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Research Article

ORGANIZATION OF CENTRAL NERVOUS SYSTEM OF INDIAN HOUSE WALL LIZARD *HEMIDACTYLUS FLAVIVIRIDIS*

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ABSTRACT

Topological organization of the central nervous system of Indian house wall lizard has been studied by Eager`s method. The central nervous system includes brain and spinal cord. The brain has prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain). The central nervous system is well developed in Indian house wall lizard *Hemidactylus flaviviridis.* The prosencephalon (forebrain) includes olfactory bulbs, cerebral hemispheres and diencephalon (thalamencephalon). The mesencephalon (midbrain) is located below the prosencephalon. It is middle part of the brain. This includes two large rounded optic lobes. These are situated dorso-laterally. The rhombencephalon (hindbrain) is located below the mesencephalon. This is posterior part of the brain. It has cerebellum and medulla oblongata. The cerebellum (metencephalon) is ill-developed. It is a narrow, flat and semicircular ridge. This covers the anterior dorsal surface of medulla oblongata. The medulla oblongata (myelencephalon) is broad in front by narrow and tapering behind.

The spinal cord is situated below the myelencephalon (medulla oblongata) of hindbrain. It is a long, whitish and somewhat dorso-ventrally flattened tube. This is lodged in the neural canal of the vertebral column.

***Keywords**: Prosencephalon, Mesencephalon, Rhombencephalon, Spinal Cord, Organization, Eager`s Method 1970*

INTRODUCTION

The lizards are among the most commonly spotted of all reptiles. There are over 3500 different types of lizards existing in all climates throughout India. The walls and ceilings are their niche where they walk and live their lives. The house wall lizard *H. flaviviridis* belongs to the family Gekkonidae of suborder Sauria or Lacertilia is second largest family of this suborder. It is said that lizards are poisonous except two species *Heloderma suspectum* and *Heloderma hornidum* are poisonous. The lizards are predator of insects hence they are useful for farmers and agriculture. They can be used for pest management.

In our present study the central nervous system as brain (prosencephalon, mesencephalon and rhombencephalon) and spinal cord of *H. flaviviridis* for better understanding of its anatomy and phylogenetic character has been presented.

MATERIALS AND METHODS

Ninety seven adult lizards, Sauria or Lacertilia of both sexes weighing 45 to 70 gms were used in this experiment. Animals were kept in the cage in the light and cool atmosphere at a room temperature (25 to 30°C). The experimental lizards were kept isolated in the separate cage from normal animal. Prior to the experiment, the specimens were acclimatized at room temperature for one day. Surgical procedures were performed with sterilized dissecting instruments. The specimens were anaesthetized by immersing with 10% formalin for 10 to 15 minutes prior to the surgery.

Operation Procedure

For perfusion, animals were anaesthetized with chloroform for 2 to 5 minutes. Completely anaesthetized lizard was kept in the operating tray. After fixing the lizard, a small longitudinal incision was made in the middle of the thorax (1CM). The rib cage was cut open right from the middle to expose the viscera. The thorax was opened to expose the heart. The pericardium was removed. Fine syringe of the perfusion set was inserted in the aorta through the posterior part of the ventricle. First of all 50 ml of physiological saline (0.75%) was allowed to pass through the aorta to the entire body, lower part of the ventricle was cut and blood was allowed to release. The whole blood of the body was replaced by physiological saline. One hundred ml. of fixative (10% formalin) was allowed to perfuse through the heart in continuation with saline. Precaution was taken to avoid the clotting of the blood which actually leads to incomplete perfusion. After the perfusion of the fixative, the animal become totally stretched. Following perfusion for about 15 minutes, the whole brain and spinal cord were dissected out and post fixed in the perfusion fluid at 4°C for twenty four hours. The brain and spinal cord were cut at 40 μm thick on AO HistoSTAT microtome at – 20°C. The serial sections were put in section collecting trays containing 2 to 10% formaldehyde solution. For maintaining the serial orders only 5 sections were placed in each bin of the tray. The sections were processed with Eager's method (1970).

Perfusion

This method is conventional technique for preserving the whole animal body by pumping the fixative through the heart in to the whole body via vascular system. The perfusion is performed by a simple infusion set. This technique works on the gravity flow principle. The perfusion bottle was kept three feet above to the operating table. The infusion set comprises to ordinary infusion set, a bottle with lid having two outlets, in one of them infusion needle was inserted and in other normal injection needle was inserted to avoid air lock. The infusion set comprises of plastic tube, an air column on both side, needle and a stopper.

RESULTS

The central nervous system is well developed in Indian house wall lizard *H.flaviviridis.* It includes brain and spinal cord. The brain has prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain) (Fig.1A&B). The prosencephalon (forebrain) includes olfactory bulbs, cerebral hemispheres and diencephalon (thalamencephalon) (Fig.1A&B).

Olfactory bulb

The olfactory part of the prosencephalon is clearly discriminated into olfactory lobes. These unite with olfactory bulb (OB) by elongated olfactory tract. As other terrestrial vertebrates, the house wall lizard also maintains a dual olfactory system like olfactory proper and accessory olfactory bulb. In the longitudinal vertical section, the accessory olfactory portion has been discriminated. This projects to amygdaloid nucleus (Fig.3). In the transverse section of olfactory part two lobes of proper olfactory portion and two small lobes of accessory olfactory bulb are clearly visible (Fig.4A&B). These two olfactory and the accessory olfactory nerves and the olfactory and accessory olfactory bulbs are paired. These are bilaterally symmetrical. These olfactory nerves terminate in either the principal olfactory formation or accessory olfactory formation of the olfactory bulbs (OB) at the rostral end of telencephalon. The olfactory nerve (ON) is broader. It is larger than accessory olfactory nerve. After originating from the olfactory part of the prosencephalon both travel together and ultimately associate with nasal epithelium. The olfactory bulb (OB) is located at the anterior end of the cerebral hemisphere (CH). This is pointed in the anterior most part. It is broader at the base. From the anterior pointed end of olfactory bulb (OB) the olfactory nerve (ON) comes out. The olfactory bulb (OB) is united to cerebral hemisphere (CH) by olfactory peduncle (OP). In both transverse and longitudinal lsections the fibers of olfactory bulb (OB) are seen directly associated with the olfactory cortex. This region is present in the lateral aspect of telencephalon. The accessory olfactory bulb is in the form of little elevation on the posteroventrolateral part of olfactory bulb (OB). Both the olfactory bulbs are connected across the mid line. The dorsal part of olfactory bulb (OB) has the extension of cerebral hemisphere (CH). This is clear from observation in longitudinal section of anterior most part of telencephalon. It is formed of seven layers. These are like layer of olfactory glomeruli (OG), layer of olfactory nerve fibers (ONF), external plexiform layer (EP), layer of mitral cells (M), internal plexiform layer (IP), layer of granule cells (GRC) and layer of ependymoglial cells (EGC) (Figs.3,4A&B).

Abbreviations used in figures

AC	anterior commissure
ADVR	anterodorsal ventricular ridge
ALH	area lateralis hypothalami
ALD	area laterodorsalis
ALV	area lateroventralis
AMD	area mediodorsalis
AMV	area medioventralis
AUR	auricular cerebelli
CC	central canal
C	cerebellum
CH	cerebral hemisphere
CO	collicular
CP	commissura posterior
STR	corpus striatum
D	diencephalon
DC	diocoel
DCX	dorsal cortex
DF	dorsal fissure
DH	dorsal horn
DVR	dorsal ventricular ridge
DMCX	dorsomedial cortex
DM	duramater
EP	external plexiform layer
FLM	fasciculus longitudinalis medialis
FT	filum terminale
FM	foramen of Monro
V-IV	fourth ventricle
GM	gray matter
GC	griseum centrale
HC	hippocampal commissure
HIP	hippocampus
H	hypothalamus
IP	internal plexiform layer
I	iter
GL	lamina granularis cerebelli
LCX	lateral cortex
LPA	lateral preoptic area
LFB	lateral forebrain bundle
LPA	lateral preoptic area
LSN	lateral septal nucleus
V-I&II	lateral ventricle
V-I	lateral ventricle
EGC	layer of ependymoglial cells
GRC	layer of granule cells
M	layer of mitral cells
OG	layer of olfactory glomeruli
ONF	layer of olfactory nerve fiber
VME	nucleus mesencephalicus nervi trigemini
DMH	nucleus hypothalamicus dorsomedialis
LH	nucleus hypothalamicus lateralis
MH	nucleus hypothalamicus medialis
LC	locus coerulus
MCX	medial cortex
MFB	medial forebrain bundle
ME	median eminence
MLF	medial longitudinal fissure
MSN	medial septal nucleus
N-VI	nervus abducens
N-VII	nervus fascialis
N-IX	nervus glassopharyngeus
N-XII	nervus hypoglossus
N-III	nervus oculomotorius
ON	nervus olfactorius
OPN	nervus opticus
N-XI	nervus spinal accessorius
N-V	nervus trigeminus
N-IV	nervus trochlearis
N-X	nervus vagus
N-VIII	nervus vestibulocochlearis
AMB	nucleus ambiguous
A	nucleus arcuatus
CERL	nucleus cerebellaris lateralis
CERM	nucleus cerebellaris medialis
TORC	nucleus centralis, torus semicircularis
COA	nucleus cochlearis angularis
NAC	nucleus commissurae anterioris
CP	nucleus commissural posterior
VDS	nucleus descendens nervi trigemini
DRI	nucleus dorsalis recessus infundibuli
ENP	nucleus entopeduncularis
NFLM	nucleus of the fasciculus longitudinalis medialis
FUN	nucleus funiculi dorsalis
FL	nucleus funiculi lateralis
GP	nucleus geniculatus pretectalis
DMH	nucleus hypothalamicus dorsomedialis
LH	nucleus hypothalamicus lateralis
MH	nucleus hypothalamicus medialis
HPE	nucleus hypothalamicus periventricularis
HP	nucleus hypothalamicus posterior
VH	nucleus hypothalamicus ventralis
VMH	nucleus hypothalamicus ventromedialis
ICO	nucleus intercolliculus
IPD	nucleus interpeduncularis, pars dorsalis
IPV	nucleus interpeduncularis, pars ventralis
NIFLM	nucleus of the interstitialis fasciculus longitudinalis medialis
L	lemniscal
TORL	nucleus laminaris, torus semicircularis
LL	nucleus lemnisci lateralis
RI	nucleus reticularis inferior
RIS	nucleus reticularis isthmi
RM	nucleus reticularis medius
RS	nucleus reticularis superior

HPE	nucleus hypothalamicus periventricularis
HP	nucleus hypothalamicus posterior
VH	nucleus hypothalamicus ventralis
VMH	nucleus hypothalamicus ventromedialis
IRI	nucleus intermedius recessus infundibuli
LP	nucleus lentiformis hypothalami, pars plicata
LE	nucleus lentiformis hypothalami, pars extensa
MC	nucleus microcellularis
XMD	nucleus motorius dorsalis nervi vagi
VIIM	nucleus motorius nervi fascialis
IXM	nucleus motorius nervi glossopharyngei
XIM	nucleus motorius nervi spinal accessori
VM	nucleus motorius nervi trigemini
VMD	nucleus motorius nervi trigemini, pars dorsalis
VMV	ncleus motorius nervi trigemini, pars ventralis
XM	nucleus motorius nervi vagi
VI	nucleus nervi abducentis
XII	nucleus nervi hypoglossi
III	nucleus nervi oculomotorii
III-D	nucleus nervi oculomotorii, pars dorsalis
III-I	nucleus nervi oculomotorii, pars intermedius
III-V	nucleus nervi oculomotorii, pars ventralis
I	nucleus nervi olfactorius
II	nucleus nervi opticus
IV	nucleus nervi trochlearis
VIII-C	nucleus nervi vestibulocochlearis, pars caudalis
VIII-D	nucleus nervi vestibulocochlearis, pars dorsalis
VIII- V	nucleus nervi vestibulocochlearis, pars ventralis
OPT	nucleus opticus tegmenti
PVN	nucleus paraventricularis
NPVO	nucleus of the paraventricular organ
PV	nucleus periventricularis
APV	nucleus periventricularis anterior
PPV	nucleus periventricularis
PD	nucleus posterodorsalis
P	nucleus praemamillaris
NPOR	nucleus of the preoptic recess
VPR	nucleus princeps nervi trigemini
PRMC	nucleus profundus mesencephali, pars caudalis
PRMR	nucleus profundus mesencephali, pars rostralis
PD	nucleus posterodorsalis
P	nucleus praemamillaris
NPOR	nucleus of the preoptic recess
RAI	nucleus raphes inferior
RAS	nucleus raphes superior
RI	nucleus recessus infundibuli
V-III	third ventricle
SC	spinal cord
VF	ventral fissure
VH	ventral horn
RSL	nucleus reticularis superior, pars lateralis
RSM	nucleus reticularis superior , pars medialis
ROT	nucleus rotundus
SCN	nucleus suprachiasmaticus
SON	nucleus supraopticus
SF	nucleus subfornicalis
SVG	nucleus subventricular gray
SOL	nucleus tractus solitarii
VRI	nucleus ventralis recessus infundibuli
VT	nucleus ventralis tuberis
VEDS	nucleus vestibularis descendens
NVIII	nucleus vestibulocochlearis
VEDL	nucleus vestibularis dorsolateralis
VETG	nucleus vestibularis tangentialis
VEVL	nucleus vestibularis ventrolateralis
VEVM	nucleus vestibularis ventromedialis
Obex	obex
OB	olfactory bulb
OP	olfactory peduncle
OV	olfactory ventricle
OLS	oliva superior
OC	optic chiasma
OL	optic lobe
PL	pallium laterale
PM	pallium mediale
PB	parabrachial region
PVO	paraventricular organ
GM	gray matter
PM	piamater
PIT	pituitary
PD	posterodorsalis
PDVR	posterodorsal ventricular ridge
POR	preoptic recess
RC	retroinfundibular commissure
SAC	stratum album centrale
SGC	stratum griseum centrale
SGFS	stratum griseum et fibrosum superficial
SGP	stratum griseum periventriculare
SO	stratum opticum
SN	substantia nigra
SIV	sulcus intermedioventralis
SLH	sulcus limitans of His
SMI	sulcus medianus inferior
SMS	sulcus medianus superior
SVG	subventricular gray
TM	tectum mesencephali
WM	white matter
VF	ventral fissure

Cerebral hemisphere (Telencephalon)

This is well differentiated somewhat oval paired structure. The anterior end of which is blunt while the posterior end is broader. The anterior blunt end associates with olfactory peduncle (OP) while the posterior broader end unites with optic lobes (OL). Two hemispheres are divided by median longitudinal fissure (MLF) (Figs.1A,&3). Internally the cerebral hemisphere (CH) of wall lizard has been demarcated into four longitudinal areas / zones. These are like area laterodorsalis (ALD), area mediodorsalis (AMD), area lateroventralis (ALV) and area medioventralis (AMV) (Figs.2&3). The cerebral cortex of wall lizard includes area laterodorsalis (ALD) and area mediodorsalis (AMD). These two areas can also be referred as lateral cortex (LCX) and medial cortex MCX). The lateroventral area (ALV) is the region of striatum (STR) while the medioventral area (AMV) is septal region around the mid longitudinal axis containing septal nuclei. The cerebral cortex of wall lizard presently studied has been discriminated into medial cortex (MCX), dorsomedial cortex (DMCX), dorsal cortex (DCX) and lateral cortex (LCX). The medial and dorsomedial cortex are the portions represented as hippocampal (HIP) formation. The dorsal cortex (DCX) is homologous to neocortex / isocortex of mammals. The lateral cortex (LCX) is termed as olfactory cortex. All the four regions of cortex are shown in figs.2&3. The cerebral cortex of it is three layered laminar structure. This can be clearly observed in medial, dorsomedial, dorsal and lateral cortex. The density of cells in dorsomedial cortex (DMCX) and medial cortex (MCX) is the same while the density of cells in dorsal and lateral cortex is the same. Downwards the layers of cortex a region called dorsal ventricular ridge (DVR) is present which bulges into the lateral ventricle designated above the basal ganglia. The dorsal ventricular ridge (DVR) is differentiated into an anterior part called as ADVR and a posterior part known as PDVR (Figs.3&5C). The complete cerebral hemisphere (CH) is separated into pallium and subpallium. The pallium contains cerebral cortex and dorsal ventricular ridge (DVR) while subpallium includes striatal (STR) and septal region. In the figs.2,3,5A&B related cerebral hemisphere, pallium and subpallium regions are depicted. The dorsal ventricular ridge (DVR) can be differentiated into three zones as dorsal zone, ventral zone and an intermediate zone between dorsal and ventral zone (Fig.5C).

The septum/ area medioventralis (AMV) zone of telencephalon of prosencephalon contains the septal nucleus. It is separated into medial septal nucleus (MSN) and lateral septal nucleus (LSN). Both medial and lateral septal nucleus run parallel to each other (Figs.3,6A&B). This observation also presents that the medial septal nucleus (MSN) can be differentiated into dorsal septal nucleus and ventral septal nucleus. The septal nucleus which is included in the area medioventralis (AMV) starts from posterior region of olfactory region. The lower ventral part of the medial septal nucleus (MSN) extends caudally to the beginning of the interhemispheric junction. The lateral septal nucleus (LSN) runs caudally upto the interhemisphere junction. The septal fibers are also seen crossing to interhemispheric junction. These fibers are forming medial forebrain bundles (MFB). The lateral septal nucleus (LSN) touches the striatum (STR) while the medial septal nucleus (MSN) touches the medial line of interhemispheric junction. The lateral septal nucleus (LSN) is in direct connection with the striatal mass.

The striatum/ area lateroventralis (ALV) part is showed in the lower ventral region of cerebral hemisphere (CH). It also constructs longitudinal zone. The density of neurons is thin in the dorsal region while more densely aggregated cells are observed in the ventral region. Rostrally the striatum (STR) merges with the granule cell layer of olfactory region (Fig.3). Caudally the striatum (STR) extends upto dorsal entopeduncular nucleus (ENP) present ventral to amygdala nucleus.

Diencephalon – Hypothalamus

The diencephalon (D) is a small central oval structure. This is surrounded by two inverted V like structure of cerebral hemisphere (CH) and V like structure of optic lobes (OL). It is visible dorsally. The lateral wall of diencephalon (D) is thick. This makes optic thalami and the floor of the diencephalon (D) in the hypothalamus (H). It can not be observed from external dorsal side. On the ventral side the two optic nerves (ON) are crossing each other forming optic chiasma (OC). The hypothalamus (H) of *H. flaviviridis* begins rostrally from the region where the 3rd ventricle starts. This continues caudally as far as the nucleus praemamillaris (P) and the median eminence (ME). Laterally hypothalamus (H) is bound by medial (MFB) and lateral forebrain bundles (LFB). All the hypothalamic nuclei are paired. The hypothalamic nuclei are separated into two regions as magnocellular region and parvocellular region.

The magnocellular region is divided into two nuclei like nucleus supraopticus (SON) and nucleus paraventricularis (PVN). The parvocellular part is classified into as nucleus suprachiasmaticus (SCN), nucleus commissurae anterioris (NAC), lateral preoptic area (LPA), nucleus of the preoptic recess (NPOR), nucleus subventricular gray (SVG), nucleus periventricularis anterior (APV), nucleus periventricularis posterior (PPV), nucleus hypothalamicus periventricularis (HPE), nucleus microcellularis (MC), nucleus subfornicalis (SF), nucleus arcuatus (A), nucleus ventralis tuberis (VT), nucleus hypothalamicus ventromedialis (VMH), paraventricular organ (PVO), nucleus of the paraventricular organ (NPVO), nucleus hypothalamicus dorsomedialis (DMH), nucleus hypothalamicus lateralis (LH), nucleus hypothalamicus medialis (MH), nucleus hypothalamicus posterior (HP), nucleus praemamillaris (P), nucleus dorsalis recessus infundibuli (DRI), nucleus intermedius recessus infundibuli (IRI) and nucleus ventralis recessus infundibuli (VRI**) (**Figs.2,3,7A,B,C,8A,B&C).

Pituitary (Hypophysis)

It is lower most part of the diencephalon. Pituitary (PIT) is located ventrally to the median eminence (ME), extends medio-laterally in tapering form. Hypophysis in presently studied *H. flaviviridis* is well discriminated and is made up of mainly two parts as neurohypophysis and adenohypophysis. The neurohypophysis is composed of neural lobe (NL). The adenohypophysis comprises of pars tuberalis (PT), pars intermedia (PI) and pars distalis (PAD) (Figs.3,9A&B).

In addition to these nuclei, few clusters of cells are observed in the caudal part of diencephalon in the presently studied *Hemidactylus flaviviridis*. These are as posterodorsalis (PD), nucleus lentiformes thalami pars extensa (LE), nucleus lentiformes thalami, pars plicata (LP), commissure posterior (CP), nucleus rotundus (ROT), nucleus geniculatus pretectalis (GP) and nucleus entopeduncularis posterior (ENP) (Figs.3,9A&B).

Mesencephalon (Midbrain)

It is well developed in Indian house wall lizard *H. flaviviridis*. This anteriorly associates with the caudal thalamencephalon of the posterior part of the forebrain. This posteriorly unites with the anterior part of the metencephalon of the hindbrain. It has two large rounded optic lobes. These two optic lobes are located dorso–laterally (Fig.1A&B).

The longitudinal sections (Figs.10&11) represent clear demarcation of midbrain and hindbrain. The latter part continues as spinal cord. The ventricles are very clear (Fig.12). These are as olfactory ventricle, lateral ventricle, foramen of Monro, diocoel, optocoel, iter, metacoel (4th Ventricle) and central canal.

In the present investigations, the following four ventricular sulci or grooves have been recognized. These are like sulcus medianus inferior (SMI), sulcus intermedius ventralis (SIV), sulcus limitans of His (SLH) and sulcus medianus superior (SMS).

From the study of different sulci and the relationship of different grooves from nuclear groups of Indian wall lizard, *H. flaviviridis*, the mesencephalon has been separated into two main longitudinal zones. These are as motor basal plate and sensory alar plate. The motor basal plate is situated medially. The sensory alar plate is located laterally. The motor basal plate is further separated into area ventralis and area intermedio ventralis. The area ventralis is somatic motor zone. The area intermedio ventralis is visceral motor zone. The area ventralis somatic motor zone contains motor nucleus of III cranial nerve (Figs.11,14A&B) and motor nucleus of IV cranial nerve (Fig.11).

In addition to these nuclear groups few scattered cells are present in this region showing different organization of neurons. These are represented as reticular (network) regions or reticular formation. The network of neurons is present very distinct rostrally to caudally tegmentum mesencephali. The zones of reticular formation can be represented in the different nuclear groups.

These are as nucleus of the fasciculus longitudinalis medialis (NFLM) (Figs.11,17A,B,18A,B,19A,B,20A,B,21A&B), nucleus interstitialis of fasciculus longitudinalis medialis (NIFLM) (Fig.11) and nucleus reticularis isthmi (RIS) (Figs.10,14A&B).

Rhombencephalon (Hindbrain)

This is well developed in Indian house wall lizard *H.flaviviridis*. It is formed of two parts as metencephalon and myelencephalon. The rostral part of the hindbrain, metencephalon associates with the anterior caudal midbrain. The caudal portion of the hindbrain, medulla oblongata connects with the rostral region of the spinal cord. The cerebellum is ill–developed. It is a narrow, flat and semicircular ridge covering the anterior dorsal surface of medulla. The medulla oblongata is triangular. This is broad in front by narrow and tapering behind. The thin and highly vascular roof of myelencephalon makes the posterior choroid plexus. Posteriorly, the medulla oblongata presents a strong ventral flexure where it passes into the spinal cord.

The area ventralis somatic motor zone has two motor nuclei as motor nucleus of VI cranial nerve (Fig.11) and motor nucleus of XII cranial nerve (Figs.11,20A&B). The area intermedio ventralis a visceral motor zone of motor basal plate contains five motor nuclei as nucleus motorius nervi trigemini (VM) (Figs.11,18A&B), nucleus motorius nervi facialis (VIIM) (Figs.11,19A&B), nucleus motorius nervi glossopharyngei (IXM) (Figs.11,19A&B), nucleus motorius nervi vagi (XM) (Fig.11), nucleus motorius nervi vagi (XM) (Fig.11) and nucleus motorius nervi spinal accessori (XIM) (Fig.11). The area intermedio ventralis is the lateral longitudinal visceral motor area of the basal plate. This extends from anterior to posterior level of hindbrain. It includes the cranial nerve nuclei of V, VII, IX, X and XI. The lateral portion of hindbrain basal plate has the similar group of motor involuntary nuclear groups making a longitudinal band throughout the hindbrain.

Metencephalic and myelencephalic medial reticular formation

The medial hindbrain reticular zone extends most anteriorly at the metencephalic region to posterior most part of medulla oblongata. At here the motor nucleus of XIIth cranial nerve is present. It makes a regular column throughout the hindbrain. In the anterior part of the hindbrain this zone is designated immediately adjacent to the hindbrain raphes. This attains the level of abducentis nucleus. In it, the cells are of small size. These are diffusely arranged. The medial reticular zone also binds laterally to the visceral motor nuclei. The cells of the reticular formation are not evenly distributed. These can be separateded into as nucleus reticularis superior (RS), the nucleus reticularis superior (RS) (Figs.16A,B,17A&B) is differentiated into lateral part of reticularis superior (RSL) (Fig.16A&B), medial part of reticularis superior (RSM) (Fig.16A&B), nucleus reticularis medius (RM) (Figs.11,18A,B,19A,B) and nucleus reticularis inferior (RI) (Fig.20A&B) and nucleus raphes (RA). The nucleus raphes (RA) is separated into nucleus raphes superior (RAS) (Figs.11,17A&B) and nucleus raphes inferior (RAI) (Figs.11,18A,B,19A,B,20A&B).

Nuclei of alar plate of cerebellum and medulla oblongata

The sulcus limitans extends throughout the hindbrain. This longitudinally separates into a basal plate and an alar plate. It is present laterally. This is discriminated into four zones. These have different nuclear organizations. These have been named as different masses of neurons. The observations of Opdam *et al*. (1976) have been taken into consideration to delimit different zones in the present study on *H. flaviviridis*. These zones are like visceral sensory zone, general somatic sensory zone, special somatic sensory zone and special visceral sensory zone. The visceral sensory zone contains nucleus tractus solitarii (Fig.11). The general somatic sensory zone has nucleus descendens and nucleus princeps of V (Figs.11,18A&B). The special somatic sensory zone is the area where the VIIIth nerve is terminating and forms vestibular nuclear complex (Figs.11,18A&B). The special visceral sensory zone is the region where the fibers of gustatory nerve are terminating (Fig.11).

In addition to these nuclei few other nuclei are also observed in the presently studied *H. flaviviridis*. These are as nucleus tractus solitarius (SOL) (Figs.11,20B,C,21B&C), vestibular nuclear complex (Fig.11), nucleus vestibularis dorsolateralis (VEDL) (Figs.11,18A&B), nucleus vestibularis ventrolateralis (VEVL) (Fig.11), nucleus vestibularis ventromedialis (VEVM) (Figs.11,18A&B), nucleus vestibularis tangentialis (VETG) (Fig.11) and nucleus vestibularis descendens (VEDS) (Figs.11,20B&C).

Spinal cord

This is well developed in Indian house wall lizard *H. flaviviridis.* It is a long, whitish and dorso-ventrally flattend tube (Fig.22A,B&C). This is lodged into the neural canal of the vertebral column. The rostral wider portion of the spinal cord (SC) joins with caudal medulla oblongata. The caudal region of spinal cord is filum terminale (FT) (Fig.22A,B&C). The structure of spinal cord is of typical vertebrate plan. The spinal cord is closely resemble to nearest lower and nearest upper vertebrates. The meninges duramater (DM) and piamater (PM) covering the brain are continuous over the spinal cord.

The sections of it present the characteristic H – shaped pattern of gray matter (GM) with well developed dorsal horn (DH) and ventral horn (VH) (Fig.23A,B&C). The white matter (WM) is located in between the gray matter(GM) and piamater (PM). A shallow mid–dorsal fissure (DF) and a prominent mid - ventral fissure (VF) are evident (Fig.24A,B&C). The central canal (CC) of spinal cord is filled with cerebro – spinal fluid (CSF). It is continuous with the fourth ventricle (IV-V) of medulla oblongata (MO).

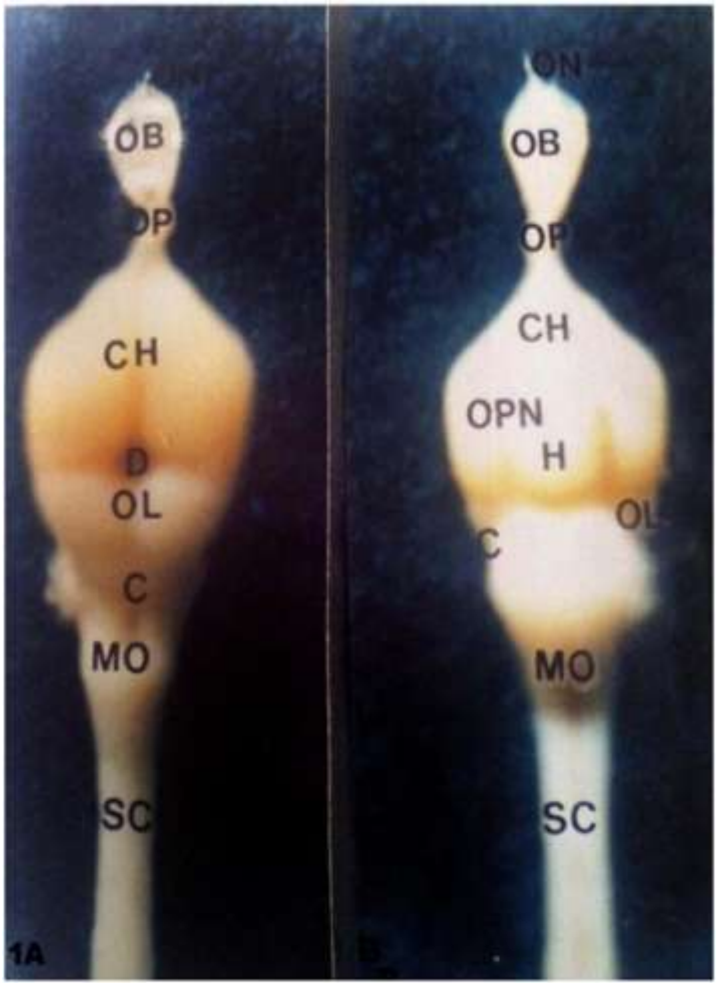
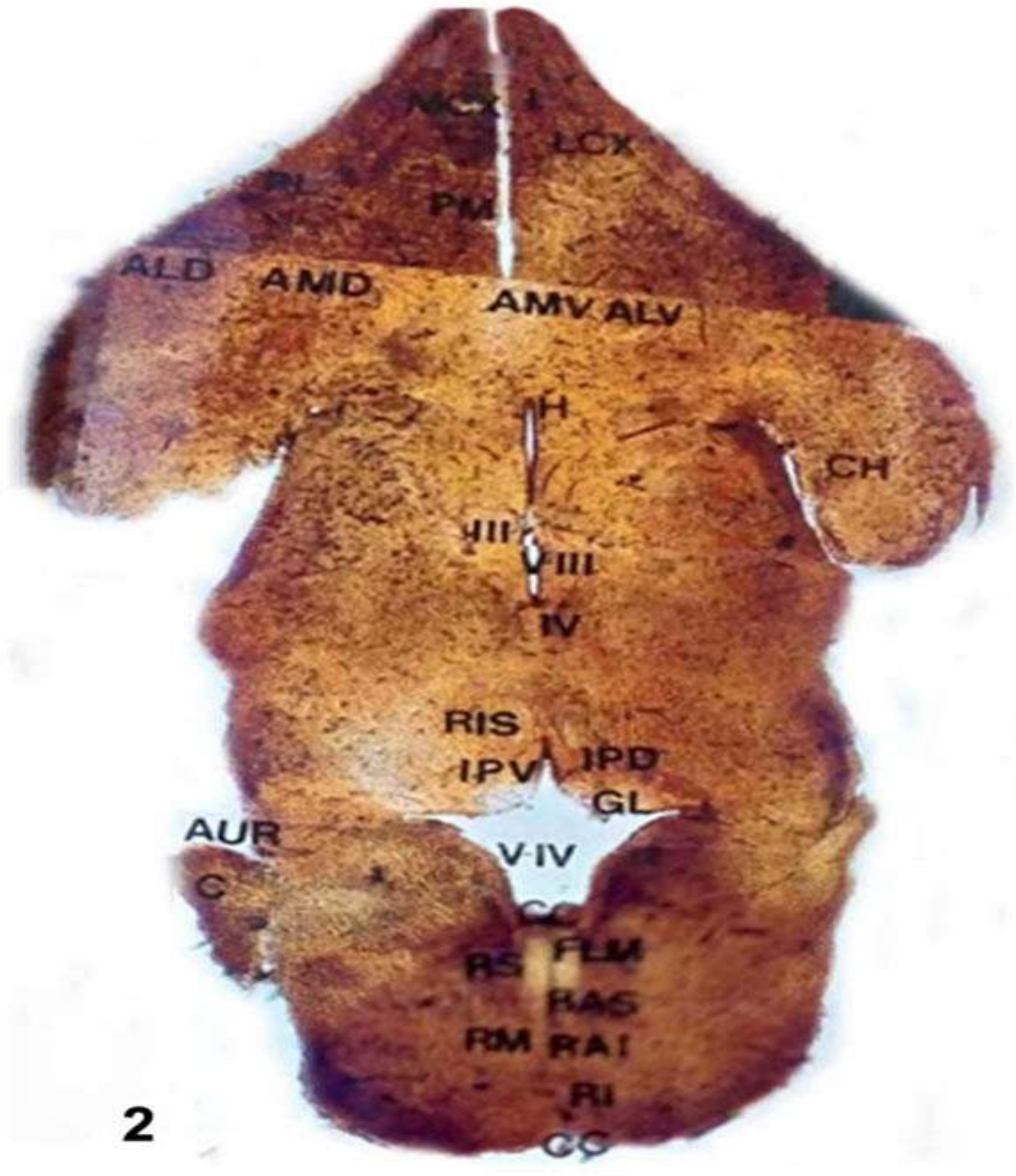


Figure 1A-B


NCX
I
LCX
BL
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ALD
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III
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Figure 2

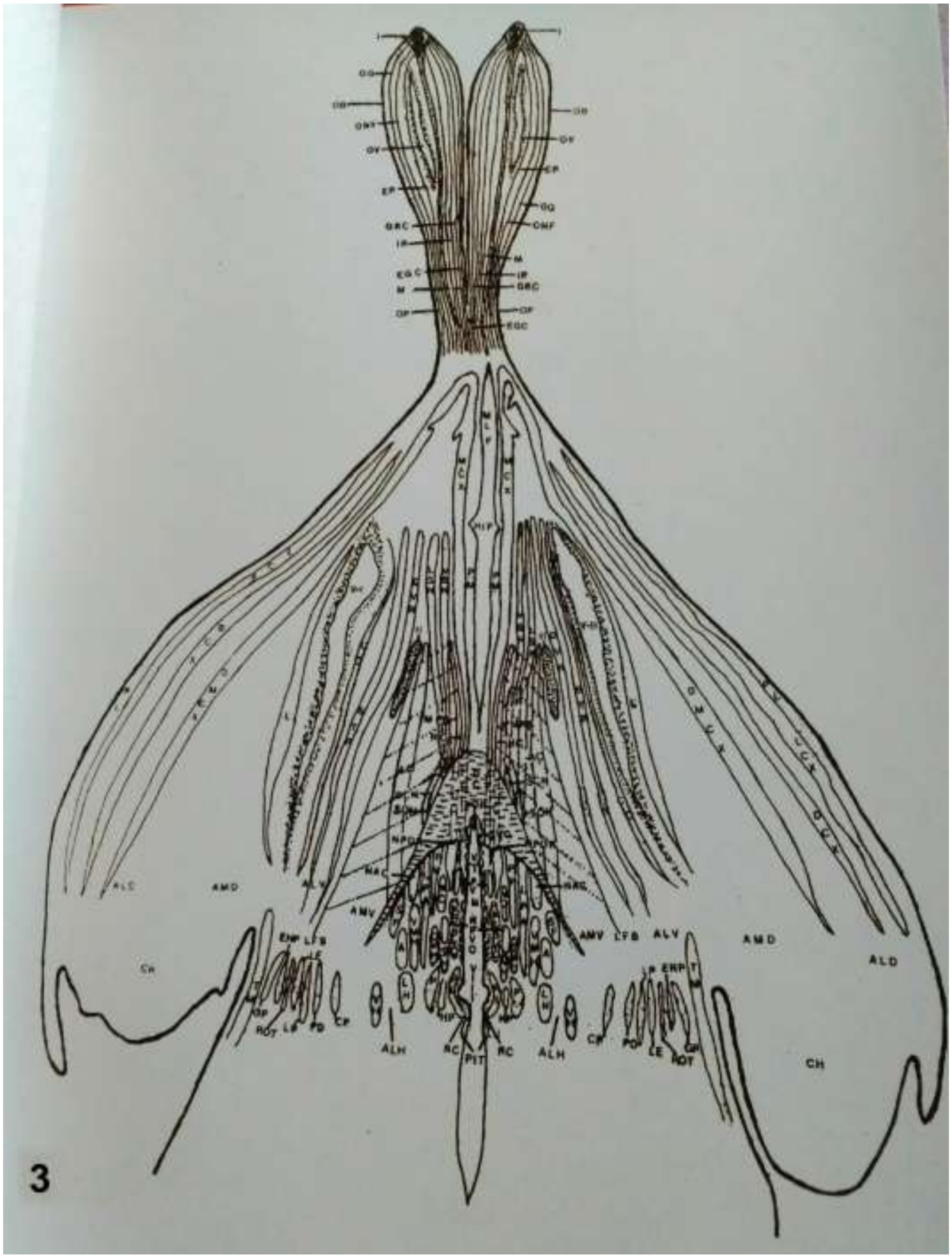
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Figure 3

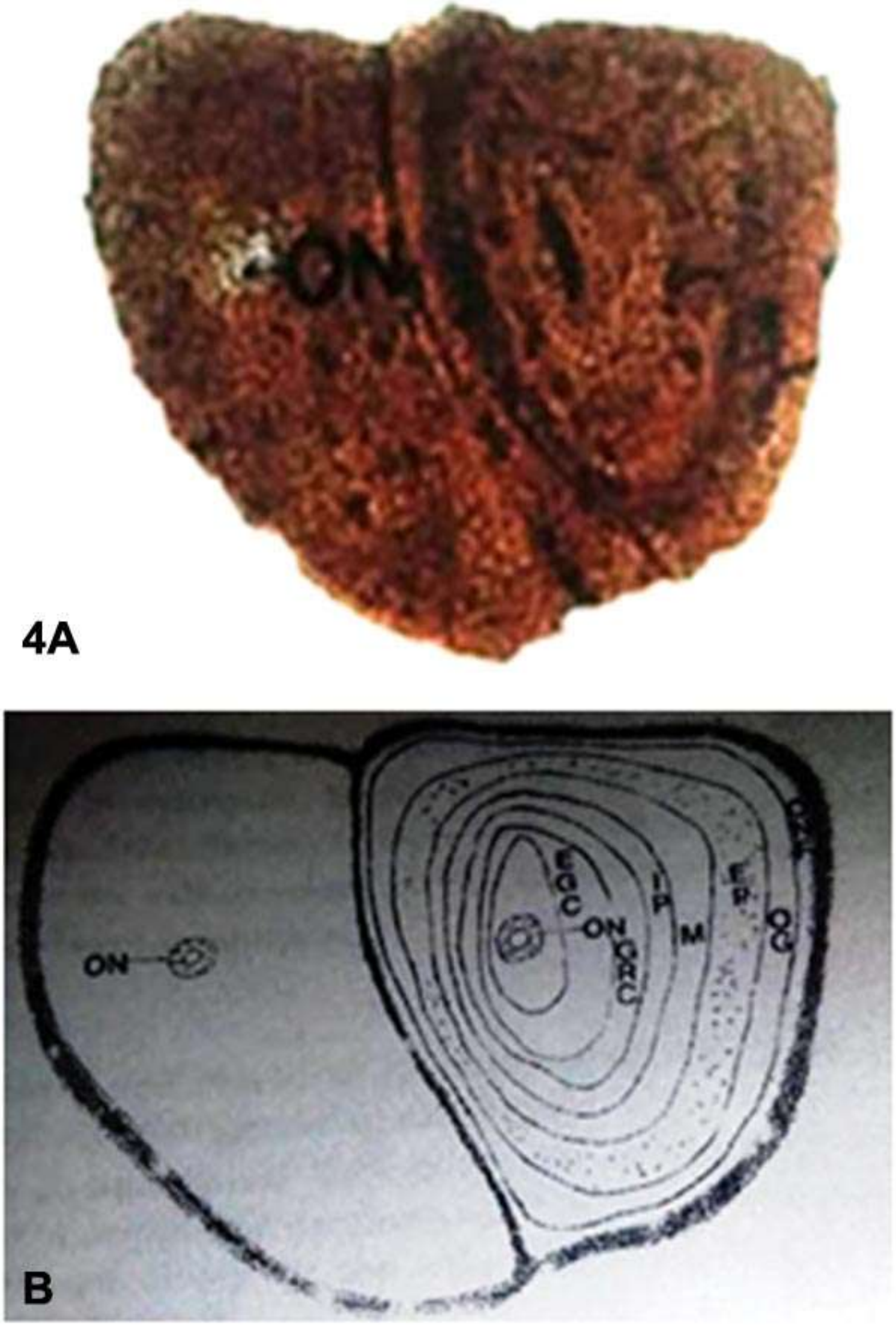
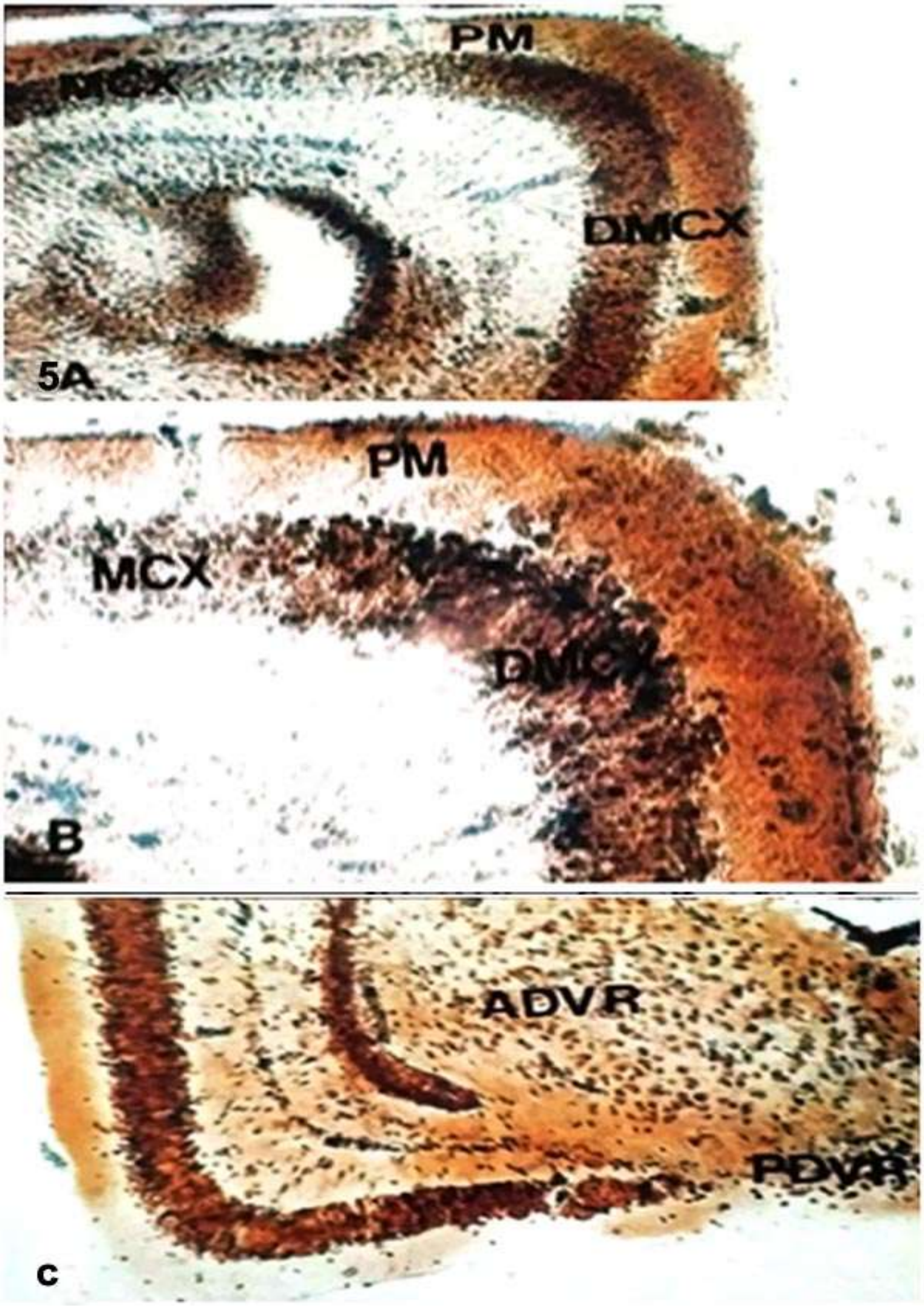


Figure 4A-B



Figures 5A-C

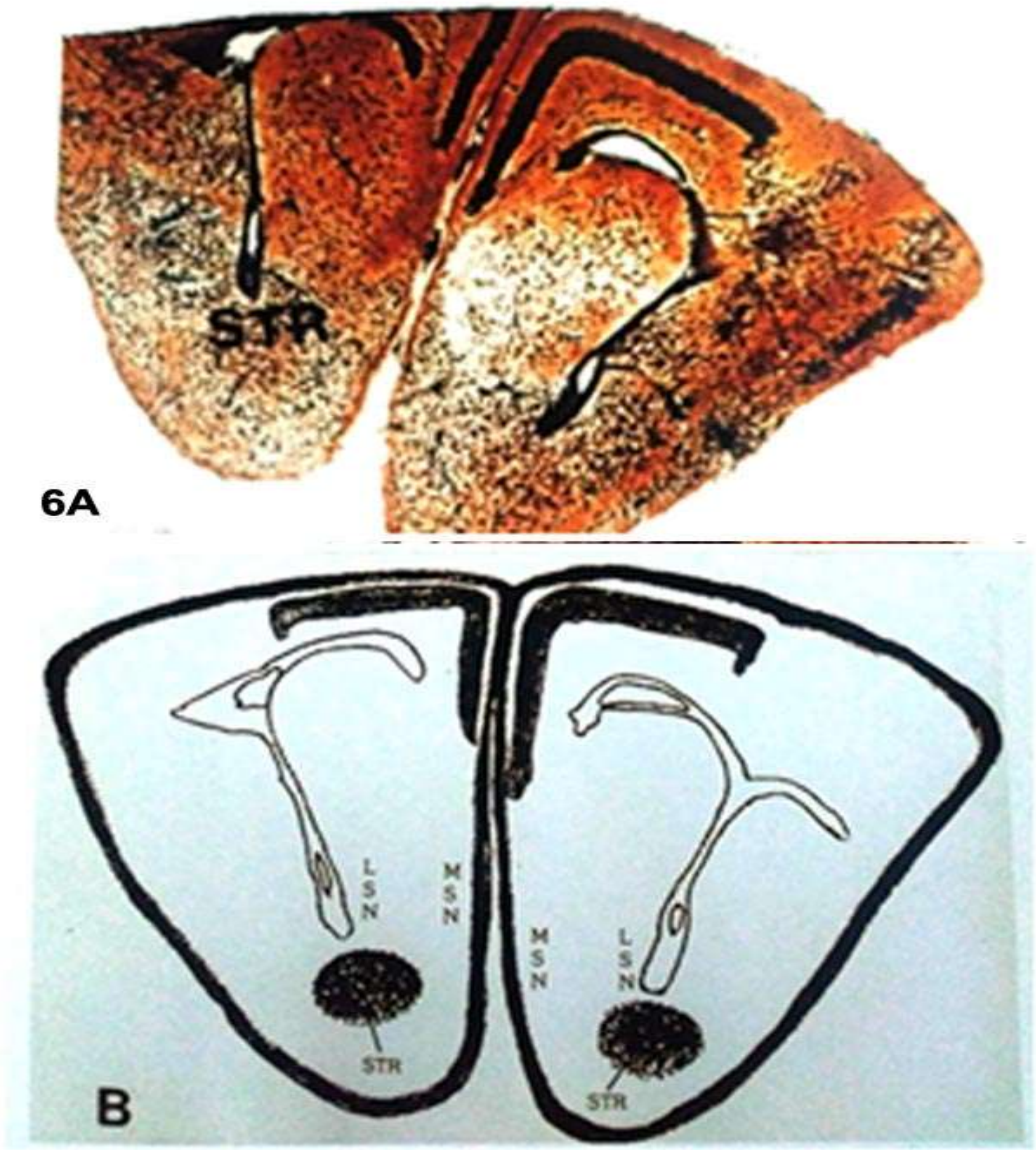


Figure 6A-B

Research Article

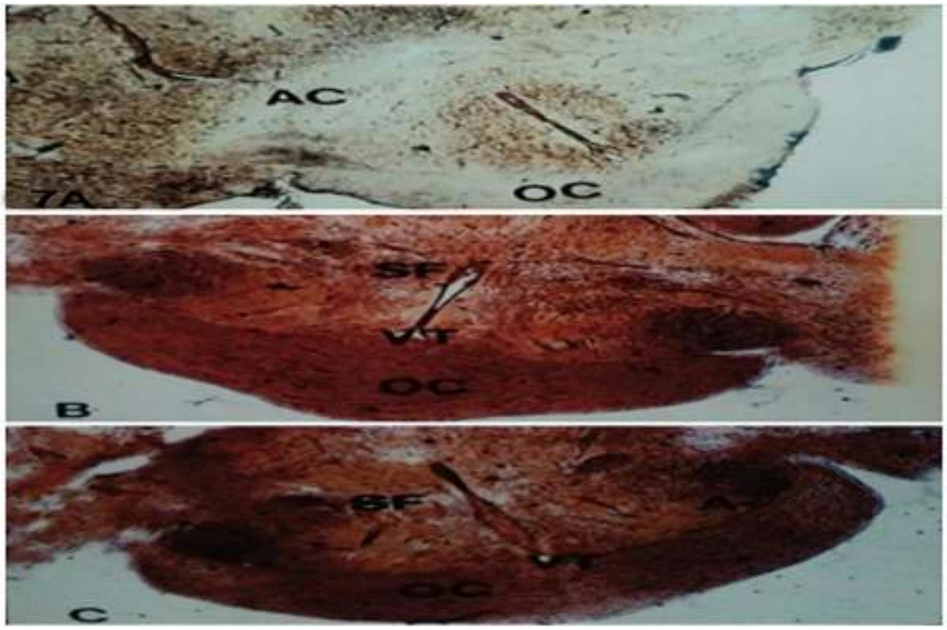


Figure 7A-C

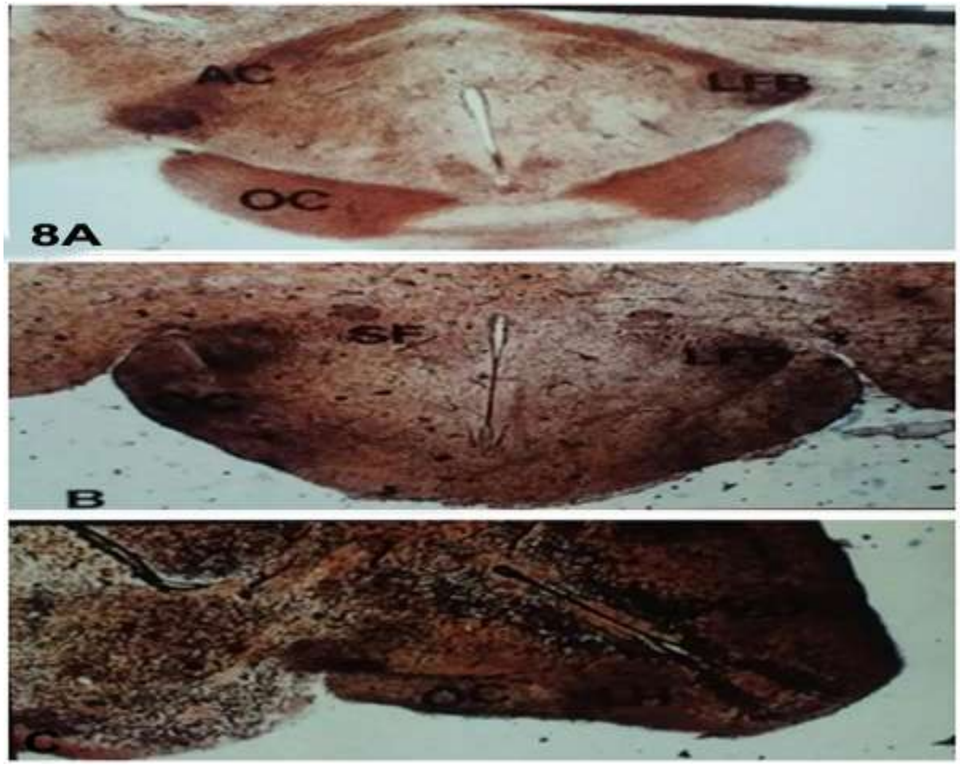


Figure 8A-C

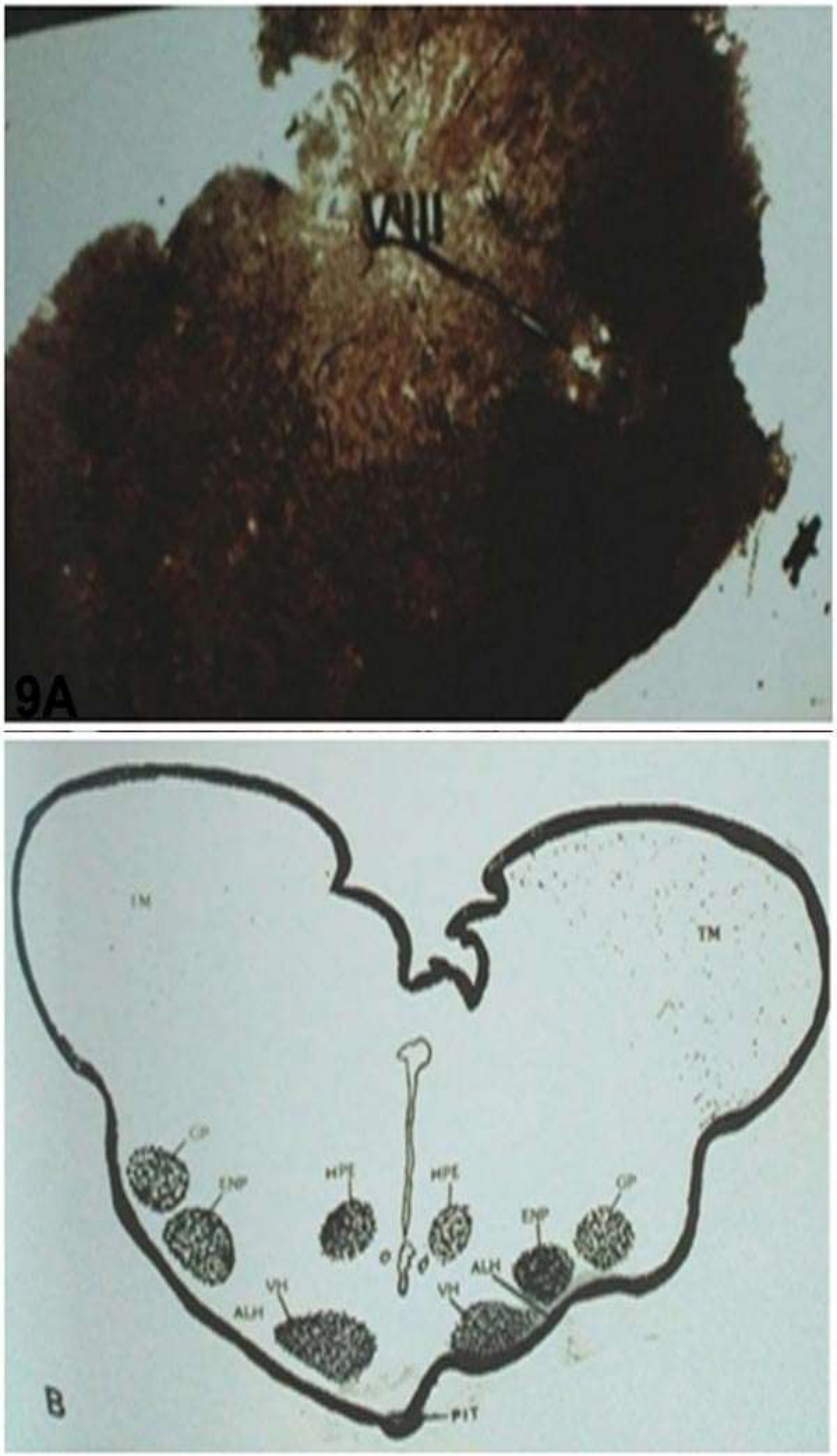


Figure 9A-B

Research Article

Figure 10

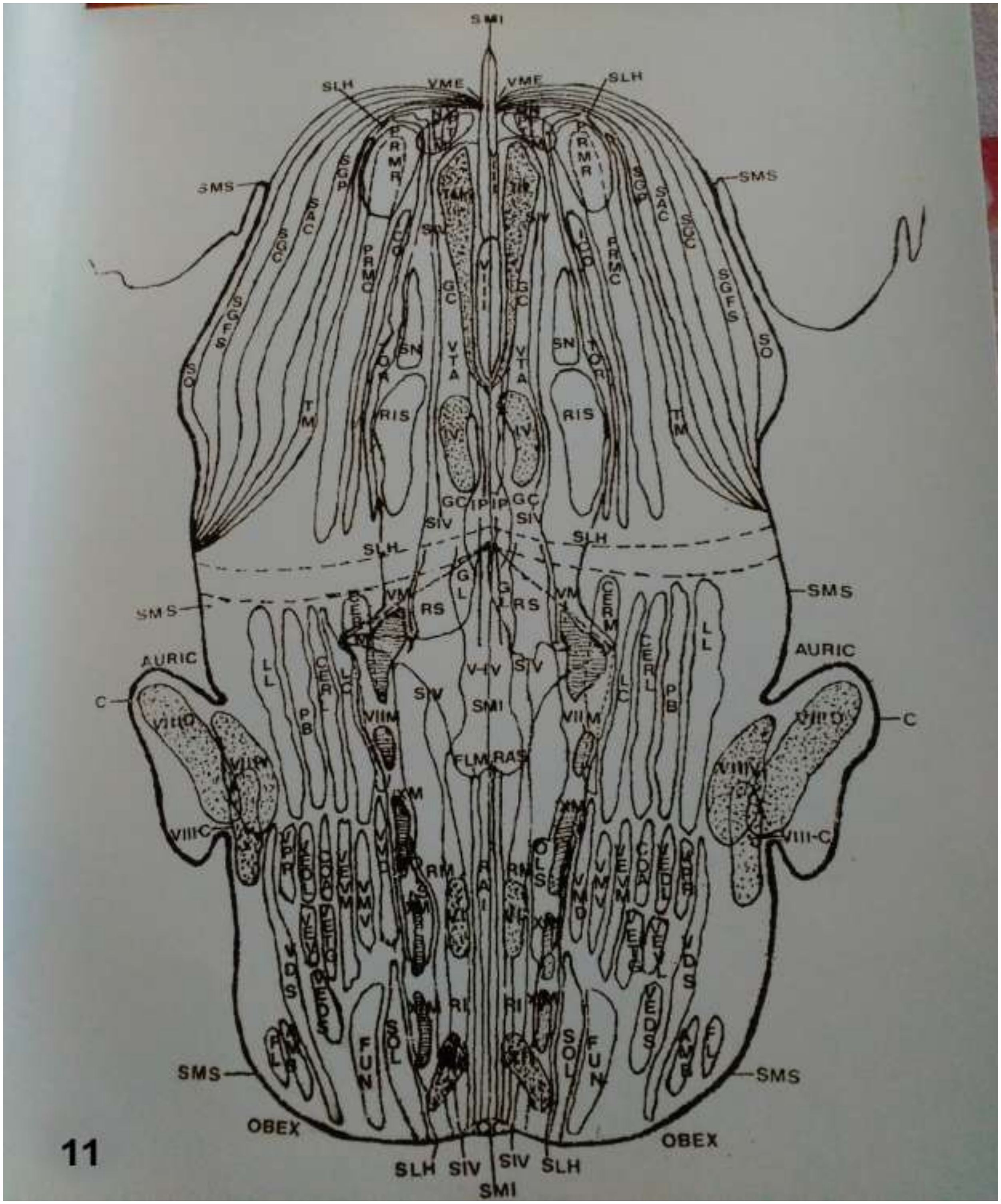

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Figure 11

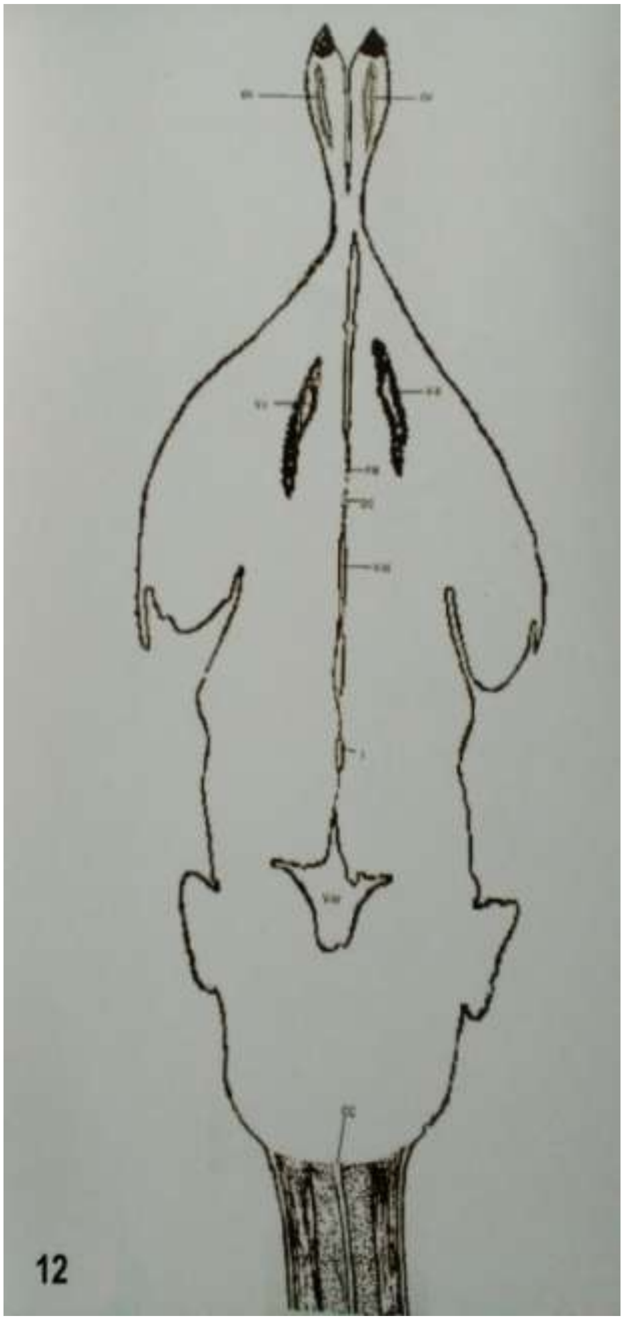

Figure 12

Figure 13A-B

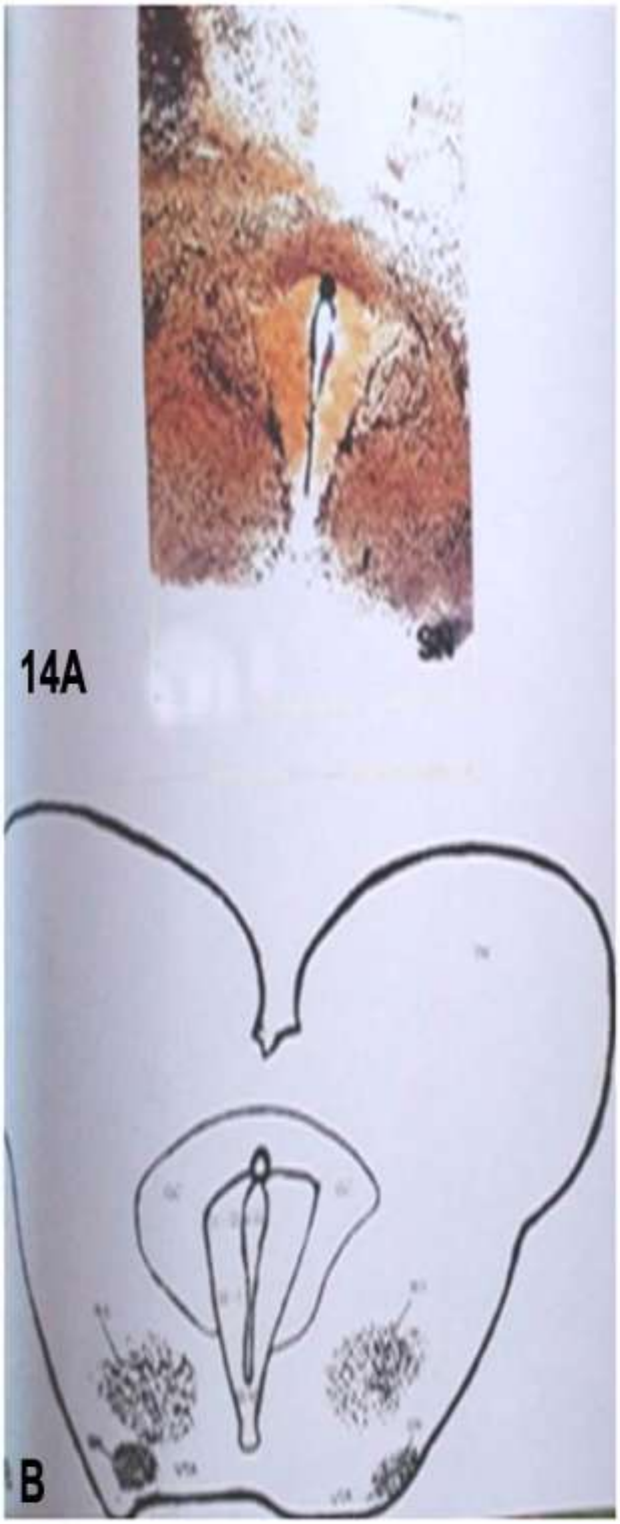

Figure 14A-B

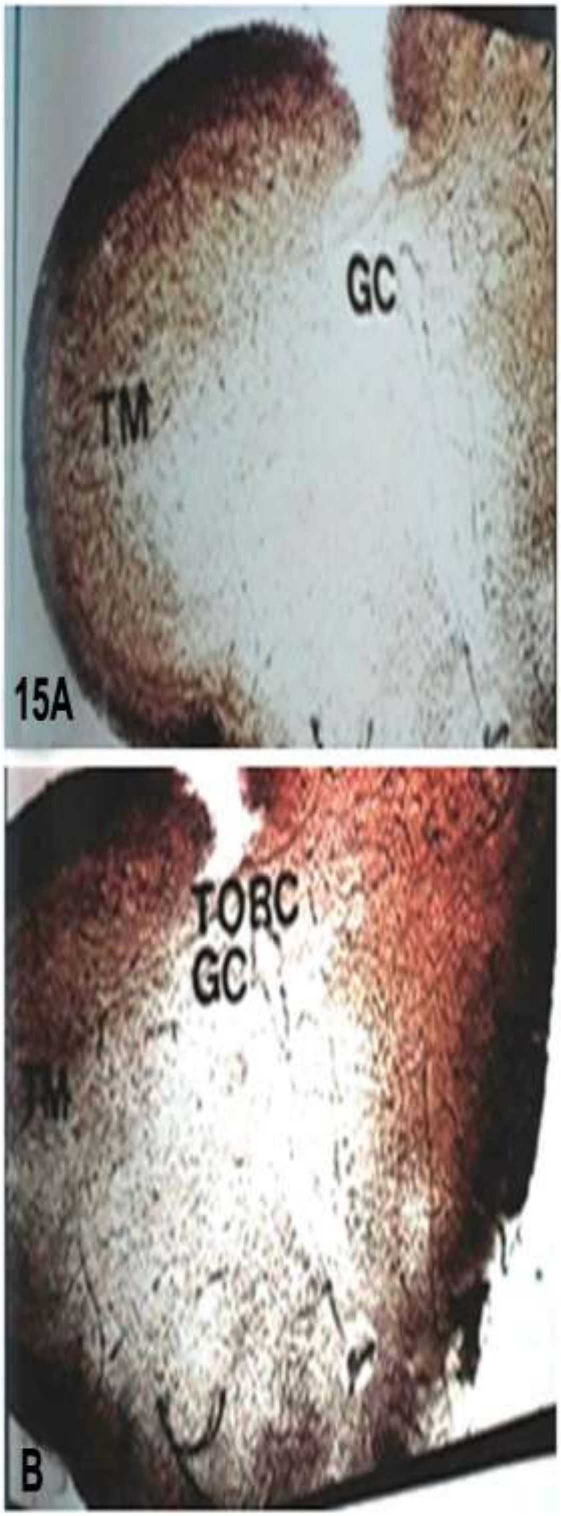

Figure 15A-B

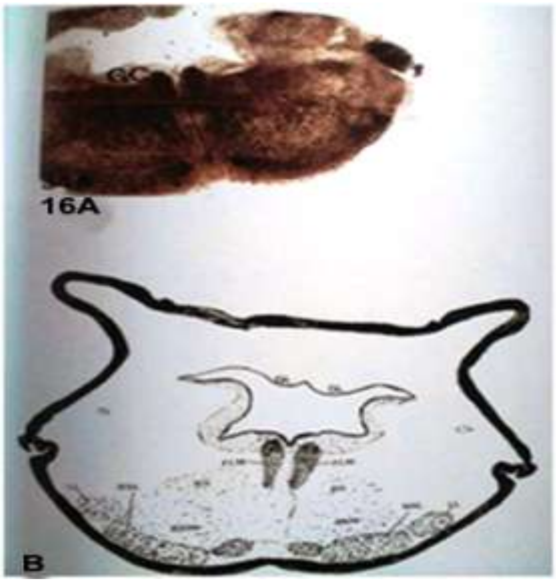

Figure 16A-B

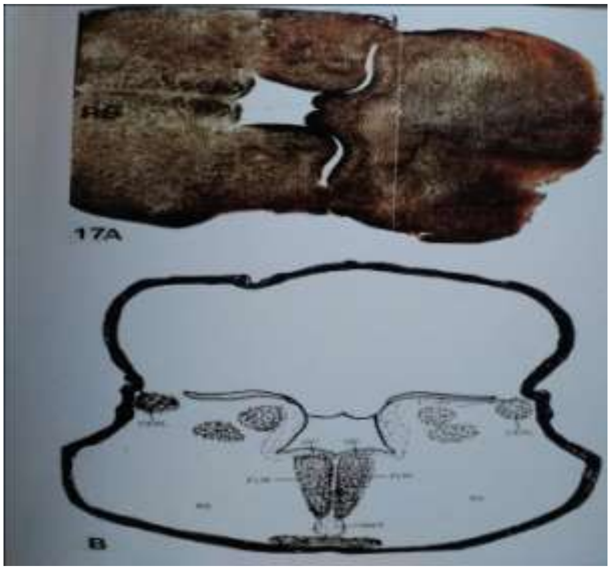

Figure 17A-B

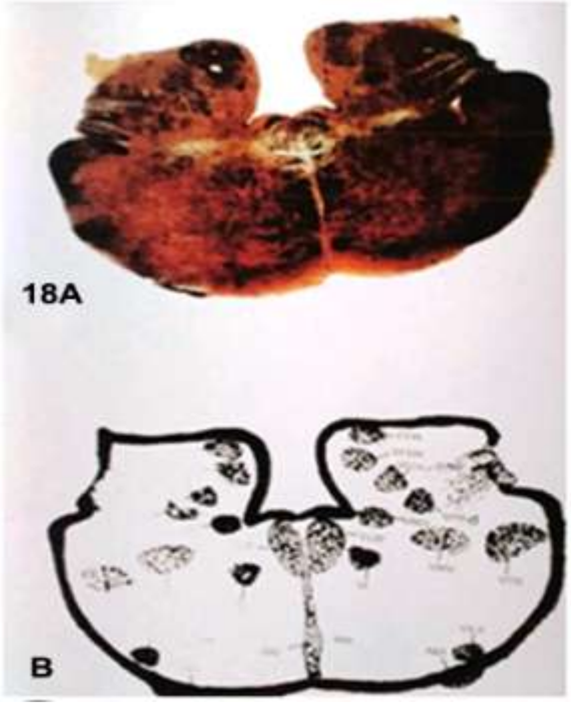

Figure 18A-B

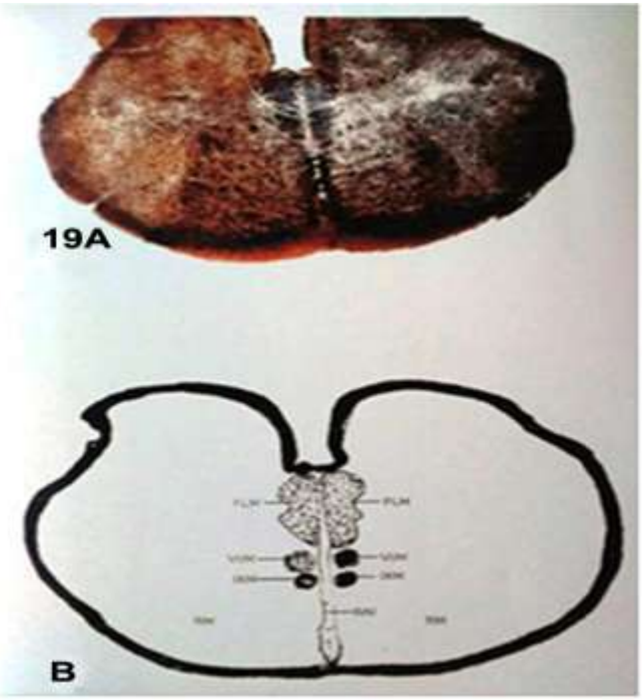

Figure 19A-B

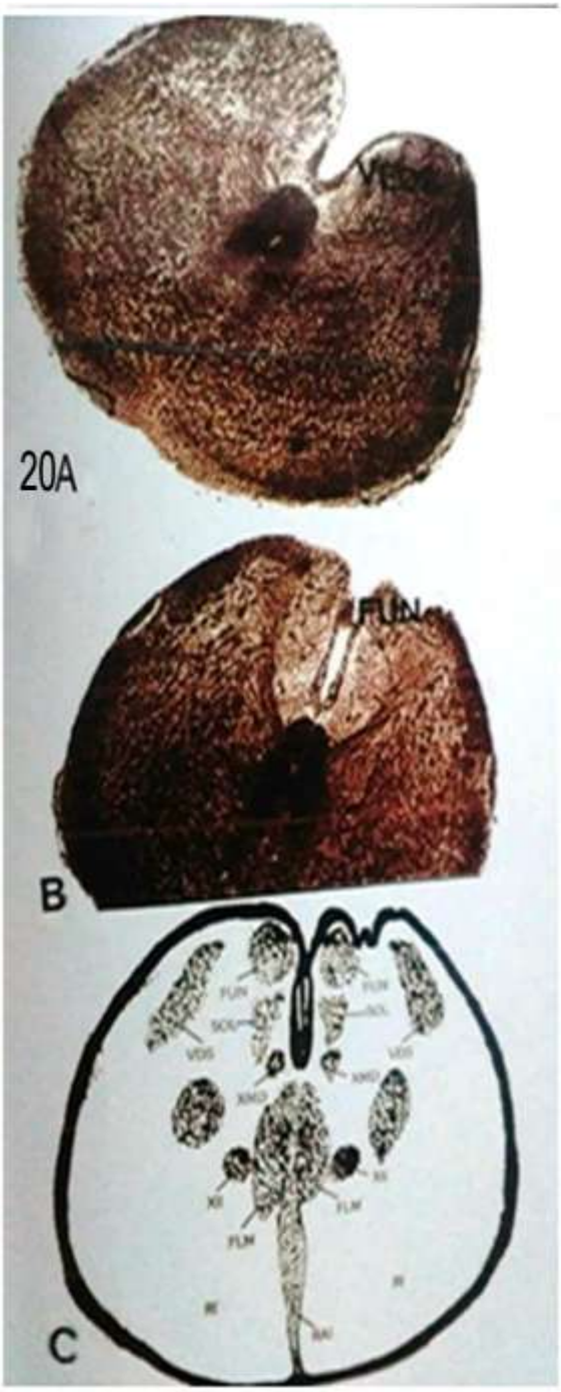

Figure 20A-C

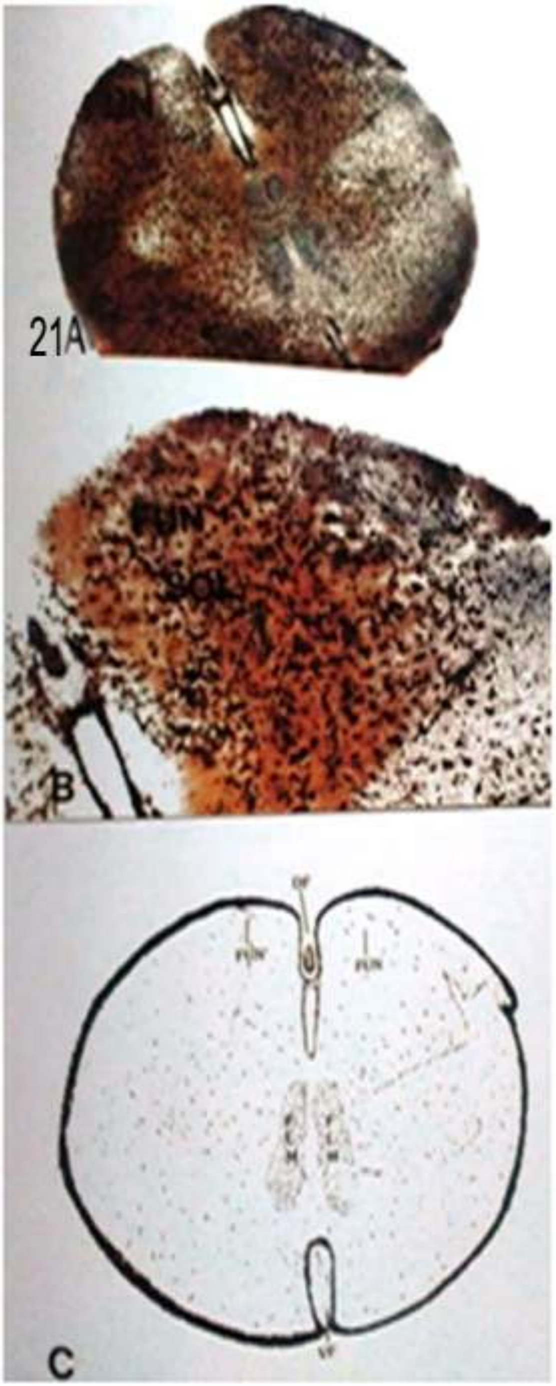

Figure 21A-C

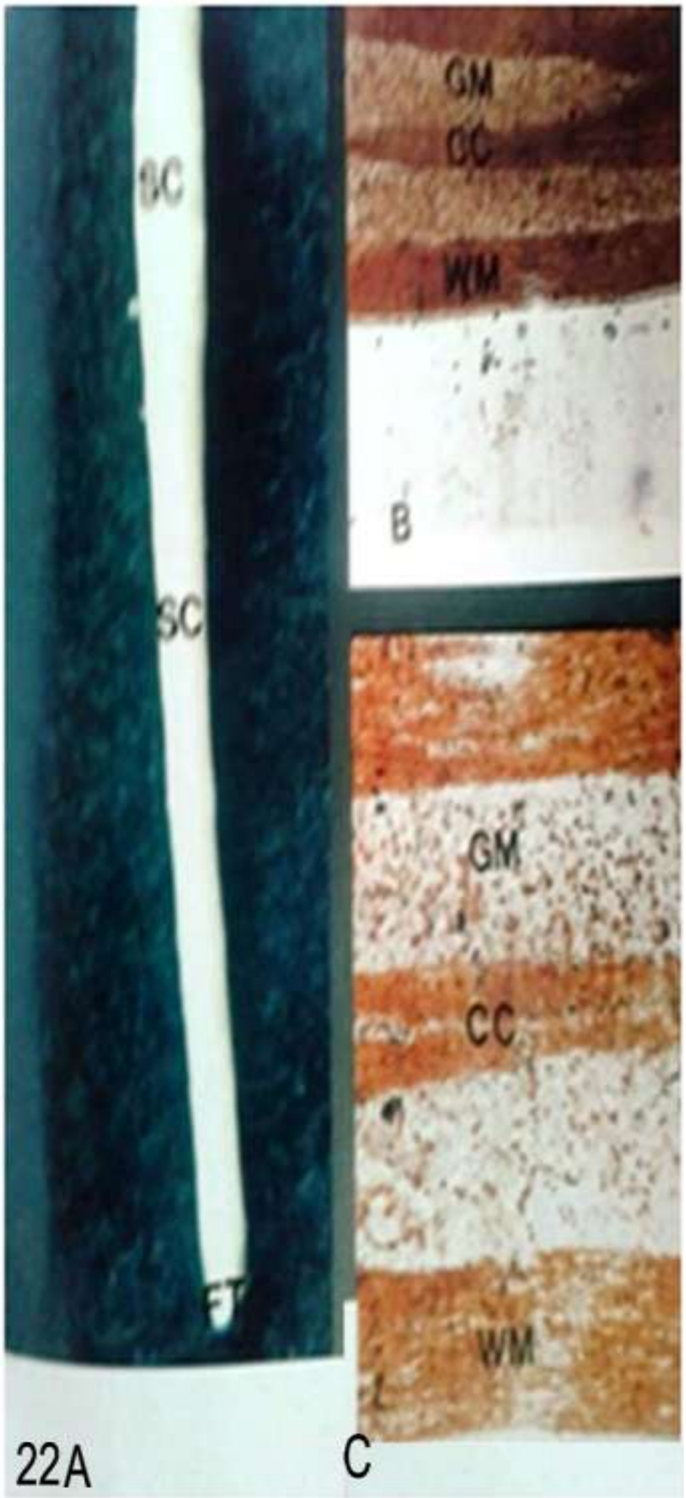

Figure 22A-C

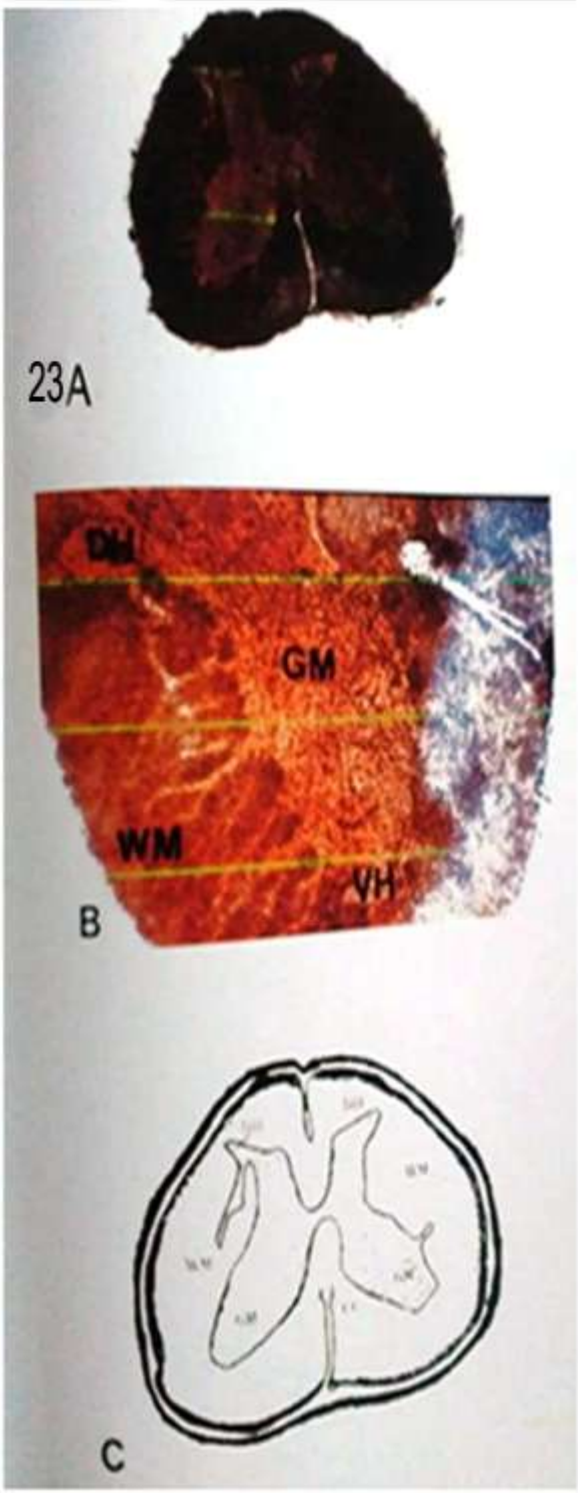

Figure 23A-C

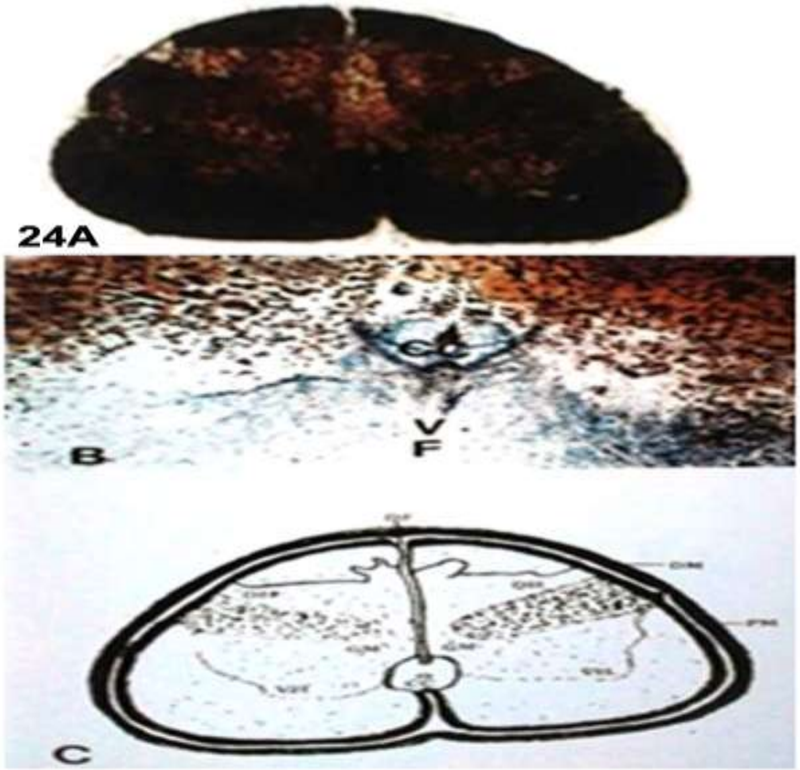

Figure 24A-C

DISCUSSION

The central nervous system is well developed in Indian house wall lizard *H.flaviviridis*. It includes brain and spinal cord. The brain has prosencephalon (forebrain), mesencephalon (midbrain) and rhombencephalon (hindbrain). The prosencephalon (forebrain) includes olfactory bulbs, cerebral hemispheres and diencephalon (thalamencephalon). The hindbrain has cerebellum and medulla oblongata. The results of the present study demonstrate that in house wall lizard *H.flaviviridis*, the basic organization of the brain divisions is the same like other vertebrates. Apparently the brain is less elongated in wall lizard as compared to frog but less developed as compared to mammals.

Olfactory lobe

The wall lizard has a dual olfactory system as olfactory proper and accessory olfactory bulb. These have separate nerves and bilaterally symmetrical orientation. The olfactory nerve is broader and larger than accessory olfactory nerve. Although the present neuroanatomical observations appear to support a hypothesis of Winans and Scalia (1970) that in amphibians, as well as in mammals, there are two parallel but morphologically distinct olfactory pathways to send information separately from the principal olfactory epithelium and the epithelium of additional olfactory organs, such as Jacobson's organ in reptiles. In mammals (Broadwell, 1974; Scalia and Winans, 1975) and reptiles (Heimer, 1969; Halpern, 1973), as well as in frog (Llinas and Precht, 1976), it has been observed that there is a parallel but separate olfactory bulb and accessory olfactory bulb projections.

The olfactory bulb is laminated structure in house wall lizard. These are layer of olfactory nerve fibers, layer of olfactory glomeruli, external plexiform layer, layer of mitral cells, internal plexiform layer, layer of granule cells and layer of ependymoglial cells.

The laminated olfactory bulb has been reported in mammals (Price and Powell, 1973) and in amphibians (Llinas and Precht, 1976). Although the lamination in frog is not well demarcated but it is very clear in mammals. In the present investigation the layers of the olfactory bulb are well differentiated which show the advancement of this structure in wall lizard over amphibians.

Telencephalon / Cerebral hemisphere

The cerebral cortex of wall lizard has been differentiated into medial, dorsomedial, dorsal and lateral regions. The cerebral cortex is three layered structure. The outer most layer shows less dense scattered neurons. Tangentially placed fibers are found in this layer. The middle layer is composed of densely packed cells and because of dense aggregation of neurons it takes very deep silver stain. The inner most third layer is just like outer most first layer but more neurons are present in this layer as compared to 1st layer.

A cortical formation is absent in amphibians but a simple three layered cortex is found throughout the telencephalon of reptiles. In mammals, the three layered prepiriform cortex and hippocampus are separated from each other by a six layered neocortex (Nieuwenhuys, 1994). The medial and dorsomedial cortex of reptilia are comparable to the hippocampal formation while the dorsal cortex is homologous to the isocortex and lateral cortex in mammalian olfactory (Aboitiz, 1999; Bar *et al*., 2000). In the present study also, the cerebral cortex is divided into medial dorsomedial, dorsal and lateral cortex which are made up of only three layers. This observation is similar to the organization of the mammalian hippocampus and olfactory cortex (Aboitiz *et al*., 2001). It has also been observed that the reptilian cortex apparently develops just like isocortex (Super *et al*., 1998). In addition to this the reptilian cortical plate, cell migration is found to be an outside in pattern common to many other CNS regions (Bar *et al*., 2000).

In the present study, below the layer of cortex a region called dorsal ventricular ridge (DVR) is present which is divided into anterior dorsal ventricular ridge (ADVR) and posterior dorsal ventricular ridge (PDVR). The DVR is divided into mainly dorsal and ventral zones but an intermediate zone between dorsal and ventral zones has been located. The DVR is a pallial structure characteristic of reptiles and birds. During the embryonic development the telencephalon of different vertebrates develops as a vesicle at the rostral end of neural tube. After this the formation differs among the different vertebrates (reptiles and aves) show the formation of DVR which protrudes into the lateral ventricle and becomes the lateral wall of the telencephalon. In mammals the floor of the hemispheres protrudes into the lateral ventricles to form the basal ganglia while the telencephalic roof expands and forms the six layers of neocortex (Ulinski, 1983). The embryonic development of telencephalon of reptiles, birds and mammals supports the homology of a part of the avian pallium called the Wulst with the superior part of mammalian neocortex (Medina and Reiner, 2000; Wild and Williams, 2000).

The DVR of reptiles is divided into Type I and Type II DVR. This division is based on the presence and distribution of neurons. The type I is called as cortical band core arrangement. The Type I DVR demonstrates three distinct zones having cell poor zone of dorsal zone, densely packed stellate neurons of second zone and scattered and at some places clusters of a neurons in the third ventral zone. Both spiny and spine poor stellate neurons are present in second and third layers. This first pattern of DVR organization is found in snakes, sphenodon, turtles and most lizards (Ulinski, 1983). The results of the present observation of DVR in Indian house wall lizard clearly show dorsal ventral and intermediate zones of DVR having spiny and non spiny stellate neurons.

The present observations on *H.flaviviridis* are in harmony with those of previous investigators on snakes, sphenodon, turtles and most lizards (Ulinski, 1983).

In aves and crocodiles Type II DVR is found. This type does not contain distinct periventricular cell cluster zone in ADVR. Isolated neurons and prominent neuronal clusters scattered in the different regions of telencephalon are characteristic of type II DVR. In addition to this, spiny with stellate shaped dendritic regions having variable number of spines are found. In *Alligator* there is a tendency for clusters to form a periventricular zone with in the dorsomedial area but not in other areas as observed in type I DVR of reptiles.

It is important to mention that the present observations of DVR in Indian house wall lizard *H.flaviviridis* correspond well with Type I DVR but different from type II DVR which is also found in birds. Despite difference in DVR organization of different reptiles there is a similarity in the basic connectivity of ADVR of reptiles and BDVR of aves. It has been suggested by Ulinski (1983) that the basic organization of the DVR is to serve as a linkage between sensory inputs and motor output. ADVR receives visual auditory and somato sensory information and sends output to the BDVR and basal ganglia. This is the basic function of mammalian isocortex. Anatomical connections indicate that the nuclear groupings of DVR could be homologous to certain areas of mammalian isocortex.

The anterior dorsal ventricular ridge (ADVR), of present investigation and other reptilia is divided into dorsolateral and ventromedial regions. The dorsolateral region corresponds to hyperstriatum of birds while the ventromedial ADVR is comparable to the neostriatum of birds. The hyperstriatum of birds and dorsolateral components of reptilian ADVR correspond to mammalian dorsolateral claustrum, dorsal endopiriform nucleus and basomedial amygdala. The ventromedial ADVR of reptilia and neostriatum of aves correspond to the ventromedial claustrum, ventral endopiriform and laterobasal amygdala of mammals. The posterior dorsal ventricular ridge (PDVR) of reptiles is comparable to the parts of smammalian amygdalar complex. This homology has been made on the basis of present observations and others reported in previous findings (Ulinski, 1990; Aboitiz, 1995).

Smith Fernandez *et al*. (1998) confirmed that the amphibian dorsal pallium, reptilian dorsal cortex and the avian Wulst express the same pallial markes as the isocortex.

The subpallium region of cerebral hemisphere includes striatum and septum. The area medioventralis zone of the forebrain includes septal nucleus in the septum which is differentiated into medial and lateral septal nucleus. Both run parallel to each other.

Halpern (1972) has shown that a large part of the medial forebrain bundle arises in the septal region and these fibers pass caudally into the preoptic area and ventral thalamus. This observation has been confirmed in the present investigation.

The boundary between septum and striatum can be observed at the ventral side of lateral ventricle. There is no change in the cellular density of septum and striatum. Although the demarcation of striatum region has been shown in coronal section of the cerebral hemispheres of reptiles, birds and mammals by Aboitiz *et al*. (2002), there is a difference in the thickening of subpallial structures in the striatum of house wall sslizard, presently studied and reported previously by investigators. The difference actually lies in the thickening of pallial structures which differentiate the striatum of subpallium structure.

Diencephalon- Hypothalamus

In the present observation hypothalamus is laterally expanded region of the diencephalon part of forebrain. In the sections of hypothalamus the two regions are differentiated magnocellular and parvocellular. The magnocellular region is divided into nucleus supraopticus (SON) and nucleus paraventricularis (PVN).

The magnocellular region is not differentiated into pisces and amphibians (Prasada Rao *et al*., 1993 and Prasada Rao *et al*., 1997). In crocodile – *G. gangeticus* (Subhedar *et al*., 1989), turtle – *L. puntata granosa* (Dwivedi and Prasada Rao, 1992), cobra – *Naja naja* (Prasada Rao *et al.* (1981), lizard – *Calotes versicolor* (Prasada Roa and Subhedar, 1977), crocodile (Subhedar *et al*., 1989) and also *H.flaviviridis* (Haider and Sathyanesan, 1974), the magnocellular region is found to contain nucleus supraopticus (SON) and nucleus paraventricularis (PVN).

The nucleus supraopticus (SON) is divided into rostral, medial and lateral regions in crocodile, studied by Subhedar *et al*. (1989) and in *H.flaviviridis* studied by Haider and Sathyanesan (1974). This observation is confirmed in the present investigation. In crocodile and cobra, nucleus retrochiasmaticus (RCN) has been additionally observed by Subhedar *et al*. (1989) and Prasada Rao *et al.* (1981) which has not been found in turtle, garden lizard and wall lizard presently studied. The present observations with respect to nucleus paraventricularis (PVN) are in line with the previous observations in crocodile, turtle, cobra and garden lizard.

It has been reported that in the ring necked snake – *Diadophis punctatus* (Philibert and Kamemoto, 1965), the iguanid lizard–*Dipsosaurus dorsalis* (Gesell and Callard, 1972), the wall lizard–*H.flaviviridis* (Haider and Sathyanesan, 1974), the garden lizard–*Calotes versicolor* (Prasada Roa and Subhedar, 1977) and also *Naja naja* (Prasada Roa *et al*., 1981) both supraoptic (SON) and paraventricular (PVN) nuclei are found in the hypothalamus differentiated clearly in the present observation also.

The neuronal aggregations in the supraopticus nucleus (SON) in the present study correspond with the *Calotes versicolor* (Prasada Rao and Subhedar, 1977) because in both cases the dense arrangement of cells having large number has been observed. However, this nucleus in *G. gangeticus* (Subhedar *et al*., 1989) is larger in size but neurons are the scattered. Which is also observed in *Naja naja* (Prasada Rao *et al*., 1981). The nucleus paraventricularis (PVN) studied by Prasada Rao and Subhedar (1977) in *Calotes* shows similarity with the present study having loosely arranged cells but in *Naja naja* (Prasada Rao *et al*., 1981) large number of polygonal neurons are found in PVN. It seems that magnocellular region of hypothalamus shows homology in *H. flaviviridis* presently studied and *Calotes versicolor* studied by Prasada Rao and Subhedar (1977).

In some reptiles it has been observed by Haider and Sathyanesan (1974), Prasada Rao and Subhedar (1977) that bridge cells are found between SON and PVN. However, these are absent in the cobra (Prasada Rao *et al*., 1981) and in the ring-necked snake (Philibert and Kamemoto, 1965). In the present investigation on Indian wall lizard neurons are clearly observed between SON and PVN which is also characteristic of avian hypothalamus (Oksche and Farner, 1974).

The two accessory magnocellular nuclei namely nucleus retrochiasmaticus and nucleus circularis have been reported in cobra (Prasada Rao *et al*., 1981) which may be substitution for the bridge cells, are absent in snake. In the present observation on wall lizard, bridge cells are observed but accessory magnocellular nucleus circularis is absent. In *H.flaviviridis* presently studied, and also by Haider and Sathyanesan (1974) three divisions of the SON have been observed and the caudal part of SON may be compared with the nucleus retrochiasmaticus of cobra reported by Prasada Rao *et al*., 1981).

Some neurosecretory neurons were observed in the median eminence in the lizards *Acanthodactylus* (Oehmke and Oksche, 1974; Oksche and Farner, 1974) and *Calotes versicolor* (Prasada Rao and Subhedar, 1977) and presently studied Indian wall lizard. Zaloglu (1973) put forward a view that seasonal difference should be taken into consideration. Although the reproductive cycle was not studied in the present investigation but no change in these neurons could be observed in the different individual animals sacrificed at different months.

In the parvocellular region, 24 nuclear entities are found in the crocodile, *Gavialis gangeticus* (Subhedar *et al*., 1989), 22 neuronal aggregations in the cobra – *Naja naja* (Prasada Rao *et al*., 1981)); 23 in turtle; 15 in garden lizard–*Calotes versicolor* (Prasada Roa and Subhedar, 1977). In the present observations 23 neuronal groups are found. Haider and Sathyanesan (1974) have not taken into consideration the parvocellular region of *H.flaviviridis* which has been studied presently. The parvocellular hypothalamic nuclei are essential for nervous control of endocrine functions (Oksche and Farner, 1974). The present observation on wall lizard and other lizards studied shows the importance of parvocellular regions in the nervous control of endocrine functions.

The nucleus praeopticus of cyclostome, fish, and amphibians is homologous to the nucleus supraopticus and nucleus paraventricularis of reptiles (Scharrer and Scharrer, 1954) which has been observed in the present study.

The nucleus anterior commissure observed in the hypothalamus of the many reptilian brains (Crosby and Woodburne, 1940; Prasada Rao *et al*., 1981) has been observed in the present study.

The nucleus microcellularis anterior and nucleus microcellularis posterior are thought to be integral components of a larger microcellular entity described by Prasada Rao and Subhedar (1977) in *Calotes*, has been observed in the present study.

The nucleus periventricularis hypothalami reported by Butler and Northcutt (1973); Senn (1974) appeared to be a part of nucleus periventricularis posterior of cobra (Prasada Rao *et al*., 1981) is observed in *H. flaviviridis* presently studied. The nucleus subfornicalis, present in *Calotes* (Prasada Rao and Subhedar,

1977) has been demarcated in the present observation which is absent in other reptiles. The presence of this nucleus only in lizard shows some importance of this group with respect to other reptilian species.

In *Calotes versicolor* (Prasada Rao and Subhedar, 1977), in aves (Oksche and Farner, 1974) in rats Szentagothai *et al*. (1968) in cobra (Prasada Rao, 1981), the nucleus hypothalamicus ventromedialis and nucleus hypothalamicus dorsomedialis is conspicuous and is comparable to that in tegu lizard (Cruce, 1974) and *H.flaviviridis* presently studied.

The nucleus hypothalamicus medialis of the present study is comparable to that in *Calotes* (Prasada Rao and Subhedar, 1977) which is also found in birds and mammals (Szentagothai *et al*., 1968; Oksche and Farner, 1974) but absent in some other reptilian species.

The nucleus arcuatus proper, located in the hypothalamus of house wall lizard and also *Calotes* (Prasada Rao and Subhedar, 1977) has not been demarcated in the majority of reptiles previously studied. The presence of such nuclei shows the importance of lacertilian reptiles.

The nucleus ventralis tuberis only described in *Calotes* (Prasada Rao and Subhedar, 1977) and presently studied wall lizard *Hemidactylus* is comparable with the similar groups of neurons in cobra (Prasada Rao et al.,1981).

Although nucleus posterior hypothalami mapped by Cruce (1974) in tegu lizard, which is not located in *Calotes* (Prasada Rao and Subhedar, 1977) has been observed in Indian house wall lizard.

The paraventricular organ is found to be well developed in cobra – *Naja naja* (Prasada Rao *et al*., 1981), was not observed in *Calotes* (Prasada Rao and Subhedar, 1977) but is demarcated by ependymal neurons in the present observation. This is also the characteristic, described as sulcus lateralis infundibuli in *Iguana* (Butler and Northcutt, 1973). This sulcus was not observed in tegu lizard – *Tupinambis* (Cruce, 1974) but found in turtle–*Chrysemys picta* (Parent and Poitras, 1974) and two species of *Lacerta* (Marschall, 1980).

The nucleus hypothalamicus lateralis of the present investigation in *H.flaviviridis* resembles similar to that of *Calotes* (Prasada Rao and Subhedar, 1977) and other reptiles (Senn, 1974; Prasada Rao *et al*., 1981).

The nucleus recessus infundibuli of Hypothalamus in *H.flaviviridis*–Indian house wall lizard presently studied is well developed and is differentiated into three regions namely dorsal, intermediate and ventral regions (nucleus dorsalis recessus infundibuli DRI, nucleus intermedius recessus infundibuli IRI and nucleus ventralis recessus infundibuli VRI). This nucleus is observed in *Calotes* (Prasada Rao and Subhedar, 1977) but not found in other vertebrates (Senn, 1974; Peter and Gill, 1975).

The nucleus praemamillary present at the posterior region of Indian house wall lizard has been topographically located in other reptilian species (Subhedar *et al*., 1989; Dwivedi and Prasada Rao, 1992). In addition to this a praemammillary nucleus is also observed in the present observation as located by previous investigations in different reptiles.

It is interesting to note that the hypothalamus of Indian house wall lizard – *H.flaviviridis* presently studied is rich in nuclear organization and is comparable with *Calotes* (Prasada Rao and Subhedar, 1977). It has been mentioned that hypothalamus of *Calotes* resembles with that of highly developed varanidae (Oksche, 1978).

Mesencephalon (Midbrain)

The mesencephalon of *H.flaviviridislus* can be divided into two separate longitudinal columns due to longitudinal zones into basal plate and alar plate. The basal plate which is situated medially contains all the nuclei of motor cranial nerves and is designated as motor plate. The laterally situated plate is designated as sensory alar plate which contains the nuclear groups of sensory nerves.

In addition to ventricular furrow the sulcus medianus inferior is the axis of brain showing bilateral symmetrical condition. The sulcus intermedio ventralis divides the basal plate into two longitudinal zones. The medial is known as the area ventralis and the lateral one is the area intermedioventralis. The area ventralis contains the cranial nerve nuclei of IIIrd and IVth called as somatic motor zone of basal plate. The lateral area intermedioventralis contains the nucleus of Vth cranial nerve.

Rostrocaudally the tegmentum mesencephali most part the different somatic nerve nuclei are situated in a definite plane which is close to median line. This longitudinal column of reticular formation continues with the nuclei of IVth and IIIrd cranial nerves. These nuclei are also present in the same plane i.e. close to the median line. The presence of sulcus medianus inferior, sulcus intermedioventralis, sulcus limitans of His, sulcus medianus superior and also the formation of motor basal plate and sensory alar plate having different nuclei of cranial nerves in the present study mentioned above are in harmony with those of previous investigators (Senn, 1972; Opdam et al., 1976; Srivastava and Srivastava, 1991, 1992).

The nucleus oculomotorii in the present investigation is present throughout the length of tegmentum mesencephali and is divided into pars dorsalis, pars intermedia and pars ventralis. The size of neurons is the same in all the region. This division of the nucleus of IIIrd cranial nerve has not been observed in frog (Srivastava and Srivastava, 1992) but has been observed in mammals.

The motor nucleus of IVth cranial nerve i.e. nucleus nervi trochlearis is present just below the nucleus nervi oculomotorii in the present investigation. This observation is comparable to that of frog (Srivastava and Srivastava, 1992). However, trochlear nucleus in *Varanus* (Barbas-Henry and Lohman, 1988) is found overlapping the oculomotor nuclear complex and is the greater part of a comma-shaped cell group situated lateral, dorsal and medial to the medial longitudinal fasciculus. This arrangement is not confirmed in the present study.

In the present investigation four functional zones in the alar plate of wall lizard are found. These zones are also found in frog (Opdam *et al*., 1976).

Rhombencephalon (Hindbrain)

The rhombencephalon of *H.flaviviridis* can be divided into two separate longitudinal columns due to longitudinal zones into basal plate and alar plate. The basal plate which is situated medially contains all the nuclei of motor cranial nerves and is designated as motor plate. The laterally situated plate is designated as sensory alar plate which contains the nuclear groups of sensory nerves.

In addition to ventricular furrow the sulcus medianus inferior is the axis of brain showing bilateral symmetrical condition. The sulcus intermedio ventralis divides the basal plate into two longitudinal zones. The medial is known as the area ventralis and the lateral one is the area intermedioventralis. The area ventralis contains the cranial nerve nuclei of VIth and XIIth and called as somatic motor zone of basal plate. The lateral area intermedioventralis contains the nuclei of VIIth, IXth, Xth and XIth cranial nerves.

Rostrocaudally the most part of rhombencephalon the different somatic nerve nuclei are situated in a definite plane which is close to median line. In the rhombencephalic part the two conspicuous groups of cells, the nuclei of XIIth and VIth cranial nerves are present. At the rostral level of these two groups the rhombencephalic reticular formation is present. These nuclei are also present in the same plane i.e. close to the median line. This longitudinal zone containing four cranial nerve nuclei and rhombencephalic reticular formation is designated as somatic motor zone or area ventralis of basal plate. The area intermedioventralis of basal plate can be observed only in rhombencephalic region . It contains nuclei of VIIth, IXth, Xth and XIth cranial nerves. This zone has been observed from cerebellar region to the beginning of 2nd spinal root.

The presence of sulcus medianus inferior, sulcus intermedioventralis, sulcus limitans of His, sulcus medianus superior and also the formation of motor basal plate and sensory alar plate having different nuclei of cranial nerves in the present study mentioned above are in harmony with those of previous investigators (Srivastava and Srivastava, 1991and 1992).

The nuclear complex of the abducens nerve of monitor lizard *Varanus exanthematicus* consists of the principal and accessory abducens nuclei. The principal abducens nucleus is located just below the fourth ventricle laterally adjacent to the medial longitudinal fasciculus. The accessory abducens nucleus has a ventrolateral position in the brain stem (Barbas-Henry and Lohman, 1988). However, in the present study on Indian house wall lizard the accessory abducens nucleus has not been found. This nucleus is identical in shape and size with respect to nucleus nervi oculomotorii like frog (Srivastava, 1989). According to

Addens (1933) in *Rana catesbeiana* an accessory nucleus is present lateral to the main abducens nucleus. Opdam *et al*. (1976) observed similar structure in frog but described it as a part of lateral reticular zone. The accessory abducens nucleus is also reported in *Bufo marinus* which was described as a part of reticularis medius by Opdam *et al*. (1976). It seems that in the present study the accessory abducens nucleus is absent because there is no clear demarcation between abducens and reticular formation. The possibility can not be ruled out that accessory abducens nucleus observed by Addens (1933) and Abbie and Adey 1950) is a part of lateral reticular formation described by Opdam *et al*. (1976).

The motor nucleus of XII cranial nerve – nucleus nervi hypoglossi is found in the caudal most region of rhombencephalon below the XIth motor cranial nerve nuclei in wall lizard. Topological position of this nucleus is comparable with that of mammals. This nucleus is developed in *Varanus* with respect to cells as compared to the present observation in *Hemidactylus*.

Senn (1972) has reported that there are two parts of nucleus nervi hypoglossi – a dorsal and a ventral but this division has not been observed either in frog – *Rana tigrina* (Srivastava, 1989; Srivastava and Srivastava, 1992) or in *H. flaviviridis* presently studied. Further studies are required in different groups of animal to find out evolutionary significance of this nucleus.

The above mentioned nuclei of VIth and XIIth cranial nerves constitute a column which is situated close to mid line of brain of Indian house wall lizard *H. flaviviridis*.

The rhombencephalon reticular formation has been studied in many species of reptiles (Newman and Cruce, 1982). They have found that reticular neurons in crocodilians and snakes are larger than those found in lizards and turtles. The reticular formation is divided into seven nuclei. A reticularis inferior (RI) is found in myelencephalon, a reticularis medius (RM) in the caudal two third of the metencephalon and a reticularis superior in the rostral metencephalon and caudal mesencephalon. Reticularis inferior can be subdivided into a dorsal and a ventral region. All reptilian species possess reticularis inferior (dorsal) and reticular medius but ventral portion of reticularis inferior is absent in turtles. These divisions are clearly observed in the present investigation on Indian house wall lizard but quite variable in appearance. The myelencephalic raphes nucleus is also quite variable in its morphology among the different reptilian families. A reticularis ventrolateralis observed in the present study is also found in snakes and teiid lizards. All the divisions and subdivisions of reticular formation have been topologically demarcated in the house wall lizard – *H.flaviviridis* which have been mentioned in observation, are comparable with mammalian species also.

The mid line group of nerves extending from the level of lower mid brain to the level of lower rhombencephalon, called nucleus raphes observed in the present study is identical in other reptiles. It is concluded that fewer number of nuclei in reticular formation of old reptilian lineages and more number of nuclei in modern reptiles are found. Certain reticular nuclei are present in those reptiles in which prominent rhombencephalic alar plate. This group has been identified from rostral to caudal rhombencephalon. The vestibular nucleus has been divided into dorsolateral, ventrolateral, ventromedial, tangential and descendens vestibular regions. At certain level the vestibular nucleus seems to mix with reticular formation. The topological divisions of VIIIth cranial nerve nuclei correspond well with the amphibia (cf. Srivastava and Srivastava, 1991) and mammals (cf. Montgomery, 1988). Since the connections of the complex have not been studied in *H. flaviviridis*, it would be too early to comment and compare the functional significance of VIIIth cranial nerve nuclei with other vertebrate species.

Spinal cord

The spinal cord is well developed. It is a long , whitish and somewhat dorso-ventrally flattend tube. This is lodged into the neural canal of the vertebral column. The structure of the spinal cord is typical vertebrate plan. The spinal cord is closely related to their nearest advanced lower and nearest advanced upper vertebrates. Although the present neuroanatomical observations appear to support a hypothesis of Cruce and Newman (1981) that the brain stem origin of spinal cord projection in the lizard. In frog (Cruce ,1974a and 1974b), reptiles (Newman *et al.*,1983), frog (Srivastava and Srivastawa,1988,1989,1990 and

2002b), lizard (Wolters, 1985; Wolters *et al.*,1984 and 1986), it has been observed that there is parallel but well developed.

The meninges duramater and piamater covering the brain are continuous over the spinal cord. The spinal cord presents the characteristic H – shaped pattern of the gray matter with the well developed dorsal and ventral horns. A shallow mid – dorsal fissure and a prominent mid ventral fissure are evident. The central canal of of the spinal cord is filled with the cerebro – spinal fluid. This is continuous with the fourth ventricle of the medulla oblongata.

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