencephalon

The rostral colliculi are bigger than the caudal colliculi in the horse and ox while in the pig the rostral colliculi are smaller than the caudal colliculi (cf Getty, 1975). The tegmental region and the cerebral crura are best developed in higher mammals (cf Ariens-Kappers et al, 1966),

Goldin (1931) studied the cerebral crura in many mammals and reported that the index of the width to length is less than I in dolichomorphs and is greater I in brachymorphs.

Diencephalon

Some information on the dimensions of the pineal gland of the pig and ox have been given and it is mentioned that the lateral geniculate bodies are larger than the medial geniculate bodies in ruminants. (cf Getty, 1975).

CYTOARCHITECTURAL STUDIES

Myelencephalon

Strzalk and Flieger (1981) found that the vagal nucleus of the camel is 126mm long and is subdivided into median, medial and lateral groups which were maintained in the whole length of the nucleus except in the caudal segments. They also found that in the camel there are four types of cells in the vagal nucleus namely, multipolar cells of medium and large size (30-70um), spindle shaped cells (40-50um), oval shaped cells (25-35um) and triangular cells (30-60um).

The vestibular nucleus was studied in two camels by Jastrzabski et al (1979/81) who subdivided the caudal vestibular nucleus into lateral and medial parts. The rostral vestibular nucleus was divided into dorsal and ventral parts.

Diencephalon

The diencephalon was studied in two camels by Kanagasuntheram et al (1970) and the following account is based on their report.

The thalamic nuclei were subdivided into the anterior group, medial group, midline group, lateral group and ventral groups. The anterior group consists of nucleus anterior ventralis, nucleus anterior dorsalis and the nucleus anterior medialis. The nucleus anterior ventralis is subdivided into three or four subgroups by fibre bundles. The nuclei anterior medialis of both sides meet in the midline to form the nucleus commissuralis inter anteromedialis.

The medial group of thalamic nuclei is made up of the nucleus medialis dorsalis, nucleus para-centralis, nucleus parafascicularis, centrum

medianum, nucleus submedius and nucleus parataenialis. The nucleus medialis dorsalis is fairly large and it fuses with the nucleus parafascicularis in its caudal half. The nucleus paracentralis is distinct and is broken up by fibre bundles presenting a reticulated appearance. The nucleus parafascicularis is not distinct as the cells are not darkly stained and as it merges in its caudal half with the nucleus medialis dorsalis. The nucleus centrum medianum is poorly developed and is made up of pale staining neurons. The nucleus submedius and the nucleus parataenialis are small.

The midline group of thalamic nuclei consisting of nucleus commissuralis interanterodorsalis, interanteromedialis, rhomboidalis, reuniens, centralis medialis and paraventricularis are not prominent in the camel.

The lateral group of thalamic nuclei are well developed in the camel and include: the nucleus lateralis pars dorsalis, the nucleus lateralis intermedia, nucleus lateralis pars posterior, nucl nucleus suprageniculatus and the pulvinar. The pretectal nucleus and the nucleus of the posterior commissure were also included in the lateral group of thalamic nuclei by the authors.

The ventral group of thalamic nuclei is made up of nucleus ventralis anterior, nucleus ventralis lateralis, nucleus ventralis posterior and the nucleus ventralis intermedius. The nucleus ventralis posterior is well developed in the camel especially the medial part.

The metathalamus is made up of nucleus geniculatus lateralis pars dorsalis and the nucleus geniculatus medialis. The nucleus geniculatus lateralis pars dorsalis is poorly laminated. Only three layers were identified limited to the rostral portion of the nucleus. The nucleus geniculatus medialis is fused with the medial extension of the pulvinar in the camel. The nucleus has no magnocellular part.

In the epithalamus of the camel two nuclei were identified: nucleus habenularis lateralis and nucleus habenularis medialis. The nucleus habenularis medialis is composed of darkstaining medium sized neurons grouped together in a compact mass.

In the subthalamus the nucleus geniculatus lateralis pars ventralis is poorly developed. The nucleus subthalamicus is lens shaped in cross section and it does not show any special features. The

substantia nigra in the camel is made up of the pars compacta, pars reticularis and the pars lateralis. The pars compacta and the pars lateralis are small and the pars reticulata is large. The nucleus reticularis pars ventralis, the entopeduncular nucleus and the H_1 and H_2 Fields of Forel were identified in the camel.

The hypothalamus was subdivided by the authors into the anterior (rostral) hypothalamic area, the middle hypothalamic area and the caudal hypothalamic area. The anterior hypothalamic area which cannot be easily separated from the preoptic area is made of the nucleus hypothalamicus anterior, nucleus suprachiasmaticus, nucleus supraopticus lateralis, nucleus supraopticus medialis and the nucleus paraventricularis. The most remarkable feature of the hypothalamus in the camel is the extensive development of the supraoptic nuclei and the paraventricular nuclei. In the middle hypothalamic area nucleus hypothalamicus dorsomedialis, nucleus hypothalamicus ventromedialis, the nucleus hypothalamicus periventricularis and nucleus tuberalis were found. Of these nuclei, the nucleus hypothalamicus dorsomedialis and the nucleus hypothalamicus ventromedialis are not prominent. In the posterior hypothalamic area, the

nucleus mammillaris lateralis, nucleus mammillaris medialis, nucleus interstititalis supramammillaris and the nucleus hypothalamicus posterior were found. The nucleus mammillaris medialis is very large in the camel and is subdivided into a ventrolateral, a dorsolateral, and a medial component.

The preoptic area is made up of nucleus preopticus medianus, nucleus preopticus principalis, nucleus preopticus interstitialis, nucleus preopticus magnocellularis, nucleus preopticus periventricularis and nucleus interstitialis pedunculi thalami inferioris.

MATERIALS AND METHODS

Forty camel heads were obtained from the Kano abattoir for the morphometric studies. The brains were removed according to the method of Harper and Maser (1975). They were stored in 4% formal dehyde formalin for at least three to four weeks. The hardened brains were removed from the formalin and the meninges carefully removed. They were then weighed whole and their weights recorded.

To isolate the brainstem the longitudinal ..s fissure between the cerebral hemispheres was gently widened with the left thumb and fingers; a scapel was inserted and the corpus callosum was cut lengthwise from the splenium to the genu. The diencephalon became visible. The internal capsule fibres were then cut carefully on one side with a scapel. The brain was turned upside down and a cut made just rostral to the optic tracts and parallel to them to facilitate cutting off the internal capsule and freeing the hemisphere on that side. The operation was repeated on the other side. Next, the cerebellum was removed by cutting its peduncles on either side and also the rostral medullary velum. The separated parts of the brain were stored in separate containers in 10% buffered neutral formalin.

The brainstems were removed, cleaned and weighed and the weights recorded. Measurements of the various parts of the brainstems were carried out and recorded. The measurements were undertaken with vernier calipers and a 30 cm ruler. A piece of thread was used to measure rounded parts like the colliculi and thalami. Photographs of the dorsal, ventral and lateral aspects were taken.

For histological studies, immediately after decapitation of the camel in the abattoir, four brains were first perfused with physiological saline solution through the common carotid artery to flush the brain free of blood. This procedure was immediately followed by perfusion of the brain with 10% neutral buffered formalin. The brains were then extracted according to the method of Harper and Masser (1975) and were immersed in formalin solution for two weeks. They were taken out and the brainstem obtained as described earlier (ante page 4). A comprehensive study of the red nucleus was done before the study of the other nuclei. For this purpose, one brainstem was processed whole and sectioned at 24mm. Every 10th section was mounted and stained (Method given below). From the study of these slides, the approximate limits of the red nucleus were determined. Having obtained the limits of the red nucleus, three

brainstems were prepared for embedding thus: Each of the three brainstems were cut into three segments by two transverse cuts. The rostral cut was made just in front of the pineal gland while the caudal cut was made 1cm caudal to the caudal colliculi to isolate the middle segment, which was essentially the midbrain with a bit of the diencephalon rostrally and a bit of the metencephalon caudally bearing in mind the approximate limits of the red nucleus earlier obtained from the preliminary studies. The three isolated midbrain segments were embedded for cutting sections in the transverse, sagittal and horizontal planes. The serial sections prepared from the midbrain were used to study the nuclei of the midbrain.

The diencephalon was processed separately after isolation. Three diencephalons were processed to be cut in the horizontal, transverse and sagittal planes. The hindbrain (medulla and pons) was also processed separately. Three hindbrains were processed to be cut serially in the transverse, horizontal and sagittal planes.

Double embedding process (Adogwa and Lakshminarasimhan, 1982)

The segments of the brainstem were double embedded in celloidin-paraffin. The various steps of the

embedding procedure are as follows:-

1. 80% alcohol 4 days
2. 95% alcohol I 1 day
3. 95% alcohol II 1 day
4. 95% alcohol III 1 day
5. Absolute alcohol/ether mixture (1:1) I 9hours
6. Absolute alcohol/ether mixture (1:1) II 9hours
7. 1% Celloidin 6 days
8. Chloroform I 18 hours
9. Chloroform II 18hours
10. Paraffin (melting point 56°C-58°C) I 12hours
11. Paraffin (melting point 56°C-58°C) II 12hours

The tissues were solidified in paraffin overnight at room temperature. The following morning paraffin II was melted out by gradually raising its temperature on a hot plate and the tissues were taken out and infiltrated with fresh paraffin III under vacuum for 2 hours. The midbrains were embedded in fresh paraffin in such a way that the orientation could result in transverse, sagittal and horizontal planes.

Serial transverse, sagittal and horizontal sections of 24um thickness were made. The sections were floated on warm water in a trough. The sections were then picked up on slides and excess water removed from the sections with a blotting paper dipped in 70% alcohol. The sections were mounted on special slides

of size 76 x 50mm because they were large. The adhesive used was Spoerri's (1939) starch after albumin was found unsuitable. The slides were kept in the incubator at 37 C for 24 hours before staining.

Staining

Three stains were used:

1. Toludine blue 'O'
2. Gallocyanin alone
3. Gallocyanin counterstained with methyl green.

These stains were used for sections of the midbrain. For the diencephalon and the myelencephalon only toludine blue 'O' was used. The stains were prepared according to the method of Augulis and Sepinwall (1969, 1971). For the midbrain sections two out of every three slides were stained with toludine blue. The third slide was stained with either gallocyanin alone or with gallocyanin and methyl green.

The staining procedure of Augulis and Sepinwall (1969, 1971); and Lakshminarasimhan (1978) were modified in this work. The details are as follows:-

1.	Xylene I	2 minutes	
2.	Xylene II	2 minutes	
3.	Xylene III	2 minutes	
4.	Absolute alcohol Chloroform	1:1	1 minute

5.	0.5% Celloidin		2 minute
6.	Air dry		1 minute
7.	80% alcohol		2 minutes
8.	Rinsed in water		
9.	Toluidne blue 'O'		20 hours
10.	Rinsed in water		
11.	80% alcohol		1 minute
12.	Absolute alcohol Chloroform	1:1	1 minute
13.	Xylene I		1 minute
14.	Xylene II		1 minute
15.	Xylene III		1 minute

The sections were then mounted in DPX. The sections were covered with 0.5% celloidin to give it added protection when the sections were found to be peeling off. Absolute alcohol/chloroform mixture (1:1) was used to prevent dissolution of the celloidin. Care was taken not to leave the sections in distilled water beyond rinsing to prevent the sections from soaking in water and peeling off.

The sections were air dried for only 2 minutes.

For gallocyanin stain alone and for gallocyanin counterstained with methylgreen, after step 8 above, the sections were mordanted for 30 minutes in 1% iron alum solution ($NH_4Fe(SO_4)_2.12H_2O$) Lavendar colour only, and freshly prepared everytime according to

Augulis and Sepinwall (1971). The sections were thoroughly washed in distilled water until no more colour came off. They were then stained in gallocyanin for 3 hours. The sections were washed by passing through many successive changes of distilled water. They were then passed through steps 10-15 and mounted in DPX. The gallocyanin and the gallocyanin/methyl green stains were intended for myeloarchitectural and cytomyeloarchitectural studies to be done later.

For the third procedure, the sections were washed after gallocyanin by passing them through successive changes of distilled water and they were then counter stained with methylgreen for 10 minutes. The sections were again properly washed and passed through steps 10-15 above after which they were mounted in DPX.

The cells were measured with ocular micrometer after calibrating with a stage micrometer (Graticules Ltd.).

A three dimensional reconstration of the red nucleus was made from serial sections thus: drawings of the transverse, sagittal and horizontal sections were made with a Leitz microscope and a Leitz tracing device on bristol board. Outlines of the nucleus were drawn from every section. Each of the outlines was cut out of the bristol board represents a section.

All the cut pieces were than arranged in the proper order of serial sections, each outline representing a section of the red nucleus. The cut board outlines were soaked in molten paraffin wax and then they were affixed one to the other in the proper order by means of a hot spatula. In this way all the cut outlines were waxed together in the proper order and in the correct topographical location of the cell categories. This reconstruction gave a model whose surface was smoothened out with a hot spatula and them immersed in cold water for some hours to solidify. This model showed the shape, the form and size (magnified to 30 times) of the red nucleus.

Outlines of the height, width and length of the nucleus were obtained from sections as follows:- if n is the number of sections containing the red nucleus and since each section is 24um thick, the total amount of tissue containing the nucleus would be n x 24um. The length of the nucleus was obtained from transverse sections, the width from sagittal sections and the height from horizontal sections. It was possible to obtain these measurements because all the sections were mounted and stained.

The shrinkage was approximately 16%.

RESULTS

Part I: Morphology Studies

The brainstem is bounded rostrally by the lamina terminalis and caudally by the first cervical nerves at the level of the foramen magnum. It is made up of the myelencephalon, metencephalon, mesencephalon and the diencephalon. The brainstem is obtained by removing the cerebral hemispheres, the cerebellum and the spinal cord.

The myelencephalon (Plates)1 - 4)

The medulla oblongata forms the myelencephalon. It is the caudalmost part of the brainstem. There is no line of dermarcation between the medulla oblongata and the spinal cord but the level of the first cervical nerves is a convenient landmark for separation. This level is between the attachments to the neuraxis of the rootlets of the hypoglossal and first cervical nerves. The rostral limit of the medulla oblongata is the pontomeduallary junction. The medulla oblongata is quadrilateral in outline and is mush wider rostrally than caudally and is compressed dorsoventrally. Its ventral surface rests on the basilar portion of the occipital bone,

while its dorsal surface is covered by the cerebellum. The ventral surface of the medulla oblongata is divided into two halves by the ventral median fissure. Each half is subdivided into a ventral and lateral part by the ventrolateral sulcus which is faintly visible. Bordering the ventral median fissure on both sides are the pyramids. The medulla oblongata is 3.8cm long and 3.3cm wide. The pyramids measure 0.5cm in width (mediolaterally) and disappears 3cm caudal to the pons (Table 2).

The most rostral part of the medulla oblongata bordering the pons is the corpus trapezoideum, which is modified into a transverse band of fibres. The corpus trapezoideum is not prominent.

There is no prominence on the rostral part of the medulla oblongata similar to the inferior olivary prominence of primates.

The dorsal surface of the medulla oblongata is grossly divisible into two parts:- A closed caudal part and an open rostral part, which is modified, along with the dorsal surface of the pons into the rhomboid fossa. The dorsal surface of the medulla is divided into two parts by the dorsal median fissure which is bounded on both sides by the dorsal funiculus. The dorsal funiculus is bounded laterally

by the dorsal lateral sulcus. The dorsal funiculus is occupied by the smaller medial fasciculus gracilis and the larger lateral fasciculus cuneatus and their nuclei both of which are pushed laterally to form the caudal border of the floor of the fourth ventricle - the rhomboid fossa. The cuneate tubercle which is the most rostral part of the dorsal funiculus is fairly large. The gracile tubercle is inconspicuous. The fossa is divided into two equal halves by the dorsomedian sulcus. Each half of the rhomboid fossa is subdivided by the sulcus limitans. The rhomboid fossa is formed by the dorsal surfaces of both the pons and the medulla oblongata. No line of demarcation can be drawn separating the two. The rostral part of the rhomboid fossa lies between the sulcus limitans and the rostral cerebellar peduncle. This, too, is poorly developed. In the caudal portion of the rhomboid fossa bordering the dorsomedian sulcus is the slight eminence of the hypoglossal trigone medial to the vagal trigone. Adjacent to the caudal cerebellar peduncle and bordered medially by the sulcus limitans is a convex prominence which extends rostrally to the caudal border of the cerebellar peduncle. This corresponds to the underlying vestibular nuclei. The dorsal cochlear nucleus is in the lateral and dorsal aspect of the caudal cerebellar

peduncle and appears as a continuation of the cochlear nerve but it is not prominent.

The metencephalon

Pons (Plate 1 & 2)

The metencephalon is made up of the pons and the cerebellum. Since the pons alone forms part of of the brainstem the present study deals with this structure only. The pons is the segment of the brainstem between the mesencephalon rostrally and the myelencephalon caudally. The dorsal surface of the pons is covered by the cerebellum and contributes to the upper half of the rhomboid fossa. The ventral surface of the pons is modified into a prominent transverse band of fibres, and is longer than it is wide. It decreases in width from the midline to the side and becomes the middle cerebellar peduncle. The ventral surface of the pons is marked by a shallow median sulcus. The pons is 1.50cm wide (craniocaudal extent) and 3.44cm long (Table 2). The fifth cranial nerve arises caudolateral to the pons at the junction of the pons and the medulla oblongata. All of the pons therefore is pretrigeminal (Plate 2). The pons is convex rostrally and plane caudally. Both the pre and postpontine sulci are prominent.

The mesencephalon (Plates 3;4)

The mesencephalon or the midbrain is the segment of the brainstem between the diencephalon rostrally and the metencephalon caudally. The mesencephalon retains to a large extent the original tubular form with no hemispheric outgrowths. The mesencephalon is subdivided into three parts:- the tectum, tegmentum, and crura cerebri or cerebral peduncles.

The tectum (Plates 3,4)

The tectum is the most dorsal part of the midbrain. Ventral to the tectum is the cerebral aqueduct. It is modified into two pairs of rounded structures, the rostral and caudal colliculi. The rostral colliculi are separated from the caudal colliculi by transverse grooves and the right colliculi are separated from the left by a sagittal groove. The rostral colliculi are much bigger than the caudal colliculi and measure 1.69cm wide, 1.4cm long and 1.1cm. wide and 0.79cm in height (Table 2). The caudal colliculi extend laterally beyond the rostral ones, and they are ovoid in shape with a prominent point which is directed dorsocaudolaterally. The caudal colliculi

are connected to the medial geniculate bodies while the rostral colliculi are connected to lateral geniculate bodies by the brachia of the medial and lateral geniculate bodies respectively. The brachia of the caudal colliculi are more prominent than those of the rostral colliculi.

The tegmentum (Plate 1)

The tegmentum is situated ventral to the mesencephalic aqueduct and is closely related to the central grey substance. Ventrally it is bordered by the cerebral crura.

The crura cerebri (Plate 2)

The cerebral crura form the ventralmost part of the midbrain bordered dorsally by the tegmentum. The cerebral crura take their origin from the cerebral cortex and converge caudally at the base of the brain. The angle of convergence of the two cerebral crura is 30°. The cerebral crura are separated from each other by intercrural fossa. This fossa is perforated by blood vessels caudal to the mammillary body and this region is known as the caudal perforated substance. Transverse crural tract divides the cerebral crura into two parts -

rostral and caudal parts. This tract is poorly developed in the camel. Each of the crura is subdivided into medial and lateral halves by a sulcus, the medial part being larger than the lateral.

The oculomotor nerve arises from the rostral end of the caudal division of the crura. The cerebral crura are 2.3cm long and 1.6cm wide (Table 2).

Diencephalon (Plates 1,2,3)

The diencephalon is the most rostral part of the brainstem. Its caudal limits are the caudal commissure dorsally and the caudal end of the mammillary body ventrally. Rostrally the diencephalon is bounded by the interventricular foramen dorsally while the optic tracts and the optic chiasma form the ventral boundary. The third ventricle separates the right and the left thalami. The rostral boundary is marked by the lamina terminalis. Laterally, the diencephalon is bounded by the tail of the caudate nucleus, the stria terminalis and the posterior limb of the internal capsule. The diencephalon is made up of the epithalamus, thalamus, hypothalamus, subthalamus and the metathalamus.

The epithalamus

The epithalamus consists of the pineal gland, habenula and the caudal commissure. The pineal gland consists of a body and a stalk or peduncle. The pineal gland which is nodular in shape is grossly divided into three or more lobes and measures 0.6cm in length, 0.8cm in width and 0.6cm in height; the stalk is 0.4cm long and is tubular (Table 2). It has a rounded base which rests in the midline between the two rostral colliculi at the junction of the thalami and the rostral colliculi. The stalk is formed by the caudal commissure and the habenular commissure and forms the habenular recess of the third ventricle. The stalk is connected to the rostral part of the pineal gland. The pineal gland is richly supplied with blood vessels at the rostral part.

The habenular (Plate 1) is a small triangular mass located on the dorsomedial aspect of the thalamus rostral to the pineal gland. The caudal commissure is a fairly large bundle of fibres which crosses the median plane dorsal to the point where the cerebral aqueduct opens into the third ventricle. Some of the fibres serve to connect together the two rostral colliculi. The habenular commissure is thick.

The thalamus (Plate 1,3)

There are two thalami which are obliquely oriented egg-shaped nuclear masses of grey matter situated on each side of the third ventricle. Each thalamus lies between the interventricular foramen rostrally and the caudal commissure caudally and extends from the third ventricle medially to the medial border of the caudal limb of the internal capsule laterally. The lateral and caudal parts of the thalamus are enlarged. A narrow lateral strip of the dorsal surface, the lamina affixa forms the floor of the lateral ventricles, this strip is adjacent to the body and tail of the caudate nucleus. Each thalamus has two ends and four surfaces. The two ends are rostral and caudal. The rostral end is narrow and forms the caudal boundary of the interventricular foramen and the expanded caudal end is called the pulvinar. The surfaces are dorsal, ventral, medial and lateral. The dorsal surface is free, convex and is separated from the caudate nucleus by the stria terminalis. Because the two dorsal surfaces are convex there is a depression in the midline between these two surfaces rostral to the pineal gland and the dorsal to the third ventricle. The ventral surface is continuous with the tegmentum of the midbrain. The

medial surface forms the medial wall of the third ventricle. Part of this surface is connected to the opposite thalamus by the thick interthalamic adhesion. The third ventricle is much reduced because of the interthalamic adhesion. The lateral surface consists of projection fibres which form the caudal limb of the internal capsule. Each thalamus is 1.48cm long 2.2cm wide and 3cm high (Table 2).

The metathalamus (Fig. 1)

The metathalamus consists of the lateral and medial geniculate bodies. The lateral geniculate bodies are large, prominent and run obliquely to the midline. They are much larger than the medial geniculate bodies which are oval and lie ventro-lateral to them. The optic tracts end in the lateral geniculate bodies. The lateral geniculate bodies overshadow the pulvinar. The medial geniculate bodies are small and inconspicuous. They lie between the lateral geniculate bodies rostrally, the cerebral crura ventrally and the caudal geniculate bodies caudally.

The hypothalamus (Plate 1)

The hypothalamus is the most ventral part of the diencephalon. It is ventral to the hypothalamic sulcus and forms the ventral and lateral walls of the third ventricle. The hypothalamus consists of the optic tracts, the optic chiasma, the infundibulum, the tuber cinereum and the mammillary body ventrally. The optic tracts and optic chiasma form the rostral limit of the hypothalamus. The tracts are flat white fibre bands coursing laterally and then disappearing into the lateral geniculate bodies. The infundibulum is caudal to the optic chiasma and forms the attachment of the hypophysis to the brain. The tuber cinereum is an elevated grey area rostral to the mammillary bodies. It is to the tuber cinereum that the infundibulum is attached. The mamillary bodies are the most caudal part of the hypothalamus. The rostrocaudal extent of the hypothalamus is 2.2cm and the width is 1.5cm (Table 2). The optic tracts are 3.5cm long from the point of crossing over to the point of disappearance into the lateral geniculate bodies (Table 2). The optic tract has a diameter of 0.5cm (Plates 2, 4, Table 2). The mamillary bodies of both sides in the camel are fused together in the midline to form a single structure. The mamillary body fuses with the tuber

cinereum and is not clearly demarcated from the latter.

The subthalamus

The subthalamus is situated between the thalamus and the tegmentum of the mesencephalon and forms a zone of transition between these two structures. Lateral to it, the internal capsule joins the cerebral peduncles and medial and rostral to it lies the hypothalamus. The subthalamus is not visible in a whole brain or in a sagittal view of a hemi section of the brain.

Cranial nerves attached to the brainstem (Plates 2,3,4)

Seven pairs of cranial nerves (the fifth to the twelfth) attach to the ventral surface of the medulla oblongata. The hypoglossal nerve is the most caudal of these and arises from the medulla oblongata at the level of the pyramidal decussation. The rootlets of this nerve are arranged craniocaudally in direct line with the ventral roots of the spinal nerves. The accessory nerve, the eleventh cranial nerve, originates from the medulla oblongata by two roots, cranial and spinal. The spinal root arises from the cervical part of the spinal cord while the

cranial root arises from the dorsolateral aspect of the medulla oblongata.

The vagus nerve, the tenth cranial nerve, is attached to the lateral aspect of the medulla oblongata by several filaments which are in series with those of the ninth cranial nerve rostrally and the eleventh cranial nerve caudally.

The ninth cranial nerve, the glossopharyngeal nerve, emerges from the ventrolateral surface of the brainstem rostral to the rootlets of the vagus nerve.

The vestibulocochlear and facial nerves arise close together near the lateral border of the trapezoid body.

The abducent nerve leaves the brainstem at the level of the trapezoid body at the lateral border of the pyramids medial to the seventh and eight cranial nerves.

The fifth cranial nerve, the trigeminal nerve, is a thick nerve attached caudolaterally to the pons. This nerve arises at the junction of the pons and the medulla oblongata. It arises in such a way that all of the pons is pretrigeminal.

The fourth cranial nerve, the trochlear nerve, is the only cranial nerve that emerges from the dorsal surface of the brainstem. It is a delicate nerve which arises caudal to the caudal colliculi.

The third cranial nerve, the oculomotor nerve, arises from the ventral surface of the brainstem, in the intercrural fossa medial to the cerebral peduncle, almost midway between the pons and the mamillary body.

The second cranial nerves, the optic nerves, as described earlier, form the rostral boundary of the brainstem. They are flat bands that cross ventromedially to form the optic chiasma, from where they run laterally to disappear into the lateral geniculate bodies. The optic nerve of the camel has a swelling before it decussates in the optic chiasma. This swelling whose significance is unknown, is peculiar to the camel.

Part III: Cytoarchitectural Studies

[illegible] II: Medulla oblongata

Cranial nerve nuclei

1. Hypoglossal nucleus: The hypoglossal nucleus (Figs. 1,2,3; Plate 5) is a long nucleus in the camel measuring 25mm long and it is made up of prominent well stained neurons that are bigger than those of the dorsally placed motor nucleus of the vagus nerve. The hypoglossal nucleus is found in the caudal medulla oblongata ventral and medial to the vagal nucleus throughout its extent. It is found close to the median raphe within the ventricular grey. The neurons are mostly of the large motor type. The nucleus is subdivided into a ventromedial, dorsolateral, and ventrolateral parts but the subdivisions are not very distinct. The dorsolateral part persists throughout the nucleus and at caudal levels of the nucleus its neurons are adjoining those of the dorsal nucleus of the vagus nerve. The dorsolateral subdivision has more compactly arranged neurons. The neurons are mostly 30-60μm in diameter.

Nucleus of Roller ( )

This nucleus is poorly developed in the camel. It is found ventral to the hypoglossal nucleus represented only by very few neurons. The neurons are large motortype similar to those of the hypoglossal nucleus (about 50um). The nucleus appears to be a subdivision of the hypoglossal nucleus.

Nucleus intercalatus (Plate 5)

This is a sharply circumscribed nucleus of medium sized multipolar neurons (30-45um) similar to those of the vagal motor nucleus to which it is closely associated. It is interposed between the vagal and the hypoglossal nuclei.

Nucleus praepositus (Figs. 5,6; Plate 6,7)

The nucleus extends rostrally from the hypoglossal nucleus. It is bordered laterally by the rostral part of the dorsal vagal motor nucleus. It is related to the medial vestibular nucleus rostrally and caudally to the hypoglossal nucleus. It does not extend as far as the abducens nucleus in the camel. The nucleus is made up of small neurons (about 15um) and is not subdivided.

Nucleus interfascicularis hypoglossi

The nucleus is found ventromedial to the hypoglossal nucleus. The neurons are found surrounding the fibers of the hypoglossal nucleus as they exit from the hypoglossal nucleus. The neurons are also dispersed within the reticular formation around the exiting fibres of the hypoglossal nucleus.

Motor nucleus of the vagus nerve (Figs. 1,2,3,4; Plates 5,8,9)

This nucleus lies close to the fourth ventricle in its rostral half, rostral to the obex and lies much deeper caudally. The nucleus is bordered laterally in its rostral part by the solitary complex, ventrally by the hypoglossal nucleus and the nucleus intercalatus and dorsally by the fourth ventricle. This nucleus forms a slender column of neurons oriented mediolaterally and almost meeting at the midline. The nucleus is thicker and more roundish rostrally where it becomes more superficially placed. It is longer than the ventrally placed hypoglossal nucleus and extends rostrally and caudally beyond the hypoglossal nucleus. The nucleus is made up of small neurons (20-35um) in its caudal half and has an admixture of small (20-30um), medium (30-50um)

and large neurons (50-70um) rostrally. However, the neurons of this nucleus are smaller than those of the hypoglossal nucleus. Multipolar, spindle-shaped and oval neurons are found dispersed within the nucleus. The spindle-shaped neurons predominate and are arranged obliquely at caudal parts of the medulla oblongata but at rostral levels the multipolar neurons predominate.

Nucleus solitarius (Figs. 2,3,4; Plates 10,11)

The nucleus is divisible into three parts according to cell size and density, and according to their relation with the motor nucleus of the vagus nerve. The subdivisions are: commissural, medial and lateral. The commissural part is a condensation of very small (about 8um) neurons in the midline at caudal levels of the nucleus. The neurons in this part have a high packing density. The medial subdivision is much larger and extends through the length of the nucleus. It is placed dorsolateral to the dorsal nucleus of the vagus nerve and it is related medially to the nucleus gracilis and rostrally to the medial vestibular nucleus. It is also made up of small neurons (about 8um) similar to those of the commissural part but are less deeply stained. The

packing density of this subdivision is lower than that of the commissural part. The lateral subdivision is found in the caudal half of the nucleus related to the medial aspect of the tractus solitarius and it is represented by a few large motor type of neurons ventrolateral to the motor nucleus of the vagus nerve. The neurons are multipolar and measure between 50-90um.

Nucleus ambiguus (Figs. 3,4; Plates 12,13)

The nucleus is small, located in the lateral reticular formation caudal to the facial nucleus and rostral to the lateral reticular nucleus. It is well circumscribed with prominent motor type neurons similar to those of the facial nucleus. It is 4.3mm long and is found at the level of the rostral part of the motor nucleus of the vagus nerve. It is medial to the spinal tract and the nucleus of the trigeminal nerve. The neurons have various shapes, and sizes. They are mostly multipolar and measure about 35um in diameter.

The vestibular complex (Figs. 6,7,8,14,15)

The vestibular complex lies beneath the vestibular area of the rhomboid fossa and is 24um long. It is

made up of four nuclei: rostral, lateral, medial and caudal vestibular nuclei. The rostral vestibular nucleus (Fig. 8) is the smallest of the four [illegible] nuclei and it is located at caudal levels of the motor nucleus of the trigeminal nerve to which it is dorsolaterally placed. The rostral vestibular nucleus is 6mm long and it is made up of small neurons. The size of the neurons range from 10um to 35um in diameter. The fairly large neurons of about 35um in diameter are few. The neurons are round or oval in shape and are multipolar. The cell density in this nucleus is low. At its caudal part it is bordered ventromedially by the lateral vestibular nucleus. The rostral vestibular nucleus is not subdivided.

The lateral vestibular nucleus (Fig.7,8; Plate 15) at its rostral end is adjacent to the rostral vestibular nucleus to which it is medially and ventrally placed. The lateral vestibular nucleus is made up of large motor type neurons. Neurons as large as 80um in diameter are found in this nucleus. The neurons are variously shaped. They are fusiform and triangular. The nucleus is subdivided into two parts:- the dorsomedial and ventrolateral. The dorsomedial part is roundish and is more compact than the ventrolateral part. The subdivision is more obvious at rostral

levels of the nucleus. The ventrolateral subdivision is in the form of a lateral prolongation of the medial subdivision. Its neurons are oriented obliquely.

The caudal vestibular nucleus (Fig. 8), is smaller than the lateral vestibular nucleus and is placed lateral to the medial vestibular nucleus. It is difficult to separate it from the lateral vestibular nucleus since both nuclei are made up of very large neurons (80um) and are not distinctly separated from each other. It is also not subdivided.

The medial vestibular nucleus (Fig. 6; Plate 14) is large and is located in the ventricular grey. It is medial to the caudal half of the lateral vestibular nucleus and also to the caudal vestibular nucleus. It is made up of small neurons (15-30um) mainly but medium sized (30-50um) neurons are also found in this nucleus where it merges with the lateral vestibular nucleus. The large and medium sized cells decrease in number rostrocaudally. The medial vestibular nucleus is replaced caudally by the medial and lateral subdivisions of the nucleus solitarius.

Cochlear nuclei

There are two cochlear nuclei - ventral and dorsal. The dorsal cochlear nucleus (Fig.7; Plates 20,21) is in the pontomedullary junction caudal to the level of the facial nerve nucleus. It is found in the tegmentum lateral to the emerging fibres of the cochlear nerve. It is a compact collection of small roundish neurons evenly distributed throughout the nucleus. The neurons are 15um in diameter.

The ventral cochlear nucleus (Fig. 7) is found at the level of the facial nucleus. It is much bigger than the dorsal cochlear nucleus and is made up of large round neurons at the ventral part of the exiting fibres of the vestibulocochlear nerve. The neurons are about 35um in diameter.

Facial nucleus (Figs 5,6; Plate 16)

The nucleus is 12mm long and is made up of large motortype neurons. It is located in the lateral tegmentum rostral to the nucleus ambiguus and caudal to the motor nucleus of the trigeminal nerve. It is made up of prominent well stained multipolar neurons. Some small (20-30um) and medium sized (30-50um) neurons are also found among the large

neurons (50-90um). Most of the neurons are about 35µm in diameter. The nucleus is subdivided into a medial, dorsal, ventral and lateral part. The ventral part contains larger multipolar neurons, the dorsal part is small and is made up of medium sized, small and large neurons. The lateral part is loosely organised and contains medium and large neurons and the medial contains mainly small neurons (Plate17) with some medium sized and a few large neurons.

Abducens nucleus (Plate 18)

This nucleus is located at the pontomedually junction beneath the facial colliculus and lateral to the medial longitudinal fasciculus. It is caudal to the motor nucleus of the trigeminal at the level of the facial nucleus. It is a small nucleus composed of medium sized multipolar neurons (30-50um) widely dispersed by fibers. It is well circumscribed and is 2.8mm long.

The trigeminal complex (Plate)

The trigeminal complex is made up of a large sensory and smaller motor components. The sensory nuclei are three in number: the nucleus of the spinal

tract, the principal sensory nucleus and the mesencephalic sensory nucleus. The nucleus of the spinal tract is continuous with the gelatinous substance of the dorsal horn caudally and rostrally with the principal sensory nucleus.

Nucleus of spinal tract of trigeminal nerve (Figs 3,4,5)

The spinal nucleus of the trigeminal tract is located medial to the spinal tract of the trigeminal nerve. The neurons are mostly small (8-15um). At caudal levels the nucleus is made up exclusively of the very small neurons (8-15um). At more rostral levels especially at the level of the cuneate nucleus (i.e. the open part of the medulla oblongata) medium sized (30-50um) neurons are found in the nucleus. The rostral part contains small neurons (8-15um) also. The nucleus is therefore subdivided into caudal, medial and rostral parts called the subnucleus caudalis, subnucleus interpolaris and subnucleus oralis respectively.

The principal or main sensory nucleus (Fig. 6) of the trigeminal nerve is located lateral to the motor nucleus of the trigeminal nerve at the level of entrance of trigeminal fibres. It is made up of small (20-30um) and medium sized (30-40um) poorly stained neurons.

The mesencephalic nucleus (Figs. 9-16; Plate 19) the trigeminal nerve extends from rostral levels of the principal sensory nucleus caudally to the caudal diencephalon rostrally. It appears to be very well developed in the camel. The arrangement of its plump neurons varies at various levels of the nucleus. The neurons are most numerous at collicular levels. At the level of the oculomotor nucleus the cell density of the nucleus is high. At medullary levels the neurons are more compactly arranged than at collicular levels where they tend to aggregate in small groups bordering the ventricular grey. At caudal diencephalic regions, only few neurons were seen. They are large neurons measuring between 40-80um.

The motor nucleus (Fig. 7; Plates 22,23) of the trigeminal nerve is located at the pontomedullary junction. It is oval in shape and is oriented dorsoventrally. The nucleus is well circumscribed, made up of motortype neurons. The neurons range between 30-50um and are mostly triangular, multipolar and oval in shape. At its largest diameter the nucleus contains about 100 neurons. It is 8.6mm long and is subdivided into dorsal, intermediate and ventral parts.

Other Nuclei of the Medulla Oblongata

Nucleus cuneatus

The cuneate nucleus is 23mm long and is placed dorsolateral to the spinal tract of the trigeminal nerve. At rostral levels the nucleus forms a cap over the tract and three parts of the nucleus were identified in relation to the spinal tract of the trigeminal nerve. These are the dorsal, the lateral and the medial parts. The dorsal part (Fig.3,4) is placed over the spinal tract of the trigeminal nerve. The medial part is small and it is related to the spinal tract of the trigeminal nerve on its dorsomedial aspect. The lateral part (Fig. 3,4,5) is placed lateral to the spinal tract of the trigeminal nerve. The dorsal part is the largest of the three parts. The neurons are generally sparsely distributed and are found in small groups. They are predominantly medium sized neurons (30-50um) with some small (20-30um) neurons and a few large neurons interspersed (50-60um) among them. The neurons of the medial cuneate nucleus (Fig. 4), are smaller (20-30um) than those of the lateral cuneate nucleus. The medial cuneate nucleus extends more caudally than the lateral cuneate nucleus.

Nucleus gracilis (Fig. 1)

This is a small nucleus placed medial to the nucleus cuneatus at lower meduallary levels. It is made up of small neurons (20-30um) which are much smaller than those of the cuneate nucleus. This nucleus is very small in the camel.

Nucleus reticularis lateralis (Figs 1,2)

The nucleus reticularis lateralis is located in the ventrolateral tegmentum caudal to the nucleus ambiguus. The nucleus is well circumscribed, large and traversed by fibres. It is lateral to the olivary complex. It is made up of motortype neurons measuring 30-35um in diameter. The neurons are fusiform, oval and triangular in shape. Some of the fusiform neurons seen in the nucleus are as long as 60um. The nucleus is subdivided in its middle part into a dorsal, ventral and ventrolateral subgroup. The ventrolateral subgroup is the largest and contains more of the larger neurons (30-60um) than the dorsal and ventrolateral subgroups. The dorsal and ventrolateral subgroups are made up of small neurons (30um). The ventrolateral subgroup is present mainly in the middle part of the nucleus.

Nucleus locus coeruleus (Figs. 10,11,12; Plates 24,25)

This nucleus (L. c.) is found at the rostral edge of the facial colliculus where it adjoins the restiform body. It is medial to the mesencephalic nucleus of the trigeminal nerve. At its rostral levels it is poorly demarcated and is dispersed among fibres of the central tegmental tract. The nucleus is better organised in its caudal half where it is obliquely oriented medial to the mesencephalic nucleus of the trigeminal nerve. At caudal levels of the nucleus it becomes related dorsomedially to the motor nucleus of the trigeminal nerve. The neurons are dark staining and are essentially of the small type (20-35um). Some medium sized neurons (30-40um) and a few large neurons (50-60um) were found in the nucleus.

Nucleus gigantocellularis

This is a large nucleus (Fig.3-6; Plates 26,27) found in the medial tegmentum on both sides of the median raphe. The nucleus extends from caudal pontine levels to the rostral half of the medulla oblongata. In its rostral two-thirds, the nucleus is placed medial to the nucleus ambiguus. The inferior olivary nuclear complex is related to the [illegible]

to this nucleus on its ventral aspect. It is made up of large (50-90um), medium (30-50um) and small (20-30um) neurons. The neurons are multipolar fusiform, triangular and oval in shape. Many of the neurons are slender and elongated and oriented mediolaterally. Neurons as large as 90um in diameter are found in this nucleus. At caudal levels, a lateral extension of the nucleus covering the dorsolateral aspect of the inferior olivary complex is found.

Nucleus paragigantocellularis dorsalis (Fig. 6)

This is a differentiated part of the nucleus gigantocellularis at the level of the medial vestibular nucleus. It is located in the dorsal medial tegmentum and it is related to the nucleus gigantocellularis on its dorsomedial aspect. The neurons are multipolar cells exclusively (50-90um).

Nucleus paragigantocellularis lateralis (Fig. 6)

This nucleus is found in the lateral tegmentum as a lateral extension of the nucleus gigantocellularis. Its cells are irregularly dispersed and are similar to those of the nucleus gigantocellularis. The neurons are large (50-90um) medium sized (30-50um)

and small (20-30um). Most of the neurons are large and medium sized. The large neurons are fusiform and multipolar, the medium sized neurons are oval and triangular in shape [illegible] and the small neurons are oval in shape.

Nucleus parvocellularis

The dorsolateral tegmentum of the lower midbrain and upper pons contains small to medium sized cells (15-40um). These are widely dispersed among fibres of the reticular formation. The neurons are smaller than those of the nucleus gigantocellularis which is ventral to it. The nucleus is not very cellular in the camel.

Inferior olivary complex

The inferior olivary nuclear complex (Fig. 1-5) is made up of characteristically small (15-30um) round and oval neurons with large nuclei. In its rostral half, it is related dorsally to the nucleus gigantocellularis and medially to the median raphe. Laterally, it is related to the superior olivary nucleus. As in other mammals the olivary complex is made up of three nuclei: the principal inferior olivary nucleus, the medial accessory inferior olivary

nucleus and the dorsal accessory inferior olivary nucleus. Of the three nuclei the dorsal accessory inferior olivary nucleus is much the smallest.

The medial accessory olivary nucleus is very large in the camel, extending throughout the length of the nucleus. The principal olivary nucleus is only found in the rostral two-thirds of the nuclear complex. In the caudal two-thirds of the principal inferior olivary nucleus, it is laminated unevenly. Two laminae were identified; the ventral and dorsal laminae. The ventral lamina is thin and long while the dorsal lamina is thick and oval in shape. In some parts, the principal olivary nucleus is split into two. The neurons are all small (15-30um) and similar.

Nucleus of superior olive

The nucleus of the superior olive (Figs. 7,8) is a collection of small (15-20um) neurons situated ventrolaterally to the motor nucleus of the trigeminal nerve in its rostral part and medial to the facial nucleus in its caudal part. It is made up exclusively of small poorly stained neurons. Some fairly large (20-30um) neurons are placed lateral to main nucleus. This might constitute the lateral part of this nucleus.

Nucleus of the trapezoid body (Figs 7,8)

It is ventral to the motor nucleus of the trigeminal nerve and rostral to the facial nucleus. Medially it is related to the superior olivary nucleus. The nucleus is a small collection of motortype neurons (20-50um).

Nuclei lemnisci lateralis and dorsalis (Fig. 10-14)

These are two nuclei (dorsal and ventral) associated with the lateral lemniscus at the level of the inferior colliculus. The nuclei are located lateral to the lateral lemniscus. The ventral nucleus is the more prominent of the two and is made up medium sized neurons (30-50um) resembling those of the locus coeruleus which is also found at the samel level. The neurons are multipolar.

The dorsal nucleus is placed ventral to the restiform body and is dorsal to the ventral nucleus. The neurons are of the small type (about 10um) resembling those of the dorsally placed nucleus parabrachialis lateralis.

Part III: Pons (Fig. 9-14, Plates 28,29,30)

The pontine grey is located in the basilar portion of the pons as a densely populated cluster of neurons divided up by fibres of the corticospinal tract into medial, ventral and lateral parts. The medial part is subdivided into dorsal and ventral portions. The medial subdivision of both sides meet in the midline. The dorsal subdivision of the medial part contains motortype neurons (35um). Some of the neurons are found within fibres of the corticospinal tract. The lateral process of the pontine grey is also subdivided into a dorsal part made up of medium sized neurons (35um) and a ventral part made up of small neurons (10-20um).

The ventral portion of the pons is made up exclusively of small neurons (10-20um).

In the caudal half of the pons medium sized (30-50um) neurons are found dorsal to the corticospinal fibres (Fig.9,10) and the medial lemniscus forming the Supralemniscal parts of this nucleus. The neurons of the supralemniscal parts are well stained and prominent.

Nucleus papilliformis

The nucleus papilliformis (Figs. 10,11) found at pontine levels where it is dorsally related to the medial lamniscus, its neurons mixing with those of the supralemniscal part of the pontine grey. It is also related to the nucleus centralis superior subnucleus ventralis and ventrally to the medial projection of the pontine grey. The nucleus is very large and is made up mainly of medium sized (30-50um) motor type neurons. The neurons have various shapes but are mostly stellate and oval. The neurons mix with those of the pontine grey from which they are easily separated because of their large size. The nucleus is subdivided into dorsomedial and ventrolateral parts in its middle parts. The ventrolateral subdivision adjoins the supralemniscal part of the pontine grey. The medial subdivision is adjacent to the nucleus centralis superior subnucleus ventralis. It ends caudally at the pontomedullary junction. The nucleus is 11mm long.

Caudal to the nucleus papilliformis and much smaller is the satellite nucleus.(Its [illegible] neurons are similar to those of the nucleus papilliformis.

Nucleus pallidus (Fig. 6, Plate 31)

This is a midline nucleus in the medulla oblongata at the level of the nucleus gigantocellularis. The neurons intermix with those of the nucleus gigantocellularis that borders it laterally. The neurons are multipolar, fusiform and oval in shape. Some of them are oriented parallel to the median raphae. The neurons are medium sized (30-50um) and small (15-30um).

Nucleus raphe obscurus (Fig. 9, 10)

This is a small nucleus found adjoining the midline at the level of the nucleus papilliformis to which it is medial. At rostral levels of the nucleus its neurons intermix with those of the nucleus papilliformis but they can be differentiated easily because the neurons are smaller and stain less deeply. The neurons measure about 15um in diameter. The nucleus is dorsal to the medial lemniscus and the medial projection of the pontine grey. In the rostral half the nucleus is at first oval in the midline then it becomes elongated until in the caudal half it extends the length of the median raphe and becomes oblique. The nucleus diverges from the midline in the caudal half and its neurons are found

within the ventrolateral part of the medial longitudinal fasciculus. The part of the nucleus bordering the midline constitutes the nucleus raphe obscurus subnucleus intraraphales and the curved part outside the midline is the nucleus raphe obscurus subnucleus extraraphales. The two parts of the nucleus are continuous. The neurons are small (15-30um) with a few medium sized multipolar neurons (30-40um). The neurons are spindle shaped oriented parallel to the raphe. It is related to the rostral end of the nucleus prepositus hypoglossi to which it is lateral and separated from the latter by some fibres of the medial longitudinal fasiculus.

Nucleus paramedianus dorsalis

This nucleus is located in the dorsal midline at the level of the abducens nucleus medial to the medial longitudinal fasciculus. The nucleus is made up of small neurons (20-30um). The neurons are oval in shape with a few multipolar neurons interspersed between them. It is a small nucleus found on both sides of the median raphe.

Nucleus subtrigeminalis (Figs, 3,4)

It is a small nucleus and is found at the level of the abducens nucleus adjoining the medial edge of the tract and nucleus of the trigeminal nerve. It is lateral to the superior olivary nucleus and the nucleus of the trapezoid body in its rostral part and becomes related to the rostral part of the facial nucleus in its caudal part. Its neurons are small (about 20um) but are bigger than those of spinal nucleus of the trigeminal tract.

Nucleus arcuatus

It is very poorly represented in the camel by a small, roundish collection of neurons located within the corticospinal fibres below the medial accessory inferior olivary complex at the level of the rostral medulla oblongata. Some of the neurons of this nucleus are medium sized (30-50um) and some are small (20-30um).

Part IV: Midbrain (mesencephalon)

The midbrain in mammals is subdivided into the tectum, tegmentum, substantia nigra and crura cerebri.

The tectum is made up of the corpora quadrigemina made up rostral and caudal colliculi. The rostral colliculi are layered (Fig. 15, 16) four layers were identified. The outermost layer or stratum zonale is a thin fibrous layer. This is followed by a thick layer of dark staining neurons, the stratum cinereum. The neurons are small (about 10um in diameter) and densely packed (Plates 47,48). The third layer is a thick fibrous layer consisting of a more superficial thick fibres and a deeper layer of thin fibres. This layer has very few widely distributed neurons. The deepest layer forms the dorsal border of the central grey. This layer is both cellular and fibrous. The cellular density is lower than that of the stratum cinereum but the neurons in the stratum are larger. Small (10-30um) and medium sized neurons (30-50um) are found in this stratum.(Plate 49).

Caudal colliculi (Fig. 11, 12)

The caudal colliculi are covered by a thing layer of fibres. The core of the caudal colliculi is made up of homogeneously organised small (8-10um) neurons.

Red nucleus (Plates 32-37)

The red nucleus of the camel is 8.05mm long, 5.00mm wide and 3.70mm high. The reconstructed model of the nucleus revealed that it is oval in shape resembling an egg but with the medial face flattened and shows a projection a little rostral to the middle on its lateral face (Plate 34). The nucleus is located in the mesencephalic tegmentum at the level of the rostral colliculi ventrolateral to the oculomotor nucleus.

Five cell types were identified in the red nucleus of the camel namely: giant, large, medium, small and the very small cells. The giant and large neurons are multipolar with a prominent nucleus centrally located within the cytoplasm (Plate 36). A small dark nucleolus is also centrally located within the clear nucleus. The ratio of the nucleus to the cytoplasm in these neurons is low. The small cells are round,

oval or fusiform shaped with large centrally located nuclei. The ratio of the nucleus to the cytoplasm in the small cells is high. The medium sized cells are intermediate between the large and small cells. The fifth type - the very small cells are limited to the lateral horn of the nucleus. They are fusiform or oval in shape with a large nucleus and a poorly staining cytoplasm. The cells are categorised as follows:- giant cells (90um), large cells (50-89um), medium cells (30-49um), small cells (20-29um) and the very small cells have a diameter of about 14um.

The minimus (very small cells) are limited in distribution to the lateral horn (Plate 34) of the nucleus. All the other types of cells are intermingled throughout the nucleus i.e., small medium and large neurons could be found anywhere in the nucleus. Two portions of the nucleus were identified:- magnocellular and parvocellular portions (Fig. 37). The magnocellular portion made up of predominantly large neurons forms the caudal two-fifths of the nucleus. The rostral three-fifths is made up of predominantly small neurons known as the parvocellular portion. In the magnocellular portion of the number of small cells increases from

the caudal to the rostral part. The caudal most part has essentially large cells. The ratio of the large, medium and small cells in this region is 12:2.5:1. The number of small cells in the magnocellular portion keeps increasing till the ratio becomes 3:1:2 at the rostral tip of the magnocellular portion. The rostral three-fifths of the nucleus consists essentially of small cells and is easily differentiated from the magnocellular portion although no gap exists between the two portions. The ratio of the large, medium and small cells in the parvocellular portion in its full extent is 1:4:15.

The magnocellular portion of the red nucleus is not subdivided in the camel even though fibres of the oculomotor nucleus in their course ventrally pass through parts of this portion (Fig. 16, Plate 32,35). The parvocellular portion is subdivided into three subgroups (Plate 37):- ventrolateralis parvocellularis, dorsomedialis parvocellularis and the minimus forming the lateral horn. The ventrolateral subgroup consists of predominantly small cells. The dorsomedial subgroup is made up of large and medium sized cells only. Small cells were not found in this part of the nucleus.

Oculomotor nuclear complex (Figs. 15,16; Plates 38-41)

The oculomotor nuclear complex of the one humped camel is made up of two lateral columns one on either side of the median raphe, the Edingerwestphal nucleus and the caudal central nucleus. The lateral columns are located dorsal to the medial longitudinal fasciculus. The nucleus is placed ventral to the periaqueductal grey at the level of the rostral colliculi. Although the nucleus is not subdivided clearly, four parts of the nucleus were observed. These are the dorsal, the intermediate, the ventral and the medial portions. The dorsal portion occupies the region dorsomedial to the medial longitudinal fasciculus, the ventral and medial portions occupy the ventral and medial parts of the nucleus close to the median raphe. The intermediate part is more laterally placed. In transverse sections, the nucleus is seen as a triangular indentation above the medial longitudinal fasciculus. In horizontal sections the nucleus has an elongated oval shape with a fairly straight medial border and a convex lateral border. The length of the oculomotor nucleus is 2.4mm; the width is 0.7mm and the height is 1.1mm. The neurons are multipolar and are medium sized (30-45um). Small neurons (20-30um) are also found in the nucleus.

The Edinger-Westphal (Fig. 17, Plates 39, 41) nucleus is made up of predominantly fusiform neurons (15-50um) medial to the lateral column. This unpaired nucleus appears in the rostral third of the lateral column and extending rostrally beyond them. The rostral median nucleus described by some authors is not separated from the Edinger-Westphal nucleus in the camel. The neurons of the Edinger-Westphal nucleus are much smaller than those of the lateral colomn. They are fusiform, oval and roundish in transverse section. The fusiform neurons predominate.

The caudal central nucleus appears in the caudal third of the lateral columns. It is a small collection of neurons connecting the two lateral columns in their dorsal third. The neurons of this nucleus are much smaller (about 20um) than those of the lateral columns, and infact resemble those of the Edinger-Westphal nucleus, but are slightly bigger. This nucleus is poorly developed in the camel.

The trochlear nucleus (Plates 42, 43)

The nucleus is found at the level of the caudal colliculi. It is a discrete and short oval collection of neurons placed dorsally in the medial longitudinal fasciculus. The neurons of this nucleus are medium

sized (30-45um) and polygonal in shape similar to those of the lateral columns of the oculomotor nuclear complex. Medially, the nucleus is bounded by the dorsal nucleus of the raphe. The trochlear nucleus is well separated from the lateral columns of the oculomotor nucleus.

Caudal to the trochlear nucleus is an accessory trochlear nucleus which is a roundish collection of neurons similar to those of the trochlear nucleus. The accessory trochlear nucleus is present on both sides and is separated from the main nucleus by a gap.

The neurons of both the trochlear and the oculomotor nuclei are medium sized and multipolar similar to those of lower motor neurons. They measure between 20-45um ir size.

The substantia nigra

The substantia nigra (Figs 15-18; Plate 45) is a large nucleus extending from cranial pontine levels to the caudal diencephalon. The caudal third of the nucleus is an oval collection of neurons. It increases in size gradually becoming a thin lamina of grey matter dorsal to the cerebral peduncles. It then gradually enlarges dorsoventrally reaching

its full size at mid levels of the red nucleus. At this level the nucleus is very large and is oval in shape. At caudal levels the nucleus is related medially to the lateral extension of the pontine grey, separated from the latter by corticospinal fibres.

Rostrally, the nucleus is related medially to the ventral tegmental area of Tsai with which it intermingles, and laterally to the lateral geniculate body. There is no sharp demarcation between the medial edge of the substantia nigra and the neurons of the tegmental nucleus of Tsai.

The nucleus is subdivided into three parts:- pars compacta, pars reticulata and pars lateralis. Pars lateralis is the smallest and the most lateral of the three.

Pars lateralis (Fig. 18) is most prominent in the caudal part of the nucleus and its neurons (15-30um) are similar to those of the pars compacta with which it is continuous.

The pars reticulata is small in the camel. This part is ventral and ventromedial to the pars compacta. The pars reticulata contains small neurons similar to those of the pars compacta (15-30um).

The nucleus substantia nigra is composed essentially of the pars compacta. The pars compacta extends throughout the nucleus and is highly cellular. The pars compacta is subdivided clearly into α, β and Y parts. The α subdivision is the largest and extends throughout the nucleus. It is continuous with the pars lateralis. The B subdivision is dorsomedial to the α subdivision at caudal levels and becomes completely medial to it (α subdivision) at more rostral levels. The B subdivision is thick and its neurons are slightly smaller than those of the α subdivision. The neurons of this subdivision have a higher packing density than those of the α subdivision. The Y subdivision is made up of fairly scattered neurons dorsomedial to the B subdivision and is only limited to middle levels of the nucleus being separated from the B subdivision by fibres. The nucleus is unpigmented.

The neurons of the nucleus are generally of the small type, being about 15um in diameter. Some neurons of up to 25um in diameter are also found in the substantia nigra but they are few.

The nucleus at its rostral end is closely related to the subthalamic nucleus dorsally. The subthalamic nucleus lies dorsomedial to the substantia nigra at its most caudal part. The substantia nigra and the

subthalamic nuclues are easily differentiated because the neurons of the subthalamic nucleus are larger (about 30um) than those of the substantia nigra. Medially, at rostral levels the substantia nigra is related to the lateral mammillary nucleus.

Nucleus paranigralis (Ventral tegmental nucleus of Tsai) (Plate 46)

This nucleus is located medial to the substantia nigra as a collection of small neurons between the substantia nigra and the interpeduncular nucleus. The neurons are about 10um in diameter. At rostral levels of the midbrain the nucleus is much larger and its neurons adjoin those of the substantia nigra from which it is difficult to separate.

Interpeduncular nucleus (Fig. 15)

It is a large nucleus in the interpeduncular fossa extending from the rostral edge of the pons to mid levels of the rostral colliculi. It is made up of very small neurons (about 10um) which stain poorly, sand are distributed evenly within the nucleus.

Nucleus of Darkschewitsch (Fig. 17)

This is a small nucleus oriented dorsolaterally along the periaqueductal grey. The predominant neurons are small, elongated and are about 10um in diameter. The nucleus is found dorsal to the oculomotor nucleus at pretectal levels.

Interstitial nucleus of Cajal

The nucleus is made up of pale staining neurons scattered among the fibres of the central tegmental tract lateral to the nucleus of Darkschewitsch and dorsal to the red nucleus. The neurons are small to medium in size. The nucleus lacks sharp boundaries. At rostral levels of the red nucleus some neurons of the red nucleus are found among those of the interstitial nucleus of Cajal. The neurons of the interstitial nucleus of Cajal measure between 15-30um.

Laterodorsal nucleus

The nucleus is situated in the periaqueductal grey medial to the mesencephalic nucleus of the trigeminal nerve and dorsal to the nucleus locus coeruleus. It is lateral to the dorsal tegmental nucleus. The neurons resemble those of the locus

coeruleus. The nucleus extends beyond the locus coeruleus rostrally to the level of the accessory trochlear nucleus. Some medium sized neurons (30um) are found within the nucleus. The neurons are elongated, triangular, oval and fusiform.

Dorsal tegmental nucleus (Fig. 13)

This nucleus is medial to the laterodorsal nucleus at isthmus levels. It is composed of very small neurons (about 10um). The dorsal tegmental nucleus is replaced rostrally by the dorsal nucleus of the raphe. The nucleus is dorsal to the medial longitudinal fasiculus.

Ventral tegmental nucleus (Fig. 13)

The neurons of this nucleus are similar to those of the dorsal tegmental nucleus but the nucleus is small and indistinct. It is related to the superior central nucleus ventrally and the mediel longitudinal fasciculus laterally. Both the dorsal and the ventral tegmental nuclei are poorly developed in the camel.

Dorsal nucleus of the raphe (supratrochlear nucleus) (Figs. 14,15, Plates 42,44). This nucleus is prominent and well developed in the camel. It starts caudal to the trochlear nucleus and extends to caudal levels

of the oculomotor nucleus. Caudally, it is related ventrally to the medial longitudinal fasciculus and replaces the dorsal tegmental nucleus. The neurons are found in between the medial longitudinal fasciculus as well as above the medial longitudinal fasciculus. At trochlear levels where the nucleus is best developed it is made up of a cluster of well stained neurons dorsal and medial to the trochlear nucleus. It is made up of small and medium sized neurons. The neurons form a dense aggregation. They measure about 35um in diameter.

Nucleus sagulum (Fig. 14)

It is found at the lateral edge of the rostral pons and the midbrain. It is distinct and densely populated and is ventral to the brachium of the inferior colliculus. The neurons are triangular, fusiform and oval in shape and stain deeply. They are small in size (10-15um).

Nuclei parabrachialis medialis and lateralis

The two nuclei are separated from each other by the rostral cerebellar peduncle at rostral levels of the pons. The nucleus parabrachialis medialis is medial to the rostral cerebellar peduncle or the

brachium conjunctivum and it is related to the nucleus locus coeruleus and to the mesencephalic nucleus of the trigeminal nerve on its medial aspect. The nucleus parabrachialis lateralis is lateral to the rostral cerebellar peduncle and fills the space between the rostral cerebellar peduncle and the lateral edge of the tegmentum. The neurons of both the medial and the lateral nuclei are small (about 10um in diameter). The neurons are roundish, oval and elongated. They have large nuclei and small cytoplasm.

Pretectal nuclei

The pretectal area has the following nuclei: a) The posterior pretectal nucleus, b) Nucleus of the posterior commissure, e) nucleus of the optic tract, d) nucleus pretectalis medialis and e) principal nucleus of the pretectal area (nucleus sublentiformis).

The posterior pretectal nucleus (Fig. 17)

This nucleus is present throughout the pretectal area. It is the largest of the pretectal nuclei. In its full size, it is roundish. It is located lateral to the nucleus of the caudal commissure,

dorsomedial to the pulvinar and ventrolateral to the rostral colliculus in its caudal parts. Its neurons are poorly stained and small (15-30um).

Nucleus of the posterior commissure (Fig. 17)

This nucleus surrounds the lateral part of the caudal commissure. Ventrally, it is related to the central tegmental tract. This nucleus is prominent in the camel and is subdivided into two parts: a small-celled dorsal part and a ventral part containing larger neurons. A few large motortype neurons are found in this area. The neurons of the small celled part are about 10um in diameter and those of the ventral part contain more of the larger neurons (about 20um) in diameter among the small neurons (about 10um).

Nucleus of the optic tract (Fig. 17)

In the caudal pretectal area, this nucleus is located dorsal to the pulvinar and ventral to the rostral colliculus. Medially, it is bordered by the posterior pretectal nucleus. The nucleus is indistinct and is made up of scattered small neurons. Its neurons are smaller than those of the pulvinar and the posterior pretectal nucleus.

Nucleus pretectalis medialis (Fig. 17)

This nucleus is coextensive with the small celled nucleus of the posterior commissure. It is made up of a dense collection of very small neurons (10um) placed dorsal to the fibres of the posterior commissure. It is placed medial to the principal nucleus of the pretectal area.

Principal nucleus of the pretectal area/nucleus sublentiformis

The nucleus is medial to the pulvinar and dorsal to the posterior pretectal nucleus. It is dorsolateral to the nucleus of the caudal commissure. The nucleus lacks sharp boundaries and is made up of scattered deeply stained small neurons (10_30um in diameter).

Linear nucleus (Figs. 15,17)

This is a midline nucleus extending from rostral pons to caudal levels of the oculomotor nucleus and it is fairly well developed in the camel. It is located in the ventral half of the median raphe where it borders the interpeduncular nucleus dorsally. The nucleus is made up of small and medium sized neurons and is fairly compact in its caudal part.

Neurons of about 20um in diameter are evenly distributed in this area. The nucleus is subdivided into rostral, middle and caudal parts. The rostral part has small neurons at rostral midbrain levels. The middle portion is almost acellular at the level of the rostral colliculi. The caudal part has the largest cellular density and is rostrall to the superior central nucleus.

Nucleus peripeduncularis

This nucleus is poorly developed in the camel. It is represented by a few small faintly stained neurons at the lateral edge of the cerebral peduncle.

Nucleus cuneiformis and nucleus subcuneiformis (Fig. 14)

These nuclei extend throughout the extent of the midbrain. They are bounded medially by the preiaqueductal grey; laterally, by the medial lemniscus and dorsally, by the quadrigeminal bodies They constitute the lateral and dorsolateral mesencephalic tegmentum. Nucleus cuneiformis is more cellular and is made up of tiny neurons (about 10um) and glial cells. Nucleus subcuneiformis is less cellular and contains small (10-30um), medium (30-50um) and some large (50-70um) neurons widely dispersed among fibres.

Nucleus pedunculopontinus

This nucleus is located in the lateral tegmentum of the midbrain ventral to the nucleus subcuneiformis. The nucleus is dorsal to the substantia nigra. At the level of the red nucleus the nucleus becomes ventral and lateral to the red nucleus. At the level of the red nucleus the neurons intermix with those of the substantia nigra ventrally and also ventromedially with the neurons of the ventral tegmental area of Tsai. The neurons of this nucleus lateral to the red nucleus are more widely dispersed and contains more medium sized neurons (30-50um) than those ventral to the red nucleus. The nucleus pedunculopontinus is made up of small (15-30um) and medium sized neurons (30-50um). Caudal to the red nucleus and medial to the medial lemniscus there is a collection of medium sized neurons (about 35um in diameter) within the nucleus. This is dorsolaterally located within the nucleus and is known as nucleus pedunculopontinus subnucleus compactus.

Part V: The Diencephalon

The diencephalon is subdivided into: the dorsal thalamus, the metathalamus, the epithalamus, the subthalamus and the hypothalamus.

Dorsal thalamus

The dorsal thalamus is covered by a layer of white matter dorsally and laterally namely the stratum zonale and the external medullary lamina respectively. The thalamus is incompletely subdivided by a vertical sheet of white matter into three grey areas viz. the anterior, the lateral and the ventral from which five nuclear groups are differentiated as follows: anterior, medial, lateral, midline and ventral groups.

The anterior group of nuclei in the camel as in other mammals include: a) nucleus anterior dorsalis, b) nucleus anterior ventralis and c) nucleus anterior medialis. They are all found in the anterior tubercle of the thalamus.

The nucleus anterior dorsalis (Figs. 20,21) is the most dorsally placed of the three nuclei. It is crescent shaped forming the dorsomedial relation of the nucleus anterior ventralis. It is well

circumscribed and it is made up of dark staining small neurons of about 15um in diameter. It is situated beneath the lateral half of the stria medullares.

The nucleus anterior ventralis (Figs. 20,21) is the largest of the anterior nuclear group. It is related to the nucleus anterior dorsalis dorsomedially, to the paracentral nucleus ventrally, to the nucleus medialis dorsalis medially and to the nucleus ventralis anterior laterally. It is made up of faintly stained neurons of about 15um in diameter. The nucleus is oval in shape and is traversed by four bands of longitudinal fibres. The nucleus is not sharply demarcated from the paracentral nucleus in its rostral part but it is well demarcated from the nucleus anterior dorsalis dorsomedially and nucleus ventralis anterior ventrolaterally. The neurons are smaller than those of the paracentral nucleus. The nucleus is related dorsally to the nucleus lateralis dorsalis in its caudal parts. The nucleus is completely replaced caudally by the nucleus lateralis dorsalis.

Nucleus anterior medialis (Figs. 21,22). This nucleus is fairly well developed in the camel. It is related to the ventromedial aspect of the nucleus anterior ventralis to which it is joined. Dorsomedially,

it is related to the nucleus parataenialis and ventrolaterally to the nucleus ventralis anterior. It is replaced caudally by the nucleus paracentralis. It is bounded dorsomedially by the nucleus medialis dorsalis. The neurons are larger and more deeply stained than those of the nucleus anterior ventralis. It is obliquely elongated and ventromedial to the nucleus anterior ventralis.

Medial group

This group is made up of nuclei situated between the midline nuclei and the internal medullary lamina. In mammals they are made up of the following: nucleus medialis dorsalis, nucleus paracentralis, nucleus centralis lateralis, nucleus parafasicularis, nucleus centrum medianum, nucleus submedius and the nuclei habenulopeduncularis lateralis and habenulopeduncularis medialis. In the camel the nuclei habenulopeduncularis lateralis and medialis are not found.

Nucleus medialis dorsalis (Fig. 52)

The largest of the medial group of thalamic nuclei is the nucleus medialis dorsalis. The nucleus is large and prominent. It is bounded by the midline nuclei medially, nucleus centralis medialis ventrally,

by the paracentral nucleus laterally and ventrolaterally, and by the anterior group of nuclei dorsally. At caudal levels of the nucleus, it is bounded by the nucleus ventralis lateralis laterally and the nucleus lateralis intermedia dorsally. At such levels the demarcation of the nucleus is poor. Followed caudally, the nucleus centralis lateralis forms the dorsolateral boundary and the nuclei parafascularis and centrum medianum form the ventral boundary. Subdivisions of this nucleus into pars parvocellularis and pars magnocellularis are not distinct. The neurons are about 20um in diameter and are ovoid in shape.

Nucleus paracentralis (Fig. 20)

The nucleus is composed of deep staining neurons. It is an obliquely oriented lamina of grey matter and it is broken up by bundles of fibres into aggregates of neurons. It forms the lateral border of the nucleus medialis dorsalis and it is bounded ventrally by the nucleus ventralis anterior with which it is continuous. Ventromedially, it is related to the nucleus submedius. More caudally it is related to the nucleus ventralis lateralis ventrally and the nucleus lateralis dorsalis dorsally. The neurons are oriented along the direction of fibres

of internal medullary lamina. The neurons are small to medium sized and measure between 20-35um in diameter. Most of the neurons are oval in shape.

Nucleus parafascicularis (Fig. 19)

The neurons of this nucleus surround the habenulopeduncular tract. It is composed of deep staining neurons (20-30um). The nucleus is ventral to the caudal part of the nucleus medialis dorsalis from which it is not easily separated. The cellular density of this nucleus is high. The nucleus is related medially to the midline nuclei and ventrally to the centromedian nucleus from which it can be differentiated because of its bhigher cellular density.

Centromedian nucleus (Fig. 19)

This nucleus is separated from the surrounding nuclei by fibres except at its medial part where its neurons mix with those of the parafasicular nucleus. The nucleus is triangular in shape with its apex pointing laterally. The nucleus has a lower cellular density than those of the surrounding nuclei. It is related medially to the parafascicular nucleus, ventrally to the nucleus ventralis posterior and

and dorsally to the nucleus lateralis posterior. The neurons are roundish and oval in transverse section. They are about 20um in diameter.

Nucleus centralis medialis (Fig. 20)

This nucleus is made up of dark neurons [illegible] similar to those of the paracentral nucleus but it has a higher cellular density. It is related laterally to the paracentral nucleus with which it is continuous. Medially, it is related to the nucleus reuniens; dorsomedially, to the ventral parts of the nucleus medialis dorsalis and ventrally [illegible] to the nucleus ventralis lateralis. The neurons are more prominent and are more deeply stained than those of the nucleus medialis dorsalis and the nucleus ventralis lateralis. They are made up of small to medium sized neurons measuring between 15 and 35um in diameter.

Nucleus lateralis pars intermedia [illegible]

The nucleus lateralis pars intermedia replaces the nucleus lateralis dorsalis more caudally. This nucleus is larger than the nucleus lateralis pars dorsalis and it is replaced more caudally by the nucleus lateralis posterior. The nucleus lateralis

pars dorsalis is contiguous with the nucleus lateralis pars intermedia. The neurons are roundish with large nucleus and are about 20um in diameter.

Nucleus lateralis pars posterior (Figs. 17,18,19; Plate 14)

The nucleus begins at rostral collicular levels in the mesencephalic grey of the rostral midbrain. At more caudal levels the nucleus appears to be a medial projection of the medial geniculate body into the mesencephalic grey. In the caudal diencephalon the nucleus is separated from the pulvinar by fibres on the dorsolateral aspect. The nucleus is triangular in shape with the apex directed dorsally. The nucleus is related ventrally to the nucleus ventralis posterior. Medially, the nucleus adjoins the centrum medianum and the parafascicular nucleus. It is related to the nucleus medialis dorsalis medially, nucleus ventralis lateralis and the nucleus ventralis posterior ventrally and the optic radiation laterally. The neurons are similar to those of the nucleus parafascicularis and nucleus medialis dorsalis. The neurons are about 20mm in diameter. They are roundish and deeply stained.

The pulvinar (Figs. 17,18; Plate 52)

The pulvinar is found in the caudal diencephalon. It is a triangular strip of grey matter interposed between the nucleus lateralis posterior and the lateral geniculate body. At rostral levels of the midbrain the pulvinar is small and extends to the surface between the lateral geniculate body and the rostral colliculi. It increases in size in the caudal diencephalon. At rostral levels of the nucleus the ventral parts are replaced by the optic radiation fibres and is indistinctly separated from the nucleus lateralis posterior. The neurons are ovoid in shape measuring about 15um in diameter. At caudal levels the pulvinar is subdivided into 2 nuclei - pulvinar lateralis and medialis. The two subdivisions have similar neurons.

Ventral group of thalamic nuclei

The nucleus ventralis anterior: This nucleus is ventral to the nucleus paracentralis at rostral levels of the thalamus. It is bounded medially by the nucleus submedius with which it fuses. More caudally the nucleus increases in size and becomes related to the nucleus anterior ventralis. Caudal to the paracentral nucleus, the nucleus ventralis

anterior is related to the nucleus medialis dorsalis medially and the nucleus lateralis intermedia laterally. The neurons are small and measure between 15-20um in diameter. A few neurons of about 30um in diameter werelalso found in the nucleus.

Nucleus ventralis lateralis (Fig. 20)

The nucleus is dorsolateral to the nucleus ventralis anterior at its rostral levels. At caudal levels, it occpuies the dorsolateral parts of the nucleus ventralis anterior. The neurons of both nuclei intermix. The neurons are widely distributed within the nucleus being broken up by fibre bundles. The neurons are larger than those of the nucleus ventralis anterior. The nucleus ventralis lateralis replaces the nucleus ventralis anterior at caudal levels. The neurons measure 20 20-30um in diameter.

Nucleus ventralis posterior (Fig. 19)

This prominent nucleus is found in the caudal diencephalon at mammillary levels where it is the most ventral of the thalamic nuclei. It starts at the level of the caudal commissure as a round collection of neurons. At this level it is medial

to the medial geniculate body and it is ventral to the nucleus lateralis posterior. The nucleus gradually becomes oval and then elongated mediolaterally. It is bordered, ventrally by the thalamic fasciculus or the Forel's field H., It is separated by fibres from the dorsally placed nucleus lateralis pars posterior dorsolaterally and the centrum medianum dorsomedially. The nucleus is separated from the third ventricle by the parafascicular nucleus. Three subdivisions of the nucleus were distinguished: medial, middle and lateral. The medial and lateral subdivisions are small. The lateral subdivision is the smallest; it is oval in shape and reticulated. The neurons of the lateral part are deeply stained similar to those of the middle. The lateral subdivision is well separated by fibres. The medial subdivision is less densely populated than the middle and the neurons stain less deeply. There is a thin lamina of sparsely populated grey ventral to the middle part of the nucleus ventralis posterior. The neurons are deeply stained measuring about 20um in diameter.

Nucleus [illegible]

Nucleus reticularis thalami (Fig. 19)

This nucleus is found in the camel dorsolateral to the zona incerta with which it is continuous. The nucleus is ventromedial to the nucleus geniculate lateralis ventralis. The neurons are round and oval in shape oriented along the fibres of the external medullary lamina. They are small neurons (15-20um) with a few medium sized neurons distributed among the small neurons. The nucleus is fairly distinct in the camel.

Midline nuclear group -

Nucleus paraventricularis (Figs. 20-22)

It is a thin lamina of grey matter bordering the third ventricle. It is a long nucleus, elongated in a dorsoventral direction. The neurons are small (15-30um) and deeply stained and are variously shaped. They are triangular, fusiform and oval in shape and are oriented along the walls of the third ventricle. It is related dorsally to the nucleus parataenealis and ventrally to the nucleus rhomboidalis. The nucleus is found at the rostral levels of the thalamus.

Nucleus reuniens (Figs. 21,21)

It is the most ventrally placed of the midline nuclei. It is related dorsally to the nucleus centralis medialis and laterally to the nucleus submedius. It is made up of darkstaining neurons (15-30um) similar to those of the nucleus centralis medialis. The nucleus reuniens is related throughout its extent to the nucleus submedius laterally.

Nucleus parataenialis (Fig. 21)

This nucleus is small and inconspicuous and appears in the rostral thalamic region below the stria medullaris. It is circular in cross section and is related laterally to the nucleus anterior dorsalis; ventrally to the nucleus medialis dorsalis and ventromedially to the nucleus paraventricularis. The neurons (20-30um) are pale staining.

Nucleus rhomboidalis (Figs. 20,21)

It is small and indistinct and appears to be continuous with the nucleus paraventricularis with the neurons of which they intermix. It is related dorsally to the nucleus paraventricularis throughout its extent, laterally, it is bounded by the nucleus

medialis centralis. The neurons are round and stain fairly deeply. They are small neurons (about 20um).

Nucleus centralis medialis (Fig. 20)

It is a fairly circumscribed collection of deep staining neurons dorsal to the nucleus reuniens and ventral to the nucleus commissuralis interantero-medialis. It is related laterally first to the nucleus anteromedialis and later to the nucleus paracentralis. Its neurons (20-30um) are similar to (but less prominent than) those of the nucleus paracentralis which adjoins it laterally. It is related dorsally first to the nucleus rhomboidalis then to the nucleus interanteromedialis and more caudally to the nucleus medialis dorsalis.

Nucleus interanteromedialis

This nucleus is not distinct, but it is supposed to be dorsal to the nucleus centralis medialis and ventral to the nucleus rhomboidalis.

Nucleus submedius (Fig. 21)

The nucleus submedius at rostral levels of the thalamus is ventral to the nucleus centralis medialis and is lateral to the nucleus reuniens. It is related laterally to the nucleus ventralis anterior. It is a fairly large nucleus. It has a higher cellular density than the nucleus ventralis anterior. It is dorsolateral to the hypothalamic sulcus and is related dorsally to the nucleus centralis medialis. The nucleus submedius is continuous laterally with the nucleus ventralis anterior. The nucleus submedius is replaced caudally by the nucleus ventralis posterior medialis. The neurons (15-30um) are deeply stained and are slightly smaller than those of the nucleus centralis medialis and those of the nucleus ventralis anterior.

Subthalamic nucleus (Fig. 19)

The nucleus begins at the level of the tuberal region of the hypothalamus and extends to the mammillary region. It is, therefore, a small nucleus found only in the caudal diencephalon. It is related dorsally and dorsolaterally to the zona inserta. Laterally the neurons are not well separated from those of nucleus of the zona incerta. Medially, the

nucleus is bounded by the mammillary nuclei and ventrally it is intimately related to the rostral levels of the substantia nigra. The nucleus is lens shaped when best developed. The neurons measure between 15-25um in diameter.

Zona incerta (Figs. 18,19)

This is a wedgeshaped area in the diencephalon situated between the ventral nuclei of the thalamus dorsally and the subthalamic nucleus ventrally. Laterally, this area is thin and is continuous with the thalamic reticular nucleus and the ventral nucleus of the lateral geniculate body. Medially, the area is bounded by the posterior hypothalamic nucleus and the lateral mammillary nuclei. This area in its caudal part is made up of sparsely distributed neurons except on its lateral part where a condensation of neurons found dorsolateral to the subthalamic nucleus constitutes the nucleus of the zona incerta. This nucleus is small and its neurons are oriented along the direction of internal capsule fibres and lenticular fasciculus. The nucleus of the zona incerta is composed of fusiform neurons measuring 10-30um long but have a width of between 10-15um. They have large nuclei and small cytoplasm.

The metathalamus

Nucleus geniculatus medialis (Figs 16,17) - At its caudal part the nucleus is related to the cerebral peduncle ventrally and the rostral colliculi dorsally. At more rostral levels it is related dorsally to the lateral geniculate body. If forms a tubercle between the lateral geniculate body and the cerebral peduncle. The nucleus is related dorsomedially to the nucleus lateralis posterior and is not easily demarcated from the latter. The nucleus geniculatus medialis extends more caudally than the nucleus lateralis posterior. The rostral third of the nucleus is intimately related to the caudal part of the nucleus ventralis posterior. At these levels it becomes oval and lies lateral to the nucleus ventralis posterior lateralis. The nucleus geniculatus medialis is well circumscribed, homogenous and is made up of deeply stained neurons. It is made up of small neurons about 15um in diameter and have small deeply stained cytoplasm with small nucleoli. The neurons are triangular, oval and fusiform in shape.

Nucleus geniculatus lateralis (Figs. 17,18,19; Plates 50-5

This nucleus forms a large tubercle on the surface of the thalamus. The nucleus is domeshaped with the convex end of the nucleus directed outwards. At caudal levels, the lateral geniculate nucleus is bounded dorsomedially by the rostral colliculi and ventrally by the medial geniculate body. The medial boundary is formed by a band of neurons referred to as the pulvinar pars geniculata which are aggregates of deeply stained neurons. The lateral geniculate body is surrounded by a fibrous coat. The lateral geniculate body is separated from the nucleus lateralis posterior of the dorsal thalamus by the optic radiation. The nucleus is large and is made up of prominent, darkstaining neurons which are homogeneously distributed. At middle levels of the nucleus, a medial and a lateral part (lamina) of the nucleus were distinquished. The medial portion is highly cellular containing small (15-20um) neurons, smaller than those of the lateral part. The lateral lamina is much bigger and is made up of bigger homogenously distributed neurons (15-30um). At rostral levels, the medial portion of this nucleus is replaced by a thick band of fibres of the optic radiation. At this level the lateral part is commashaped, the dorsal part being much bigger than the ventral part.

Nucleus geniculatus lateralis pars ventralis

The nucleus is much smaller than the nucleus geniculatus lateralis pars dorsalis. At caudal levels this nucleus is lateral to the ventral extension of the nucleus geniculatus lateralis pars dorsalis. This nucleus is not subdivided. The neurons are similar to those of the nucleus geniculatus lateralis pars dorsalis.

Hypothalamus

The preoptic area connects the diencephalon with the telencephalon. The anterior hypothalamic area passes into the preoptic area without any demarcation in its rostral part. Ventrally, the area is bounded by the rostral part of the supraoptic nucleus, laterally, by the nucleus of the diagonal band of broca and dorsally, by the ventral part of the anterior commissure. This is made up of small neurons of about 12um in diameter and faintly stained.

Nucleus preopticus medialis (Figs.23,24)

The nucleus is dorsal to the nucleus preopticus principalis. It is related laterally to the internal capsule and medially, it is joined with the same

nucleus of the opposite side. The nucleus is made up of small neurons of about 12um in diameter. The neurons are roundish and oval in shape. They have a large nucleus and a small cytoplasm.

Nucleus preopticus principalis (Figs. 23,24)

It is ventral to the nucleus preopticus medialis. Laterally, it is related to the diagonal band of broca and ventrally, to the supraoptic nucleus and the optic decussation. The neurons are small about 12um in diameter in transverse section. It is larger than the nucleus preopticus medialis and the neurons have large nuclei.

Nucleus preopticus interstitialis

Lateral to the nucleus preopticus principalis and medial to the diagonal band of broca is an area made up of small elongated neurons. The cellular population in this area is low and the neurons are oriented obliquely. This area forms the nucleus preopticus interstitialis.

Nucleus preopticus periventricularis

The nucleus is in the periventricular grey in the preoptic area made up of darkstaining small neurons.

Nucleus supraopticus lateralis (Figs. 21,22; Plate 53)

This is a well developed nucleus in the camel It is a band of darkstaining neurons (10-30um) dorsal to the optic tract. It is found at rostral levels of the diencephalon.

Nucleus supraopticus medialis (Fig. 20)

The neurons of this nucleus are similar to those of the nucleus supraopticus lateralis. It is medial to the optic tract and caudal to the optic chiasma. It begins at caudal levels of the nucleus supraopticus lateralis and it is larger than the latter. The nucleus is an elongated band of highly concentrated deeply stained neurons (10-30um).

Nucleus paraventricularis (Fig. 21)

It is a vertically oriented nucleus in the paraventricular area of the rostral hypothalamus. It is elongated densely populated and is close to the third ventricle. The neurons stain deeply and resemble those of the supraoptic nucleus. They vary in size ranging from about 8um to 35um in diameter. Medium sized (30-50um) and large mototype neurons

(50-60um) are found in the nucleus. (Fig. 19)

Posterior hypothalamic nucleus

This nucleus is found in the posterior hypothalamus where it is dorsolateral to the supramammillary nucleus. It is formed as a condensation of small neurons (10-20um) lateral to the ventral part of the third ventricle. The neurons stain deeply. A few medium sized (30-40um) neurons are interspersed among the small neurons. This nucleus is bordered laterally by the zona incerta. It is related dorsally to the nucleus ventralis posterior. Small neurons predominate in the nucleus.

Medial mammillary nucleus (Fig. 19)

It is a fairly large nucleus in the caudal hypothalamic area. The neurons of this nucleus are very small and dustlike in appearance. The nucleus is single and homogeneous. The neurons are mostly oval or round in shape (8-15um). The nucleus is well demarcated by a capsule of fibres from the surrounding grey. It is bounded laterally by the lateral mammillary nuclei of both sides and dorsally by the supramammillary nucleus.

Nucleus mammillary lateralis

This nucleus surrounds the lateral aspect of the medial mammillary nucleus. It is smaller than the latter. It is made up of darkstaining neurons (15-30um) that are bigger than those of the medial mammillary nucleus. The nucleus is related medially to the medial mammillary nucleus, laterally to the cerebral peduncle and the subthalamic nucleus, dorsomedially to the posterior hypothalamic nucleus and dorsolaterally to the zona incerta.

Nucleus supramammillaris

The neurons of this nucleus are continuous medially with those of the nucleus supramammillaris. This is a thin nucleus placed dorsal to the nucleus mammillary medialia and connects the nucleus mammillary lateralis of both sides. The neurons are similar to those of nucleus mammillary lateralis (15-30um) and are deepstaining. It is related dorsally to the posterior hypothalamic nucleus, ventrally, to the medial hypothalamic nucleus and laterally to the nucleus mammillary lateralis.

Anterior hypothalamic nucleus (Fig. 23)

A condensation of small neurons (8um) in the anterior hypothalamic area is the anterior hypothalamic nucleus. This nucleus is fairly large in the camel.

Nucleus suprachiasmaticus (Fig. 22)

The nucleus is poorly developed in the camel. It is made up of tiny neurons (8um) appearing dustlike ventral to the rostral end of the nucleus hypothalamic paraventricularis at the medial edge of the hypothalamus.

Nucleus hypothalamicus dorsomedialis (Fig. 20)

This nucleus is located dorsomedial to the fornix in the dorsal hypothalamic area. It is not well separated from the neurons of the dorsal and lateral hypothalamic areas. It is continuous ventrally with the nucleus hypothalamicus ventromedialis from which it is easily separated . The neurons are very small (8?15um) and poorly stained.

Nucleus hypothalamicus ventromedialis (Fig. 20)

It is made up exclusively of tiny neurons (8um) in the middle hypothalamic area ventral to the nucleus hypothalamicus dorsomedialis. The neurons

of this nucleus are much smaller than those of the nucleus hypothalamucus dorsomedialis. Infact, it is made up exclusively of glia like cells.

Nucleus tuberalis

This nucleus is located lateral to the nucleus hypothalamicus ventromedialis at the ventral edge of the hypothalamus. It is roundish and is composed of deeply stained small neurons (8um). The neurons are similar, to those of the nucleus hypothalamicus ventromedialis.

Perifornical nucleus

The fornix is surrounded by deepstained neurons (10-20um) at caudal levels of the middle hypothalamus. These constitute the perifornical nucleus.

Lateral hypothalamic area (Fig. 20)

This area extends throughout the hypothalamus. It is best seen in the middle hypothalamic area. This area is made up of scattered medium sized (30-50um) and small (15-30um) neurons.

DISCUSSION

The diencephalon is considered in this thesis as part of the brainstem because it is the rostral continuation of the medulla oblongata, pons and the mesencephalon in the midline. It also retains the tubular structure of the neural tube. The diencephalon has been considered by some authors as part of the telecephalon because of its close relationship functionally and developmentally with the latter, since the diencephalon and the telencephalon develop from the prosencephalon. Therefore these authors consider the brainstem to include the medulla oblongata, pons and the midbrain. However some authors like Jenkins (1972) feel that the diencephalon is part of the brainstem.

The myelencephalon

The corpus trapezoideum forms the most rostral part of the medulla oblongata as has previously been mentioned. The corpus trapezoideum in the camel is a thin flat band measuring 0.5cm wide. It is so thin that it is almost inconspicuous but the pontomedullary junction which forms the cranial border of the corpus trapezoideum is conspicuous. The corpus trapezoideum is large relative to the pons

in lower mammals. In the wallaby the ratio of the craniocaudal extent of the pons to that of the corpus trapezoideum is 1:1; in the deer the ratio is 1.5:1, in the pig, sheep and giraffe the ratio is 2:1; in the Indian ox and the camel the ratio is 2.5:1 (Marsden and Rowland, 1965). The corpus trapezoideum progressively decreases in size relative to the pons in higher primates until in man the corpus trapezoideum is completely covered by the pons and is not visible on the ventral surface of the medulla oblongata (Marsden and Rowland, 1965).

The pyramids develop parallel to the cerebral hemispheres and the cerebellum, and, therefore, increase from lower mammals to man as one ascends the evolutionary ladder. This increase in size in primates is related to the increasing precision and finesse of motor activities in these animals (Marsden and Rowland, 1965). In most lower animals and in the camel, the pyramids are relatively small compared to the size of the brain. This may be correlated with the inability of these lower animals to perform skilled limb movements since precise motor coordination demands increased control of individual muscle activity by the central nervous system and this is exerted through pyramidal and extrapyramidal pathways, and through cerebellar activity (Marsden and Rowland, 1965).

The inferior olive was studied in a variety of mammals by Marsden and Rowland (1965) and was found to be highly developed in primates especially in man where it abuts from the ventral surface of the medulla oblongata lateral to the pyramids. The olive does not show on the camel brain as is the case with other members of the artiodactyla and this was thought to be related to the poor perfection of brachiation as a mode of locomotion since the inferior olive is well developed in primates where brachiation as a mode of locomotion is perfected (Marsden and Rowland, 1965).

Metencephalon

The pons has been studied in a large number of mammals by Marsden and Rowland (1965) who found that the pons increases progressively in size in craniocaudal extent and surface projection from lower mammals to higher mammals.

In the spiny anteater, the caudal border of the pons is straight but the rostral border is indented laterally by exceptionally large trigeminal nerves resulting in a tongue of pons projecting cranially between the nerves. In the wallaby, the cranial and caudal borders of the pons are regularly convex. The pons is separated from the corpus trapezoideum

by a horizontal groove from which emerges the trigeminal and facial nerves. In the domestic cat, the cranial border of the pons is clearly convex but the caudal border is slightly convex. The surface projects ventrally and is divided by a midline depression on either side of which are paramedian elevations. A well marked groove separates the caudal border of the pons from the trapezoid body. The trigeminal nerve and facial nerve emerge from this groove. Harper and Maser (1975) studied the pons in some members of the artiodactyla (Table 3). The following measurements of the width of the pons were given:- pig (1.83cm), domestic sheep (2.64cm), bighorned sheep (2.93cm), great horned cattle (4.63cm), European wisent (4.82cm) and the American plains buffalo (1.37cm).

In the macaque monkey the pons has remarkably increased in size compared to the other animals already mentioned. The cranial border is markedly convex on either side of a deep midline indentation and the paramedian elevations extend cranially to cover the crura cerebri. The surface projects ventrally and laterally. No groove separates the caudal border of the pons from the corpus trapezoideum and less than half of the pons is post trigeminal.

In man all the features of the pons are accentuated and so the pons reaches its highest development. The paramedian elevations are large, extending cranially to cover the crura cerebri and caudally to cover the pyramids. The trigeminal nerve emerges in such a way that two-thirds of the pons is post trigeminal (Marsden and Rowland, 1968). So in the primates and man where the pons is thus developed, the postpontine sulcus is obliterated and the pons grows to cover the corpus trapezoideum (Marsden and Rowland, 1965).

In the camel the pons is not well developed. The 1.5cm width of the pons in camel compares favourably with the width of the pons in the zebu cattle (1.4cm) and in the buffalo (1.4cm). The pons is smaller in the camel than in the pig, measure domestic sheep, bighorned sheep, where they 1.8cm, 2.6cm and 2.9cm respectively. It is very much smaller than in the greathorned cattle and the American Wisent where they measure 4.6cm and 4.8cm respectively (Table 3). The pons in the camel has inconspicuous paramedial elevations. The whole of pons is pre-trigeminal. All these characteristics of the pons in the camel show that the pons is poorly developed in this animal probably due to the small size of the corticopontocerebellar tract which is the major pathway involving the pons.

Mesencephalon

As previously mentioned, the rostral colliculi are in the visual pathway while the caudal colliculi form part of the auditory pathway. In most mammals, the caudal colliculi are smaller than the rostral colliculi; in some, the rostral and caudal colliculi are about equal in size while in others the caudal colliculi are bigger (Ariens-Kappers et al. 1960). The rostral colliculi are relatively smaller in mammals than in lower vertebrates because of the greatly developed thalamic optic centres in mammals (Ariens-Kappers et al. 1960). The rostral colliculi are much bigger than the caudal colliculi in the camel (Table 1) as in the horse and ox, but they are about equal in size in the dog and are smaller than the caudal colliculi in the pig (Getty, 1975). In the dog and especially in the pig, the sense of hearing is generally known to be acute; this may be related to the large caudal colliculi. The significance of development of the colliculi has been discussed (vide page 190, 156).

The crura cerebri, like the tegmentum dorsal to it, has increased relatively in mammals and becomes most developed in higher mammals. They carry the fibres between the cerebral cortex, the brainstem and the spinal cord. The extent of the cerebral

crura varies in different species in proportion to the development of cerebral hemispheres, being most well developed in man (Ariens-Kappers et al. 1960). The crura cerebri in the camel as in other mammals is well developed. Goldin (1931) studied the cerebral peduncles in ruminants, cats, dogs, primates and man and showed that in primates and especially in man the index of the proportion of the width to the length is high. It is less than 1 in the dolichomorphs and is greater than 1 in the brachymorphs. In lower animals as in the camel, the index is much less (0.8). Goldin (1931) related this to the development of the cerebral hemispheres pointing out that there is an increase in width and a decrease in length with the great development of the cerebral hemispheres.

Transverse crural tract, a thin fibre tract, divides the crural surface into two parts - rostral and caudal parts. The crural surface is subdivided longitudinally by furrows. In the ox and the horse the furrows subdivide the crural surface into three distinct fibre bundles; in the pig, the crural surface can be separated into a larger lateral and a small medial portions while in the dog the crural surface is subdivided by many longitudinal grooves (Getty, 1975). In the camel the crural surface is subdivided into lateral and medial portions like in

the pig but the lateral portion is smaller than the medial portion. The significance of these sub-divisions is not known. The transverse crural tracts are well developed in the canine (Getty, 1975) but are poorly developed in the camel. These tracts run from the medial geniculate body to the caudal colliculus and may be involved in the auditory pathway.

The diencephalon

The diencephalon consists of the epithalamus, the thalamus, the metathalamus, the hypothalamus and the subthalamus. The epithalamus in turn consists of the pineal gland, habenulae and the caudal commissure. One of the most remarkable features of the brainstem of the came is the large pineal gland measuring 6mm longitudinally, 8mm traversely and 6mm craniocaudally.

The pineal gland of the camel is comparable to that of man and the perissodactyla; it is larger than that of the dog and the pig but smaller than that of ox (Tilney, 1919). In man, (Tilney, 1919) the longitudinal diameter of the pineal gland as measured by various workers ranges between 5-12mm, the transverse diameter

between 3-8mm and the anteroposterior extent ranges between 2-5mm and the pineal gland weighs 0.22gm.

In the perissodactyla the pineal gland measures 8mm longitudinally, 6mm transversely and 6mm rostrocaudally; it weighs 0.44gm (Tilney, 1919). In the pig, the pineal gland measure 10mm longitudinally, 5mm transversely, 5mm rostracaudally and weighs 0.4gm (Tilney, 1919). In the dog it measures 1mm long (Getty, 1975) and weighs 0.08gm (Tilney, 1919). In the ox the pineal gland is very large, measuring 15mm longitudinally, 7mm transversely and 7mm rostrocaudally (Tilney, 1919). In mammals the form of the pineal gland varies considerably but in most cases it is coneshaped. (Tilney, 1919). The significance of such a large pineal gland as seen in the camel and the ox is not known. This may be related to its functions which are still controversial. More work is needed to explain the special gross features (morphological) of the pineal gland in the camel.

The function of the pineal gland is related to gonadal function (cf. Crosby et al, 1962). According to the authors pinealectomy stimulates gonadal hypertrophy, precocius opening of the

vagina and the lengthering of the estrus, while pineal extracts cause gonadal atrophy and the slowing down of vaginal opening. It has been reported (cf Leeson and Leeson, 1970) that melatonin a hormone present in the pineal gland of mammals caused the shortening of estrus and the loss of weight of ovaries. Pineal tumors in children (cf Leeson and Leeson, 1970) were associated with delayed puberty as a result of increased pineal activity.

The habenula is a small triangular mass located on the dorsomedial aspect of the thalamus rostral to the pineal gland. The habenula is poorly developed in the camel. The habenula is well developed in most primitive animals especially those that rely heavily on the sense of smell it is poorly developed in the animals that have poor olfactory sense (cf Sarnat and Netskey, 1974). The habenular is not well developed in camel and this may be correlated to the poor development of the olfactory bulbs in the brain of camel (Ghaji, 1980). Probably the sense of olfaction is poor in the camel.

The thalamus

The thalamus reaches the peak of its development in mammals and is progressively better developed in passing from lower to higher mammals and ultimately in man it is best developed (cf Ariens-Kappers et al., 1960). The thalamus in the camel is 1.48cm long (Table 3) compared to a length of 4cm in man (cf Warwick and Williams, 1973). The rostral tubercle of the thalamus in the camel is poorly developed as compared to man. The caudal end of the thalamus does not extend beyond the caudal commissural region while in man the caudal limit corresponds almost to that of the caudal colliculus (cf Ariens-Kappers et al., 1960). The greatly enlarged thalamus in mammals especially in man is an indication of the complexity of function of this structure in primates and man.

All sensory impulses, except those of olfaction, terminate in the thalamus from where they are relayed to specific areas of the cerebral cortex. In this way the thalamus is the chief integrating centre for the neuraxis. The thalamus is also concerned with the maintenance and regulation of states of consciousness, alertness, awareness and motor functions (cf Carpenter, 1972). The specific

sensory relay nuclei include: the medial and lateral geniculate bodies and the ventral posterior nucleus. The medial geniculate body receives fibres from the inferior colliculus and projects fibres to the transverse temporal gyrus of Heschl via the geniculotemporal radiation. The lateral geniculate body receives fibres through the optic tract and projects those fibres to the cortex surrounding the calcarine sulcus through the geniculocalcarine fibres or the optic radition. The ventral posterior nucleus project fibres to the post central gyrus (cf Carpenter, 1972).

The metathalamus

The metathalamus exhibits striking features. While the medial geniculate bodies are small, the lateral geniculate bodies are very large in general. The lateral geniculate bodies form part of the visual pathway along with the rostral colliculi both of which are very large in the camel (Table 2, Plate 3).

The hypothalamus

The mammillary body varies grossly in different mammals. In the ruminants, a round whitish elevation in the rostral parr of the intercrural fossa characterises the mammillary body. It is often subdivided into symmetrical halves which in large ruminants are visible only through a thin gray surface area (Getty, 1975). In the dog and man the mammillary body is paired while in the camel as in the pig and horse (Getty, 1975) it is one solid unpaired mass. Further work should be undertaken to know the significance of differences in the gross features of mammillary body.

Medulla oblongata and pons

The discussion of the medulla oblongata will be done in two parts. The cranial nerve nuclei will be discussed first, followed by the discussion of the nuclei other than those of the cranial nerve nuclei. The nuclei of the trigeminal, abducens, the facial, vestibulocochlear, glossopharyngeal, vagus, spinal accessory and the hypoglossal will be discussed here.

The trigeminal nuclear complex in the camel as in other mammals is made up sensory and motor nuclei. The sensory nuclei are: the spinal nucleus, the principal (main) nucleus and the mesencephalic nucleus. The spinal nucleus of the trigeminal nerve is subdivided into caudal, middle and rostral parts in the camel as in other mammals (Jenkins, 1972). These parts correspond to the subnucleus caudalis, subnucleus interpolaris and subnucleus rostralis. The caudal part of the subnucleus caudalis is not subdivided in the camel though it is reported to be subdivided into three parts in primates (Crosby, 1962) namely, the zonal, the gelatinous and the magnocellular parts. The principal nucleus of tne trigeminal nerve is continuous with the spinal nucleus without any sharp demarcation. The neurons just as in the spinal nucleus of the trigeminal nerve are

small. The principal (main) and the spinal nucleus of the trigeminal nerve are similar to those of other mammals. The motor nucleus of the trigeminal nerve is large in the camel and is made up of large motor type neurons. This nucleus gives out special visceral efferent axons which innervate the muscles of mastication (Jenkins, 1972). The well developed motor nucleus of the trigeminal may be related to the size of the muscle of mastication in the camel. A big animal like the camel is likely to have big muscles of mastication.

The abducens nucleus is small in the camel. The nucleus is not subdivided into a reticular and compact parts as is the case in the cat, dog, rabbit, goat and in the macaque monkey (Ariens-Kappers, 1960). The compact part in these animals contain large neurons. The nucleus in the camel corresponds to the reticular part of the nucleus in those animals mentioned above. The abducens nucleus in the camel is placed lateral to the medial longitudinal fasiculus. In carnivores and phocaena, the abdusens nucleus has a more medial position beside the medial longitudinal fasiculus (Ariens-Kapper, 1960). The laterodorsal position of this nucleus in camel and in some other animals, according to the above authors, is an indication of the importance of

connections between this nucleus and the vestibular nuclei.

The facial nerve nucleus in the camel is fairly large and is subdivided into medial and lateral parts. The facial nerve nucleus is not as differentiated as in the rat in which three to six subdivisions of this nucleus have been reported (Martin and Lodge, 1977). In the gorilla, Noback and Goss (1959) identified five subdivisions of this nucleus. According to Courville (1966) this nucleus is subdivided in all the animals studied so far but there are disagreements on the number of the subdivisions in the nucleus even in the same species of animals. Thus the facial nerve nucleus of the camel resembles that of other mammals,

The vestibulocochlear nerve is made up of two functionally different nerves; the vestibular and the cochlear nerves. Correspondingly there are the vestibular and cochlear nuclei. The vestibular nuclear complex of the camel is made up of the rostral vestibular nucleus, the lateral vestibular nucleus, the medial vestibular nucleus and the caudal vestibular nucleus as in other mammals (Brodal and Pompeiano, 1957, Noback and Goss, 1959). However, the small to

medium sized neurons at the lateral border of the lateral vestibular nucleus referred to as group 'L' in the cat was not found in the camel. Also the collection of fairly large neurons in the ventro-lateral part of the caudal vestibular nucleus referred to as group 'F' in the cat (Brodal and Pompeino, 1957) was not found in the camel. The rostral vestibular nucleus and the caudal vestibular nucleus are not subdivided in the present study in contrast to the report of Jastrzebski et al (1981) according to whom the rostral vestibular nucleus in the camel is subdivided into dorsal and ventral parts, and the caudal vestibular nucleus into two or three parts. The significance of these subdivisions is not known.

The cochlear nuclei are distinguished into dorsal and ventral parts in the camel as is the case in other mammals. The ventral cochlear nucleus is the larger of the two in the camel. It is undifferentiated into anterior and posterior parts as in the cat (Rose, 1960). The ventral nuclei of the rat is well developed, they are subdivided into four groups. The ventral cochlear nucleus is well developed in the chiroptera, rodents, and the carnivores (Ariens-Kappers et al. 1960). The dorsal cochlear nucleus is not well

developed in man as in some lower mammals, such as the guineapig, cat and the rabbit (Ariens-Kappers et al. 1960). The dorsal and ventral cochlear nuclei are not big in the camel as in the rodents, carnivores and the chiroptera. The poor development of the cochlear nuclei, the small size of the caudal colliculi and medial geniculate bodies, as well as the poorly developed nucleus of the the trapezoid body may indicate that the sense of hearing in the camel may be poor because all the nuclei mentioned above form parts of the auditory pathway.

Vagal nucleus

The motor nucleus of the vagus nerve is fairly large in the camel and is subdivided into a small celled region caudally and a rostral portior made up of an admixture of small, medium and large neurons. Strzalka and Flieger (1981) reported that the vagal nucleus of camel was subdivided into medial, median and lateral secondary groups. The same authors reported the length of this nucleus to be 126mm long in the camel as opposed to 33mm of the present study. The vagal nucleus appears to be subdivided in a rostrocaudal order in the rabbit (Getz and Sirnes, 1949) and in the monkey (Malone, 1913).

This nucleus is not subdivided in the rat (Contreras et al. 1980).

Nucleus solitarius

The nucleus solitarius in the camel is divisible into commissural, medial and lateral parts. These subdivisions agree with those of Carpenter (1972) but differs from the subdivisions reported for the gorilla by Noback and Goss (1959), according to whom there are four subdivions of this nucleus: dorsal sensory nucleus, ventral sensory nucleus, subnucleus gelatinosa and the commissural nucleus. The nucleus solitarius appears to be better developed in the gorilla than in the camel.

Nucleus ambiguus

The nucleus ambiguus is small in the camel. The nucleus is shorter in the camel (4.3mm) than in the gorilla (11mm) and in man 16mm (Noback and Goss, 1959). The significance of this variation in the nuclei of the vagus nerve needs to be studied more elaborately by physiological means.

The hypoglossal nucleus

The hypoglossal nucleus in the camel is subdivided into ventromedial, ventrolateral and dorsolateral parts as in the carnivore, Myrmecophaga jubata and Tamandua tetradactyla, primates and man. In these species of animals they are fairly well developed but in the ant-eater the nucleus is very large and well differentiated. This is correlated with the great length of the tongue in this species (cf Ariens-Kappers et al. 1960). The lack of sharp demarcation between the various subdivisions of this nucleus in the camel and the size of the nucleus in the camel could be attributed to the fact that the tongue in this animal is not very long.

The perihypoglossal nuclei

The perihypoglossal nuclei in the camel are poorly developed. The nucleus of Roller is poorly represented by only a few neurons; the nucleus prepositus is made up exclusively of small neurons. The only nucleus that is fairly well developed is the nucleus intercalatus. The nucleus of Roller in the camel is similar to that in the mouse, rat and shrew by not being distinct in these animals (Barnard, 1940). The nucleus of Roller appears to

be better developed in primates than in the sub-primates; it is well developed in monkey (Barnard, 1940) and it is better developed in the chimpanzee (Brodal, 1983). The nucleus intercalatus, on the other hand, is poorly developed in the monkey and the chimpanzee (Brodal, 1983) but it is well developed in the cat in which animal it fuses rostrally with the nucleus prepositus and ventrally with the nucleus of Roller at its rostral part (Brodal, 1952). The nucleus intercalatus is scarcely developed in the opossum (Brodal, 1952). The function of these perihypoglossal nuclei is still poorly understood and so it is difficult to relate the poor development of these nuclei in camel to any features in this animal.

The inferior olivary complex

The inferior olivary complex of the camel is made up of a principal inferior olivary nucleus, a medial accessory olivary nucleus and a dorsal accessory olivary nucleus as in man (Crosby et al. 1962) and other mammals (Bowman and Sladek, 1973; Martin et al. 1975). The inferior olive in the camel is not large enough to produce any prominence on the brainstem grossly, unlike in primates and man discussed earlier (vide ante page 40). The inferior

olivary complex is, therefore, not as large as those of primates and man. The lack of olivary prominence on the brainstem of the camel may be due to the fact that the principal inferior olivary nucleus is not big. According to Crosby et al (1962) the caudoventrolateral portion of the principal inferior olivary nucleus is ontogenetically and phylogenetically the newest part of the nucleus and lack of the usual olivary eminence on the brainstem is due to the poor development of the caudoventrolateral portion. According to Ariens-Kappers et al. 1960, the progressive development of the ventrolateral or main inferior olivary mass in mammals is accompanied by the development of the hemispheres of the cerebellum. Its increase in size according to the above author corresponds with an increase in connections with the cerebellum. It is concerned with carrying proprioceptive impulses from at least the upper regions of the body by way of the spino olivary and olivocerebellar paths (Ariens-Kappers et al. 1960).

According to Jenkins (1972), the majority of efferent fibres of the cerebellum are the olivo-cerebellar fibres. The cerebellum discharges to the motor centers of the spinal cord through the

cerebello-olivary and olivo-spinal fibres (Ariens-Kappers et al., 1960). The poor development of the principal (main) inferior olivary complex may be related to its poor connections with the cerebellum. According to Ariens-Kappers et al. (1960) the greater development of the principal inferior olivary nucleus in primates is a consequence of the finer regulation of the various movements of the extremities. The principal inferior olivary nucleus may be a relay centre for impulses essential to the complex muscular coordinations from the spinal cord and the brainstem to the neocorebellum (Ariens-Kappers et al. 1960).

The medial accessory inferior olivary nucleus is better developed than the principal inferior olivary nucleus in the camel. The medial accessory olivary nucleus is the largest of the three subdivisions in the rat (Goffinet, 1983). It is also reported to be well developed in mice (Goffinet, 1983). The medial accessory olivary nucleus is well developed in lower animals that are good swimmers due to the very great development of the trunk which is much larger than the hindquarters. This may account

for the well developed medial accessory inferior olivary nucleus. However, the dorsal accessory olivary nucleus is much better developed in the rat and the guinea pig than it is in the camel (vide ante page 3). In this regard it is simple to those of the opposum (Martin et al. 1973), cat (Walberg, 1956), monkey (Bowman and Sladek, 1973) and man (Olszewski and Baxter, 1954). The dorsal accessory inferior olivary nucleus does not fuse with the dorsal lamella of the principal inferior olivary nucleus in the camel as in the rat (Gwyn et al. 1977) neither does it fuse with the ventral lamella as in the cat (Walberg, 1956) or with both the ventral and the dorsal lamellae as in the pig (Breazile, 1967). The significance of these variations are to be investigated physiologically.

Nucleus gracilis

This is very small and inconspicuous in the camel. This nucleus is much smaller than nucleus cuneatus. The nucleus gracilis is composed of second order neuron of ascending axons from the dorsal root ganglia of spinal nerves of the same side (Jenkins, 1972). The nucleus is the terminal station of axons of the ipsilateral hindlimb and caudal body regions while the nucleus cuneatus is the termination of the

axons of the forelimb and upper body regions (Jenkins, 1972). In the gorilla (Noback, 1959a) the nucleus gracilis is large. The poorly developed nucleus gracilis in the camel may be related to the reduction of the number of afferent fibres from the hindlimbs and caudal body regions. There are probably more afferent fibres from the caudal body regions and the hindlimbs in the gorilla than in the camel.

Nucleus cuneatus

The nucleus cuneatus in the camel is much better developed than the nucleus gracilis. The nucleus is subdivided into three parts in the camel. In mammals, the nucleus cuneatus is subdivided into medial and lateral nuclei (Ariens-Kappers, 1960; Jenkins, 1972). The afferent fibres from the forelimbs and upper body regions terminate in the nucleus cuneatus. These afferent terminations from the upper body regions and the forelimbs may be more in the camel than afferents from hindlimbs and caudal body regions. The lateral cuneate nucleus is fairly well developed. The lateral cuneate nucleus gives rise to the dorsal external arcuate fibres to the cerebellum (Jenkins, 1972). The external arcuate fibres convey proprioceptive

impulses from cervical spinal nerves to the cerebellum.

The nuclei gracilis and cuneatus are well developed in carnivores, edentates and primates (Ariens-Kapper et al. 1960). In the Atelidae and the Cebidae they are so well developed that they cannot be easily separated from each other because they have grown into each other (Ariens-Kapper et al. 1960). The nuclei gracilis and cuneatus give rise to the internal arcuate fibres that cross to become the medial lemniscus which project to the ventral posterolateral nucleus of the thalamus. The ventral posterolateral nucleus of the thalamus in the camel is small, smaller than the ventral posteromedial nucleus which is the relay nucleus for afferent fibres from the head region. The ventral posterolateral nucleus is a relay centre for general somatic afferent exteroceptive and proprioceptive impulses from the body region (Jenkins, 1972). The large ventral posteromedial nucleus and the large trigeminal nerve of the camel compared with the small posterolateral nucleus of the thalamus and the small nucleus gracilis in this animal may show that the afferent fibres from the head region are more than those from the entire body region. Afferents from the long neck and the head region are

likely to be well developed in this animal because in the desert where the camel browses on trees and shrubs the head and the neck are most useful for this exercise and when the camel is resting the head and neck are usually held up in the air while the rest of the body lies on the ground.

Lateral reticular nucleus

This nucleus is large in the camel and contains large neurons, It is well circumscribed and contains a fairly compact collection of neurons. Also the nucleus is subdivided into three parts; dorsal, ventral and ventrolateral. The ventrolateral part is the largest and contains large neurons while the dorsal and ventral groups contain smaller neurons than those of the ventrolateral group. In the cat the lateral reticular nucleus is subdivided into a large-celled part and a small-celled part (Crosby et al. 1962). In the gorilla, according to Noback (1959b), the nucleus reticularis lateralis is subdivided by Olszewski and Baxter (1954) into subnucleus ventralis and subnucleus dorsalis. Berman (1968) subdivided the nucleus in the cat into internal, external and infratrigeminal parts. In

the rabbit and kitten Brodal (1948) subdivided the nucleus into magnocellular, parvocellular and subtrigeminal parts. In the opossum three subdivisions were also described: external, internal and trigeminal parts. (Andrezit et al. 1977). Species differences were associated with the relationship of this nucleus with the spinal tract of the trigerinal nerve (vide ante page 47), and so the subdivisions of this nucleus have been named taking into account this relationship. However, in the camel as in many animals (Taber, 1961; Petrovicky, 1966) the nucleus lies beneath the descending tract of the trigeminal. The subdivisions of this nucleus are therefore differently named from those of the cat and the opossum above.

The lateral reticular nucleus receives spinoreticular fibres which originate as far caudal as lumbosacral levels (cf Jenkins, 1972) which carry impulses of proprioceptive and tactile stimuli that are projected to the cerebellum (cf Crosby et al. 1962). The well developed lateral reticular nucleus in the camel may be as a result of a well developed spinoreticular pathway which may augment the poorly developed dorsal column sensory system in the camel especially the fasciculus and nucleus gracilis.

Pontine grey

The pontine grey of the camel is similar to that of the cat and rabbit (Brodal and Jansen, 1940); macaque monkey (Sunderland, 1940), and the human (Olszewski and Baxter, 1954). In these animals as in the camel the pontine grey is subdivided into medial, lateral, ventral and dorsal parts. The supralemniscal portion of the pontine grey in some animals (Mihailoff and King, 1975) and man (Olszewski and Baxter, 1954) was also distinguished in the camel.

The relay nuclei of the auditory system are poorly developed in the camel. These are the trapezoid nucleus; nucleus of the superior olive and the nucleus of the lateral lemniscus. The poorly developed relay nuclei and the small size of the caudal colliculi and the medial geniculate body may suggest that the auditory system of the camel is poorly developed. According to Ghaji (1983) there is no clearly defined first and second acoustic areas (A_I and A_{II}) in the camel cerebral hemisphere as described in the cats and monkeys nor is the area clearly defined as in some lower primates.

The degree of development of the nucleus subventricularis, nucleus paramedianus dorsalis, nucleus arcuatus and nucleus pararaphales is said to parallel the development of the stria medullaris in animals (Olszewski and Baxter, 1954). The brain of the camel like those of man and the gorilla (Noback, 1959b) has poorly developed nucleus arcuatus, nucleus paramedianus dorsalis and nucleus pararaphles and lacks stria medullares. This phylogenic trend of poor development in the camel needs further investigation.

Raphae nuclei

The medullary raphe nuclei include the nucleus raphae obscurus, nucleus raphae pallidus, nucleus raphae pontis, nucleus raphae medulla oblongata. These nuclei are similar in the camel to those of the gorilla described by Noback (1959b).

THE MIDBRAIN

The midbrain is made up of the tectum, the tegmentum, the substantia nigra and the cerebral crura. The tectum is made up of the quadrigeminal bodies (the paired rostral and caudal colliculi). The tegmentum is made up cranial nerve nuclei (trochlear and oculomotor nuclei) and the tegmental nuclei of which the red nucleus is most prominent. The rostral colliculi, the red nucleus, the trochlear and the oculomotor nuclear complex, substantia nigra and the pretectum show characteristic features in the camel and so these nuclei will be discussed in detail.

The tectum

The remarkable size of the rostral colliculi in the camel is the striking feature of the tectum in this animal. Histologically, the rostral colliculi in the camel is laminated as in other mammalian forms. According to Kanaseki and Sprague (1974) the lamination of the superior colliculus appears to be similar in all mammalian forms. In the camel four layers were identified in the rostral colliculus: layers I, II, III and IV. Layers I and II correspond to the stratum zonale and stratum griseum suferficiale

(Stratum cinereum) of most authors (Crosby, 1962; Getty, 1975).

These two layers appear to be less controversial than the remaining layers. Of the remaining layers Getty (1975) distinquished three layers, a superficial, middle and deep layers which is composed of fibres principally with some scattered neurons. The superficial and middle layers correspond to layer III in this work while the deep layer correspond to layer IV in this study. In the cat Kanaseki and Sprague (1974) differentiated seven layers (I - VII). Their laminae I and II correspond to laminae I and II in this work. Their lamina III and IV correspond to lamina III in this work and their lamina V, VI and VII correspond to lamina IV in this study. According to Crosby et al (1962) the stratum griseum superficiale is found only in mammals. In the camel this stratum is fairly well developed. In this study it appears that the stratum opticum and the stratum lemnisci of some authors are grouped together into lamina III although the stratum opticum could fairly be well differentiated since its fibres appear to be thicker than those of the underlying stratum lemnisci. The stratum opticum, according to Crosby et al (1962) receives fibres from the optic tract

while the stratum lemnisci receives its fibres mainly from the cortex.

The stratum opticum is reported to be notably reduced in primates and well developed in lower animals (Crosby et al. 1962). In the camel this layer is fairly distinct. The stratum lemnisci is the largest afferent system to the rostral colliculus in primates and man and it is concerned with the regulation of certain eye movements. Layer IV in this work appears to correspond to the deep grey and white layers of Crosby (1962). This layer could not be subdivided in the camel because it could not be easily differentiated into grey and white layers. This layer consists of the efferent fibres from the rostral colliculus (Crosby, 1962). The rostral colliculus is partly a visual reflex centre but it is largely a part of the pathway for indirect visual responses that are mediated through the cortex (Crosby et al 1962). Casagrande et al (1972) reported that the well developed rostral colliculus of the tree shrew plays an important part in pattern vision. According to the authors tree shrews discriminated between an inverted and an upright triangle even after total removal of area 17 (striate cortex). They also reported that shallow lesions of the rostral colliculus in the tree shrews resulted in normal cage behaviour in this

animals while deep lesions of the rostral colliculus caused more profound reactions; the animals sat motionless and appeared to be blind. The large rostral colliculi of the camel may aid in visual functions other than just visual reflexes. Since according to Slatter (1981) the visual cortex is not the sole area for interpretation of visual stimuli in domestic animals. According to the above author, in some animals (dog, cat) the rostral colliculus is believed to be an integrative centre for the more fundamental aspects of vision because when the visual cortex is removed from the dog light perception and discrimination of differences in intensity of light are retained unaltered, but familiarity of surroundings is lost and the animal moves cautionsly as if blind.

The function of the rostral colliculus is yet to be fully understood. Since the lateral geniculate bodies in the camel are poorly laminated (vide post page 215) it is likely that some of its functions (as those in primates and man) may be carried out by the well developed rostral colliculi.

Red nucleus

The red nucleus has been studied by numerous workers in various animals (Massion, 1967). The nucleus has been sharply defined by its central position in the mesencephalic tegmentum, its colour and its capsule which is formed by fibres of the brachium conjuntivum which surround and traverse it (Hinman and Carpenter, 1959). According to Hough and Wolff (1939) the peculiar colour of the red nucleus is due to its vascularity. This nucleus is the most striking feature of the midbrain of the camel. It is well circumscribed caudally but it is less so at its rostral end in the camel. One of the most conspicuous features of this nucleus is its large size. When fully formed it occupies most of the mesencephalon. Its size in the camel is 8.35mm long, 5.00mm wide and 3.7mm high (Table 4), when compared to the sizes of the red nucleus reported in literature (Table 4) it is found to be the largest ever reported among the artiodactyla. It is much bigger than that of the buffalo (Paily, 1975) and the pig (Otabe and Horowitz, 1970) which were reported as 5.88mm long, 2.86mm wide and 2.99mm high, and 6.09mm long, 3.66mm wide and 2.37mm high respectively. It is also much bigger than those of the primates and the cat (Table 4).

The nucleus is portioned into a magnocellular and parvocellular parts in the camel; the magnocellular part is made up essentially of large motor type neurons while the parvocellular part is made up predominantly of small neurons. This separation of the red nucleus into a caudal magnocellular and a rostral parvocellular part was also reported in the pig by Otabe and Horowitz (1970). According to the above authors the pars parvocellularis of the red nucleus occupied the rostral three-fifths of the red nucleus in the pig while the pars magnocellularis occupied the remaining two-fifths. The magnocelular part of the nucleus in this animal was reported to be composed of large, medium and small neurons (65% large, 28% medium and 7% small) according to Otabe and Horowitz (1970). The observations in the camel (Adogwa and Lakshminarasimhan (1982) and present study; and in the pig (Otabe and Horowitz, 1970) seem to contradict the view held in the review of the mammalian red nucleus by Massion (1967) that in ungulates the separation of the red nucleus into the parvocellular and magnocellular parts was not well defined. In most mammals, according to Massion (1967) the parvocellular part is well separated from the magnocellular part. However, in the cat Grofova and Marsala (1961) did not differentiate a

magnocellular portion from the parvocellular portion because all the four kinds of cellular types were represented in all parts of the nucleus. Nevertheless, the workers observed that 40% of the large neurons were confined to the caudal one-fourth of the nucleus. While the parvocellular part of the red nucleus is small in marsupials but has developed considerably in monkeys, apes and man the magnocellular part is poorly developed in anthropoids and especially in man, but is well developed from the marsupials to the monkeys in the evolutionary scale (Massion, 1967). Phylogenetically, the red nucleus in birds and reptiles is homogeneous and contains large cells only while in man the red nucleus is composed essentially of the parvocellular part. The evolutionary trend is, therefore, towards magnocellular regression and parvocellular prominence as is evidenced by the primate and human brains.

Subdivisions of the various parts of the nucleus in mammals have been reported although Grofova and Marsala (1961) were unable to subdivide the parts of the nucleus in the cat. In the rat (Reid et al 1975) distinguished a ventrolateral subgroup and a dorsomedial subgroup. In the pig (Otabe and Horowitz, 1970) delimited nucleus dorsolateralis and nucleus ventromedialis in the parvocellular part.

He also distinguished nucleus ventromedialis magnocellularis and nucleus dorsomedialis magnocellularis in addition to the nucleus cornualis. In the camel, in addition to a ventral subdivision (pars ventralis), a dorsomedial subdivision was also delimited in the magnocellular part, apart from the cornu lateralis. The nucleus ventralis in the camel may be synonymous with the nucleus ventrolateralis in the rat and the pig discussed above.

It was presumed that there were two major efferents from the red nucleus: rubrospinal and rubrothalamic. The rubrospinal fibres were presummed to originate from the magnocellular part of the nucleus while the rubrothalamic fibres originated from the parvocellular part of the nucleus (Massion, 1967). This subdivision was questioned earlier to Massion (1967) first by Preisig (1904), then by Brodal and Gogstad (1954) and by Pompeino and Brodal (1957), who demonstrated that cellular sizes and efferents were not linked and that there were rubrospinal neurons even in the parvocellular part of the nucleus. Conde and Conde (1980) have related the structure and size of the neurons in the red nucleus of the cat to their efferents. According to the authors the rubrospinal neurons which were star shaped were 36±14um in diameter and had numerous

dendrites. 85% of these neurons were found in the caudal two-thirds of the red nucleus. The rubrothalamic and rubroolivary neurons were 27±9um in diameter and 80% of these neurons were located in the rostral third of the nucleus. The rubrospinal fibres do not originate exclusively from the magnocellular portion of the nucleus.

The neurons of the red nucleus are very large in the camel. Most of them even the small ones, are larger than those of the surrounding nuclei. The neurons are larger than those of other animals (Table 4). Such larger neurons were reported by Macchi (1951) in the horse. The giant cells seen in the camel (91-100um) have not been reported in any other animal. Grofova and Marsala (1961) reported extraordinary large elements in the caudal pole of the nucleus in cat but they were 80 to 90um in diameter.

In the camel five cell types were found: giant, large, medium, small and very small. In the pig, Otabe and Horowitz (1970) distinguished four types of neurons: the large, medium, small and the minimus. In the rat, Reid et al (1975) identified giant, large, medium and small neurons and in the cat. Conde (1980) using Golgi-cox technique differentiated four types of neurons in the red

nucleus of the cat: types A, B, C, and D.

From the size and the large type of neurons in the red nucleus of the camel the nucleus could be said to be very greatly developed in this animal. The significance of the giant cells in camel is not known since no physiological studies have been made so far. They resemble the ventral horn motor neurons of the spinal cord and it is possible that they have rich and extensive synaptic connections similar to the spinal motor neurons. It is believed that, "The size of the neuron cell body generally reflects the amount of cytoplasm being supported in the cell processes" (Copenhaver et al 1971). Thus, according to the above authors the largest neuronal cell bodies are those with the longest and thickest axons. Moreover the connection of these neurons to the purkinje cells and the great size of the cerebellum among the artiodactyla may account for the great muscular coordination and control exercised by the cerebellum and extrapyramidal tracts through the greatly developed rubrospinal tract since the environment in which the camel walks is the desert or semi-desert area and the camel has to traverse large tracts of sandy soil.

The large red nucleus of the camel with its well developed magnocellular portion is likely to produce a well developed rubrospinal tract which is expected in an animal as large as the camel with long limbs. While the coricospinal tract is most concerned with voluntary, discrete and skilled movements in primates and man, the rubrospinal tract performs this function in other animals (Carpenter, 1972). In evolutionary terms the red nucleus in the camel with its well developed magnocellular portion differs significantly from those of higher primates and conforms to those of lower mammals that depend on the rubrospinal tract for muscle tone and coordination.

Even though the red nucleus has been studied in various animals the model of this nucleus as produced in this work has not been done for any animal (Plate 34). (Adogwa and Lakshminarasimhan, 1982). The model shows the features of the nucleus clearly. The nucleus is oval in shape with a broader rostral end and a caudal rounded and more pointed end. The lateral horn or cornu lateralis is prominently seen in the model (Plate 34).

Oculomotor and trochlear nuclei:

These are the only cranial nerve nuclei in the midbrain.

The oculomotor nuclear complex is similar to that of other mammals and has prominent lateral columns (made up of large motor type neurons), Edinger-Westphal nucleus and the caudal central nucleus. In the camel as in most mammals (Clark, 1926), the large celled element is divisible into the dorsal, medial, ventral and lateral parts even though, the demarcations are not sharp.

The caudal central nucleus of the camel differs from that described for man and the monkey (Ariens-Kappers, 1936 and Warwick, 1953), gorilla (Noback and Goss, 1959) in being poorly developed. It also lacks the central prolongation of its rostral pole - the central nucleus which extends dorsally between the two columns of the Edinger-Westphal nucleus in man. The neurons of the caudal central nucleus are small and resemble those of the Edinger-Westphal nucleus. The significance of this poor development in relation to function needs to be investigated.

The visceral nuclei of primates are very well developed consisting of two distinct nuclear groups that merge rostrally (Carpenter, 1978). According to Carpenter (1978), the Edinger-Westphal nucleus consists of two slender columns of small cells dorsal to the rostral three-fifths of the lateral columns, and the cells of the anterior median nucleus lie in the median raphe between the two lateral nuclei. The visceral nuclei in the camel are less well developed than those of primates. In the camel, the Edinger-Westphal nucleus is not separated from the anterior median nucleus. There is no part of the Edinger-Westphal nucleus in the camel that corresponds to the two slender columns dorsal to the rostral three-fifths of the lateral columns in primates. The significance of the poor development in the camel needs to be investigated physiologically. The oculomotor is made up of somatic and visceral portions i.e. the lateral somatic cell columns and the Edinger-Westphal nucleus. The somatic portion innervates the extrinsic eye muscles while the Edinger-Weshphal nucleus gives rise to preganglionic parasympathetic fibres that project to the ciliary ganglion.

The trochlear nucleus of the camel, like that of most mammals is a compact collection of neurons similar to those of the lateral columns of the oculomotor nucleus. The rostral pole of the trochlear nucleus is well separated from the caudal end of the oculomotor nucleus. This arrangement is different in some primates (Crosby, 1962; Warwick, 1973) where the trochlear nucleus forms

a caudal appendage of the oculomotor nucleus from which it is difficult to separate. As reported for man (Crosby, 1962) and the marmoset (Reis and Machado, 1981) an accessory trochlear nucleus was found in the camel. The separation or otherwise of the trochlear nucleus from the oculomotor nucleus has an evolutionary importance. In lower mammals (Ariens-Kappers, 1960) and in the human embryo a considerable distance exists as in the camel between the trochlear and the oculomotor nuclei. But in later stages of human development there is a tendency for the two nuclei to be joined together. The significance of this phylogenic trend is not clear and so needs further investigation.

The substantia nigra

As in other mammals this nucleus is subdivided into pars compacta, pars reticulata and pars lateralis. The pars lateralis is the smallest part of this nucleus in the camel as in man (Olszewski and Baxter, 1954) and the cat (Hanaway et al 1970). The pars lateralis is known to be the oldest part of the nucleus in lower animals and is the only part of the nucleus represented in submammalian forms (Crosby, 1962). The pars lateralis is reported to be poorly represented in mammals and least

developed in man in whom it is in significant (Warwick and Williams, 1973). Its poor development in the camel is, therefore, expected.

The pars compacta and the pars reticulata form the major portions of this nucleus in the camel as in other mammals. The pars reticulata is very small while the pars compacta is extensive in the camel being clearly subdivided into α, β and γ subdivisions as in man (Crosby, 1972). The substantia nigra in the camel is similar to those of the gorilla and man (Noback, 1959) in its general arrangement but may be different from those of the gorilla and man in the extensive development of its x subdivision of the pars compacta. According to Carpenter (1972) the substantia nigra is part of the extrapyramidal system and receives afferent fibres mainly from the caudate nucleus and putamen. The caudate nucleus projects to rostral parts of the substantia nigra while the putamen projects to all parts of the substantia nigra. According to Carpenter (1972) the substantia nigra projects to the striatum and to certain thalamic nuclei and nigrostriatal fibres appear to arise mainly from the large cells of the pars compacta. These cells synthesize and store catecholamines (dopamine, norepinephrine, and serotonin) from where they are transported to the

axon terminals in the striatum. In the camel the large cells of the pars compacta are the cells of the x subdivision (which is very large in the camel). The extrapyramidal system is more important in subprimates than the pyramidal system (Palmer, 1976). The large substantia nigra (especially the pars compacta) along with the exceptionally large red nucleus may indicate that the extrapyramidal system is well developed in this animal since both the red nucleus and the substantia nigra are parts of the extrapyramidal system. The camel is a very big animal and it traverses sandy soil; so the locomotor system is expected to be highly developed and brain centres of this system are also expected to be highly developed as is the case in the camel.

Pretectum

The pretectal nuclei of the camel are: Nucleus of the posterior pretectal area, nucleus pretectalis medialis, nucleus of the optic tract and possibly nucleus pretectalis anterior (principal pretectal nucleus of Carpenter and Pierson, 1973). Of these the nucleus of the posterior pretectal area is the largest. The others are ill defined. In the cat, Kanaseki and Sprague (1974) recognized seven nuclei:-

1. Nucleus pretectalis anterior pars compacta or

dorsalis. 2. Nucleus pretectalis anterior pars reticularis or ventralis. 3. Nucleus pretectalis medialis. 4. Nucleus pretectalis olivaris. 5. Nucleus pretectalis posterior. 6. Nucleus tractus opticus and 7. Nucleus pretectalis subopticus. Of these nuclei nucleus pretectalis olivaris, nucleus pretectalis subopticus were not identified in the camel. Nucleus pretectalis anterior is poorly defined in the camel and is, therefore, not subdivided in this animal. In the cat, according to these authors the nucleus of the optic tract is the best developed of the pretectal nuclei but this nucleus is ill defined in the camel. Although the nucleus pretectalis posterior is well developed in the cat, it is not as developed in this animal as in the camel. The pretectal area is less developed in the monkey. Carpenter and Sprague (1973) were able to distinguish only three nuclei in this area: nucleus of the optic tract, nucleus sublentiformis and nucleus of the pretectal area. The nucleus sublentiformis appears synonymous to the nucleus pretectalis anterior of Kanaseki and Sprague (1973). This nucleus is the largest in the monkey. The posterior pretectal nucleus was not seen in the monkey. (This nucleus is the largest nuclei of the pretectal nuclei in the camel). The pretectum may be less eleborate and possibly less

important in primates and man. Fibre analysis of the retinopretectal projections has shown that in higher primates there is a considerable reduction in the number of retinopretectal fibres. The functional significance of this phylogenic trend of development of the retinopretectal fibres needs physiological investigation.

Diencephalon

The diencephalon as mentioned earlier is subdivided into the epithalamus, the dorsal thalamus (usually referred to as thalamus), the metathalamus, subthalamus and the hypothalamus. The epithalamus comprises the pineal gland the habenular nuclei and the striae medullares (Carpenter, 1972). According to this author the pineal body does not contain true nerve cells and it is usually considered to be an endocrine gland. The epithalamus of camel resembles that of other mammals. The habenulae of the camel is made up of the medial and lateral habenular nuclei as in other mammals.

The thalamus is the most complex of the subdivisions of the diencephalon. The thalamus is subdivided by the internal medullary lamina into an outer and an inner part. This lamina bifurcates

to include within its branches the anterior nuclear group of the thalamus. The lateral part is subdivided into dorsal and ventral groups and a midline group is differentiated from the medial group. Accordingly there are five groups of thalamic nuclei.

The anterior nuclear group in the camel as in other mammals is made up of three distinct but small nuclei; nucleus anterior dorsalis, nucleus anterior ventralis and nucleus anterior medialis. The nucleus anterior ventralis and the nucleus anterior medialis are joined in the camel as in many other animals. The differentiation between the two nuclei is difficult in some animals although this is not the case in camel since the neurons of the nucleus anterior medialis are larger than those of the nucleus anterior ventralis. Some authors have subdivided the anterior nuclear group into an accessory anterior nuclear group and a principal anterior nuclear group because the nucleus anterior ventralis and the nucleus anterior medialis are usually joined (Le Gros Clark, 1930). The nucleus anterior dorsalis is particularly small in man consisting of scattered cell groups near the surface of the diencephalon (Ariens-Kappers, 1960). The nucleus anterior dorsalis shows enormous

proportions in the macroscelides (Le Gros Clark, 1929b). Kanagasuntheram (1970) reported that the nucleus anterior ventralis is subdivided in some lorisoids into a medial magnocellular and a lateral parvocellular portions. Apart from a few minor differences the anterior nuclear group of the thalamus appears to be fairly stable in most mammals. In primates the nucleus anterior ventralis is the largest of the three nuclei (Herbert, 1963). In the human thalamus the nucleus anterior dorsalis is very poorly developed. Toncray and Krieg (1946) were unable to find the nucleus anterior medialis in the human thalamus and Sheps (1945) found only traces of this nucleus in the human thalamus. The precise function of these nuclei (anterior group of thalamic nuclei) is yet to be fully worked out. This group of nuclei was thought to have an olfactory function (Le Gros Clark, 1949b) by early workers on the thalamus but more recent studies (Maclean, 1955) show that this group may be concerned in affective emotional responses rather than olfaction. However the poor development of the anterior group of nuclei in camel may be significant in relation to the poor sense of olfaction in this animal as is evident from its small ill developed olfactory bulbs.

The midline nuclear group in the camel is not very well developed. Of these nuclei, the nucleus paraventricularis is the best developed. The nuclei rhomboidalis, reunions and centralis medialis were fairly distinct. Others like the nucleus commissuralis interantermedialis, nucleus commissuralis interanterodorsalis and nucleus commissuralis interanteroventralis could not be delineated. The midline nuclei according to Ariens-Kappers et al (1960) are best developed in lower forms where there is extensive interthalamic adhesion. In higher mammals the amount of fusion between the thalami is decreased and consequently the midline nuclei have become vestigeal or have completely disappeared. It is possible that the thalamic adhesion in camel is decreased and the midline nucleus group is not well developed.

The medial nuclear group include: the nucleus medialis dorsalis, nucleus paracentralis, nucleus centralis lateralis, nucleus parafascicularis, centrum medianum, nucleus tractus habenulopeduncularis lateralis, nucleus tractus habenulopeduncularis medialis, nucleus parataenialis and the nucleus submedius.

The nuclei centromedianus, parafascicularis, paracentralis and centralis medialis are considered

by some authors (Crosby et al. 1962 and Carpenter, 1972) as members of the intralaminar group of thalamic nuclei because they are found within the internal medullary lamina which separates the medial from the lateral subdivisions of the thalamus. The above authors have, therefore, subdivided the medial group of thalamic nuclei into a medial group proper and an intralaminar group. Other authors (Warwick and Williams, 1973) with whom the author of this thesis is in agreement do not recognise the intralaminar nuclei as separate from the medial group of thalamic nucleus. The medial group of thalamic nuclei are not discrete in the camel because their boundaries are rather indistinct. Exceptions to this are the nucleus medialis dorsalis and the paracentral nucleus which are distinct in the camel. The neurons of these nuclei are large and well stained. The neurons of the paracentral nucleus stain much deeper than those of the surrounding nuclei. The nucleus medialis dorsalis is large but it is undifferentiated into magnocellular and parvocellular parts. This nucleus is similar in this regard to that of the anteaters (Kaelber, 1966) but differs from that of the dog (Rioch, 1929) and many primates (Olszewski, 1952). In the dog and in many primates definite parvocellular and magnocellular parts were

differentiated. In the ferret (Herbert, 1963) a lateral small part and a medial large celled smaller part were identified. In the lorisoids Kanagasuntheram (1968) reported a small lateral parvocellular and a larger medial magnocellular portions. The small celled element becomes progressively more conspicuous in higher primates (Le Gros Clark, 1930). The nucleus dorsomedialis is a way station between the hypothalamic centres and the prefrontal cortex in primates and man. This nucleus in camel is undifferentiated into magno and parvocellular portions as in other mammals (e.g. dog, primate and man). This is probably reflected in the poor affective tone (poor anatomic substrata for emotional experiences) in the camel in correlation with the poorly developed prefrontal cortex.

The nucleus centralis lateralis is not found in the thalamus of the camel. This nucleus which is the lateral projection of the nucleus paracentralis is very well developed in the anteaters (Tamandua and Myrmecephaga) and in the dog and cat but is reduced in primates (Kaelber, 1966).

The nucleus centrum medianum is poorly developed in the camel. It is not distinct and its neurons have a lower density than those of the surrounding nuclei. In the ferret unlike in the camel, the

nucleus is larger than any other nucleus of the medial group except the nucleus medialis dorsalis (Herbert, 1963). This nucleus is well developed in primates. The nucleus according to Crosby (1962) is represented in carnivores by a mere cluster of neurons while in primates especially in anthropoids and man it is developed into a conspicuous mass (Crosby et al 1962). In these animals where it is well developed, according to the above author, it is subdivided into a more lateral small-celled portion and a medial large celled part.

The nuclei tractus habenulopeduncularis medialis and lateralis were not found in the camel.

Many differences in the terminiology have grown up over the years with respect to the ventral group of thalamic nuclei. A review of these terminologies is given by Crosby et al (1962). The terminologies used by this author are those of Olszewski (1952) according to which the ventral group of thalamic nuclei is subdivided into nucleus ventralis anterior; nucleus ventralis lateralis and nucleus ventralis posterior.

The most remarkable part of the dorsal thalamus in the camel is the nucleus ventralis posterior.

This nucleus is very large and is made up of the nucleus ventralis posterior medialis and nucleus ventralis posterior lateralis. The nucleus ventralis posterior medialis is bigger than the nucleus ventralis posterior lateralis. The nucleus ventralis posteromedialis is subdivided into a lateral and a medial part. The lateral part of this nucleus is prominent and persists throughout the extent of the nucleus. The large nucleus ventralis posteromedialis was also observed by Kanagasuntheram et al (1970) in the camel. These authors have correlated the large size of the nucleus ventralis posteromedialis with the large trigeminal nerves in the camel. According to Kanagasuntheram et al (1970) a similar finding has been reported by Le Gros Clark (1932) in ornithorynchus and by Rose and Mountcastle (1952) in the rabbit. In the lorisoids (Kanagasuntheram, 1970), the nucleus ventralis posterolateralis is the larger of the two nuclei. This seems to be the case in most mammals (Crosby et al, 1962) and also in the camel(present study).

The lateral group of thalamic nuclei is fairly well developed in the camel. The most prominent of the lateral group in the camel are the nucleus lateralis posterior and the pulvinar. The pulvinar in primates is remarkably large. This nucleus in the

rhesus monkey is well developed and is divisible into medial, lateral and caudal portions (Ariens-Kappers et al 1960). According to Crosby et al (1962) it is well developed only in the highest mammals though it is present in subprimate forms. It consists of several nuclear masses in man (Crosby et al 1962).

The metathalamus of the camel shows some interesting features. The lateral geniculate body is very large and is made of a dorsal and ventral nucleus. Kanagasuntheram et al (1970) also observed the remarkable development of the lateral geniculate body and related it to the large size of the optic nerves. These authors also observed that the lateral geniculate body of the camel was bigger than those of sheep and the pig in which the dorsal nucleus was confined only to the dorsolateral corner of the thalamus. The dorsal nucleus is laminated in primates and six layers were identified (Glickstein, 1967; Kanagasuntheram, 1968) while this nucleus is poorly laminated in lower forms as reviewed in the literature.(vide ~~ante page 67~~). These layers ~~named~~ from inside outwards, are distinguished into a magnocellular and parvocellular portions, layers 1 and 2 are magnocellular while the remaining layers are parvocellular (Jones, 1966). Functionally, the lamination

is correlated with the level of the decussation of optic fibres. Crossed fibres of the optic tract distribute to layers 1, 4 and 6 while uncrossed fibres terminate in layers 2, 3 and 5 (Minkowski, 1920; Hubel and Wiesel, 1979). According to Crosby (1962) approximately 60 percent of the retinal fibres were crossed and 40 percent uncrossed to the large-celled laminae. In the lower mammals in most cases three layers were found (Szteyn, 1967).

In the mole in which the optic nerves are very minute the lateral geniculate nucleus is represented only by a tiny cluster of cells. In the camel this structure displayed a very peculiar organisation. The lamination of this structure is poor even though the nucleus is large. Only two layers could be distinguished in this animal. The third layer mentioned by Kanagasuntheram (1970) is indistinct. Since lamination of this structure is correlated with the level of optic decussation, the level of optic decussation in the camel may be low. According to Carpenter (1972), phylogenetically, the nucleus first differentiates into three cell layers and becomes six layered in forms where the optic tracts show a partial decussation.

According to Slatter (1981) the visual cortex is not the sole area for interpretation of visual stimuli in domestic animals. According to the above author, in some animals (dog, cat) the superior colliculus is believed to be an integrative center for the more fundamental aspects of vision because when the visual cortex is removed from the dog light perception and discrimination of differences in intensity of light are retained, unaltered, but familiarity of surroundings is lost and the animal moves cautiously as if blind. Based on the reports of Slatter (1981) and the findings of the present study one could say that the camel may have good visual reflexes. It may be concluded that the metathalamus is well developed in the camel but poorly laminated (histologically) and since in the desert environment there is no imminent danger from other animals as in the forest environment, may be the visual function is not so acute as is evident from the comparatively poorly developed striate cortex (area 17) (Ghaji, 1983) and the poorly laminated lateral geniculate bodies. This would also corroborate against the presummed acute vision (McKnight, 1969) in the camel. This finding is not in conformity with the observation of Mcknight (1969)

according to whom the camel has acute sense of vision. However, the visual reflexes that are necesary for motor coordination of the camel in the desert sandy soil may be better developed as is evident from the large size of the lateral geniculate body and the rostral colliculi.

The ventral nucleus of the lateral geniculate body was studied in some mammals by Niimi et al (1963) and the following discussion is based on their studies. According to the authors the ventral nucleus of the lateral geniculate body is poorly developed in lower mammals, reaches its highest peak of phylogentic development in ungulates and becomes reduced as the mammalian scale is ascended. This nucleus is very poorly developed in the camel being much smaller than the dorsal part of the lateral geniculate body and is not differentiated into internal and external layers as in the cow where the nucleus is best developed showing internal and external layers. The external layer is subdivided into a medial dense celled and a lateral loose celled sublayers. The internal layer is also well developed and is subdivided into pars dorsalis and pars ventralis. The ventral nucleus of primates is the least developed among the mammals studied by Niimi et al (1963) and consisted largely of the internal layer which fuses

medially with the zona incerta. In the carnivores the nucleus is less developed than in ungulates but and the internal layer is also subdivided into dorsal and ventral parts. In lower mammals the ventral nucleus is also poorly developed but it is composed of internal and external layers. In the bat and mouse it is poorly differentiated but in the mouse the internal layer is differentiated into dorsal and ventral parts. Since the nucleus is poorly developed in lower mammals and in the primates, it is difficult to say whether the poorly developed ventral nucleus of the lateral geniculate in the camel is a progressive or regressive development phylogenetically.

The hypothalamus

The hypothalamus forms the most ventral part of the diencephalon. It is divided into right and left halves by the third ventricle and it is demarcated from the dorsal thalamus by the hypothalamic sulcus. Rostrally, the hypothalamus is continuous with the preoptic area. Four levels of the hypothalamus were distinguished by Crosby et al (1962). They are, the mammillary level, tuberal level, infundibular level and the supraoptic level. Carpenter (1972) subdivided

the hypothalamus into: supraoptic region, tuberal region and the mammillary region. Carpenter's subdivision of the hypothalamus is followed in this thesis. A sagittal line passing through the anterior pillar of the fornix according to Carpenter (1972) separates the hypothalamus into lateral and medial hypothalamic areas. According to Ingram (1940) there is a remarkable similarity of the nuclear structure in the hypothalamic region of all mammals. The hypothalamic nuclei in the camel conform to those described for other animals except for a few minor differences. The most remarkable feature of the supraoptic region in the camel are the prominent supraoptic and the paraventricular nuclei. The supraoptic nucleus is very well developed consisting of prominent medial and lateral supraoptic nuclei and the paraventricular nucleus is subdivided into dorsal and ventral parts. The nuclei are well developed in anteaters like Tamandua tetradactyla and Myrmecophaga jubata (Kaelber, 1966). The paraventricular nucleus and the supraoptic nuclei have neurosecretory function. They are believed to elaborate neurosecretory substance which could be stained by Gomori's chrome alum hematoxylin or aldehyde fuchsin (Crosby et al 1962). These neurosecretory materials believed to be oxytocin and vasopressin are transported down the hypothalamo-hypophyseal tract into the pars

nervosa of the hypophysis. The paraventricular nucleus is concerned with the production of oxytocin while the supraoptic nucleus is concerned with the secretion of the antidiuretic hormone. According to Crosby et al (1962) destruction of the supraoptic nucleus and its fibres causes increased thirst while lesions in the ventromedial nuclei causes hypodipsia with increased concentration of serum sodium. The lateral hypothalamic nucleus when stimulated, according to the authors elicits polydipsia. In the regulation of water intake therefore, the lateral hypothalamic area and the ventromedial thalamic nucleus function antagonistically to the supraoptic nucleus (Crosby et al 1962). The well developed supraoptic nuclei in the camel may help in the remarkable water balance in this animal. As reviewed in the literature the camel survives well in dry and arid land with little water. Infact it can survive for days without water, a feat that many animals cannot perform. The strikingly well developed supraoptic and paraventricular nuclei in the camel were also reported by Kanagasumtheram (1970).

In the tuberal region of the hypothalamus in the camel the nucleus dorsomedialis hypothalamicus and the nucleus ventromedialis hypothalamucus were found as in other mammals to be indistinctly separated from

each other. However, the nucleus hypothalamicus dorsomedialis contains larger neurons than the nucleus hypothalamicus which is made up exclusively of small glia like neurons and is indistinct. Therefore the nucleus hypothalamicus dorsomedialis of the camel is more prominent than the nucleus hypothalamicus ventromedialis on account of its larger cells. This view contradicts that of Kanagasumtheram et al (1970) according to whom the nucleus hypothalamicus ventromedialis of the camel is extremely large and produces a ventral swelling projecting beyond the surface of the remainder of the middle hypothalamic region. According to Ingram (1940) the nucleus hypothalamic ventromedialis is conspicuous in the monkey but less conspicuous in man. The nucleus is also reported to be prominent in both Galago and Slow Loris by Kanagasuntheram et al (1968). Kaelber (1966) reported the nucleus to be poorly developed in Tamandua and said that the poor development of this nucleus in the animal might reflect the relative docility and phlegmantic nature of this animal. However, according to Ingram (1952) destructive lesions in the ventromedial hypothalamic nucleus changed a formerly tame, gentle cat into a growling, hissing, unfriendly animal an observation which Kanagasuntheram et al (1968) have extended to explain the well developed ventromedial nucleus in the

lorisoids. The poorly developed ventromedial nucleus in the camel are in agreement with the findings of Ingram (1940) reflects the docility and phlegmatic nature of the camel. The nucleus tuberalis also is poorly developed in the camel, compared to that of other related mammals.

In the mammillary area the nucleus mammillary medialis is the most conspicuous in the camel made up of small neurons. Although Kanagasuntheram et al (1962) reported that this nucleus is subdivided into three parts: ventrolateral, dorsolateral and medial parts, such a division was not seen in the present work. The nucleus is undivided.

The nucleus mammillary lateralis found in the camel comprises the smaller deeply stained nucleus lying along the lateral and ventrolateral border of the medial mammillary nucleus. This nucleus, according to Crosby (1962) has been described in lower mammals but its homologue in primates and man is not clear.

The nucleus premammillaries is poorly represented in the camel. This nucleus is poorly developed also in some ungulates, like the cow (Gadamski and Lakomy, 1972) and the sheep (Walento et al 1969). The supramammillary nucleus is fairly distinct in the

camel. It is reported in the cow by Gadamski and Lakomy (1972), and in sheep by Walento et al (1969). This nucleus is not well defined in man (Crosby, 1962). The most characteristic features of the human hypothalamus according to Carpenter (1972) are the sharply circumscribed tuberal nuclei, the large size of the medial mammillary nuclei and the extensive distribution of large cells in the posterior and lateral hypothalamic areas. In the camel the most striking features are the large supraoptic and paraventricular nuclei and to some extent the medial mammillary nucleus.

SUMMARY AND CONCLUSION

A comprehensive study of the brainstem of the camel is presented in the thesis. The study was carried out in two parts:- morphologic and cytoarchitectural. Forty brains were used for the morphological studies and the measurements were made with the calipers. For the cytoarchitectural studies of the brainstem nuclei the brainstems were divided up into three parts: the diencephalon, the mesencephalon, and the pons and medulla oblongata. Transverse, horizontal and sagittal sections were obtained from each of these parts at 24um and the sections were stained with toluidine blue. The morphological studies indicate that (1) pyramids, gracile tubercle, corpus trapezoideum, transverse crural tract, the medial eminence and the facial colliculus are very small and in some cases inconspicuous, (2) that there is no inferior olivary prominence as well as the stria medullaris of the fourth ventricle, (3) that the pons, the medial geniculate bodies, the mammillary body and the cerebral peduncles are small, and (4) that the trigeminal nerve, the rostral colliculi, the lateral geniculate bodies and the hypophysis are large. The cytoarchitectural studies have shown that the red

nucleus, the oculomotor nucleus, the lateral geniculate nucleus, the substantia nigra, the lateral group of thalamic nuclei, nucleus ventralis posteromedialis, the paraventricular and supraoptic nuclei well developed.

The model of the red nucleus shows that it is oval in shape with a small lateral projection.

The brain of the camel is not highly developed in evolutionary terms because of the poorly developed thalamus, pons, pyramids, cerebral peduncles, inferior olivary nucleus, nucleus gracilis, and the presence of the large magnocellular part of the red nucleus. The remarkable water conservation in the camel may be due to the well developed supraoptic nucleus in this animal. The senses of vision, audition and olfaction are poorly developed in the camel. The rubrospinal tract is presumably better developed than the pyramidal tract because of the greatly developed red nucleus. Proprioception and exteroception are poor in the camel especially from the hindquarters while the neck and the face are likely to be richly supplied with sensory fibres because of the large trigeminal nerve and the prominent nucleus ventralis posteromedialis. The nucleus gracilis, and to some extent cuneatus are

poorly developed in the camel. These along with the poorly developed nucleus ventralis postero-lateralis indicates that proprioception and exteroception from the fore and hind quarters are poor in the camel.

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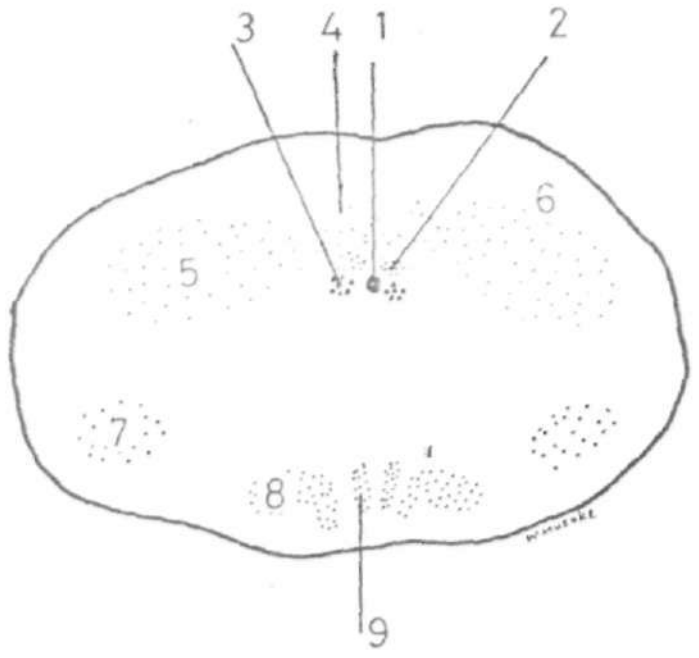


FIG. 1

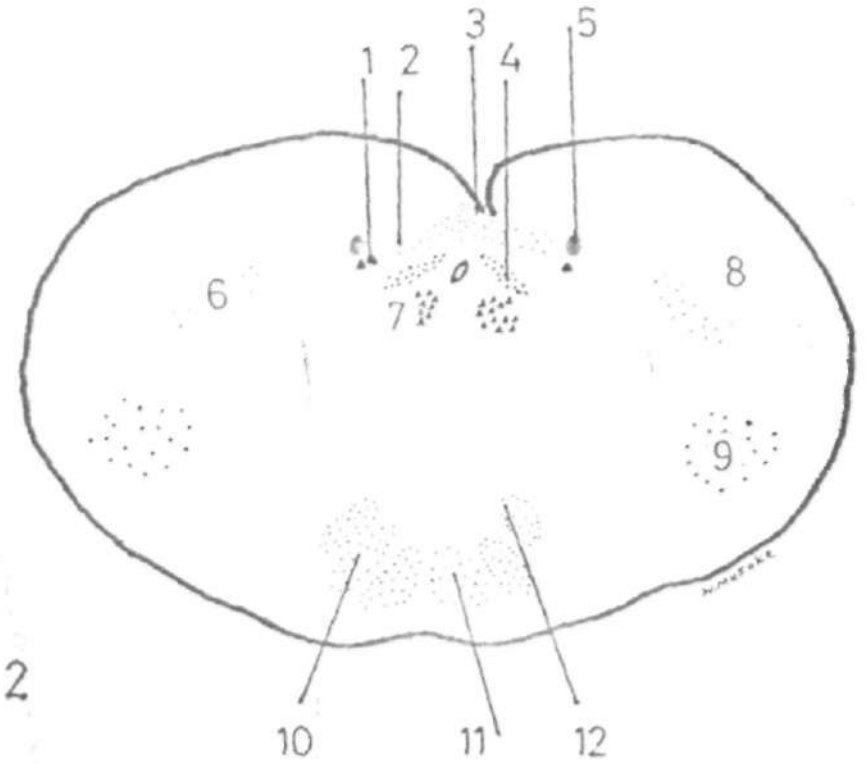


FIG. 2

Fig. 1: Transverse section of the caudal-most level of medulla oblongata

1. Central canal
2. Vagal nucleus (motor nucleus)
3. Hypoglossal nucleus
4. Nucleus gracilis
5. Spinal nucleus of the trigeminal nerve
6. Spinal tract of the trigeminal nerve
7. Lateral reticular nucleus
8. Principal inferior olivary nucleus
9. Medial accessory olivary nucleus.

Fig. 2: Transverse section of the caudal medulla oblongata at the level of the vagal and hypoglossal nuclei

1. Lateral subdivision of nucleus solitarius
2. Medial subdivision of nucleus solitarius
3. Commissural subdivision of the nucleus solitarius
4. Vagal nucleus (motor nucleus)
5. Tractus solitarius
6. Spinal nucleus of the trigeminal nerve
7. Hypoglossal nucleus
8. Spinal tract of the trigeminal nerve
9. Lateral reticular nucleus
10. Principal inferior olivary nucleus
11. Medial accessory inferior olive
12. Dorsal accessory inferior olive

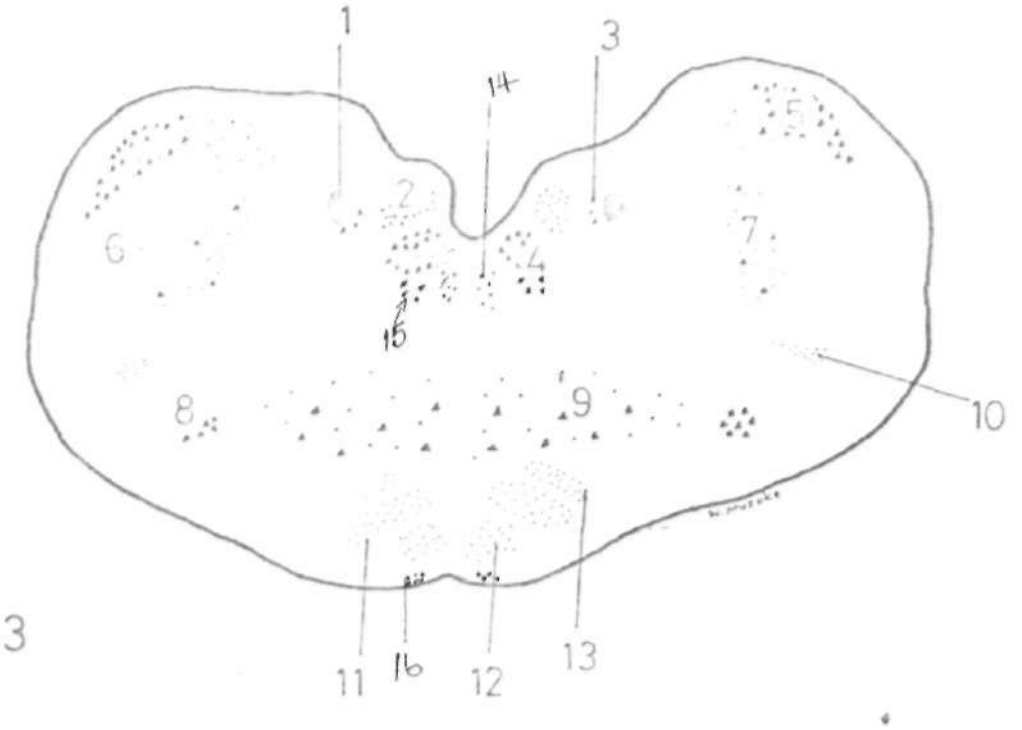


FIG. 3

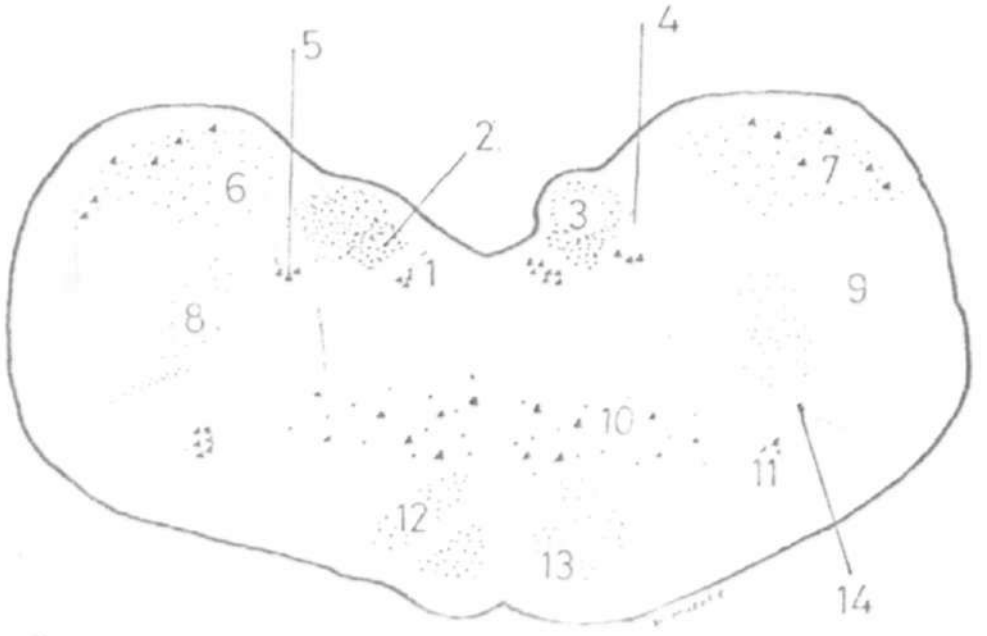


FIG. 4

Fig. 3: Transverse section of the medulla oblongata at the level of the inferior olivary nucleus

1. Tractus solitarius
2. Vagal nucleus (motor nucleus)
3. Lateral subdivision of nucleus solitarius
4. Hypoglossal nucleus
5. Nucleus cuneatus
6. Spinal tract of the trigeminal nerve
7. Spinal nucleus of trigeminal nerve
8. Nucleus ambiguus
9. Nucleus gigantocellularis
10. Nucleus subtrigeminalis
11. Principal inferior olivary nucleus
12. Medial accessory olivary nucleus
13. Dorsal accessory inferior olivary nucleus
14. Nucleus interfascicularis hypoglossi
15. Nucleus of Roller
16. Nucleus arcuatus

Fig. 4: Transverse section of the medulla oblongata at the level of the cuneate nucleus

1. Hypoglossal nucleus
2. Vagal nucleus (motor nucleus
3. Commissural subdivision of the nucleus solitarius
4. Tractus solitarius
5. Lateral subdivision of the nucleus solitarius
6. Nucleus cuneatus (medial part)
7. Nucleus cuneatus (lateral part)
8. Spinal nucleus of trigeminal nerve
9. Spinal tract of trigeminal nerve
10. Nucleus gigantocellularis
11. Nucleus ambiguus
12. Principal inferior olivary nucleus
13. Medial accessory inferior olivary nucleus
14. Nucleus subtrigeminalis.

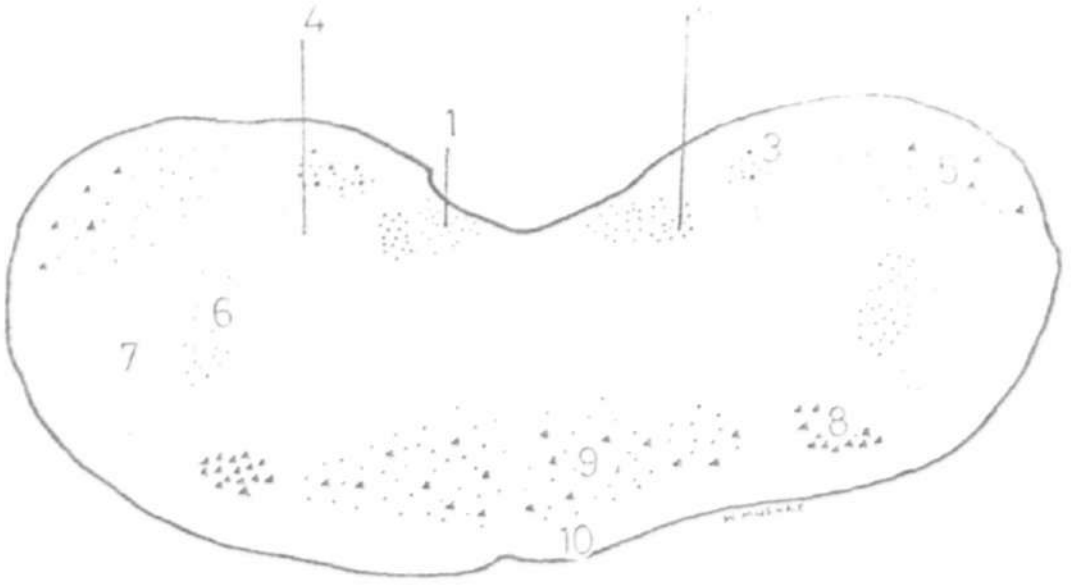


FIG. 5

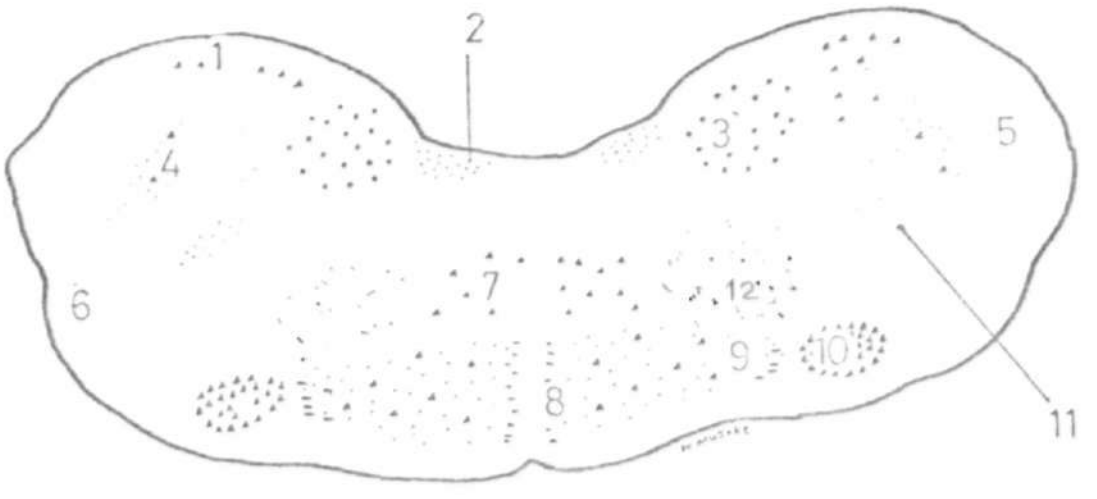


FIG. 6

Fig. 5: Transverse section of the medulla oblongata at the level of cuneate nucleus

1. Nucleus preepositus
2. Vagus nucleus
3. Medial vestibular nucleus
4. Tractus solitarius
5. Lateral cuneate nucleus
6. Spinal nucleus of trigeminal nerve
7. Spinal tract of trigeminal nerve
8. Facial nerve nucleus
9. Nucleus gigantocellularis
10. Cerebral peduncle.

Fig. 6: Transverse section of the medulla oblongata at the level of the facial nucleus

1. Caudal vestibular nucleus
2. Nucleus praepositus
3. Medial vestibular nucleus
4. Principal sensory nucleus of the trigeminal nerve
5. Caudal cerebral pedunche
6. Spinal tract of the trigeminal nerve
7. Paragigantocellularis dorsalis
8. Nucleus pallidus
9. Paragigantocellularis lateralis
10. Facial nucleus
11. Spinal nucleus of the trigeminal nerve.
12. Nucleus parvocellularis

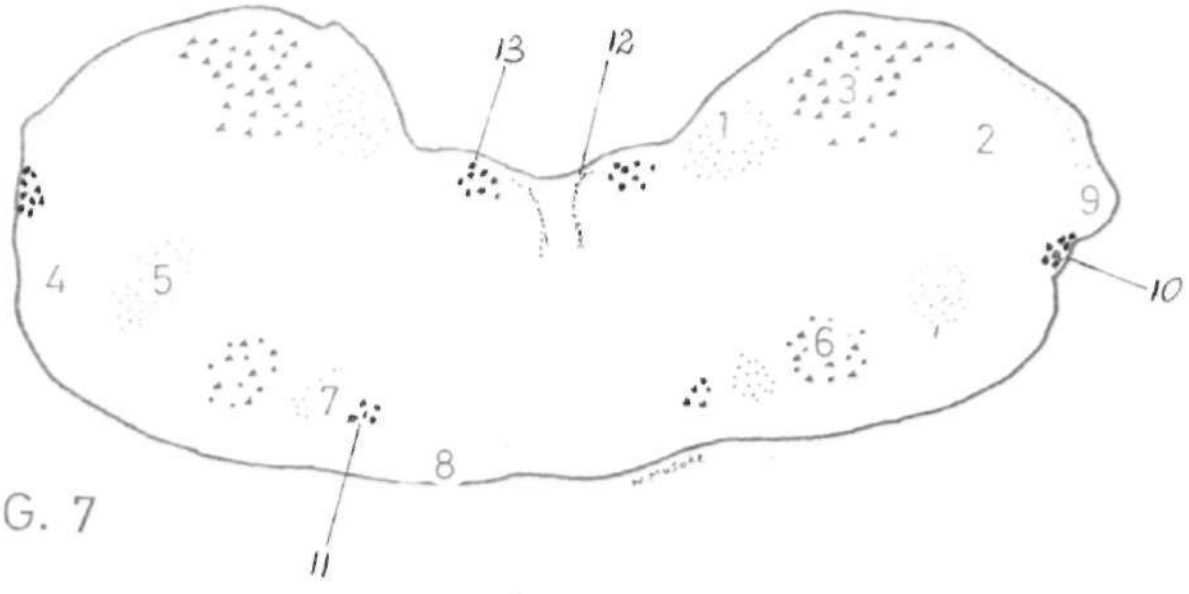


FIG. 7

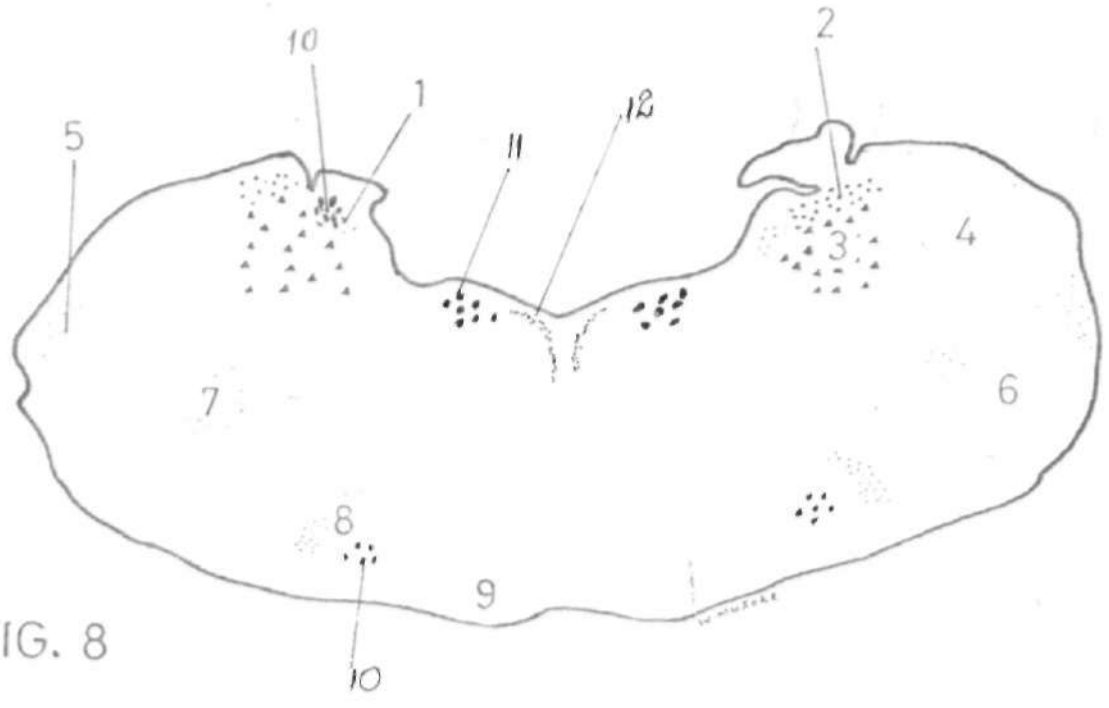


FIG. 8

Fig. 7: Transverse section of the medulla oblongata at the level of lateral vestibular nucleus

1. Medial vestibular nucleus
2. Caudal cerebellar peduncle
3. Lateral vestibular nucleus
4. Spinal tract of trigeminal nerve
5. Spinal nucleus of the trigeminal nerve
6. Motor nucleus of the trigeminal nerve
7. Nucleus of the superior olive
8. Cerebral peduncles
9. Dorsal cochlear nucleus
10. Ventral cochlear nucleus
11. Nucleus of the trapezoid body
12. Nucleus paramedianus dorsalis
13. Abducens nucleus.

Fig. 8: Transverse section of the rostral medulla oblongata at the level of the rostral vestibular nucleus

1. Medial vestibular nucleus
2. Rostral vestibular nucleus
3. Lateral vestibular nucleus
4. Caudal cerebral peduncle
5. Dorsal cochlear nucleus
6. Spinal tract of trigeminal nerve
7. Spinal nucleus of trigeminal nerve
8. Nucleus of superior olive
9. Cerebral peduncle.
10. Nucleus of the trapezoid body
11. Abducens nucleus
12. Nucleus paramedianus dorsalis.

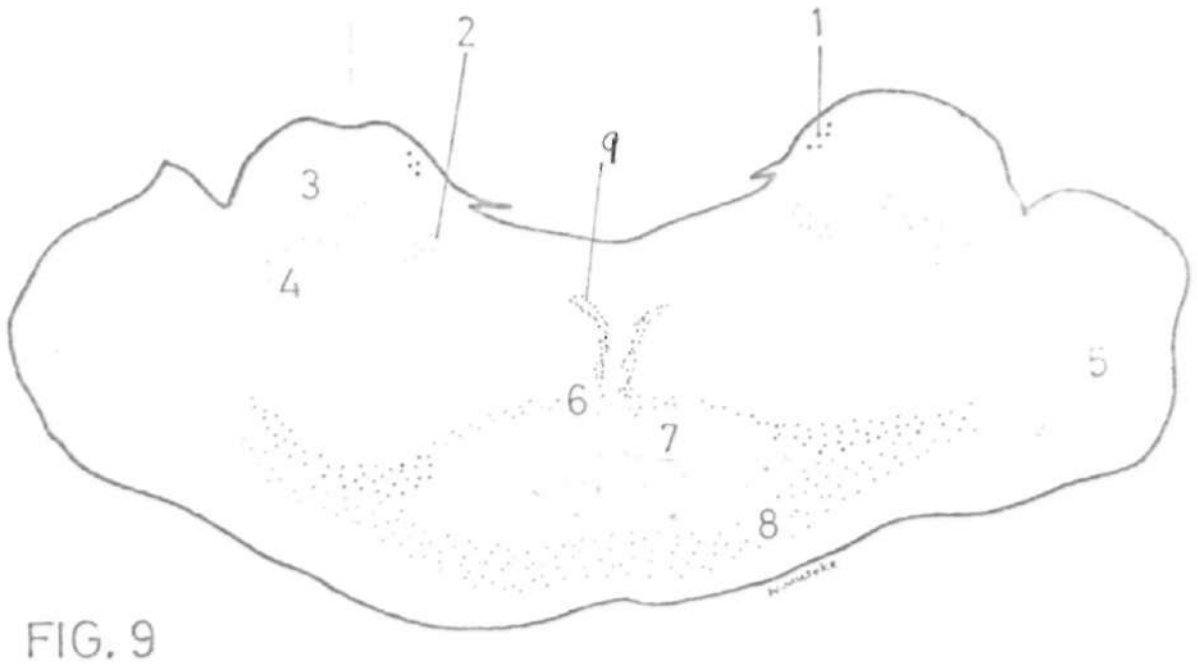


FIG. 9

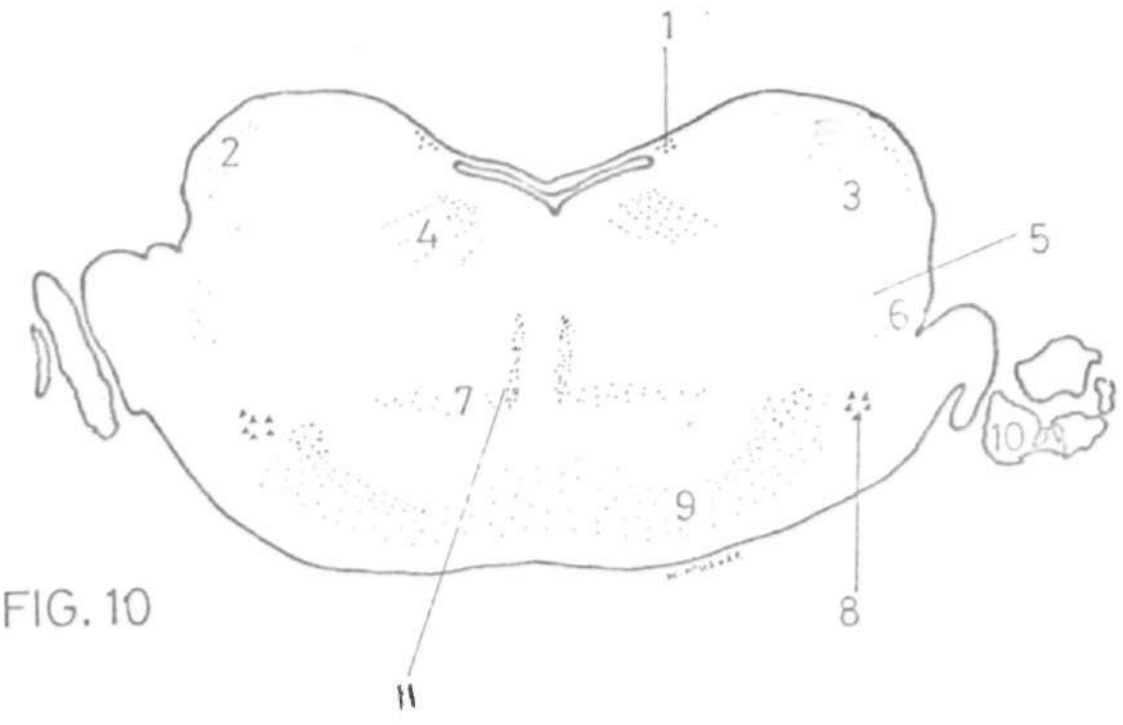


FIG. 10

Fig. 9: Transverse section of the brainstem at the pontomedullary junction

1. Mesencephalic nucleus of the trigeminal nerve
2. Nucleus locus coeruleus
3. Inferior cerebellar peduncle
4. Nucleus locus coeruleus
5. Middle cerebellar peduncle
6. Supralemniscal part of pontine grey
7. Medial lemniscus
8. Pontine grey
9. Nucleus raphae obscurus

Fig. 10: Transverse section of the brainstem at the level of the trigeminal nerve

1. Mesencephalic nucleus of the trigeminal nerve
2. Pedunculopontine tegmental nucleus
3. Rostral cerebellar peduncle
4. Locus coeruleus
5. Lateral lemniscus
6. Dorsal nucleus of the lateral lemniscus
7. Nucleus papilliformis
8. Ventral nucleus of the lateral lemniscus
9. Pontine grey
10. Trigeminal nerve.
11. Nucleus raphae obscurus.

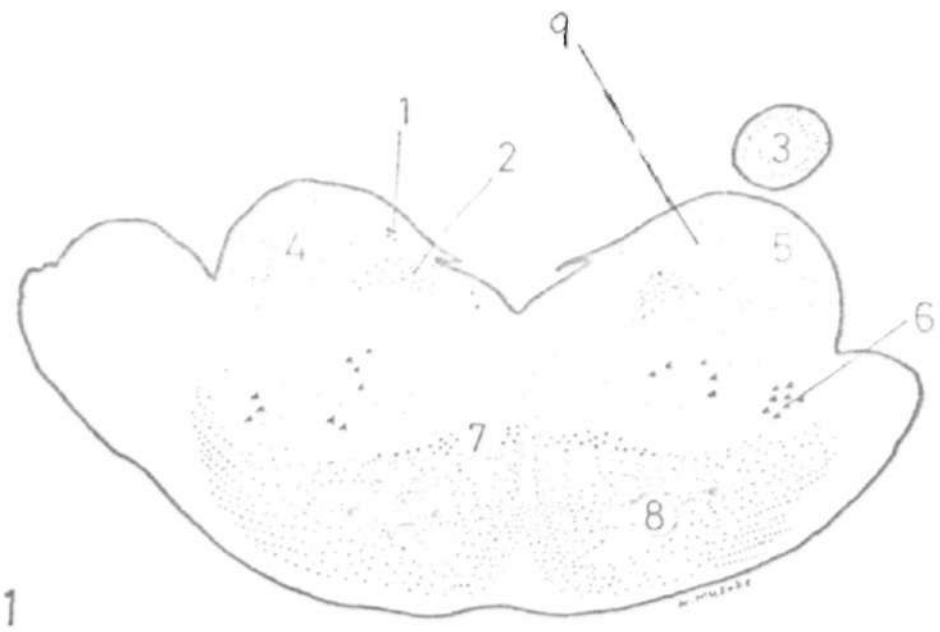


FIG. 11

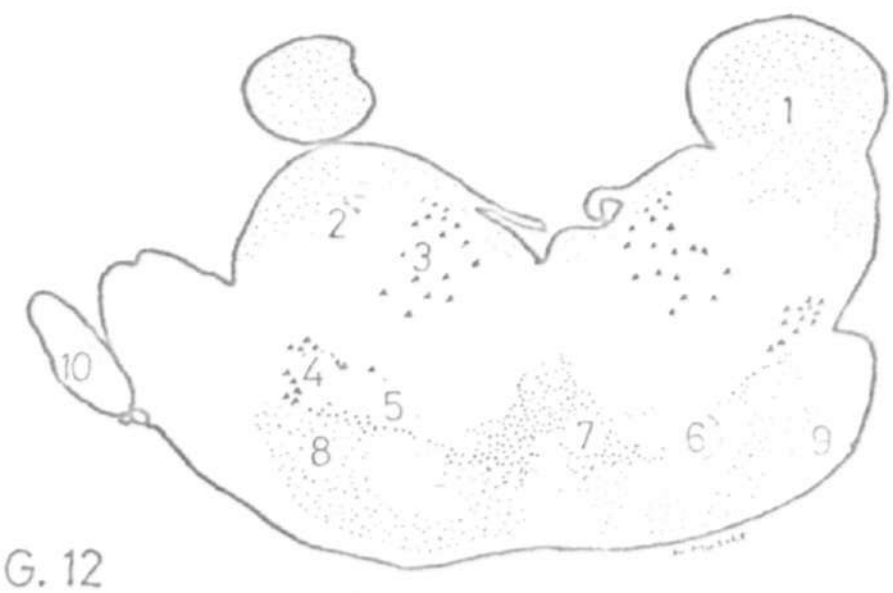


FIG. 12

Fig. 11: Transverse section of the caudal midbrain

1. Mesencephalic nucleus of trigeminal
2. Locus coeruleus
3. Caudal colliculus
4. Rostral cerebellar peduncle
5. Nucleus parabrialis lateralis
6. Ventral nucleus of the lateral lemniscus
7. Nucleus papilliformis
8. Pyramidal tract (corticospinal fibres)
9. Nucleus parabrachialis medialis

Fig. 12: Transverse section of the midbrain at the level of the locus coeruleus

1. Caudal colliculus
2. Rostral cerebellar peduncle
3. Locus coeruleus
4. Ventral nucleus of lateral lemniscus
5. Medial lemniscus
6. Pyramidal tract
7. Pontine grey (medial projection)
8. Pontine grey (lateral projection)
9. Middle cerebellar peduncle
10. Trigeminal nerve

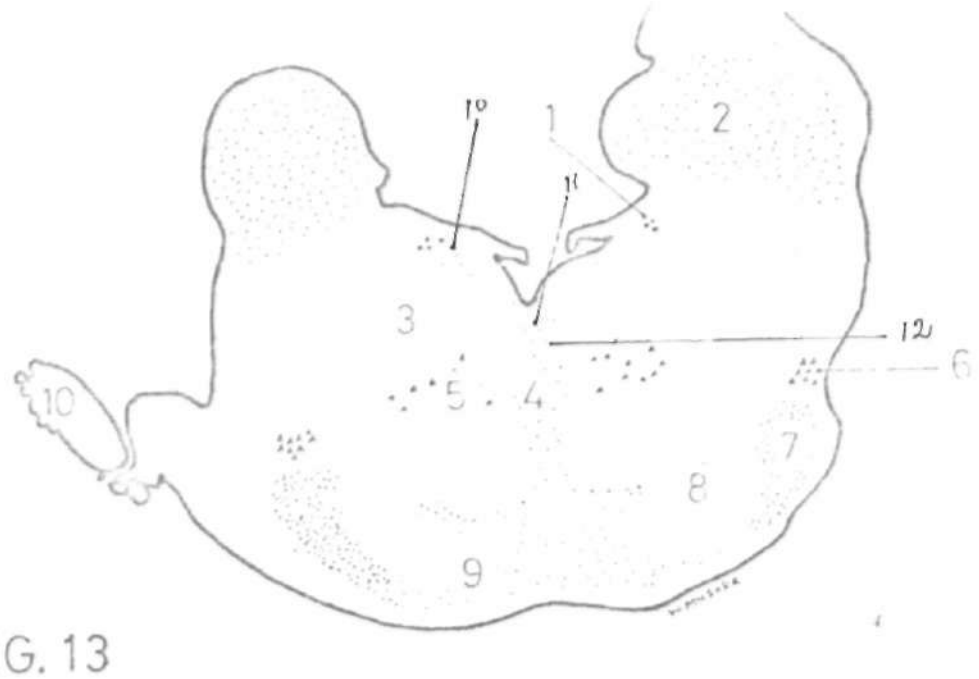


FIG. 13

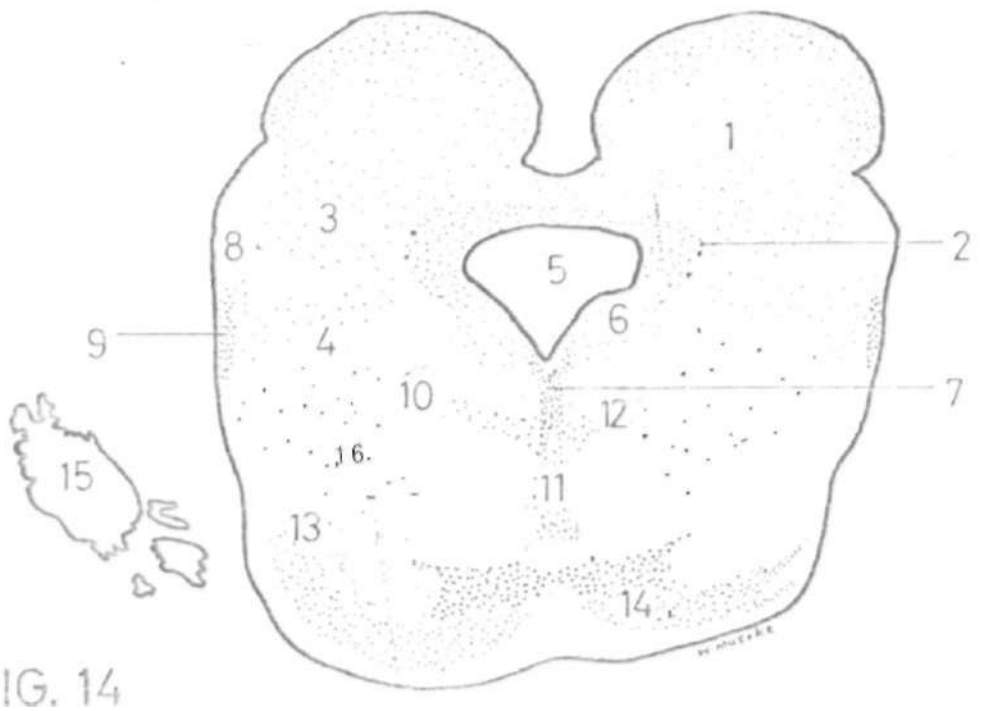


FIG. 14

Fig. 13: Transverse section of the midbrain at the level of the caudal colliculus

1. Mesencephalic nucleus of trigeminal nerve
2. Caudal colliculus
3. Central tegmental tract
4. Superior central nucleus
5. Deep tegmental grey
6. Ventral nucleus of lateral lemniscus
7. Lateral projection of pontine grey
8. Pyramidal tract
9. Pontine grey (medial projection)
10. Laterodorsal nucleus
11. Dorsal tegmental nucleus
12. Ventral tegmental nucleus
13. Trigeminal nerve

Fig. 14: Transverse section of the midbrain through the caudal part of the rostral colliculus

1. Rostral colliculus
2. Mesencephalic nucleus of the trigeminal nerve
3. Nucleus cuneiformis
4. Nucleus subcuneiformis
5. Central canal
6. Periaqueductal grey
7. Dorsal tegmental nucleus
8. Brachium of caudal colliculus
9. Nucleus sagulum
10. Central tegmental tract
11. Superior central nucleus
12. Lateral subdivision of the superior central nucleus.
13. Medial Lemniscus
14. Pontine grey
15. Trigeminal nerve
16. Pedunculopontine nucleus

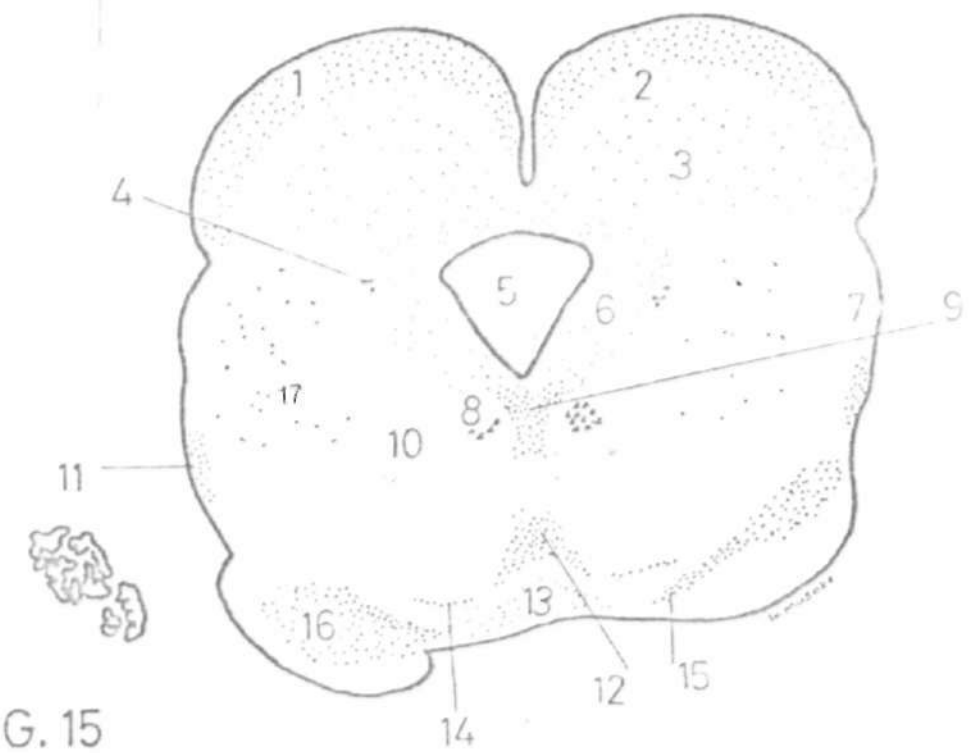


FIG. 15

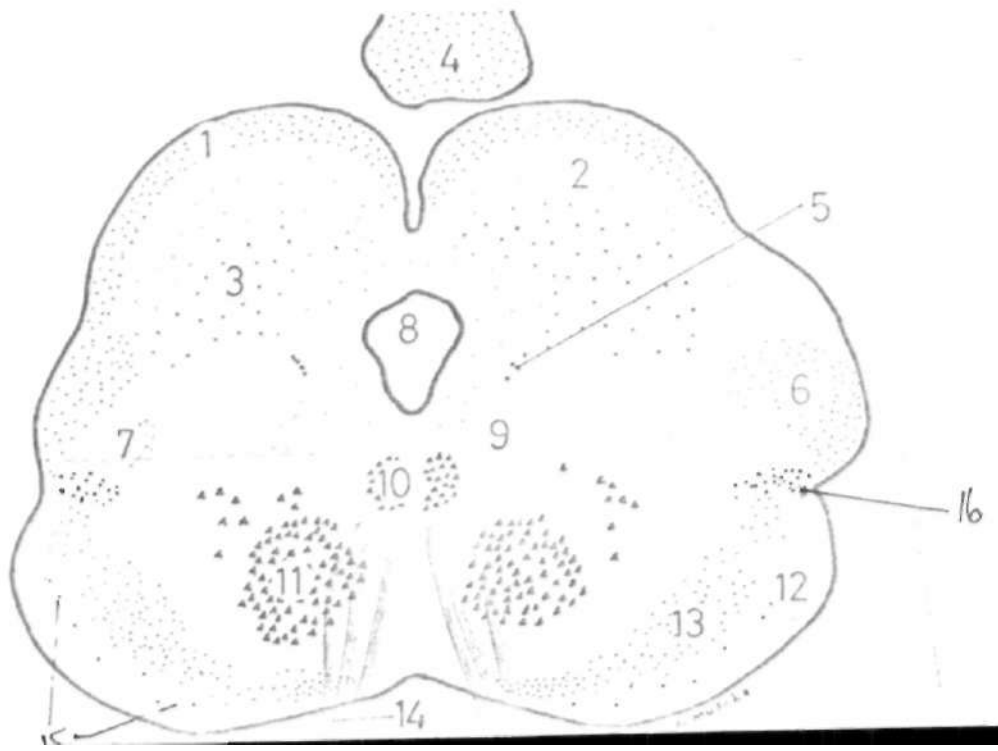


FIG. 16

Fig. 15: Transverse section of the midbrain at the level of the trochlear nucleus

1. Stratum cinereum
2. Middle layer of white and grey matter
3. Deep layer of white and grey matter
4. Mesencephalic nucleus of the trigeminal nerve
5. Cerebral aqueduct
6. Periaqueductal grey
7. Brachium of the rostral colliculus
8. Trochlear nucleus
9. Supratrochlear nucleus
10. Central tegmental tract
11. Nucleus sagulum
12. Linear nucleus
13. Interpeduncular nucleus
14. Substantia nigra pars
15. Substantia nigra pars
16. Substantia nigra pars
17. Nucleus pedunculopontinus.

Fig. 16: Transverse section of the midbrain at the rostral level of the red nucleus

1. Stratum cinereum
2. Middle layer of white and grey matter
3. Deep layer of white and grey matter
4. Pineal gland
5. Mesencephalic nucleus of the trigeminal nerve
6. Medial geniculate body
7. Medial lemniscus
8. Cerebral aqueduct
9. Central tegmental tract
10. Oculomotor nucleus
11. Red nucleus
12. Cerebral peduncle
13. Substantia nigra
14. Fibres of the red nucleus
15. Pars reticulata of substantia nigra
16. Nucleus peripeduncularis

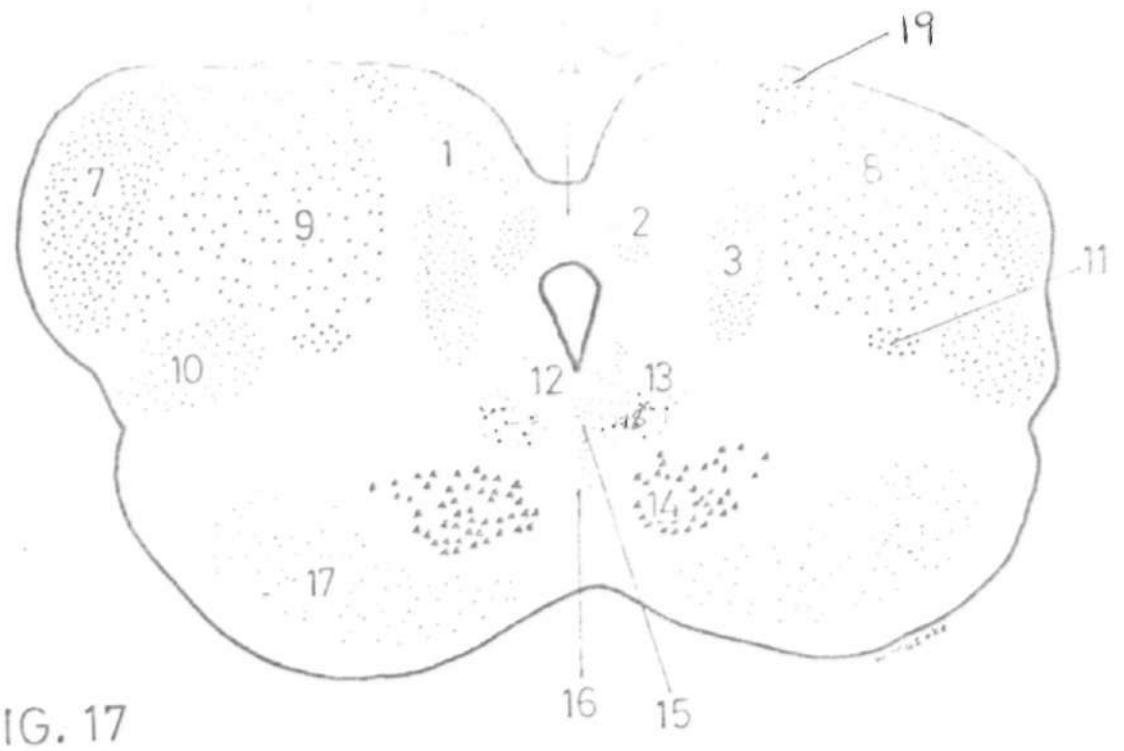


FIG. 17

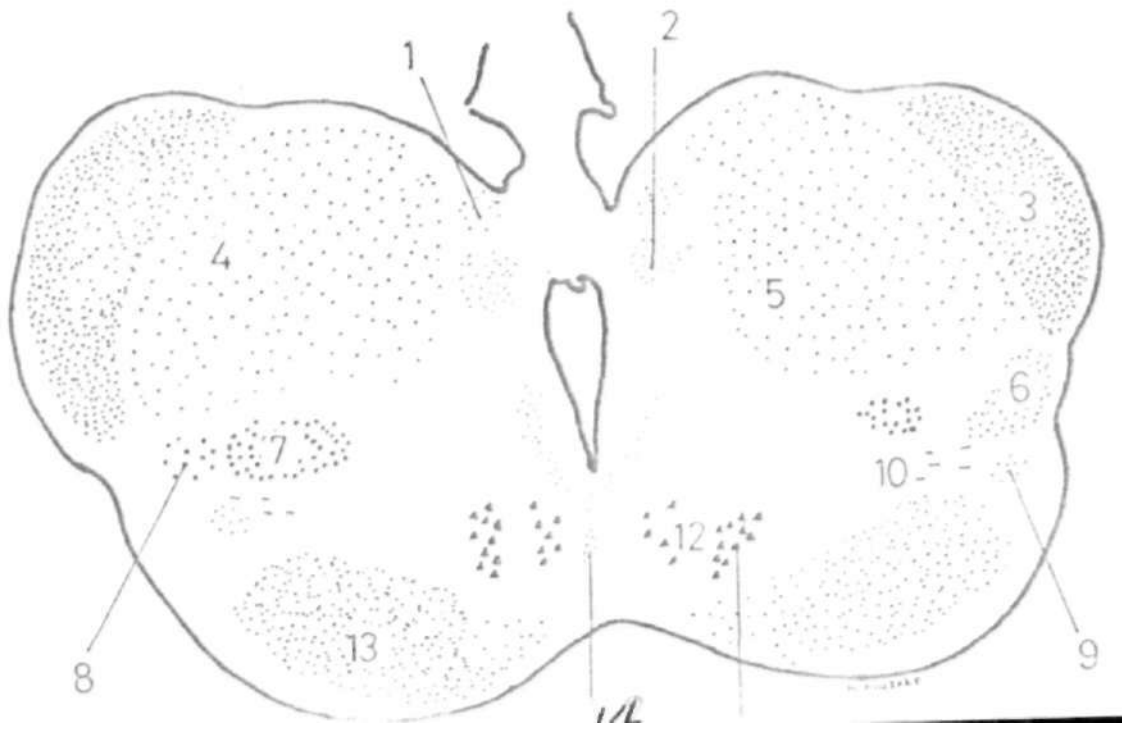


Fig. 17: Transverse section of the diencephalon at the level of the pretectum

1. Principal nucleus of the pretectal area/ nucleus sublentiformis
2. Nucleus of the posterior commissure
3. Posterior pretectal nucleus
4. Posterior commissure
5. Stratum cinereum of rostral colliculi
6. Pineal gland
7. Nucleus geniculatus lateralis pars dorsalis
8. Pulvinar
9. Nucleus lateralis posterior
10. Medial geniculate body
11. Nucleus ventralis posterior
12. Nucleus of darkschewitch
13. Central tegmental tract
14. Red nucleus
15. Edinger Westphal nucleus
16. Linear nucleus (rostral part)
17. Substantia nigra.
18. Interstitial nucleus of cajal
19. Nucleus of the optic tract

Fig. 18: Transverse section of the diencephalon at the level of the caudal commissure

1. Lateral habenular nucleus
2. Nucleus of the posterior commissure
3. Nucleus geniculatus lateralis pars dorsalis
4. Pulvinar
5. Posterior lateral nucleus
6. Medial geniculate body
7. Nucleus ventralis posterior medialis
8. Nucleus ventralis posterior lateralis
9. Nucleus substantia nigra pars lateralis
10. Zona incerta
11. Red nucleus
12. Habenulopeduncular tract
13. Substantia nigra pars compacta
14. Edinger Westphal nucleus

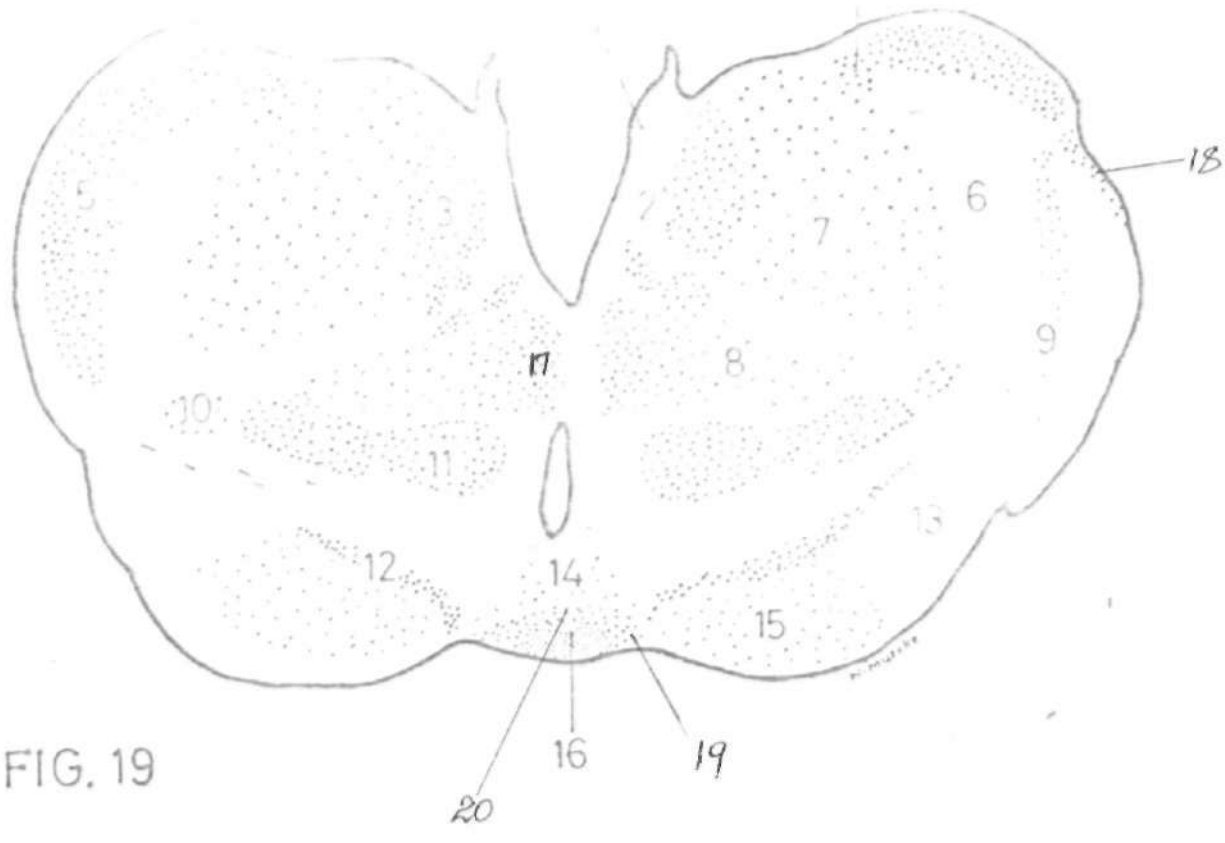

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FIG. 19

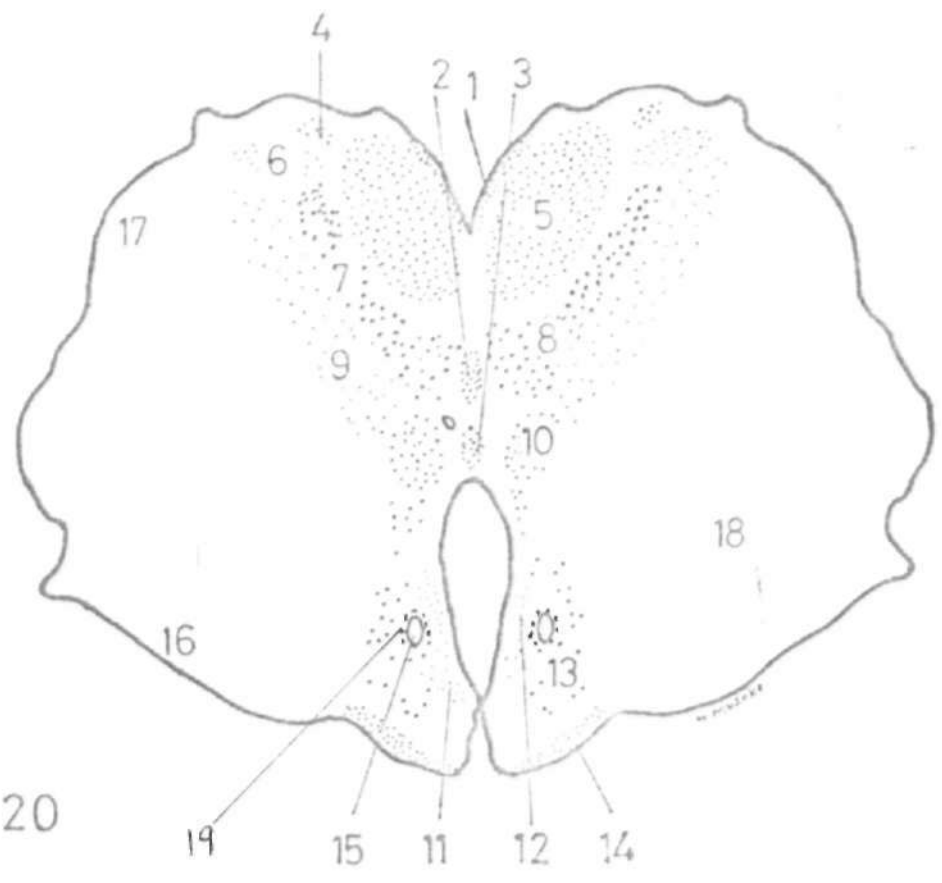

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FIG. 20

Fig. 19: Transverse section of the diencephalon at the mammillary level

1. Medial habenular nucleus
2. Habenulopeduncular tract
3. Habenulopeduncular nucleus
4. Pulvinar pars geniculata
5. Nucleus geniculatus lateralis pars dorsalis
6. Fibres of the optic radiation
7. Nucleus lateralis posterior
8. Centromedian nucleus
9. Reticular nucleus (Nucleus reticularis thalami)
10. Nucleus ventralis posterior lateralis
11. Nucleus ventralis posterior medialis
12. Subthalamic nucleus
13. Cerebral peduncle
14. Posterior hypothalamic nucleus
15. Substantia nigra
16. Medial mammillary nucleus
17. Nucleus parafascicularis.
18. Nucleus geniculatus lateralis pars ventralis
19. Nucleus mammillary lateralis
20. Nucleus suprammillaris.

Fig. 20: Transverse section of the diencephalon at the tuberoinfundibular level

1. Paraventricular nucleus
2. Rhomboidal nucleus (Nucleus Rhomboidalis)
3. Nucleus reuniens
4. Anterodorsal nucleus (nucleus antero-dorsalis)
5. Dorsomedial nucleus (Nucleus medialis dorsalis)
6. Anteroventral nucleus
7. Paracentral nucleus
8. Nucleus centralis medialis
9. Nucleus ventralis lateralis
10. Nucleus submedius
11. Nucleus hypothalamicus ventromedialis
12. Nucleus hypothalamicus dorsomedialis
13. Lateral hypothalamic nucleus
14. Nucleus supraopticus medialis
15. Fornix
16. Optic tract
17.) Internal capsule
18.)
19. Perifornical nucleus

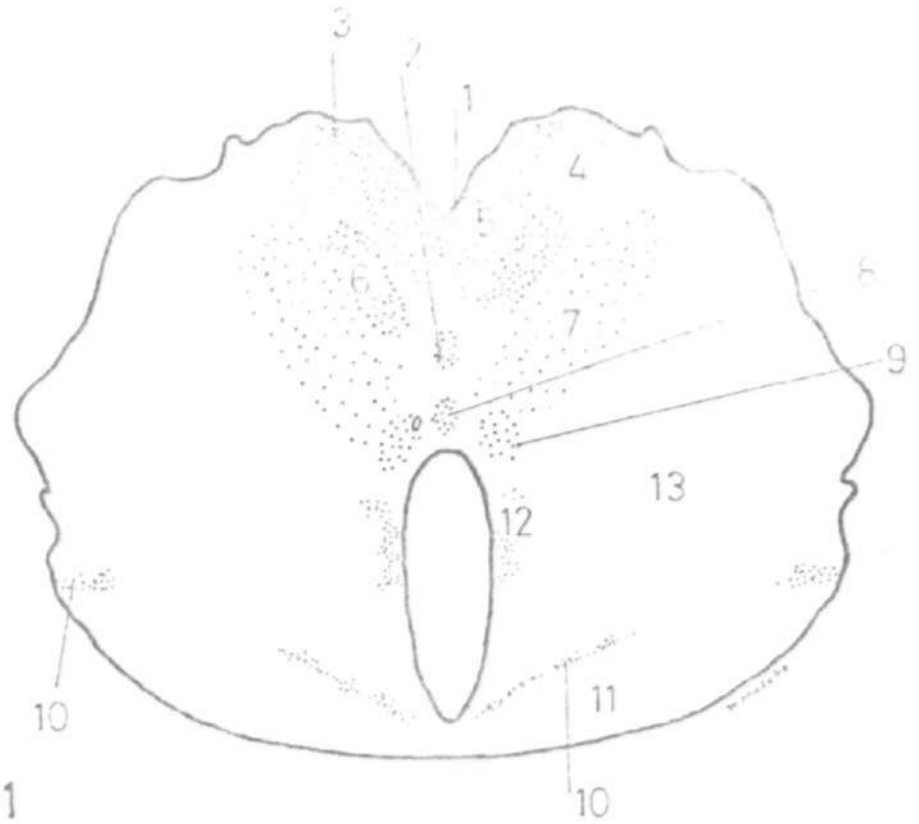


FIG. 21

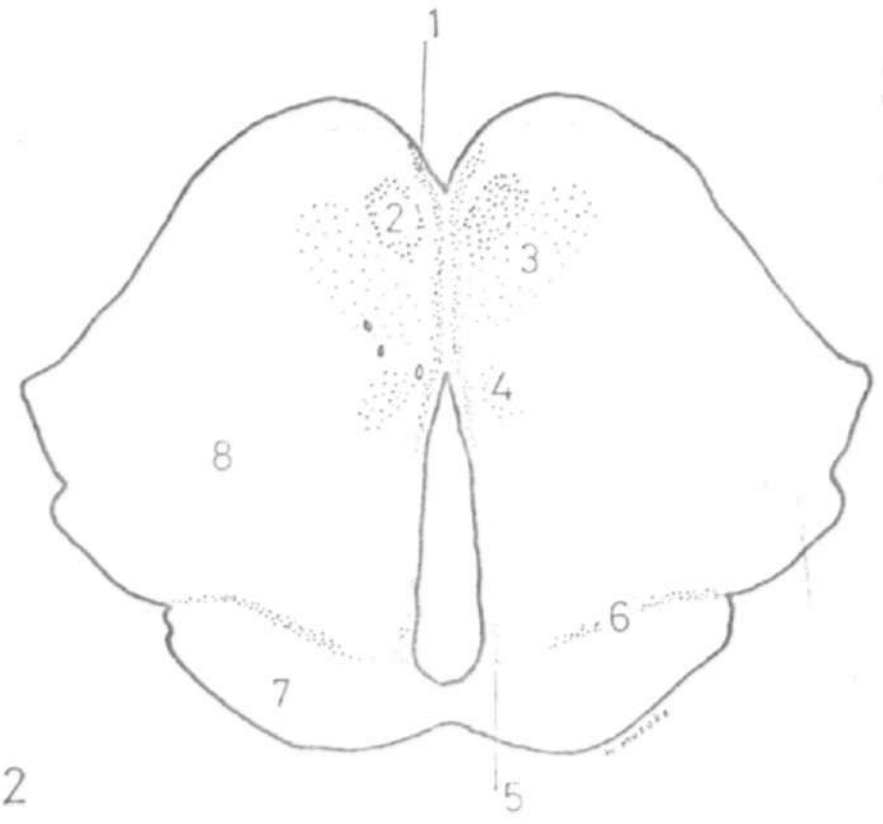


FIG. 22

Fig. 21: Transverse section of the diencephalon at the level of the anterior thalamic nucleus

1. Nucleus praeventricularis
2. Nucleus rhomboidalis
3. Nucleus anterior dorsalis
4. Nucleus anterior ventralis
5. Nucleus parataenialis
6. Nucleus anterior medialis
7. Nucleus ventralis anterior
8. Nucleus reuniens
9. Nucleus submedius
10. Nucleus supraopticus Lateralis
11. Optic tract
12. Paraventricular nucleus of hypothalamus
13. Internal capsule

Fig. 22: Transverse section of the diencephalon at the level of supraoptic nucleus

1. Paraventricular nucleus
2. Nucleus anterior medialis
3. Nucleus ventralis anterior
4. Nucleus submedius
5. Suprachiasmaticus nucleus
6. Supraoptic nucleus (supraopticus lateralis)
7. Optic tract
8. Internal capsule

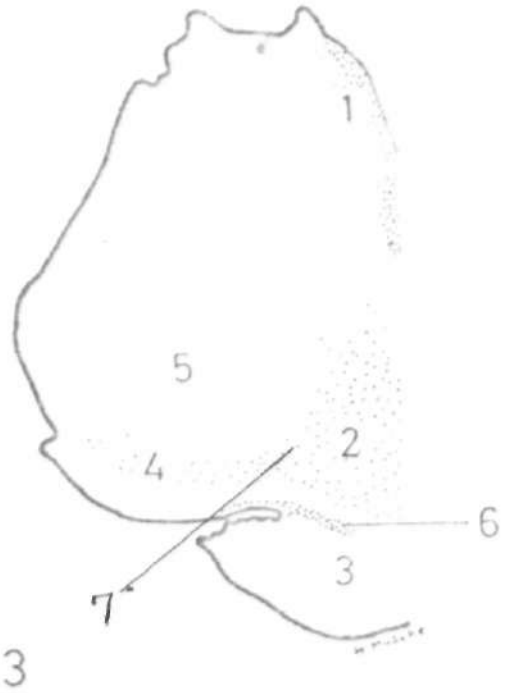


FIG. 23

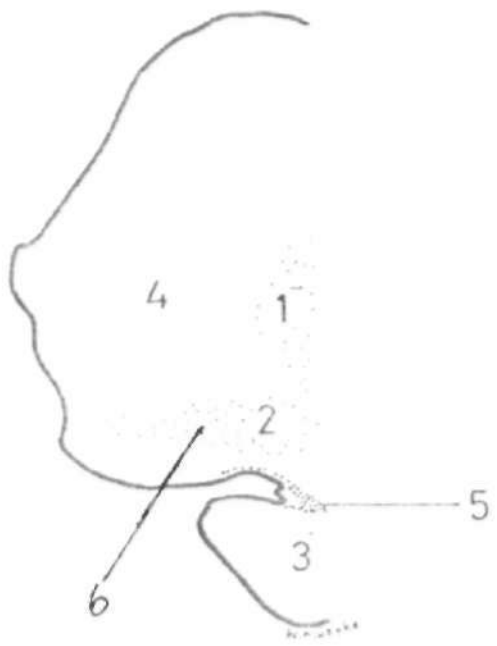


FIG. 24

Fig. 23: Transverse section of the diencephalon at the level of the anterior hypothalamic nucleus

1. Paraventricular nucleus
2. Anterior hypothalamic nucleus
3. Optic tract
4. Nucleus preopticus magnocellularis
5. Internal capsule fibres
6. Nucleus supraopticus lateralis
7. Nucleus preopticus interstitialis

Fig. 24: Transverse section of the diencephalon at the level of the preoptic area

1. Nucleus preopticus medialis
2. Nucleus preopticus principalis
3. Optic tract
4. Internal capsule fibres
5. Nucleus supraopticus lateralis.
6. Nucleus preopticus interstitialis

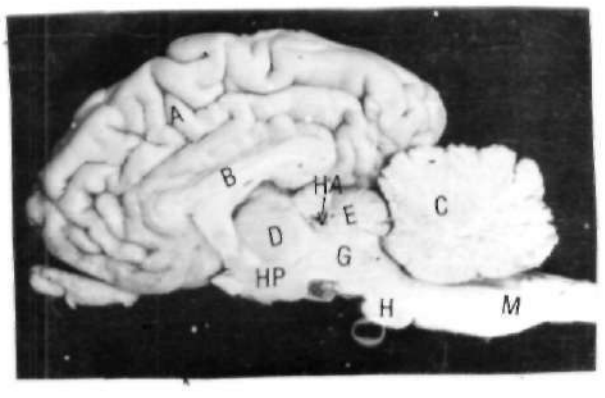


PLATE 1

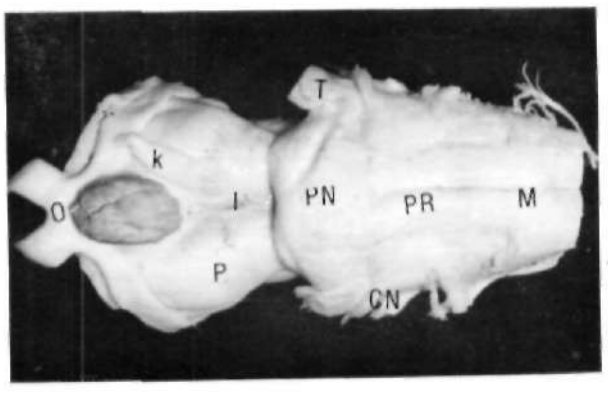


PLATE 2

Plate 1: Midsagittal section of the camel brain

A - Cerebrum

B - Corpus callosum

C - Cerebellum

D - Thalamus

E - Tectum

G - Tegmentum

H - Basilar pons

M - Medulla oblongata

HA - Habenular

HP - Hypothalamus

Plate 2: Ventral view of the brainstem

O - Optic chiasma

K - Oculomotor nerve

I - Interpeduncular fossa

P - Cerebral peduncle (crura cerebri)

PN - Pons

PR - Pyramidal tract

M - Medulla oblongata

T - Trigeminal nerve

CN - Cranial nerves

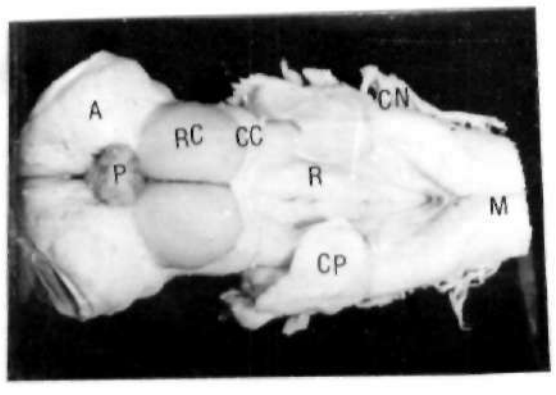


PLATE 3

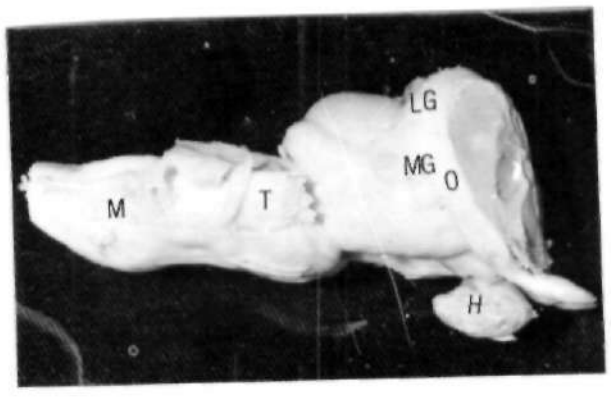


Plate 3: Dorsal view of the brainstem

A - Diencephalon

P - Pineal gland

RC - Rostral colliculi

R - Rhomboid fossa

CC - Caudal colliculi

CN - Cranial nerves

M - Medulla oblongata

CP - Cerebellar peduncles

Plate 4: Lateral view of the brainstem

LG - Lateral geniculate body

mG - Medial geniculate body

O - Optic tract

H - Hypophysis (pituitary body)

T - Trigeminal nerve

CC - Caudal colliculus

RC - Rostral colliculus

M - Medulla oblongata

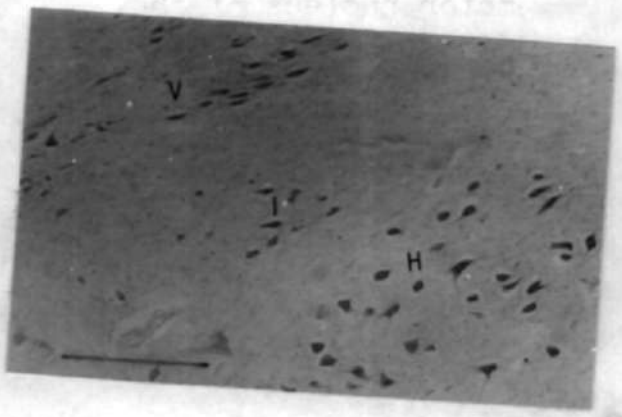


PLATE 5

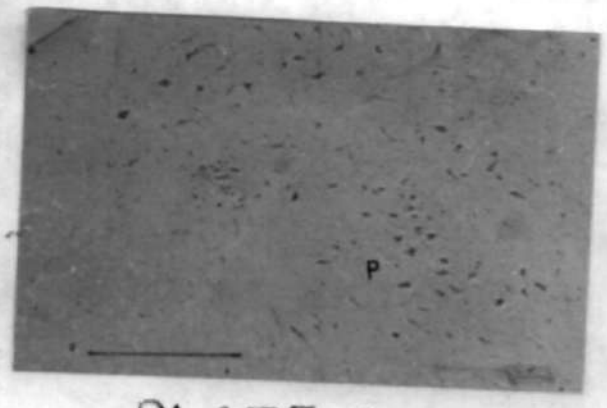


PLATE 6

Plate 5: T.S. of medulla oblongata showing the motor nucleus of the vagus nerve (V) Nucleus intercalatus (1) and the hypoglossal nucleus (H)

Bar represents 1000um

Plate 6: T.S. of medulla oblongata showing nucleus praepositus

P - Nucleus praepositus
Bar represents 1000um.

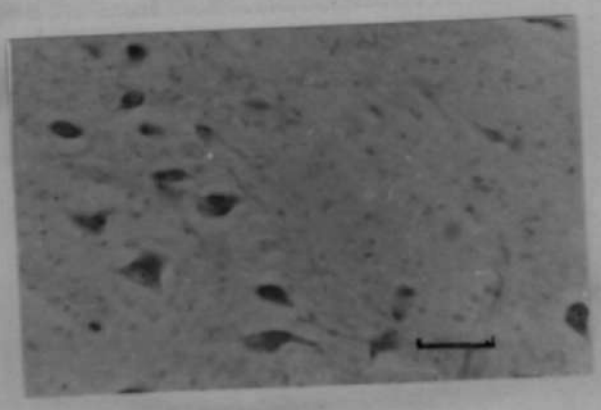


PLATE 7

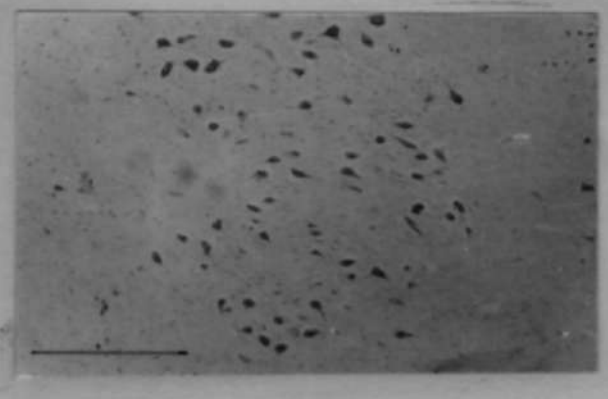


PLATE 8

Plate 7: Neurons of nucleus praepositus enlarged

Bar represents 3000um

Plate 8: Neurons of the vagal nucleus

Bar represents 1000um

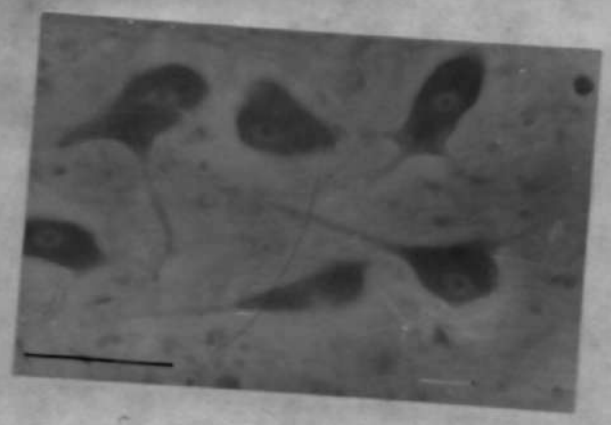


PLATE 9

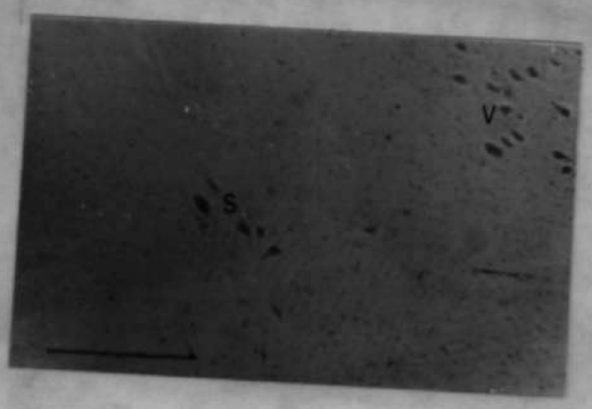


PLATE 10

Plate 9: Some neurons of the vagal nucleus enlarged
Bar represents 1000um

Plate 10: The relationship of the lateral subdivision of the nucleus solitarius (s) to vagal nucleus (N) shown in this plate
Bar represents 1000um

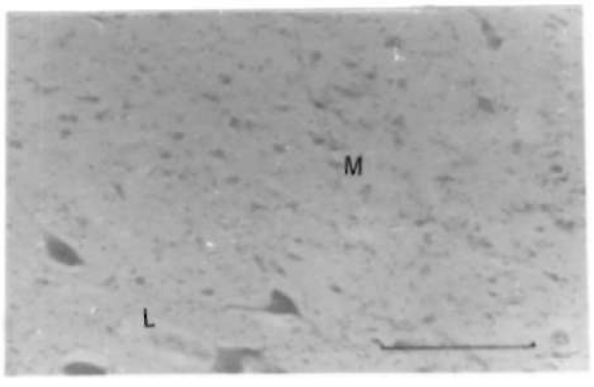


PLATE 11

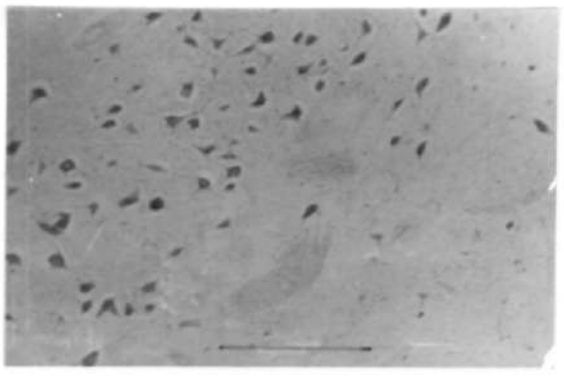


PLATE 12

Plate 11: The medial (M) and lateral parts of the nucleus solitarius. Note the large neurons of the lateral part and the glial like neurons of the medial part

Bar represents 1000um

Plate 12: Nucleus ambiguus. The neurons are large and multipolar

Bar represents 1000um.

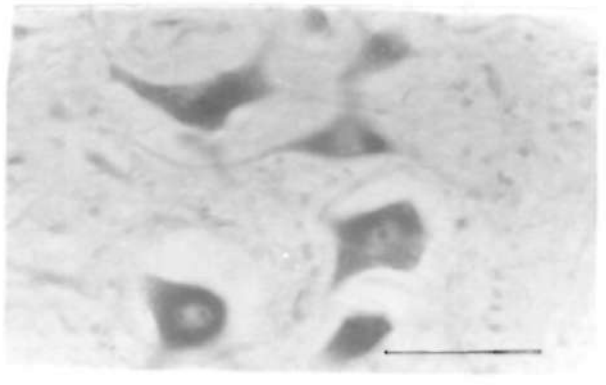


PLATE 13

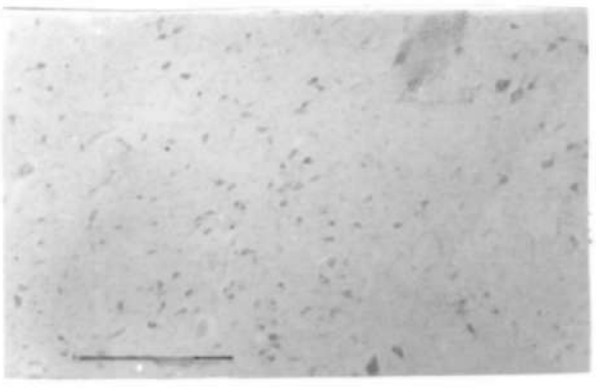


PLATE 14

Plate 13: Some neurons of the nucleus ambiguus enlarged -

Bar represents 1000um

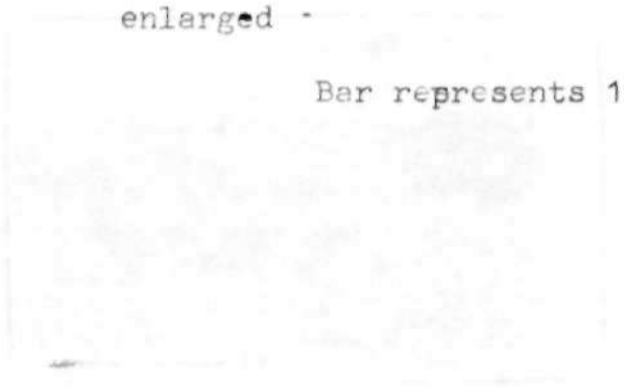


Plate 14: Medial vestibular nucleus. Note the small neurons

Bar represents 1000um.



PLATE 15

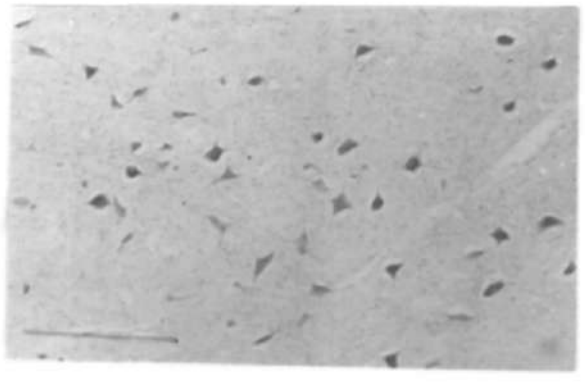


PLATE 16

Plate 15: Lateral vestibular nucleus. The neurons are large and multipolar

Bar represents 1000um

Plate 16: Facial nucleus. The neurons are also large and multipolar (Lateral part of the nucleus)

Bar represents 1000um

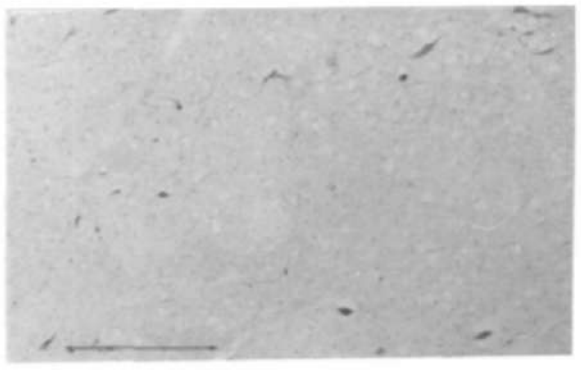


PLATE 17

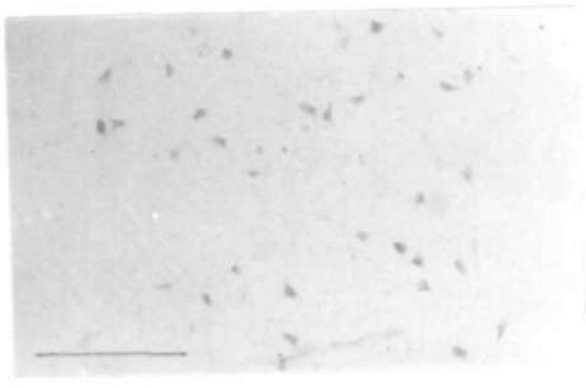


PLATE 18

Plate 17: Neurons of the medial part of the facial nucleus. Note: these neurons are small compared to those of the lateral part (Plate 16)

Bar represents 1000um

Plate 18: Neurons of the abducens nucleus

Bar represents 1000um

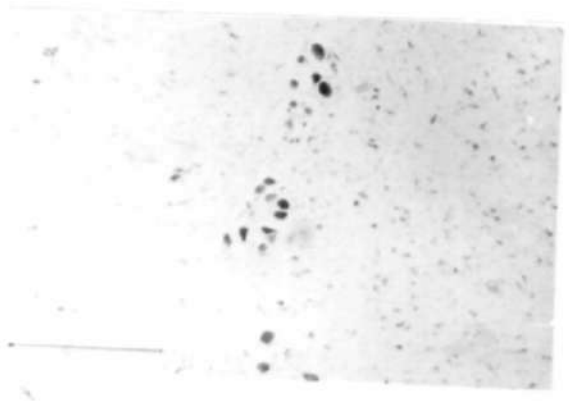


PLATE 19

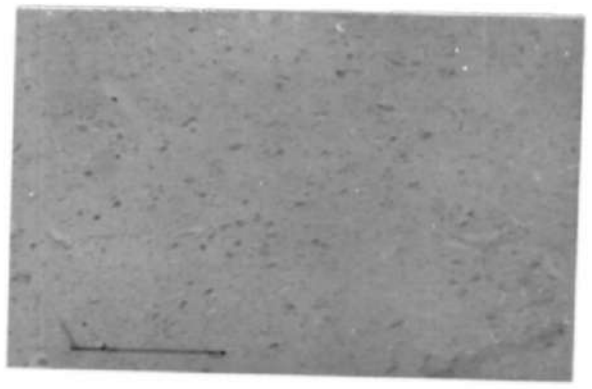


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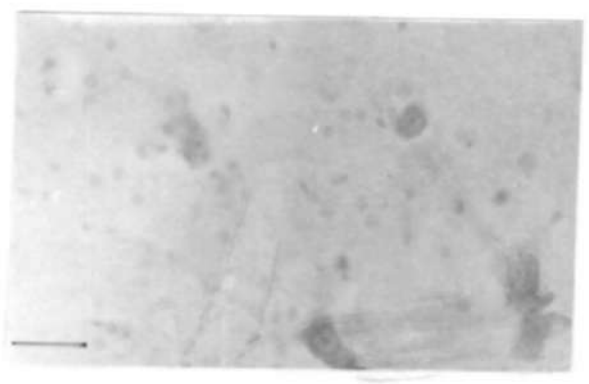


PLATE 21

Plate 19: Mesencephalic nucleus of the trigeminal nerve shown (aggregates the lateral edge of the periaqueductal grey (Rostral midbrain level)

Bar represents 1000um

Plate 20: Neurons of the dorsal cochlear nucleus

Note: their small size

Bar represents 1000um

Plate 21: Enlarged neurons of the dorsal cochlear nucleus

Bar represents 1000um.

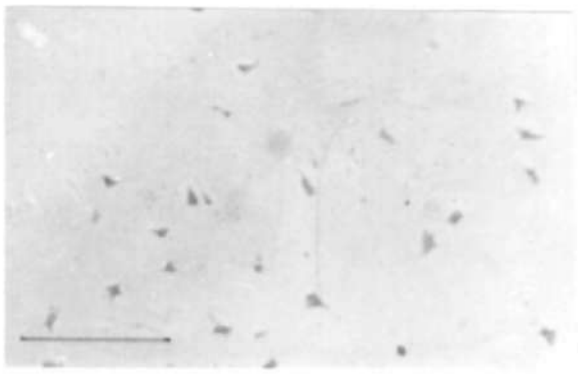


PLATE 22

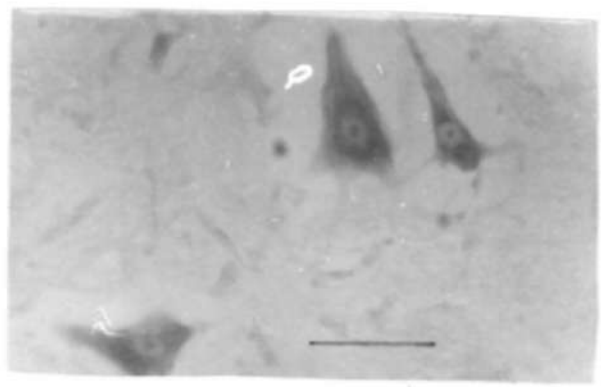


PLATE 23



PLATE 24

Plate 22: Neurons of the motor nucleus of the trigeminal nerve

Bar represtnts 1000um

Plate 23: Some of the neurons of the motor nucleus of the trigeminal nerve enlarged

Bar represents 1000um.

Plate 24: Locus coeruleus nucleus. Note: the elongated shape of the neurons.

Bar represents 1000um.

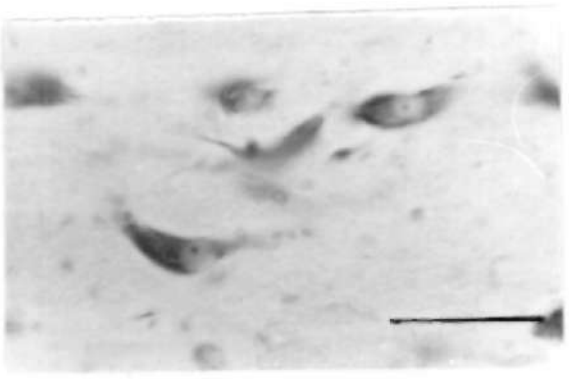


PLATE 25

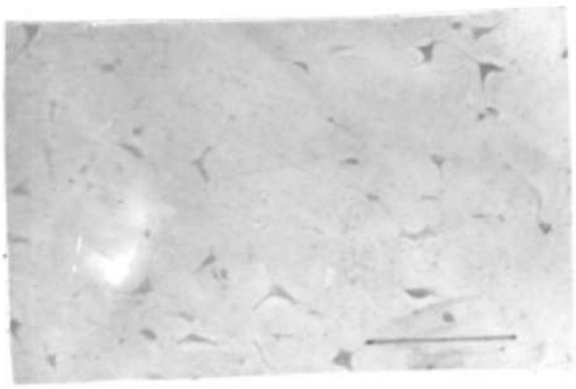


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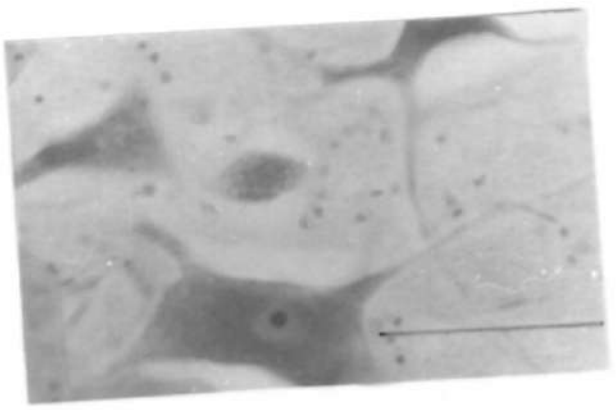


PLATE 27

Plate 25: Some neurons of locus coeruleus enlarged
Bar represents 1000um

Plate 26: Neurons of the nucleus gigantocellularis.
Note: The neurons are large and irregularly arranged
Bar represents 1000um

Plate 27: A few neurons of the nucleus gigantocelularis enlarged
Bar represents 1000um.

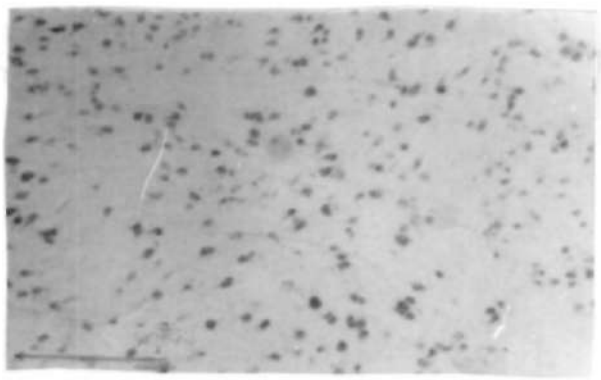


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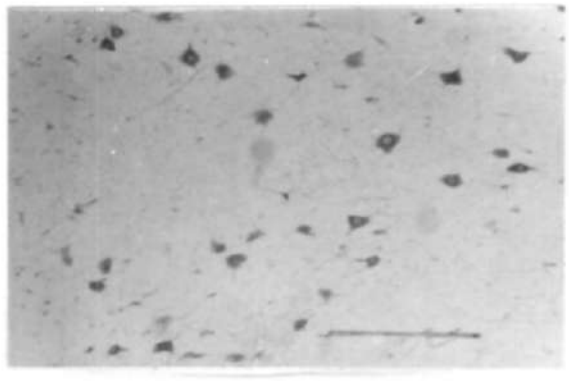


PLATE 29

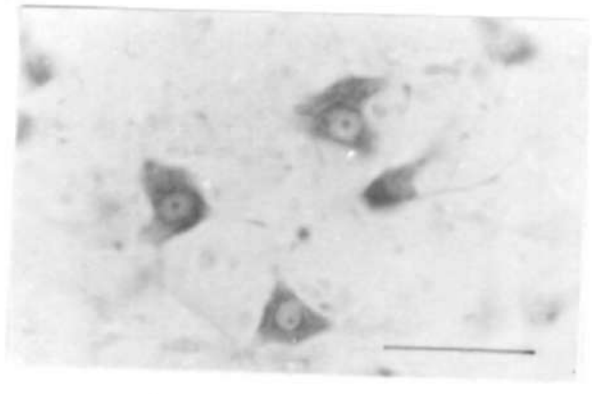


PLATE 30

Plate 28: Neurons of the pontine grey (ventral part)

Bar represents 1000um

Plate 29: Neurons of the dorsal part of the pontine grey

Bar represents 1000um (1000μm)

Plate 30: Some of the above neurons of the dorsal part of pontine grey enlarged

Bar represents 1000um.

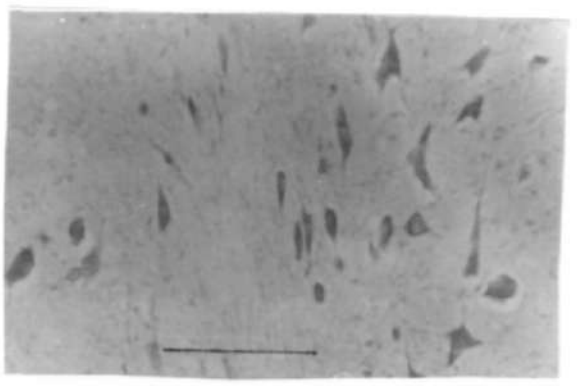


PLATE 31

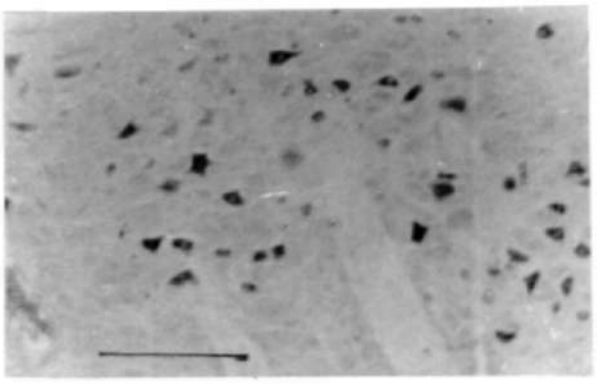


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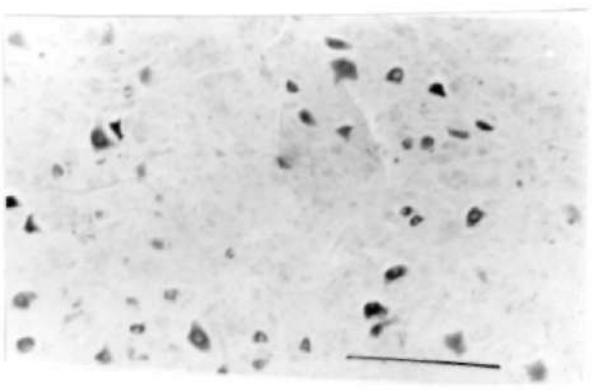


PLATE 33

Plate 31: Nucleus pallidus. Note neurons are oriented dorsoventrally along the midline. On both sides are neurons of the nucleus gigantocellularis

Bar represents 1000um

Plate 32: Fibres-of the oculomotor nucleus passing through the red nucleus

Bar represents 1000um

Plate 33: Neurons of the red nucleus. Note: the large size of the neurons

Bar represent 1000um.



PLATE 34

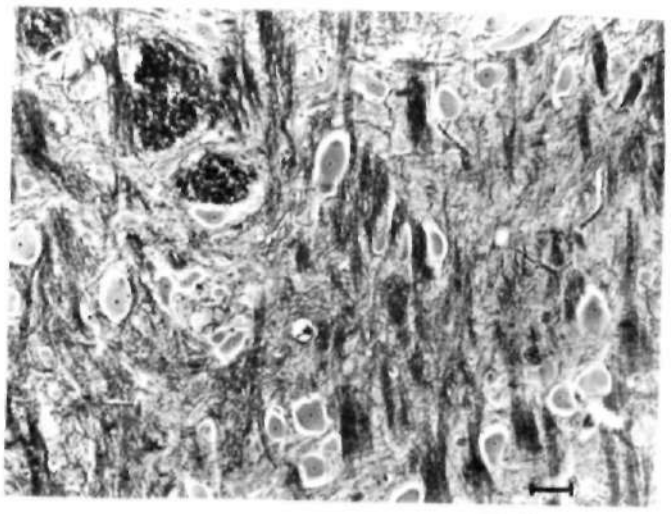


PLATE 35

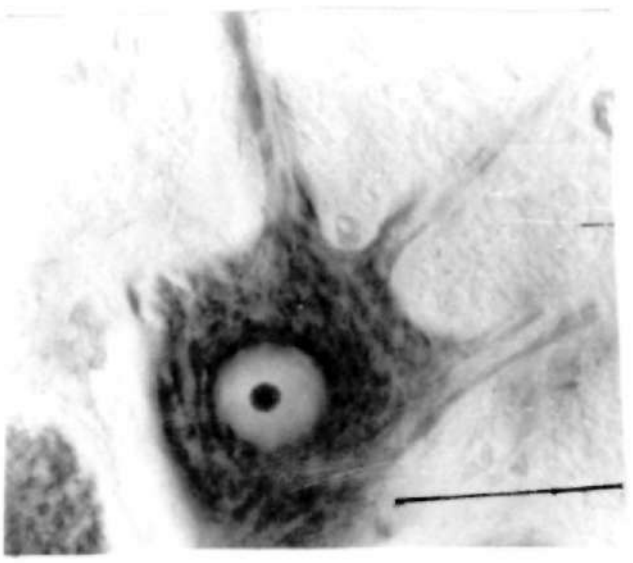


PLATE 36

Plate 34: Photograph of the model of the red nucleus. C (Caudal), R (Rostral), A (lateral horn).

Bar represents 1000um

Plate 35: Gallocyanin/methyl green stained section showing fibres passing through the magnocellular part of the red nucleus

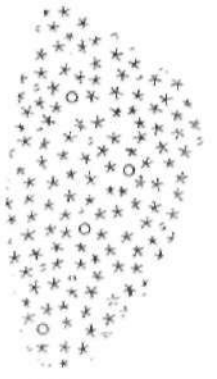
Bar represents 5000um.

Plate 36: A large neuron of the magnocellular part of the red nucleus enlarged

Bar represents 9000um.



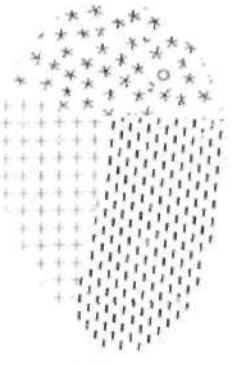
S 262



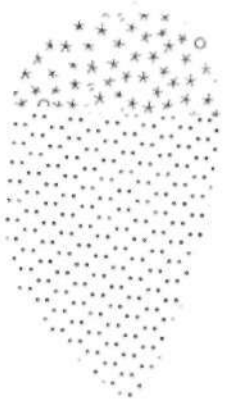
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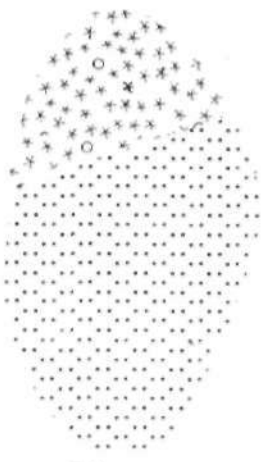
S 283



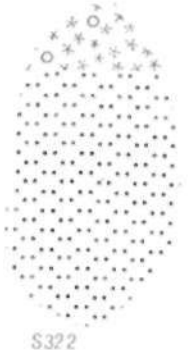
S 294



S 303



S 314



S 322



S 332



S 343

PLATE 37

Plate 37: Serial sagital sections of the red nucleus at various levels showing subdivision of the red nucleus into caudal magnocellular and rostral parvocellular portions. The subdivisions of the parvocellular portion are also shown.



(P M)
Pars magnocellularis



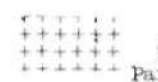
(P P)
Pars parvocellularis



(C L)
Cornu lateralis
(minimus cells)



(P V)
Pars ventralis



(P D)
Pars dorsomedialis

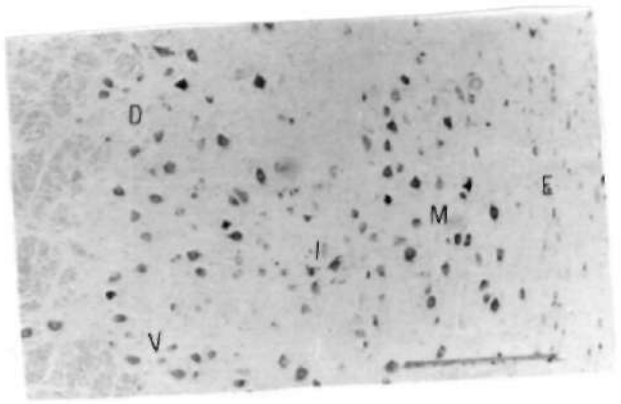


PLATE 38

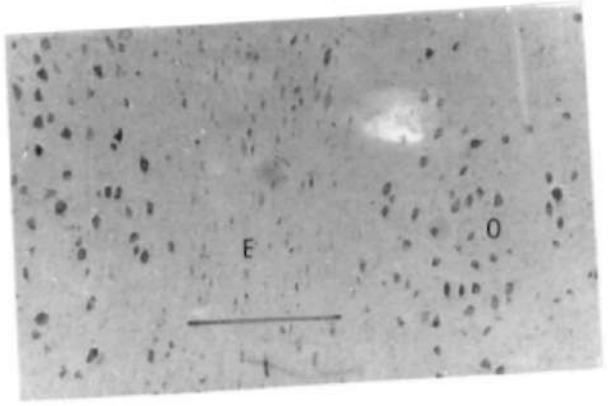


PLATE 39

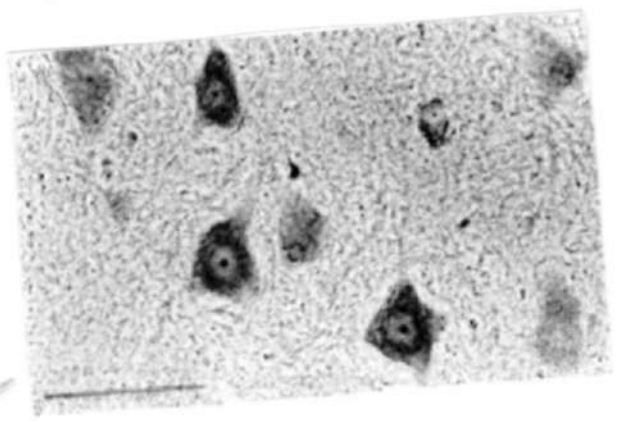


PLATE 40

Plate 38: A section through the oculomotor nucleus showing the subdivisions of this nucleus

D - Dorsal
V - Ventral
I - Intermediate
M - Medial
E - Edinger-Westpharl nucleus

Bar represents 1000um

Plate 39: Edinger Westphal nucleus (E) bordered on both sides by the oculomotor nuclei (O)

Bar represents 1000um

Plate 40: Some neurons of the oculomotor nucleus enlarged

Bar represents 1000um

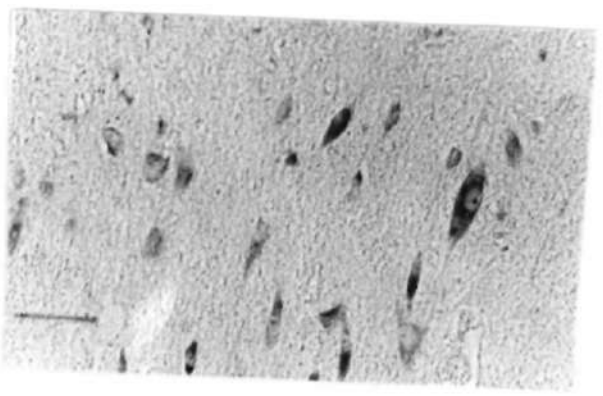


PLATE 41

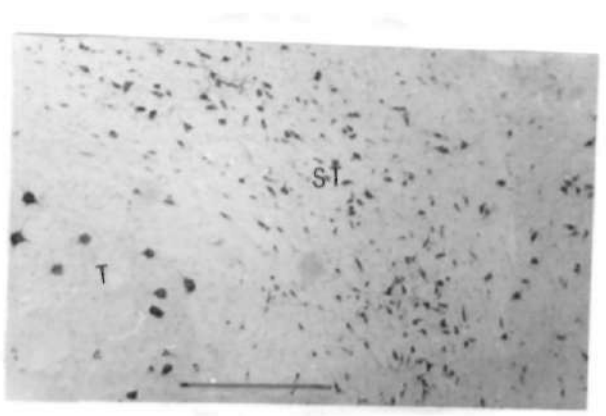


PLATE 42

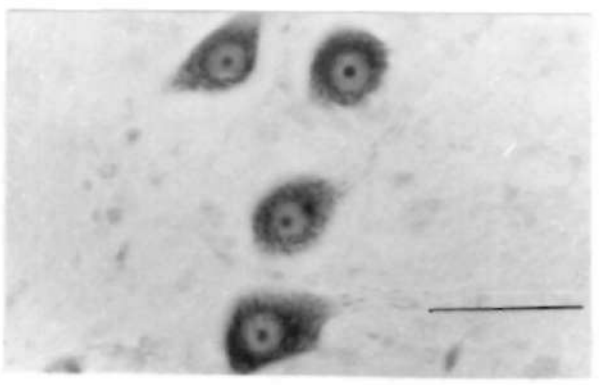


PLATE 43

Plate 41: Some neurons of the Edinger Westphal nucleus. Note the elongated appearance of the neurons

Bar represents 1000um

Plate 42: The relationship of the trochlear nucleus (T) to the supratrochlear nucleus (ST) is shown in this plate

Bar represents 1000um

Plate 43: A few neurons of the trochlear nucleus.

Bar represents 1000um.

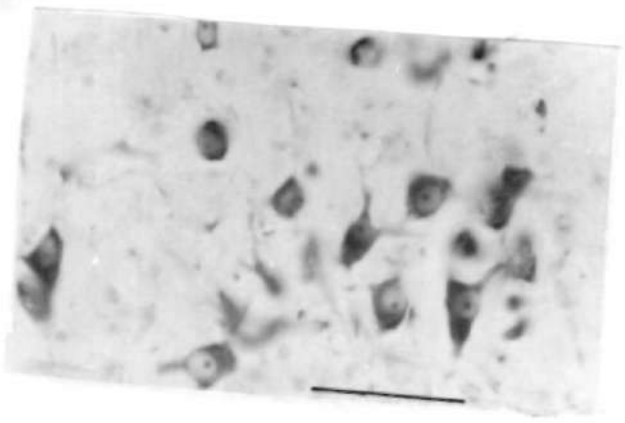


PLATE 44

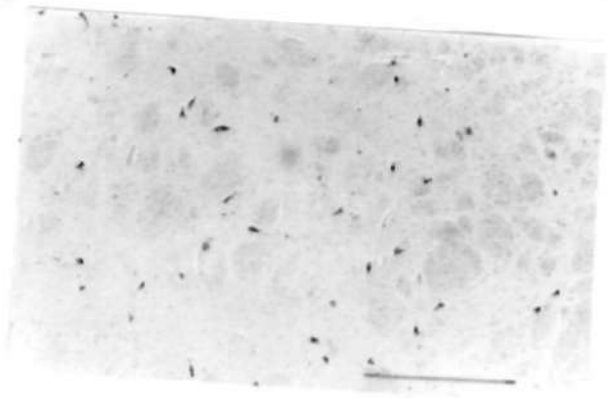


PLATE 45

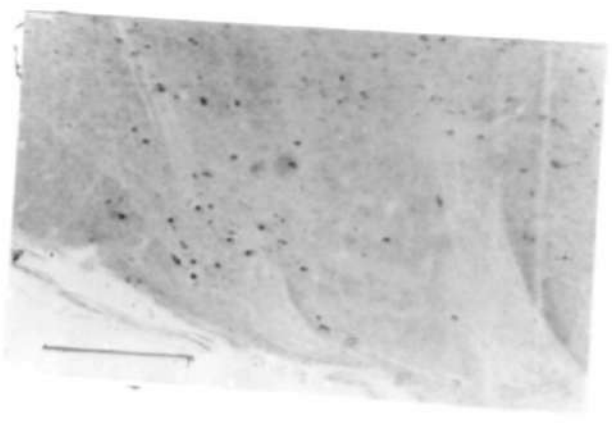


PLATE 46

Plate 44: Some neurons of the supratrochlear nucleus. Note: the dark staining
Bar represents 100.0um

Plate 45: Neurons of the substantia gelatinosa.
Note: the tiny but well stained neurons
Bar represents 1000um

Plate 46: Fibres of the oculomotor nucleus exiting through the nucleus of the ventral tegmental area of tsai
Bar represents 1000um

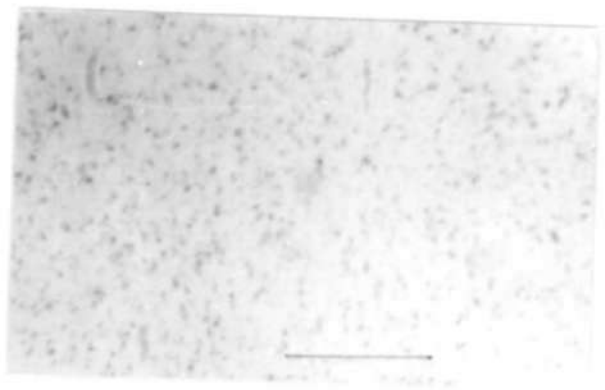


PLATE 47

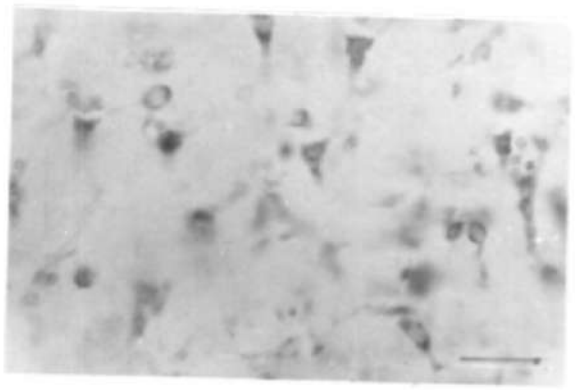


PLATE 48

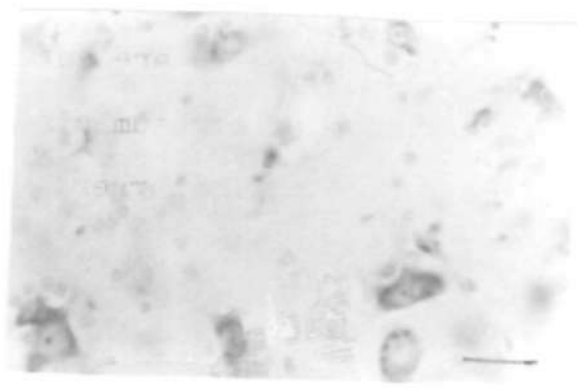


PLATE 49

Plate 47: Cells of the stratur cinereum.
Note: their dustlike appearance
Bar represents 1000um

Plate 48: Cells of the stratum cinereum enlarged
Bar represents 500um

Plate 49: Some cells of the deep grey stratum
of the rostral colliculi enlarged
Note: the cells are not as well stained
as those of stratum cinereum (Plate 48)
and are fairly larger.
Bar represents 500um.

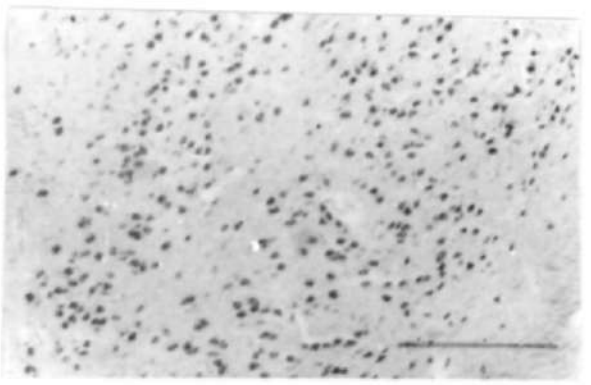


PLATE 50

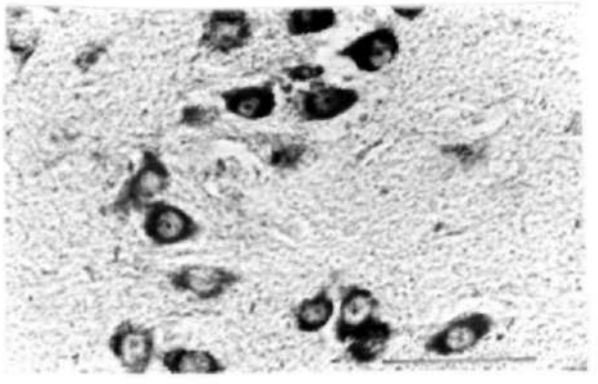


PLATE 51

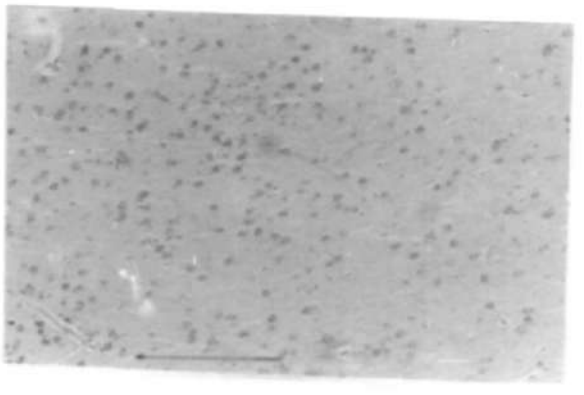


PLATE 52

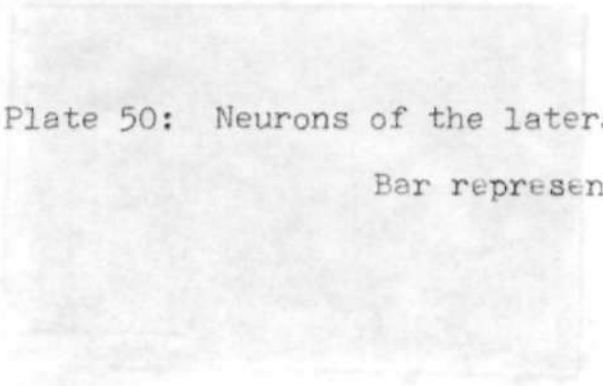


Plate 50: Neurons of the lateral geniculate body

Bar represents 1000um

Plate 51: Neurons of lateral geniculate body

enlarged

Bar represents 1000um

Plate 52: Neurons of the pulvinar

Bar represents 1000um

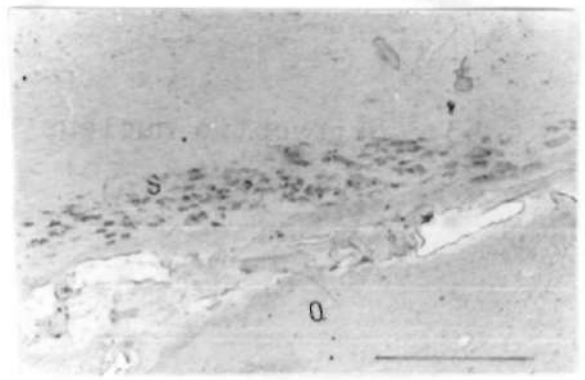


PLATE 53

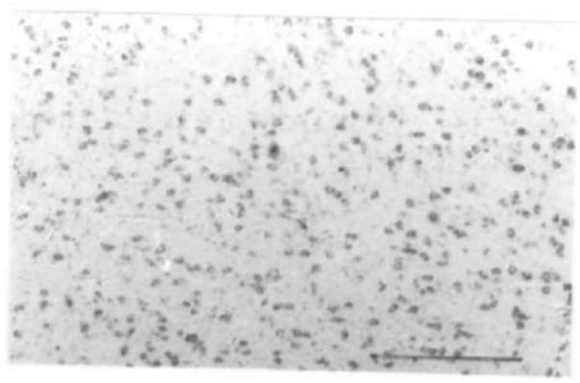


PLATE 54

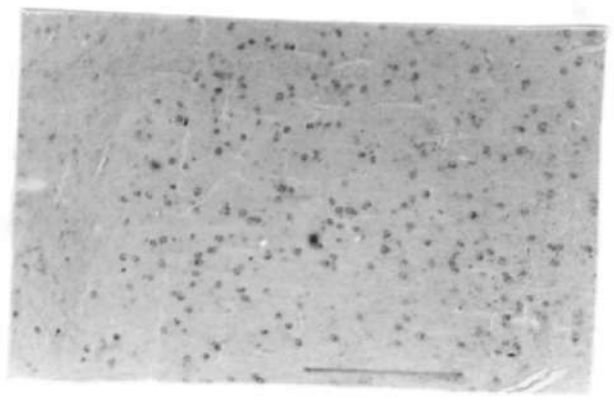


PLATE 55

Plate 53: Supraoptic nucleus situated above the optic tract (O)

Plate 54: Nucleus lateralis posterior

Plate 55: Nucleus ventralis posteromedialis

Table 1: Slaughter figures in major towns of the far North for five years

Year	Kano	Kaduna	Borno	Sokoto
1976	8,213	1,396[1]	692	3,222
1977	7,940	1,243	487	2,254
1978	11,321	976	291[2]	5,624
1979	7,517[3]	1,186[3]	143[3]	2,491[3]
1980	11,381	1,812	251[3]	4,092

1. Slaughter figures for 11 months only
2. Slaughter figures for 4 months only
3. Slaughter figures for 3 months only

Source: Quarterly livestock market survey of Federal Livestock Department

Table 2: Morphometric Characteristics of the camel brain (measurement in cm.) before processing

	No. of Specimens	Mean Length	Mean Width	Mean Height	Mean Weight
Thalamus[1]	40	1.5	2.2	3	-
Hypothalamus[2]	40	2.2	1.5	-	-
Optic tract[3]	40	3.4	0.5	-	-
Pons[4]	40	1.6	3.4	-	-
Medulla oblongata	40	3.8	3.3	-	-
Rostral colliculus	40	1.9	1.4	1.1	-
Caudal colliculus	40	0.52	0.8	0.70	-
Cerebral peduncles	40	2.3	1.6	-	-
Length of tegmentum[5]	40	1.5	-	-	-
Length of tectum[6]	40	2.1	2.5	-	-
Pineal gland	40	0.6	0.8	0.6	0.2
Hypophysis	40	1.7	1.3	1.00	0.4
Brainstem[7]	40	9.1	-	-	53.5
Wholebrain	50	-	-	-	476.8

1. Stria terminalis to cranial edge of rostral colliculi
2. Rostral edge of optic chiasma to caudal edge of mamillary body
3. Length is from optic chiasma to lateral geniculate body
4. Length is rostrocaudal extent
5. Caudal edge of mammillary body to rostral edge of pons
6. Rostral edge of rostral colliculi to caudal edge of caudal colliculi
7. Pontomedullary junction to just after hypoglossal nerve.

Table 3: Comparative morphometric characteristics of the brainstem of the Zebu cattle, buffalo and camel

	Zebu[1] Cattle	Buffalo[2]	Camel[3]
Length of Hypothalamus[4]	2.60	2.00	2.2
Length of mesencephalic tegmentum 5	1.4	1.5	1.5
Width of pons[6]	1.44	1.4	1.6
Length of pyramids	2.9	2.6	3
Length of myelencephalon			
Length of trapezoid body[7]	0.6	0.5	0.5 cm
Lateral extent of trapezoid body	3.7	3.3	3.4
Length of mesencephalic	-	2.6	2.1
Tectum			
Brain wt(gm)	457.6		476.81

1. Dandio (1980), DVM. Project, ABU, Zaria
2. Harper and Maser (1975)
3. Present study
4. Rostral edge of optic chiasma to caudal edge of mammillary body
5. Caudal edge of mammillary body to rostral edge of pons
6. Rostrocaudal measurement
7. Rostrocaudal extent
8. Cranial edge of rostral colliculi to the caudal edge of caudal colliculi

Table 4: Measurements of the red nucleus of some mammals

Species	Length	Width	Height
Camel	8.4	5.00	3.7 (present study)
Buffalo	5.9	2.9	3.00 (Paily, 1975)
Pig	6.11	3.7	2.4 (Otabe & Horowitz, 1970)
*Macaca cyclopsis	5.72	-	-
*Macaca mulata	4.3	2.5	2.3
*Cat	3.11	-	-

*Date obtained from Massion (1967).