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THE COMPARATIVE STUDY OF THE CENTRAL NERVOUS SYSTEM BETWEEN LARVAE AND ADULTS OF HOUSE FLIES, *MUSCA DOMESTICA* L. (MUSCIDAE, DIPTERA, HEXOPODA).[1]

AGATHA SU-CHIN TUNG[2], AND WEN-YUNG LEE[3]

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ABSTRACTS

The central nervous system of house flies in the larval stage includes two brain hemispheres and one compound ventral ganglion. Both of them send nerves to the respective organs. In the adult house flies, the central nervous system contains the cephalic and the thoracic ganglionic center; their nerves also innervate the respective organs. Histologically, the central nervous system of the larval house flies does not so differentiate like that of the adult house flies. Both of the larval and adult ganglia contain the same ganglion cells; giant cells, large ganglion cells, small ganglion cells, neuroglial cells and Schwann cells. The ganglia and their nerves of the larval house flies are invested by neurilemma and perineurium with perineurium cells. But the ganglia and their nerves of the adult house flies are surrounded only by neurilemma with neurilemma cells.

INTRODUCTION

During the metamorphosis of holometabolous insects, the central nervous system changes from the larval form into the adult form. According to the recent references, these changes have been studied by Pipa (14) in *Galleria mellonella* L. (*Lepidoptera. Pyrallidae*) and also by Heywood (8) in *Pieris brassicae* L. (Lepidoptera, Pyrallidae). They obtained the same results of changes during metamorphosis that the connectives between the brain and suboesophageal ganglion shorten; the mesothoracic, the metathoracic and the 1st and the 2nd abdominal ganglia of the larva fuse completely; the two (in *G. mellonella*) and three (in *P. brassicae*) abdominal ganglia form an abdominal neuron center. The metamorphosis of the central nervous system in *Drosophila* (6), the region between the suboesophageal ganglia and the 1st thoracic ganglia becomes constricted forming the cephalothoracic cord; two brain hemispheres unite mediodorsally and develop the eye ganglia; eight pairs of abdominal ganglia combine into one. Hewitt (7) has studied the nervous system of the larva and the adult in the house flies *Musca domestica* L. However. he only gives a brief description in anatomical structure. The metamorphosis process in holometabolous insect is not only in anatomical changes but histological also. This paper reports and compares the central nervous system of

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1 This study was submitted by the senior author for the B. S. degree, Department of Biology, The Fu-Jen Catholic University, 1968.

2 Present address: Depatement of Entomology and Parasitology, University of California, Berkeley, California, U.S.A.

3 Associate Research Fellow, Institute of Zoology, Academia Sinica.

the larval and the adult house flies and provides information for the studies of the transformation during metamorphosis.

MATERIALS AND METHODS

The insect materials was obtained from routine laboratory cultures kept at 20-25°C. Its eggs hatched in 1-2 days, the length of the larval stage was 5-7 days and that of the pupal stage 6-7 days. In about 4-5 days after the flies emerging, they were ready to oviposit.

The 4 days old larvae and the newly emerged adults were fixed in KAAD mixture (13), then dissected with the micro-dissecting scissors under a stereoscopic microscope of 4-12.5 x, 4-18 x magnification for the studies of macroanatomical changes. The neural structures were stained with a 1% solution of Methylene Blue during the dissection; usually the house flies were flood for 15-20 sec. With Methylene Blue, then washed with Ringer's Solution to remove the excess stain. Histological examination was carried out by means of whole mounts. The specimens were fixed in Bouin's Fluid (5) for 24-48 hours, and washed in 50% alcohol to remove the excess picric acid. The specimens were dehydrated via the series, embedded in tissue mat (m.p. 60°C) and cut at 8 μ. The sections were stained with Delafield hematoxylin and 0.5% Eosin in 95% alcohol.

The preparations were examined with the 4x, 10x and 40x plan achromatic lens of Olympus research microscope and the Fluoritic lens of Leitz research microscope. The microphotographs were made with Leitz Wetzlar Aristophot. The drawings were made through the eye piece micrometer.

RESULTS

I. *Macro-anatomy:*

A. The Larval Stage:

The central nervous system of the larval stage of the house flies, *Musca domestica* L., (Fig. 1 and 2) consists of two brain hemispheres and a big compound ventral ganglionic mass. It is located in the *forth* segment from the head of the whole insect body and reaches to about the end of the fifth segment.

The two brain hemispheres are connected ventrally; the oesophagus passes through the connection and runs backward dorsally above the ganglionic mass. The ganglionic mass is anteriorly connected to the ventral point of fusion of the two brain hemispheres. It consists anteriorly and posteriorly of the suboesophageal ganglion, the three pairs of thoracic ganglia, and the eight pairs of abdominal ganglia. From this composition, the ganglionic mass appears as an elongate shape and compact mass of ganglionic tissue.

Two pairs of nerves, the pharyngeal nerves, and the dorsal prosternal nerves, extend from each side of anterior region of the brain hemispheres, the pharyngeal nerves send off three branches innervation the pharynx muscles, and the dorsal prosternal nerves innervate the dorsal prosternal muscles and the integuments of the head. One pair of nerves, the papillar nerves innervating the larval papille, come from each side anterior region of the ganglionic mass. From the region of the first and second thoracic ganglia, there are four nerves arising on each side, the thoracic nerves for the 1st and 2nd leg pair discs and accessory nerves. Each of these nerves sends off branches which innervate the muscles and the integuments of the 1st and 2nd thoracic segments. The 3rd thoracic ganglion has no nerves directly connecting with the leg disc; thus the thoracic nerves innervating the 3rd segment arise from the third thoracic ganglion directly. Each of the abdominal ganglia sends off a pair of nerves. These nerves proceed without visible branching until they reach the portions of the respective segments which they innervate to the various tissue.

On the dorsal side of the abdominal ganglionic region. There are seven unpaired nerve fibres, the median nerves (Fig. 3). These nerves originate from the medline of the ganglion. Each median nerve terminates at the bifurcation into a pair of lateral branches in respective segment which extend outward to the intersegmental muscles and the integument of the intersegmental fold.

B. The Adult Stage:

During the adult stage, the centra, nervous system (Fig. 4-6 and Fig. 15) conl sists of the cephalic and the thoracic ganglionic centers.

(a) The Cephalic Ganglionic Center and Its Nerves:

The cephalic ganglionic center lying transversely in the head capsule, is a body devoid of conspicuous bulges; it is laterall-elongated and terminates in larve optic lobes. It is perforated by a narrow median canal, through which the oesophagus passes. The supraoesophageal portion, or brain proper, includes the median protocerebrum and its lateral optic lobes, the deutocerebrum, marked externally by a pair of low anteroventral swellings from which the antennal nerves arise, and the vestigial tritocerebrum which is not differentiated externally. The brain is bent backward and the deutocerebrum lies farther forward than the protocerebrum. A single ocellar peduncle (Fig. 4-6) arises medially from the posterodorsal region of the protocerebrum and forks into three short branches, which attach to three dorsal ocelli. The optic lobes (Fig. 4 and 5) appear as broad lateral extensions of the protocerebrum connecting directly with the compound eyes, a deep constriction near junction with the eye marking the location of the outer chiasma. Each of the antennal nerves (Fig. 4-6), arising from the deutocerebrum, gives off the branch to the dorsal wall of the head, and into the antenna (Fig. 27). The fibers of the circumoesophageal connectives disappear in the house flies. The ventral portion of the cephalic nerve mass, the suboesophageal ganglion (Fig. 6), gives off three pairs of ventral nerves to the proboscis, and is joined posteriorly to the unpaired cervical connective. The three pairs of ventral nerves extended from position ventrad and mesad of the antennal nerves, leave the ganglion anteriorly near the oesophageal canal and pass down the proboscis. The pharyngeal nerves give off branches to the muscles and integuments of the rostellum of the proboscis. The labral nerves, loop anteriorly and dorsally meeting the corresponding nerve of the opposite side and uniting with a single nerve which is an nerve of the stomodaeal nervous system, then, it crosses to the pharyngeal nerves and enters the labrum to connect with its muscles and integuments. The third pair of suboesophageal nerves, the labial nerves, arise from the ventral side of the suboesophageal ganglion and give off a smaller sensory fiber crossing both of the pharyngeal nerves and the labral nerves to the maxillary palpi. The principal branch of the labial nerves innervate the muscle of the base proboscis and the haustellum, then continues ventrally to the labellum and the sense organs.

(b) The Thoracic Ganglionic Center and Its Nerves:

The thoracic ganglionic center (Fig. 4-6 and Fig. 28-30) is an single elongate, compact mass of ganglionic tissue and extends longitudinally in the ventral part of the thorax below the alimentary canal. It is supported and beheld in place behind the middle by the arms of the mesofurca and posteriorly by the metafurca. The thoracic ganglionic center is joined anteriorly by the cervical connective to the suboesophageal ganglion and gives off posteriorly a median nerve trunk to the abdomen. A pair of cervical nerves to the muscles of the neck spring from the sides of the cervical connective. From each of the three thoracic segmental centers, which constitute the greater part of the thoracic ganglionic mass (Fig. 4-6), there arises three pairs of nerves: namely, dorsal nerves, accessory nerves and ventral nerves, in addition, a pair of very short nerves, prosternal sense organ, connects directly to two scolopophorous sense organs which lie close to the anterior and of the ganglion. Of the dorsal nerves, the first pair innervates the prothoracic muscles and the prosternal sense organs through a basal branch on each side; the second pair innervates the direct and indirect wing muscles and the sense organs of the wings; and the third pair goes to the halteres. The accessory nerves also innervate the muscles; the first pair extends toward the anterior spiracles and the third pair toward the posterior spiracles. The three pairs of ventral nerves, give off branches to innervate the muscles of the legs and the sense organs of the respective thoracic segments.

The small caudal portion of the ganglionic mass behind the roots of the metathoracic ventral nerves, is the abdominal ganglionic center. There arises a thick median trunk, which gives off nerves to the anterior and posterior segments. In the Figure 4 and the Figure 5 show that the divergence of forks from the median trunk is different from the male and the female; the latter appears more regular than those of the former, and the terminal branches innervate the genital segments and internal reproductive organs.

II. *Histological Studies:*

A. The larval Stage:

The brain hemispheres and the ventral compound ganglionic mass are invested in the nerve sheath (Fig. 13-14) consisting of the neurilemma and the perineurium which are continuous over the nerves, the former is outmost acellular layer which arrounds the ganglia. The latter is the cortical layer of the ganglion cells, and their massed fibrous processes constitute the internal medullar neuropile.

In the brain hemispheres (Fig. 11-12), the cortical cells are smaller than the other ganglion cells, and are arranged laterally into two layers representing the formation center. Between these two layers of the cortical cells appears as a group of thin wall of ganglion cells.

The segmentation of the ganglionic mass is distinguished the suboesophageal, the thoracic and a series of abdominal ganglionic regions by the fibres with vertical arrangement.

The ganglion cells are peripherally lying between the perineurium and the neuropile. They vary in size and staining properties. In the Figure 13 and 14, several types of these cells can be recognized. The terminology used in this description of ganglion cells is after Albert Miller (12). Giant cells, from $12\mu\times7\mu$ to $16\mu\times11.5\mu$, have the largest ovoid nuclei with very obscure cytoplasm and contains much dense-staining granules which are formed by the chromatin. They are singly scattered among the other ganglion cells. Large ganglion cells, have round or oval nuclei, 6.6-9.6μ in diameter, rich in chromatin and the pale staining cytoplasm. They are found in groups among the other ganglion cells. Small ganglion cells, the nuclei are small and oval in shape, 4-5μ in diameter; clumps of chromatin lie along the nuclear membrane or in the central part of the nuclei irregularly, and the little cytoplasm forms an inconspicuous pale-staining rim. They are scattered in the large ganglion cells and the giant cells or in groups among them. Neuroglial cells have elongated nuclei from $3.5\mu \times 5\mu$, the chromatin lies in clumps peripherally along the nuclear membrane, and the obscure cytoplasm appearing as a thin membrane extending from the nuclei. They are mainly scattered in and around the neuropile, and also the fibers of the larger nerves. There are some perineurium cells scallered in the perineurium and between the neurilemma and perineurium. They have round nuclei 5μ-7μ in diameter, and contain a great number of dense-staining granules of chromatin in the nuclei. Schwann cells with the obscure cytoplasm, the nuclei are round in shape, 9μ in diameter clumps of chromatin scatter in the nucleus. They are lying obliquely between the axons.

B. The Adult Stage:

The brain (Fig. 17-18) of the adults like that of the larvae, consists of the neuropile in the central part, and the cortical layer of ganglion cells. In the peripherary, in the neuropile, the compact masses of nerve endings are glomeruli, and there are some special fibrous tracts which are formed by the dense clusters of fibers. The surface of the brain is covered by a very thin nucleated neurilemma, The cells on the neurilemma are the neurilemma cells.

The protocerebrum or the forebrain, (Fig. 19-25), is the dorsal and the largest part of the cerebral mass which innervates the compound eye and the ocelli. It includes the neuropile masses of the lateral protocerebral lobes, and the median pars intercerebralis. The fibrous and glomerulous masses of the protocerebrum include the dorsal corpora pedunculata, the media dorsal pons cerebralis, the corpus centrale, and the ventrolateral corpora ventralia. It also includes the optic tract and the protocerebral commissure. At two lateral side. of the protocerebrum, it connects with the optic lobes. The ocellar peduncle (Fig. 17 and 24) are at the dorsum. Corpora pedunculata (Mushroom bodies, Fig. 20-21) are the most conspicuous formations and important association centers which are pair mushroom shaped situated in the dorsal part of the protocerebrum between the protocerebral lobes and the pars intercerebralis. Each one can be divided into an outer and an inner lobe. The outer lobe is a compound calyx which is formed of cup-shaped by the fibrous mass. The inner lobe is a long, large and thick fibrous stalk or pedunculi, which extends forward ventrocephalad through the neuropile and terminates into two roots: the median root goes to the lateral sides of the corpus centrale and corpora ventralia; the dorsal root goes posteriorly and dorsally anterior part of the brain. The pons cerebralis (Fig. 20-22 and 25) is a transversely curved, forked shape of glomeruli lying in tne dorsomedian part between the pars intercerebralis. Ventrad of two forks, there is a tubercle on each side; these may belong to a part of the pons cerebralis. The corpus centrale (Fig. 20-22) is the central part of the brain, lying medially ventral to the pons intercerebralis. It includes four groups of glomerulous masses: a large flatten dorsal mass, a oval mass over lying in the center and two small ventral masses (tubercles of central body). The corpora ventralia (Fig. 20-22) are a pair of glomeruli lying ventrolaterally, ventrad of the corpus centrale, and the connected by a fibrous tract the protocerebral commissure, which passes beneath the corpus centrale. The optic tract, (Fig. 23), is a transverse bundle of fibers connecting the optic centers of the two compound eyes. It passes behind the corpus centrale. Other fibrous tracts run in various direction in the protocerebrum including the tracts going to the ocellar center, ocellar tract the middle of protocerebrum, the median tract, (Fig. 19) and deutocerebrum called deutocerebral tract (Fig. 22). Each optic lobe (Fig. 18) consists of three principal association centers, namely, a distal periopticon, a median opiopticon, and a proximal opticon. The periopticon is the zone nearest the compound eye and receives the optic nerves which forms a postretinal fiber layer form the inner ends of the ommatidia. It consists of an outer granular layer of ganglion cells and an inner medullary layer of parallel nerve fibers arranged perpendicularte the outer layer. The middle zone is termed the epiopticon and is connected with the periopticon by crossing fibers that form the outer chiasma. The epiopticon has a distinctly laminated structure owning to the stratified arrangement of the terminals of the penetrating axon coming from the outer layer of ganglion cells, which lie within the inner portion of the outer chiasma. The inner zone is the opticon and united with the epiopticon by means of the inner chiasma where interspersed ganglion cells are also present. The nerve fibers of this layer cross completely in a manner similar to those of the outer chiasma. The opticon subdivided into two secondary parts of fibrous masses, names: The laminated anterior and posterior. These two parts are connected each other by the fibers coming from the inner chiasma. The larger anterior part is connected to the protocerebral lobe and to the opticon of the opposite side by fibers in the optic tracts. Optic tract is composed of fibers that connect with the opticon and with the epiopticon. The ocellar center (Fig. 17) are three ganglionic centers of the facial ocelli lying in the distal parts of the ocellar peduncle which is origined between two lobes of the pyramical ganglion (Fig. 29) which has been described by Lowne (11) as a lobe made of large closely packed cells. The fibers from the ocellar centers go to the lower part of the brain, where they are associated with the terminals of branches from the optic tracts of the compound eyes. The deutocerebrum (Fig. 17 and 19-23) is the second biggest division of the brain, but it is almost fused with the protocerebrum on one side and the tritocerebrum on the other. It is chiefly composed of the paired distinct antennal lobes (Fig. 23), from which the antennal nerve arises, Each antennal lobe consists of the lateral part of the ganglion cells and the principal part of the numerous glomeruli in the neuropile which connect with the antennal nerves. The antennal glomeruli of opposite sides are connected by a fibrous tract, the deutocerebral commissure, which passes above the oesophagus, and is confluent with the protocerebral commissure of the corpora ventralia.

The tritocerebrum (Fig. 25) is almost vestigial. However, it still includes a pair of the tritocerebral lobes lying above the suboesophageal ganglion and are connected with each other by the transverse fibers of the tritocerebral commissure beneath the oesophagus. It is very difficult to sdentify clearly between the tritocerebrum and the suboesophageal ganglion.

The suboesophageal ganglion (Fig. 16 and 25) is the ventral ganglionic center of the head and contains the neuropile masses and the peripheral layer of the ganglion cells. It gives off, we have discussed before, three paired nerves to the mouth part, and a fiber tract run through the cervical connective to the thoracic nerve mass.

The thoracic ganglionic center (Fig. 28-31) consists of the large neuropil mass forming the central part, and the ganglion cells arranging peripherily. The fiber tracts pass the neuropile in various direction. The ganglion is invested in the nucleated neurilemma, which is continuous over the cervical connectives and the nerves. In the Figure 28 and 30, the neuropile is clearly distingusihed four regions by the ganglion cells. It indicates the thoracic ganglionic center which is formed by the fusion of the prothoracic, the mesothoracic, the metathoracic and the abdominal ganglion, Each thoracic ganglion includes pairep neuropile masses surrounded by the cortical ganglion cells and sends off the corresponding nerves. The abdominal ganglion consists of a single neuropile mass with the peripheral ganglion cells medially behind the paired neuropile masses of the metathoracic ganglion and sends off the median abdominal nerve trunk to the abdomen.

The ganglion cells in the adult house flies are similar to those of the larvae (Fig. 26 and 31). The cortex is also a mixture of three types of ganglion cell: the large and the small ganglion cells and the giant cells. The small ganglion cells and the giant cells mainly locate in the cephalic and the thoracic ganglionic centers· The large ganglion cells are mostly found in the cephalic ganglionic center and the mesothoracic, the metathoracic, and the abdominal ganglionic regions, singly or in a groups among the other ganglion cells. The neuroglial cells are mainly found in several places: around some glomeruli in the brain and scattered among the fibers of the larger nerve trunks, between the cortex and the neuropile, along the nerve tracts in the central regions of the neuropile. The neurilemma cells, with flattened nuclei from $5\mu \times 2\mu$, are surrounded by the obscure cytoplasm. They are scattered in the neurilemma that forms a continuous covering over the surface of the cephalic and the thoracic ganglionic centers and the nerves.

DISCUSSION

Two aspects of the central nervous system are discussed:

(1) A. Comparative study of certain parts of the central nervous system between the larval and the adult stage of the house flies, and the results observed by Hewitt (7).

(2) A comparative study of certain parts of the central nervous system between the house flies and some other insects.

During the metamorphosis, the central nervous system of the house flies are not only changed in size and shape, but also the whole structure. In the larval stage, two brain hemispheres are connected ventrally, where is perforated by the oesophagus and the ventral ganglionic mass lies underneath. The ventral ganglionic mass is anteriorly connected to the ventral point of fusion of the brain hemispheres and consists of the suboesophageal ganglion, the three thoracic ganglian, and the eight pairs of abdominal ganglia to form a compact ganglionic mass. They are located in the forth segment and reach to about the end of the fifth segment. In the adult house flies, the suboesophageal ganglion is fused with the brain and hardly distinguished externally. Both of the suboesophageal ganglion and the brain form the cephalic ganglionic center, which is connected with the thoracic ganglionic center by a fused paired of nerve strands, the cervical connective. The cephalic ganglionic center is located in the head capsule and the thoracic ganglionic mass is in the thorax.

Nerves sending are also different between the larval and the adult stage of the house flies. In the larval stage, the brain hemispheres give off two pairs of nerves: the pharyngeal nerves and the dorsal prosternal nerves. Each ganglionic region of the ventral ganglionic mass give various nerves: the suboesophageal ganglion sends off one nerve from each side, the papillar nerve; two nerves arise from each side of the region of the prothoracic and the mesothoracic ganglia, thoracic nerves and the accessory nerves, the former nerves directly innervate the leg discs which accompany with the other nerves; the latter innervate the corresponding segments. The region of the metathorax has only one nerve on each side, the metathoracic nerve and the leg disc is absent. From the region of each abdominal ganglion sends off a pair of nerves and the unpaired median nerves innervating the respective segments. In the adult house flies, the cephalic ganglionic center laterally elongate and terminates in large optic lobes. The brain includes the most largest protocerebrum arising the ocellar peduncle, the second largest deutocerebrum sending off the antennal nerves, and the reduced tritocerebrum. The sub-oesophageal ganglion sends off three pairs of nerves: the pharyngeal nerves innervating the rostellum of the proboscis, the labral nerves dividing into two branches, one uniting with the stomodaeal nerve, the other principal branch entering the labrum-epipharynx, the labial nerves innervating the basiproboscis and the haustellum as well as giving a sensory fiber to the maxillary palpi. The thoracicg anglionic center includes three thoracic ganglia constituting the greater part of the ganglionic mass, and arising three pairs of nerves: the ventral nerves innervating three pairs of legs, the dorsal nerves accompany with the accessory nerves innervating the muscles and the respective organs of three thoracic segments. A pair of cervical nerves to the muscles of the neck spring from the sides of the cervical connective, and a pair of very short nerves, prosternal sense organs, lying close to the anterior end of the prothoracic ganglion region. The abdominal ganglion of the adult house flies lacks any segmentations and is much smaller than that of the larvae; it is a small caudal portion of the thoracic ganglionic mass. There arises only one thick median trunk, from which gives off nerves.

In histology, the larval ganglia are invested in the nerve sheath consists of noncellular layer, the neurilemma, and cellular layer, the perineurium. Their neuropile or glomeruli of the brain hemispheres and the ventral ganglionic mass are very simple. The segmentation of the ventral ganglionic mass is distinguished by the fibres which vertically lies in the middle of the ganglionic mass. However, the adult central nervous ganglia are only invested in the nucleated neurilemma. The neuropiles of the cephalic ganglionic center is very complex and includes various parts, such as: protocerebral lobes, corpus centrale, corpora ventralia, corpora pedunculata, ...etc., and five nerve tracts exist runing in various directions. The region of the thoracic ganglionic mass are clearly indicated by the ganglion cells. Most of the ganglion cells in the larval stage are similar to that of the adult stage. In the larval brain heminpheres, there are another kind of cell, cortical cells, constituting the formation centers. It is hardly to find the neuroglial cells in the larval ganglia.

The nerve sheath, Pipa (15) states in *Galleria mellonella* L. that the perilemma consists of a cellular perineurium and an acellular neurilemma (neural lemma). Heywood (8) studied *Pieris brassicae* L. and found that there were two layers of the nerve sheath in the larval stage, the outer noncellular layer was termed the neurilemma and the underlying layer of cells refered as the perilemma. In this study, we use the term "perineurium" for the inner cellular layer and the "neurilemma" for the outer noncellular layer. Heywood also found that the perilemma existed during the larval stage and disappeared during the 48th to 58th hour of the pupal life. It presumably dissolved by some substances in the blood or removed by phagocytes. The perilemma had degenerated completely, the neurilemma remained intact ; the perilemma cells covered all the neuron centre and the connectives and formed the nucleated neurilemma. These are similar to those of the house flies, there are cellular layer, the perineurium (perilemma) inside and the noncellular layer, the neurilemma outside during the larval stage, and only a cellular layer, the neurilemma in the adult stage. The change from two layers of nerve sheath into one might also occured during metamorphosis.

Hewitt (7) reported that in the larva house flies, there are only a single pair and two unpaired median nerves sending from the median dorsal line of the posterior half of the abdominal ganglion; he termed these nerves as the accessory nerves. The first pair nerves supply the 7th segment, the 2nd unpaired nerve to the 8th segment and the 3rd unpaired nerve to the 9th segment. However, in this present study, seven unpaired nerves are found at the median dorsal line of the abdominal ganglion; each nerve terminates in the respective segment and bifurcate into two lateral branches to innervate the intersegmental muscles and the integument of the intersegmental fold.

In the adult house flies, the results of Hewitt (7) are almost the same as those of this present study. However, Hewitt did not mention a pair of nerves to the Scolopophorous sense organs, which are sent from the anterior end of the thoracic ganglionic center. Basides the pattern of the abdominal nerves of the female which arise from median trunk differs from that of the male. Hewitt did not indicate the difference.

The central nervous system of the house fly is similar to that of some other Dipterans. Miller (12) reports that the central nervous system of the larvae of *Drosophila* also includes two brain hemispheres and ventral ganglionic mass. Two nerves, the eye nerves and the antennal nerves, arising from each brain hemispheres. However, both of these two nerves can not be seen in the larvae of the house flies, the pharyngeal nerves and the dorsal prosternal nerves instead. It seems that the maxillary nerves in *Drosophila* are same to the papillar nerves in the larval house flies. Satija (17) studied the blow flies, *Calliphora erythrocephala* and reported that the brain exhibits a very complex form, including the protocerebrum, the deutocerebrum, the tritocerebrum and the suboesophageal ganglion. However, the tritocerebrum is reduced. These are similar to those of the house flies. Dethier (4) reported in the blow flies, *Phormia regina* M. and mentioned about the innervation of the proboscis. The proboscis of *P. regina* is innervated entirely by the labrofrontal and the labial nerves. The labrofrontal nerves extend from the brain, the positions are slightly ventrad and mesad of the antennal nerves. These nerves may be same as the pharyngeal nerves and the labral nerves in the adult house flies. However, in the house flies, the pharyngeal nerves and the labral nerves are separately extended from the ventral side of the suboesophageal ganglion. The labrofrontal nerves of the blow flies, *P. regina* pass down the proboscis from each side of the oesophages. Each one short branch. The branch nearer the midline divides again, and part of it, the frontal connective curved anteriorly and dorsally meeting the corresponding branch of the opposite side and uniting with it in a single nerve which is one of the stomodaeal nerves. The main branch of these nerves extend down the proboscis to the labrum. The labial nerves of *P. regina* is same as that of the house flies. The labial nerves in *P. regina* divide into two large branches after extending from the suboesophageal ganglion. The median branch extends ventrally along the posterior portion of the proboscis to the labellum. The lateral branch, immediately subdivides: The more dorsal branch sends a small twig to the muscles of the rostrum; the remaining branch passes anterior to the muscles of the haustellum and the rostrum, then the muscles of the haustellum and ventrally down the proboscis, and also a subdivision to send fibers to the maxillary palpi. In the house flies, the labial nerves arise from the ventral side of the suboesophageal ganglion, then continues ventrally to the labellum and gives off a smaller sensory fibers to the maxillary palpi. Miller (7) reported in *Drosophila* that a very fine nerve extends from the base of the pharyngeal nerve to the labial nerve of the same side, close to the suboesophageal ganglion. The fine nerve found in the house flies, presumably fused in the suboesophageal ganglion.

The structure of the brain in some Diptera: *Calliphora* (Robinean-Desvoidy). *Sarcophaga* (Meigen), *Tubifera* (Meigen) and Eristalis (Latrali) were reported by Jarnicka (10). The blow flies, *Calliphora erythrocephala* by Satija (17) and *Drosophila* by Miller (12). The brain of the adult house flies are very similar to that of those insects. The corpus centrale consists of the central body, ellipsoid body and the pair of circular ventral tubercles. The central body of convex-concave shape with the convex part directed dorsolaterally in the largest. The central body is kidney-shaped in *Calliphora,* and ellipsoid shape is found from the specimen of the other insects. The central body is ovel shape in *Musca domestica* L. The ventral tubercles in those genera consist of a delicate to fibrous mass and are connected with the central body by crossing fibers. Hertweck (6) found four ventral tubercles in the brain of *Drosophila,* while Power (16) observed there only two. There are only two ventral tubercles in the house flies. Jarnicka (10) indicated that the corpora pedunculata bodies in to four genera: *Calliphora, Sarcophaga, Tubifera* and *Eristalis* are little developed, and Power (16) also reported only inconspicuous corpora pedunculata in dipterous brain. But Satija (17) did not agree with them, he thought that at least they are fairly prominent in *Calliphora erythrocephala.* In the house flies, the corpora pedunculata is well developed. Jarnicka (10) states that the protocerobral bridge in *Calliphora* and other studied genera is slightly bent posteriorly and ventrally, and is undivided. Cuceati (2) described the protocerebral bridge in Sarcophaga is undivided. The inner part of the bridge is composed of delicate fibers, and the surrounding fibers are thicker. Fibers which pass through the pons cerebralis run further towards the central body and ramify there. According to Power (16), the protocerebral bridge of *Drosophila* is divided into two lateral parts called the protocerebral lobes by a fissure which corresponds to the median line of the brain. Miller (12) did not mention about this point in *Drosophila. Musca Domestica* L. has two lateral divided protocerebral lobes as those of *Drosophila* reported by Power (16). The pons cerebralis in the house flies appears as an undivided single forked shape like that of *Calliphora* (17). However, there is a tubercle in the ventral portion of each fork in the house flies and without those tubercle in *Calliphora.* Jarnicka (16) reported that he failed to find direct connections between the antennal glomerules and the optic lobes from *Calliphora, Sarcophaga, Tubifera* and *Eristalls.* Lowne (11) is of the opinion that a tract establishes fibrous connections between the eye and the antennal lobe and has labelled it as the oculo-olfactory tract. The indicated segmentations in three paired thoracic ganglia and a single abdominal ganglion of the house fly is much identified to that of the Drosophila (12); they are distinguished by the ganglion cells in the adult and by the connective tissue running vertically in the middle region of the ganglion during the larval stage.

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EXPLANATION OF ILLUSTRATIONS

Fig. 1-2. Diagram of the dorsal view of the central nervous system during the larval stage, 15 x.

Fig. 3. Diagram of the lateral view of the central nervous system during the larvel stage, 30 x.

Fig. 4. Diagram of the dorsal view of the female central nervous system during the adult stage, 16 x.

Fig. 5. Diagram of the dorsal view of the male central nervous system during the adult stage, 16 x.

Fig. 6. Diagram of the lateral view of the female central nervous system during the adult stage, 16 x.

Fig. 7-10. Sagittal section of the brain hemisphere and the ventral compound ganglionic mass during the larval stage, 150.4 x.

Fig. 11. Horizontal section of the brain hemisphere during the larval stage, 150.4 x.

Fig. 12. Cross section of the brain hemisphere and ventral compound ganglionic mass during the larval stage, 150.4 x.

Fig. 13. Cross section of the ventral compound ganglionic mass during the larval stage, 601.6 x.

Fig. 14. Sagittal section of the ventral compound ganglionic mass during the larval stage, 601.6x.

Fig. 15. Sagittal section of the cephalic and the thoracic ganglionic center during the adult stage, 52.64 x.

Fig. 16-17. Sagittal section of the cephalic ganglionic center during the adult stage, 150.4 x.

Fig. 18. Sagittal section of the optic lobe of the cephalic ganglionic center during the adult stage, 150.4 x.

Fig. 19-25. Sagittal section of the cephalic ganglionic center during the adult stage, 150.4 x.

Fig. 26. Sagittal section of the deutocerebrum and the antennal nerves during the adult stage, 601.6 x.

Fig. 27. Sagittal section of the antenna during the adult stage, showing the distribution of the nerve fiber in antenna, 150.4 x.

Fig. 28. Sagittal section of the thoracic ganglionnic center, 150.4 x.

Fig. 29. Horizontal section of the thoracic ganglionic center during the adult stage, 150.4 x.

Fig. 30. Sagittal section of the posterior portion of the thoracic ganglionic center, 223 x.

Fig. 31. Sagittal section of the anterior portion of the thoracic ganglionic center, 601.6 x.

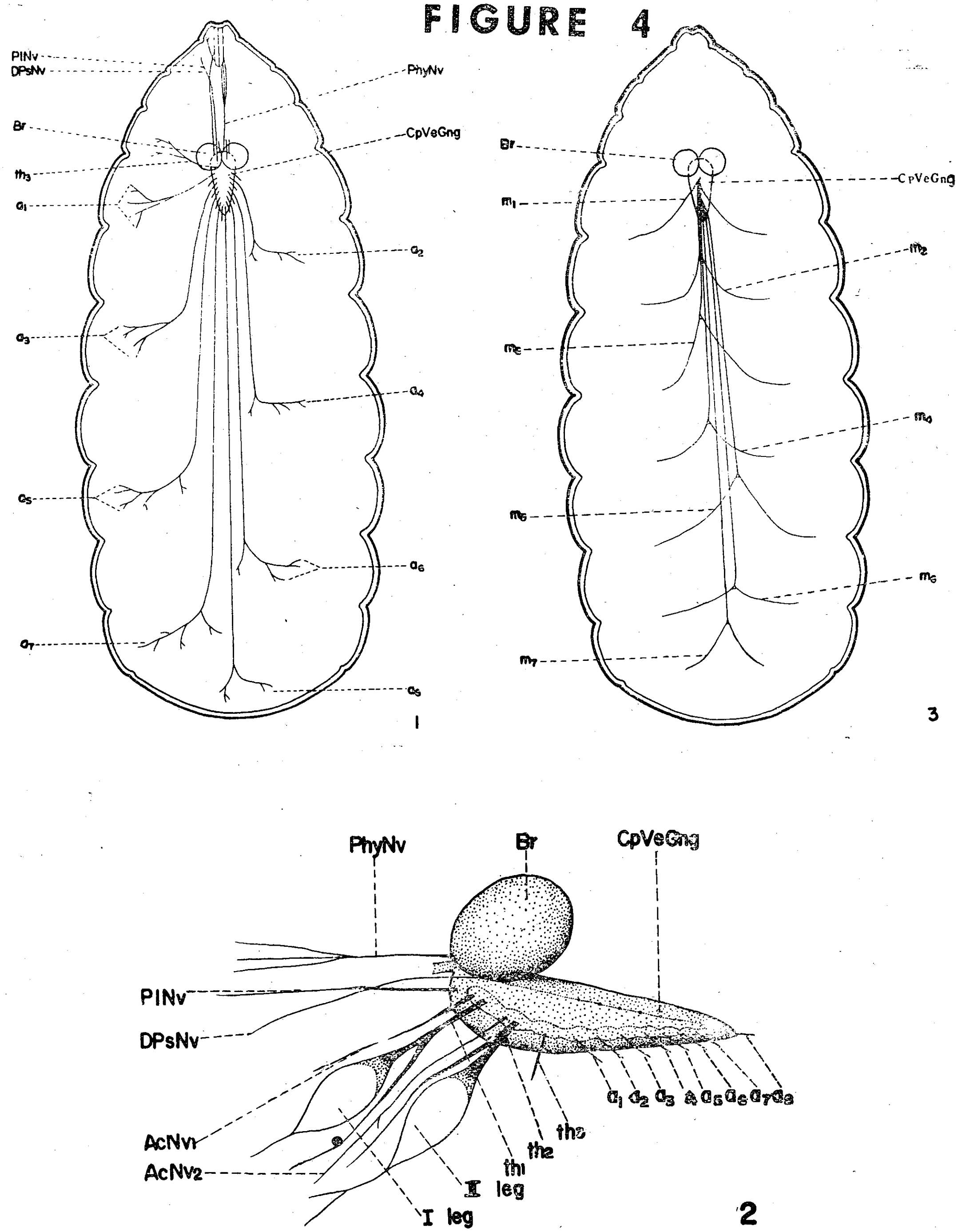
ABBREVIATION

a_{1-8}——First to eight abdominal nerve
AbGng——Abdominal ganglionic center
$AbNv_{1-4}$——First to four abdominal nerve
Ab_tNv——Terminal abdominal nerves
AbNrTr——Thick abdominal nerve
$AcNv_{1-3}$——First to third accessory nerve
AntL——Anternal lobe
AntNv——Antennal nerve

Br——Brain hemisphere
Br_1——Protocerebrum
Br_2——Deutocerebrum
Br_3——Tritocerebrum
Cc——Corpus centrale
Com_1——Protocerebral commissure
Com_2——Deutocerebral commissure
Com_3——Tritocerebral commissure

Cpd——Corpora pedunculata
CpdClx——Compound calyx
CpdStk——Thick fibrons stalk (poduncuIs)
CpGng——Cephalic ganglionic center
CpVeGng——Compound ventral ganglionic center
Cv——Corpora ventralis
CtCl——Cortical cells
Cvcon——Cervical connective
CvNv——Cervical nerve
DNv_{1-3}——First to third dorsal nerve
DpsNv——Dorsal prosternal nerve
DT——Deutccerebral Tract
FmC——Formic center
GCl I——Ganglionic cells of the outer layer in optic lobe
GCl II——Ganglion cells of the inner layer in optic lobe
GCl III——Interspersed ganglionic cells in optic lobe
GtCl——Gaint cells
Hlt——Halters
ICh——Inner Chiasma
I——Distal periopticon
II——Median epiopticon
$III_{a,b}$——Proximal opticon
LbNv——Labial nerve
I Leg——First log disc
II Leg——Second log disc
LGCl——Large ganglion cells
LrNv——Labral nerve
m_{1-7}——First to sevent median nerves
MT——Median tract
MxPlp——Maxillary palpi
Nlm——Neurilemma
NlmCl——Neurilemma cell
NglCl——Neuroglial cell
Npl——Neuropile
O——Ocelli
OCh——Outer Chiasma
Oe——Oesophagus
OPdcl——Ocellar peduncule
OpL——Optic lobe
OpT——Optic tract
PcrL——Protocerebral lobes
PhyNv——Pharyngeal nerve
PGng——Pyramidal ganglion
Picr——Pars intercerebrum
PlNv——Papillar nerve
Pner——Pars cerebrum
Pum——Perineurium
PumCl——Perineurial cells
PSO——Prosternal sense organ
SGCl——Small ganglion cell
SsTr——Sensilla trichodea
SwCl——Schwann cell
SoeGng——Suboesophageal ganglion
TgNv——Tegumental nerves
TriL——Tritocerebral lobe
Th_1——Protothoracic nerve
Th_2——Mesothoracic nerve
Th_3——Metathoracic nerve
ThGng——Thoracic ganglionic center
VNv_{1-3}——First to third ventral nerves

FIGURE 4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CpVeGng
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1
Br
CpVeGng
m1
m2
m3
m4
m5
m6
m7
3
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Br
CpVeGng
PlNv
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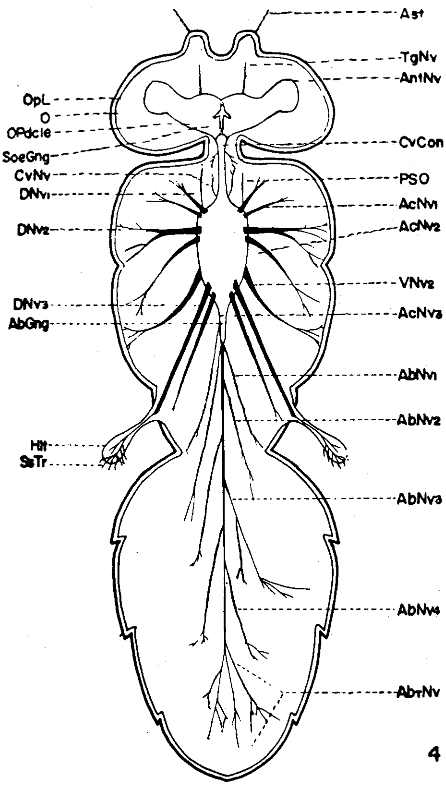
I leg
2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VNv2
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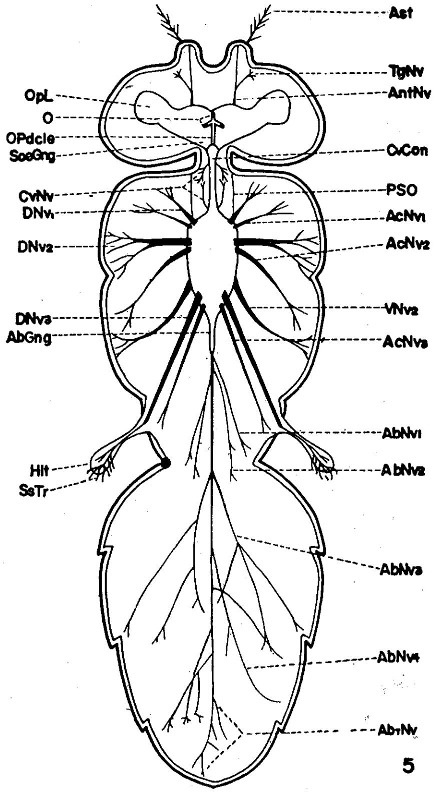
AbNv4
Ab7Nv

4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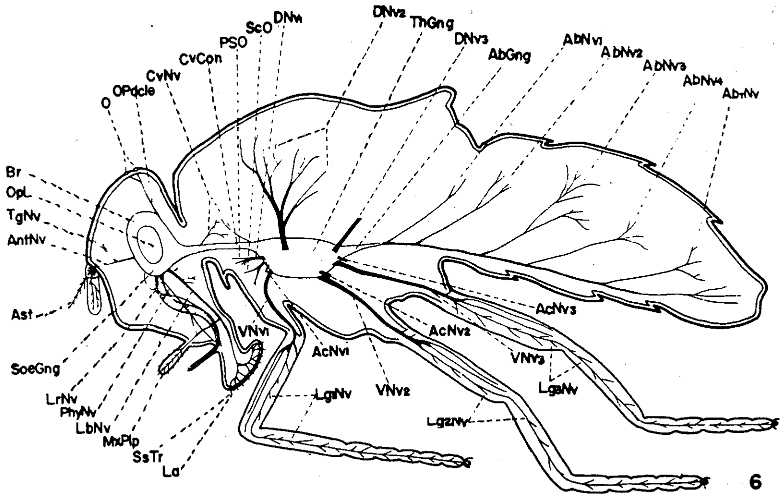
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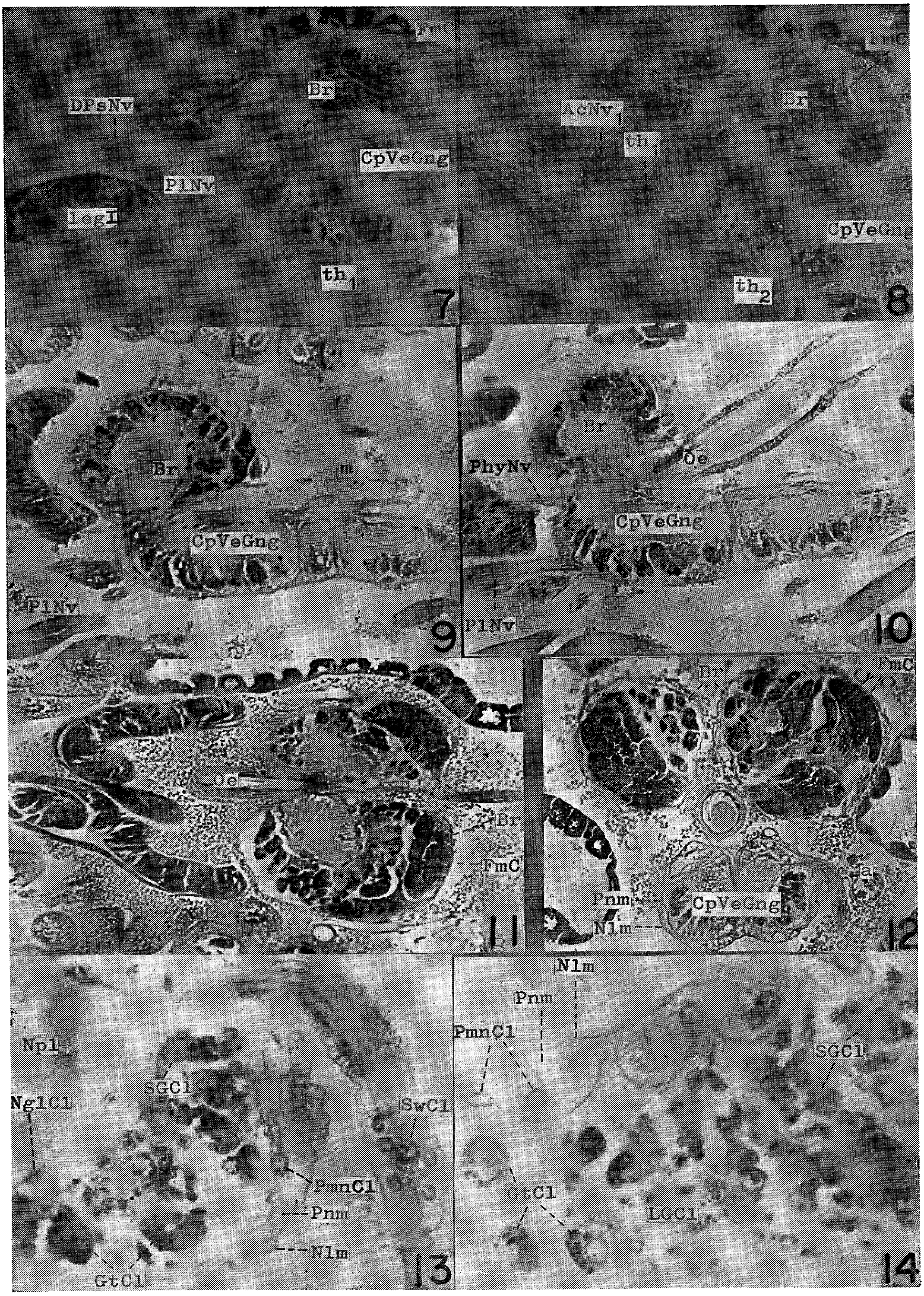
6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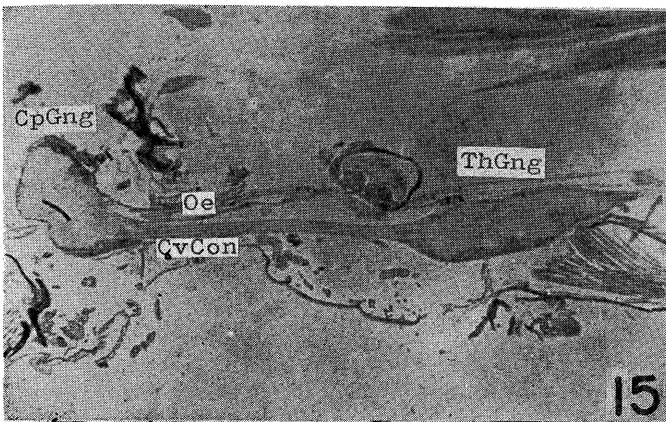
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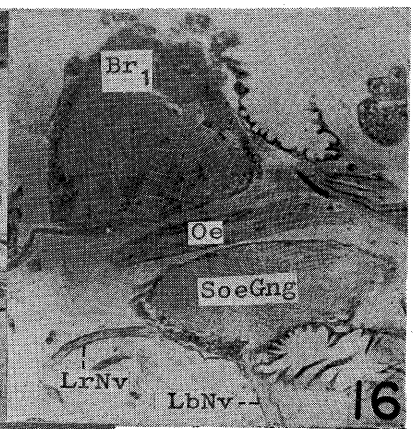
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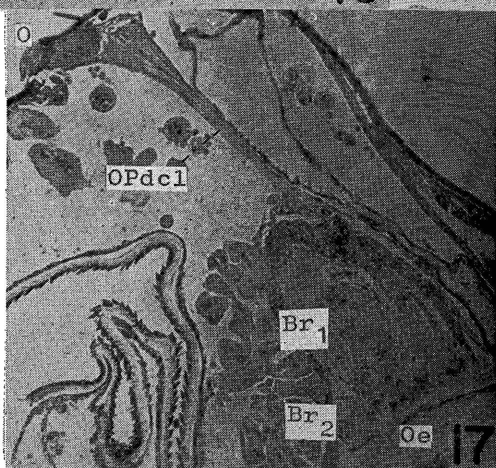
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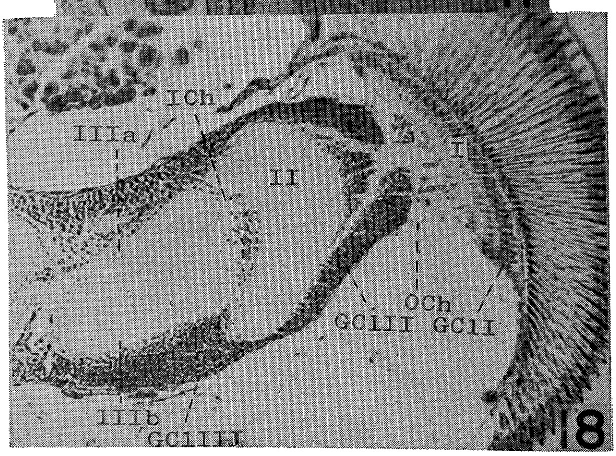
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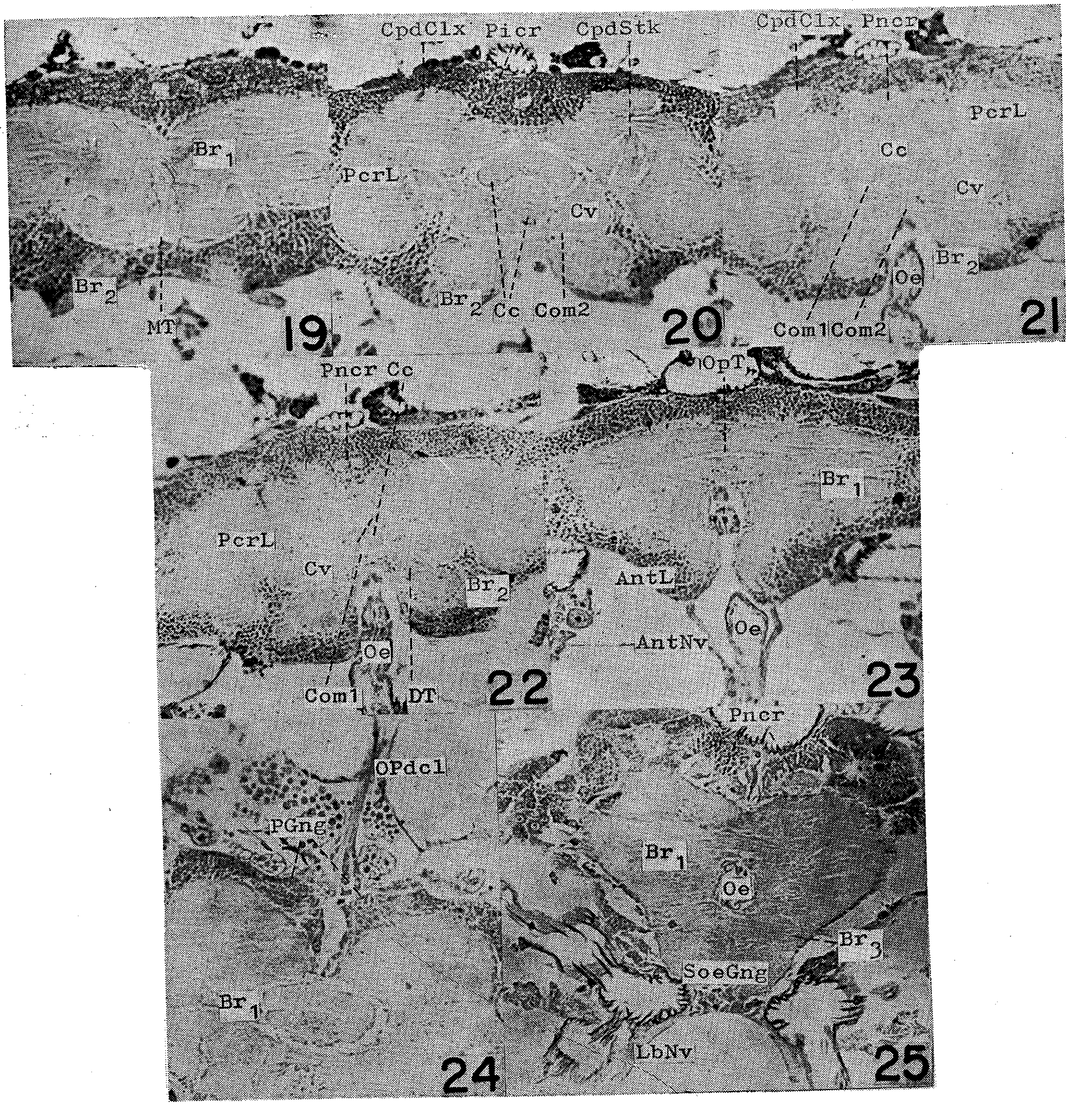
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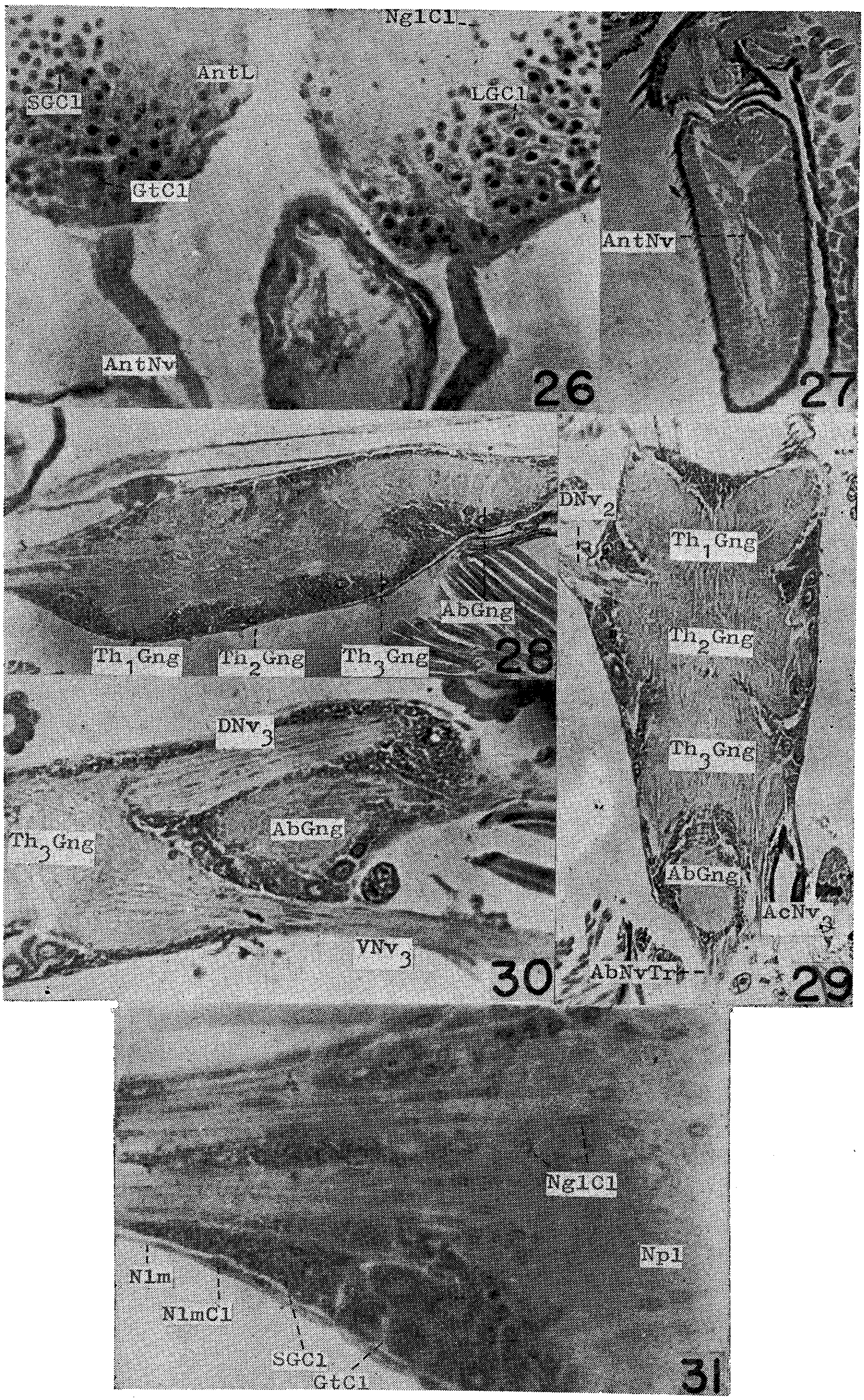
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