Insect nervous system

Zoo 514
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Nervous System

- The nervous system is the primary mechanism of conduction and control in the body .

- In insects it serves as an elaborate (complex) connecting link between the sense organs and the effectors' organs (muscles and sometimes glands).

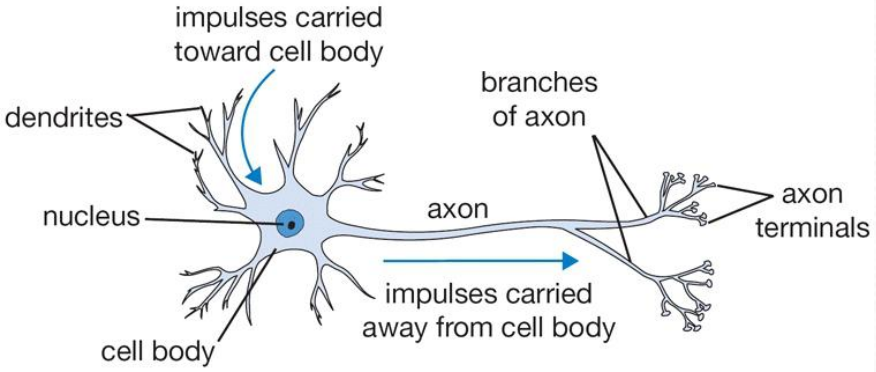
Cells in the nerve system

1. Nerve cells (=Neurons): Conducting cells that transduce, transmit or process nerve impulses.

2. Glial cells: Non-conducting supporting cells that surround neurons and help to protect neurons and maintain stable ionic environment .

Neuron

- **The basic unit of the nervous system is the neuron.**
- **It consists of a nucleated cell body (neurocyte) giving off slender cell extension (axon) .**
- **The neuron may have several dendrites , but only one axon.**



Axon

- **A slender cell extension arises from the cell body of the neuron which transmits nerve impulses from one cell to the next.**

- **Collaterals**

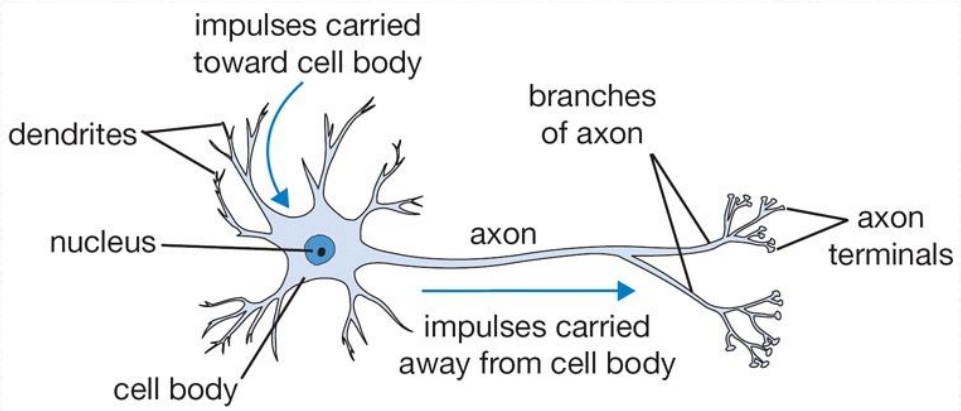
- Lateral branches arising from the axon generally near its origin.

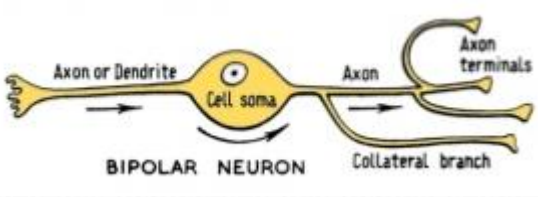
- **Dendrites**

- They are fibrils arising directly from the nerve cell body. They are specialized for the reception of the stimuli and transmitting impulses towards the central cell body

- **Terminal arborisation**

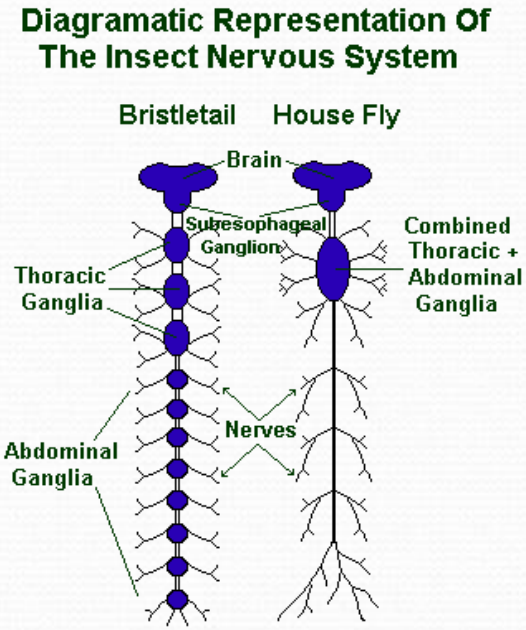
- Both axon and collateral end in fine branching fibrils , these are the terminal arborizations.

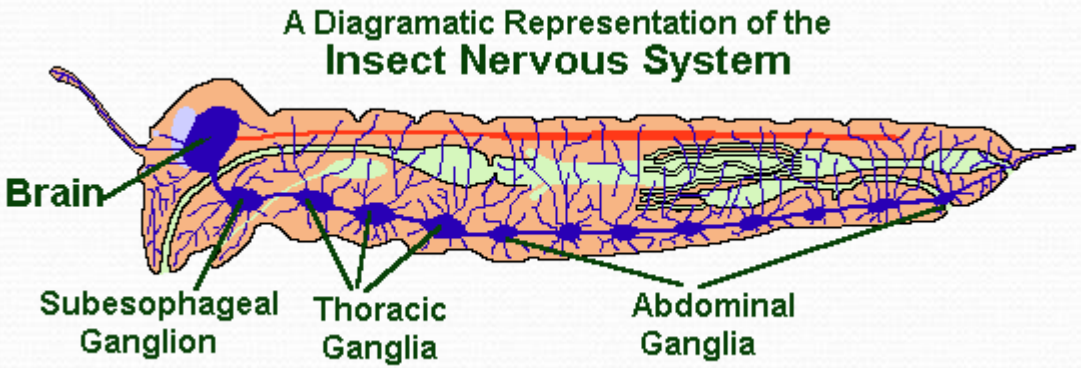




Ganglion

- The greater part of the neuron and their processes do not occur singly but are aggregated in a series of segmental ganglia .
- The ganglia are united by longitudinal connectives which constitute the central nervous system.





Neuron classification

- **Types of neuron: two ways of classification**

- Structurally by the number of extensions:

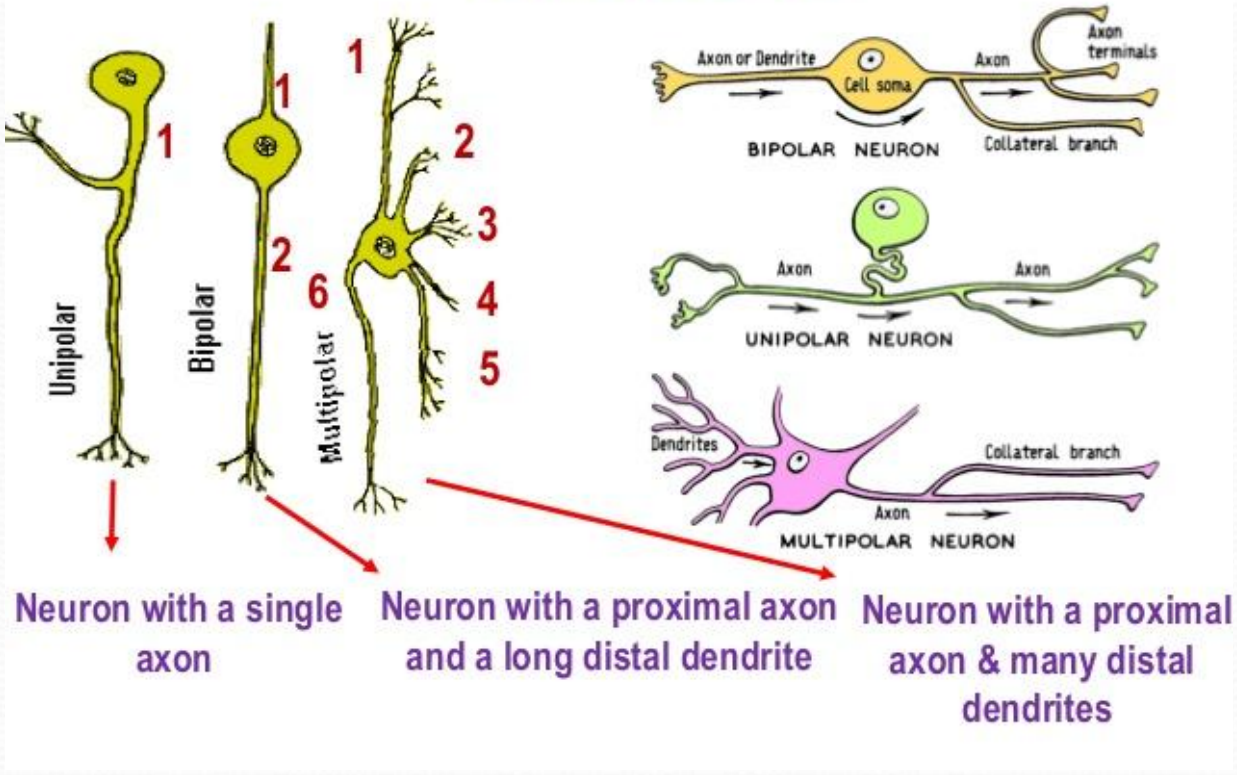
1- Unipolar neurons have one projection extending from the soma (Most insect neurons are of this type).

2- Bipolar neurons have two projection extending from the soma (the peripheral sense cells are of this type).

3- Multipolar neurons have many projections extending from the soma. However, each has only one axon.

INSECT NERVOUS SYSTEM

A. STRUCTURAL BASIS



- Functionally:

1- Sensory (afferent)

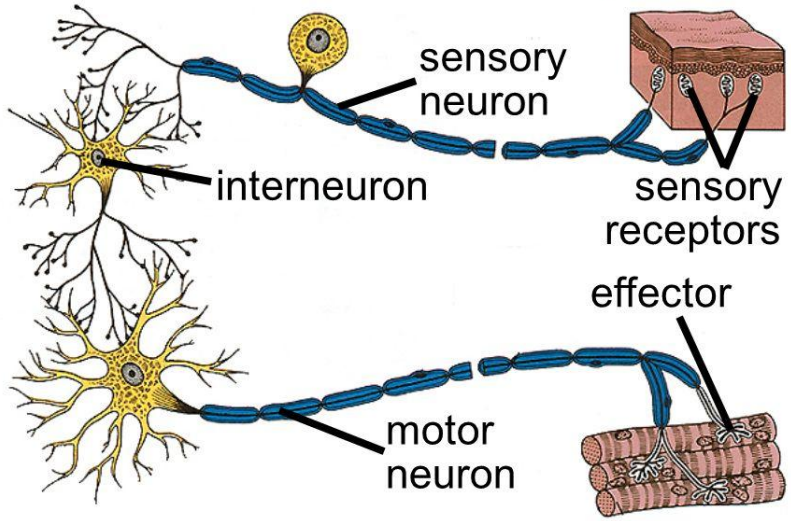
- Sensory neuron convey impulses inwards from the sense organs.

2- Motor (efferent)

- neurons convey the impulses mainly outwards to the effector organs mainly the muscles .

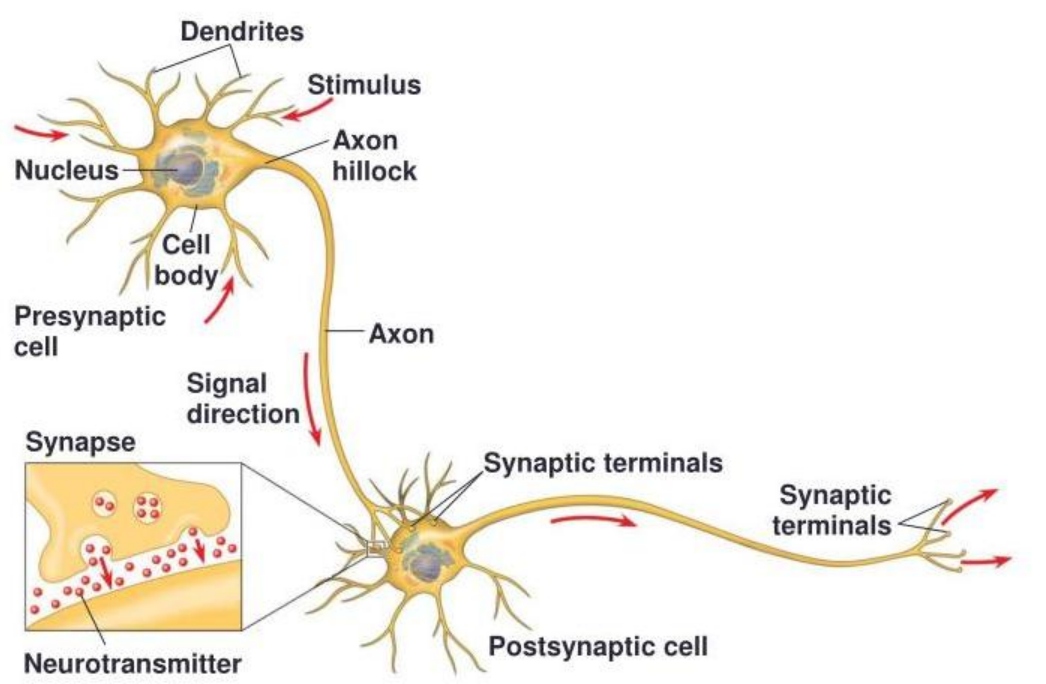
3- Association (internuncial)

- Association neurons link the sensory and motor neurons together within the central nervous system.



Synapsis

- The site at which the axon of one neuron contacts the dendrite of another is called a (synapsis) it is the point which neurons receive information from or convey it to other cells.



Nerve Sheath

- The ganglia of the nervous system is clothed in a non-nervous sheath which is differentiated into a non cellular neural lamella and cellular perineurium.
- The neural lamella comprises a thin outer homogeneous layer containing narrow filaments , and a much thicker layer which consists of collagen like fibrils – like protein in a matrix and neutral muco- polysaccharide.

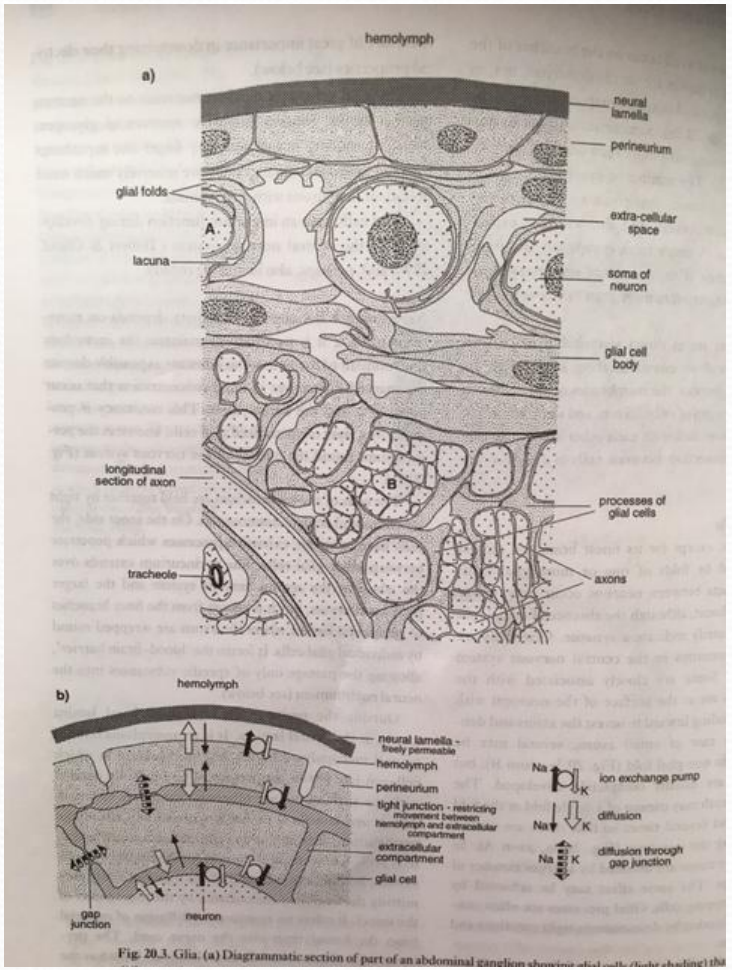


Fig. 20.3. Glia. (a) Diagrammatic section of part of an abdominal ganglion

- The neural lamellar is probably secreted by cells in the perineurium and other cells may be contributed too.
- Neural lamella provides mechanical support for the central nervous system, holding the cells and axon together while permitting the flexibility necessitated by the movements of insect. They offer no resistance to diffusion of material from the hemolymph into the nerve cord.
- The perineurium extends over the whole of the central system and the larger peripheral nerves, but it is absent from the fine branches. It forms the blood-brain barrier allowing the passage only of specific substances into the neural environment.

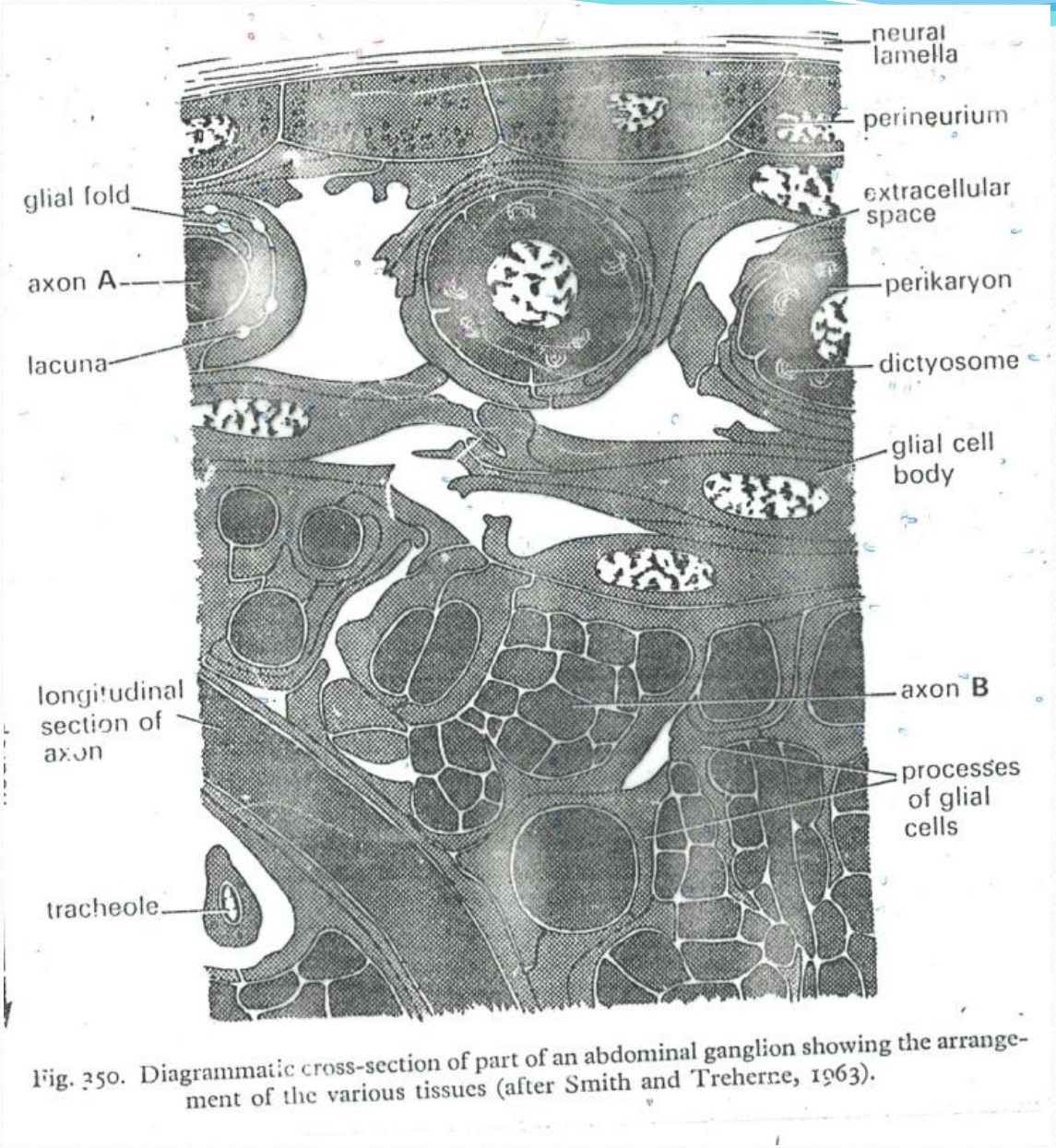
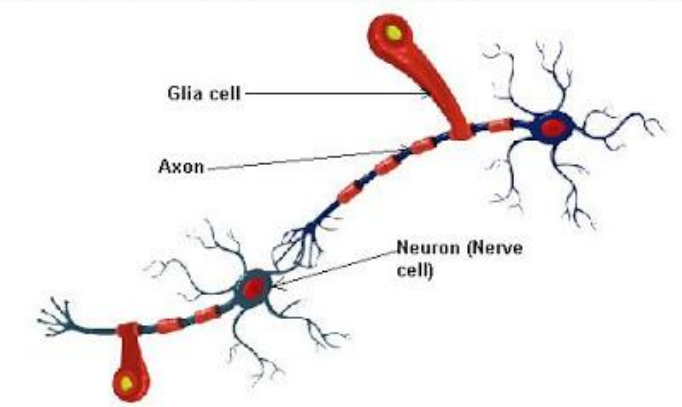


Fig. 350. Diagrammatic cross-section of part of an abdominal ganglion showing the arrangement of the various tissues (after Smith and Treherne, 1963).

Glial cells

- The Glial cells form an insulating protective sheath almost wholly investing round each neuron .
- They serve to insulate the axons from each other.
- They also pass nutrient materials to the neuron.



Extra – cellular spaces

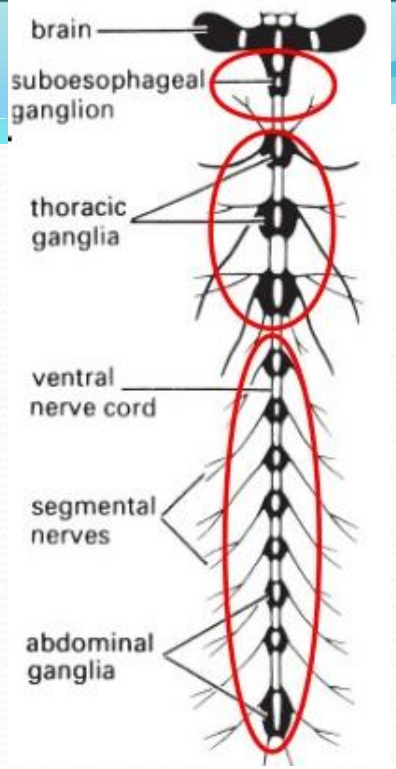
- These are spaces between the glial cells.
- The fluid in the extra – cellular spaces bathes the nervous elements directly and is therefore of great importance in nervous conduction.
- It differ in composition of ions from the hemolymph.

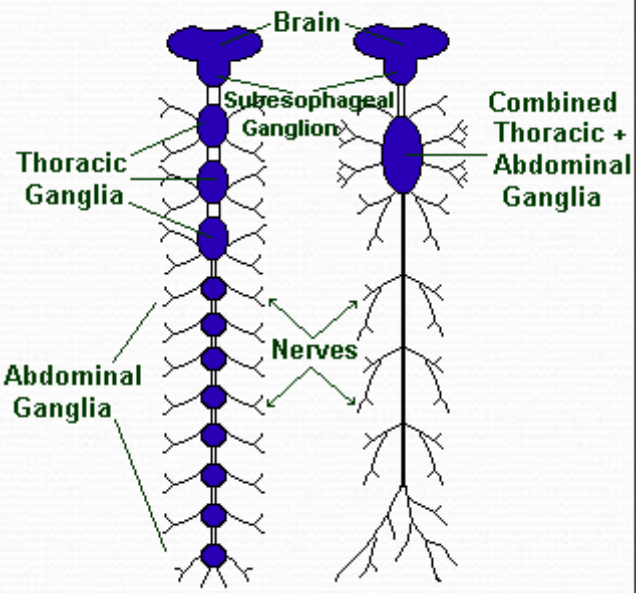
- The nerve term is commonly applied to bundles of sheathed neuronal extensions leading from ganglia to various parts of the body .
- A nerve generally includes both motor and sensory extensions .
- A nerve trunk is a larger nerve .
- The central nerve cords : are two longitudinal nerve trunks running side by side connecting the ventral chain of segmented ganglia .

Ganglia

- The somata of interneurons and motor neurons are aggregated to form the ganglia of the central nervous system.
- The somata are grouped peripherally, and the center is occupied by the terminal arborizations of sensory axons, by the dentritic arborization of motor neurons, and by axons and arborizations of interneurons.
- Primitively, a pair of ganaglia is present ventrally in each postoral segment.
- Some segmental ganglia fused to form the brain.
- So the central nervous system is consists of brain followed by a series of segmental ganglia.
- Adjacent ganglia are joined by a pair of interganglionic connectives that contains only axons and glia; there are no soma or synapses.

- The first ganglion is the subesophageal ganglion.
- There are three thoracic ganglia, but in some insects they fuse to form a single ganglion.
- The largest number of ganglia are the abdominal ganglia which present in the abdomen.
- Sometime most or all of the ventral ganglia are fused to form a single compound ganglion as in the blood sucking bug.





Nutrition of the ganglia

- The ganglia are almost the only solid organs in the insect body - The respiratory needs are provided by the tracheae and tracheoles which penetrate with the ganglia.
- There is no circulation of body fluids inside the ganglia.
- Nutrient and excretion must be provided by diffusion through the sheath of the ganglia.

Anatomically , the insect nervous system is divided into

1- Central Nervous System (C.N.S.).

2- Visceral (Sympathetic) Nervous System (S.N. S.)

3- Peripheral Nervous System.

- All the three parts are connected with each other .

Central Nervous System

- The C. N.S. is divided into

1 – The Brain

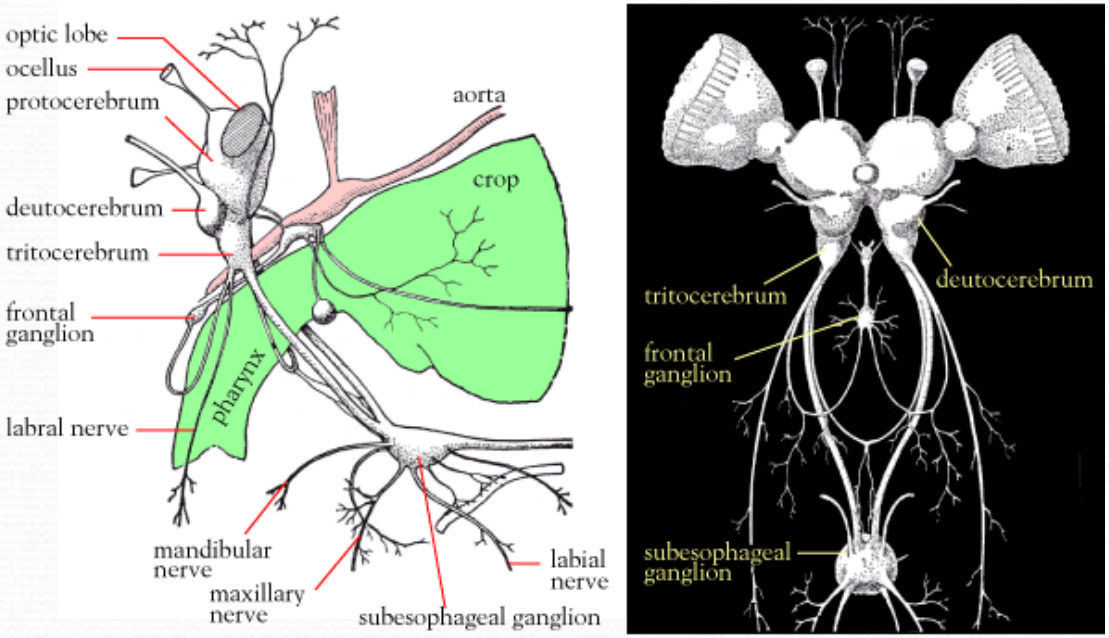
2 – The Suboesophageal ganglion

3 – The Ventral nerve cord

1- Brain

- It is the dorsal ganglion center of the head.
- Is lying above the anterior end of the stomodeum.
- It is subdivided into three main regions:
  - Protocerebrum associated with the eyes and thus bearing the optic lobes.
  - Deutocerebrum innervating the antennae.
  - Tritocerebrum concerned with handling the signals that arrive from the body.

Figure 6

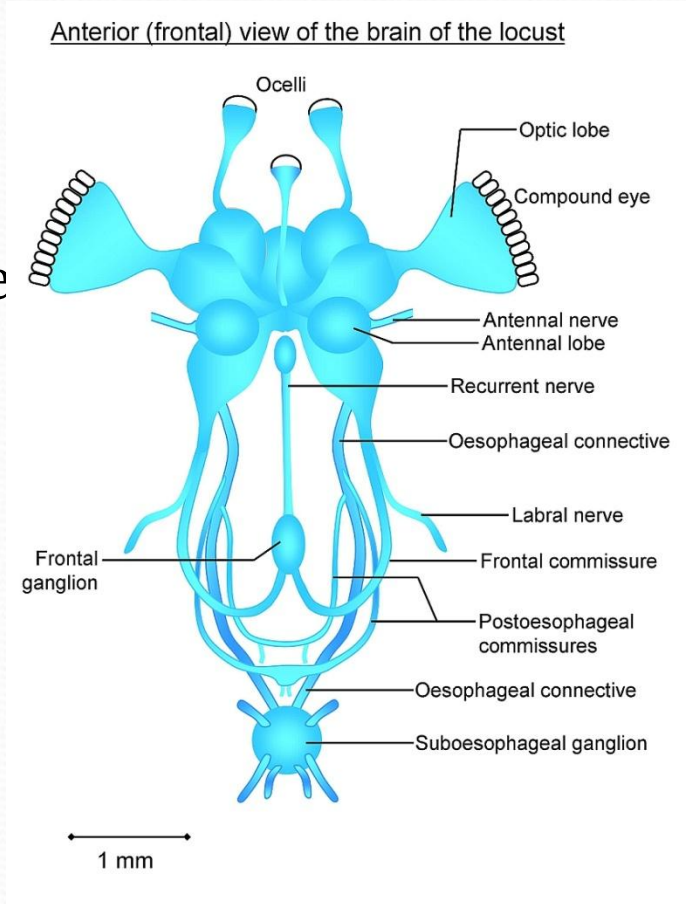


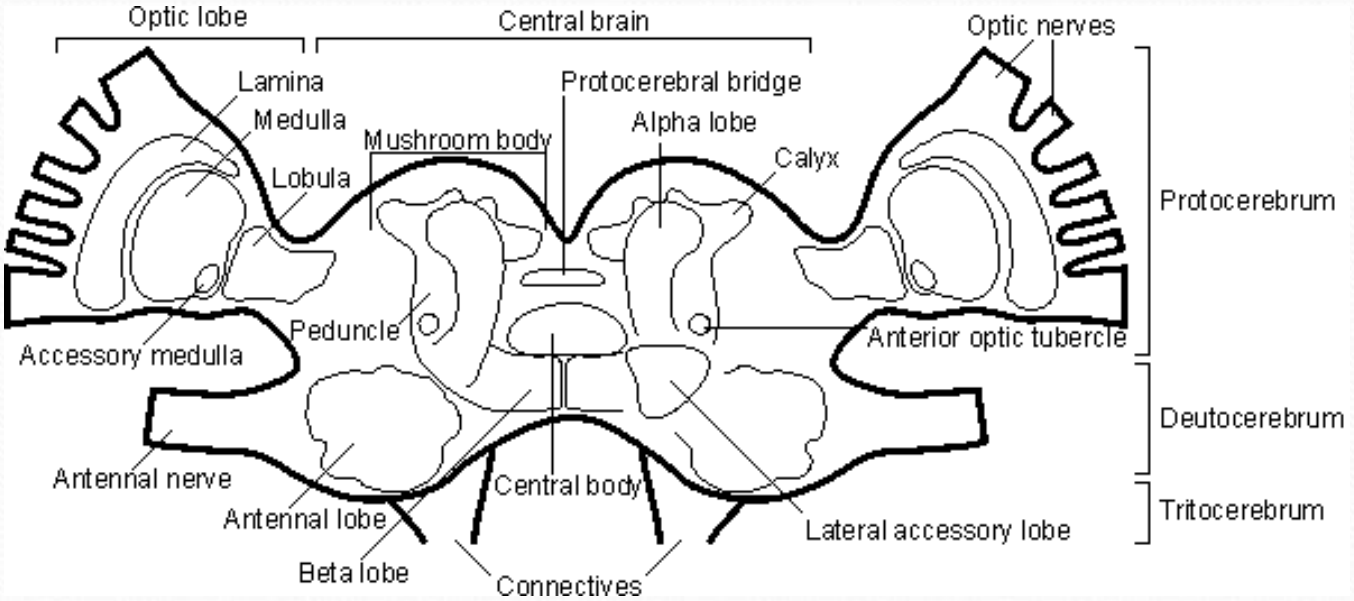
Central nervous system of a grasshopper

Protocerebrum

- It is the greater part of the brain .
- It is bilobed and continues laterally with the optic lobes.
- It is formed by the united ganglia of the of the preantennal segment .
- It is consisted of :

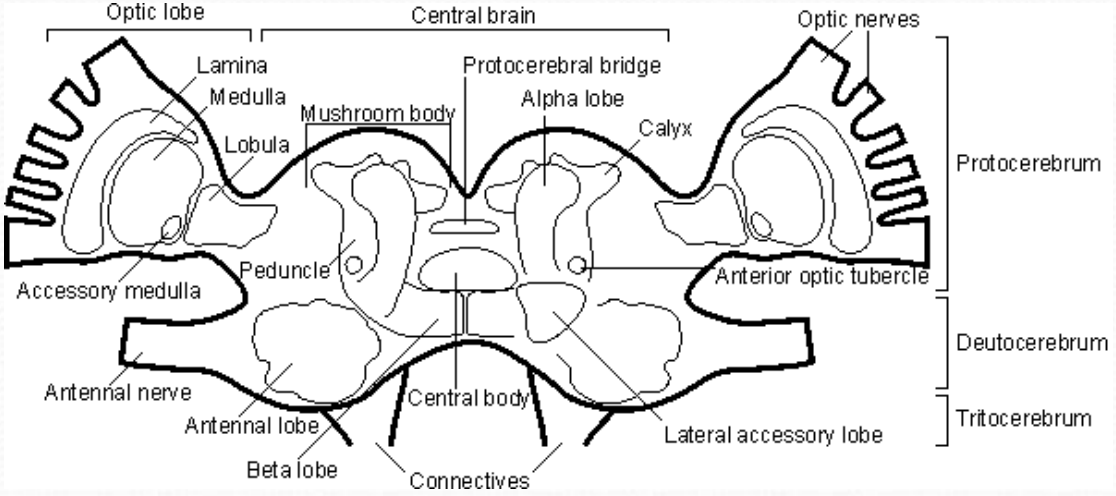
1- protocerebral lobes (central complex): ; The principle features are the protocerebral bridge, the central body and lateral accessory lobes.




Optic lobe
Central brain
Optic nerves
Lamina
Medulla
Lobula
Mushroom body
Protocerebral bridge
Alpha lobe
Calyx
Protocerebrum
Peduncle
Accessory medulla
Anterior optic tubercle
Deutocerebrum
Antennal nerve
Antennal lobe
Central body
Tritocerebrum
Lateral accessory lobe
Beta lobe
Connectives

2- Optic lobes:

- They are the lateral extensions of the protocerebrum to the compound eyes.
- they are responsible for processing the inputs from the eyes
- Each lobe consists of three principal zones of nerve tissues known as the lamina, the medulla and the lobula complex, connected by similar number of layers of nerve cells.



Or known as:

a – The ganglion layer "periopticon "

b – The medulla externa " epiopticon". They are connected with the ganglion plate by outer chiasma.

c – The medulla interna " opticon" . They are connected to the medulla externa by inner chiasma .

- The fibers of the optic nerve issue from the inner aspect of the " medulla interna " and are divided into anterior and posterior bundles.

3- Mushroom bodies " Corpora Pedunculata "

- Located at the sides of the pars intercerebralis.
- Each consists of a flattened cap of neuropil, the calyx, from which a stalk runs ventrally before dividing into two or sometimes three lobes known as the α,β and γ lobes
- They are given their form by a large number of interneurons, called Kenyon cells, that have their somata above the calyx.
- They are seen as higher centers regulating behavior.

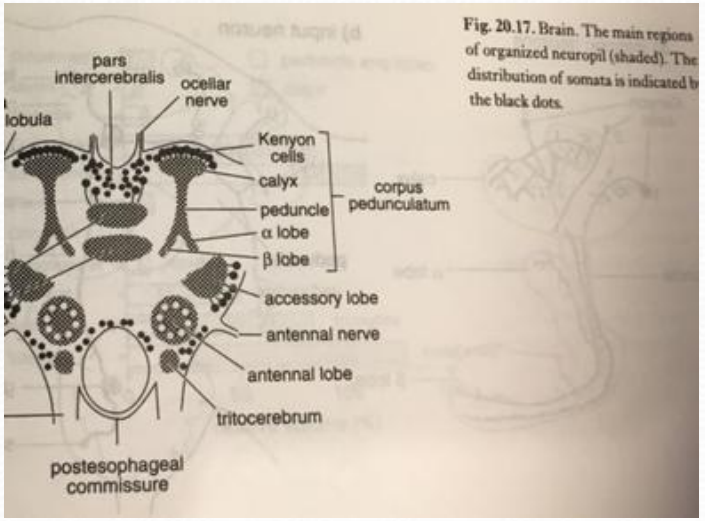
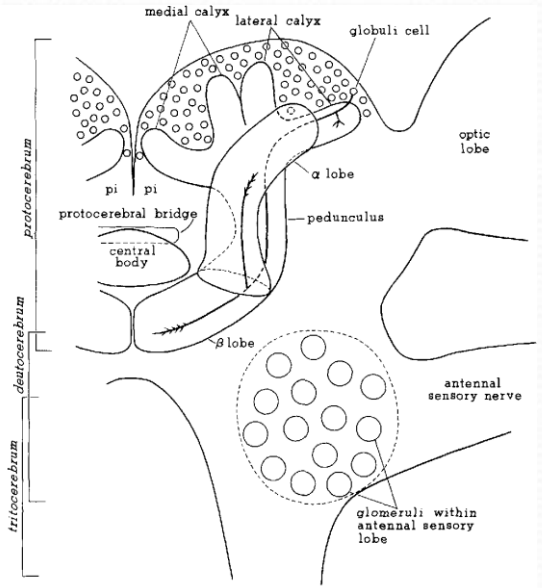


Fig. 20.17. Brain. The main regions of organized neuropil (shaded). The distribution of somata is indicated b the black dots.



- The relative size of this part is related to the complexity of behavior shown by the insect.
- Changes occur in the mb with age and experience.
- MB receive input from neurons carrying information from the antennal lobes.
- The MB are involved in olfactory and in some insects in visual learning.

- Between the mushroom bodies , four small ocellar lobes are represented , an ocellar nerve takes its origin from each of which . The two outer nerves supply the lateral ocelli . The inner unite to supply the median ocellus.

Deutocerebrum

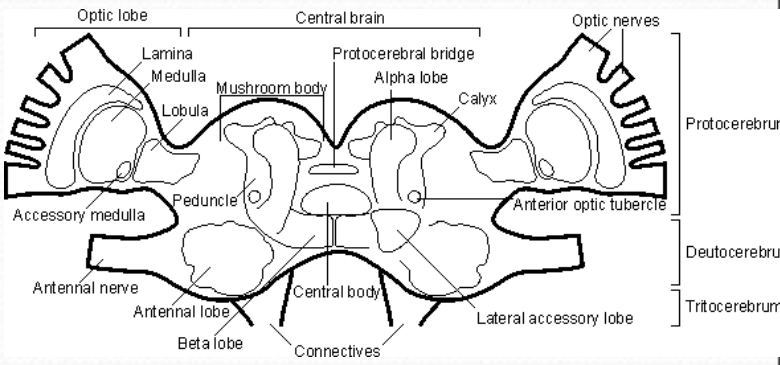
- It represents the fused ganglia of the antennary segment . It consists of

1 – Antennary (olfactory) lobes

- Prominent swellings situated on the anteroventral of the brain and innervate the antennae .

- Connected with the mushroom body of its side and the central body by " Optic – olfactory chiasma.

2- the antennal mechanosensory and motor center.



- Nerves arising from deutocerebrum:

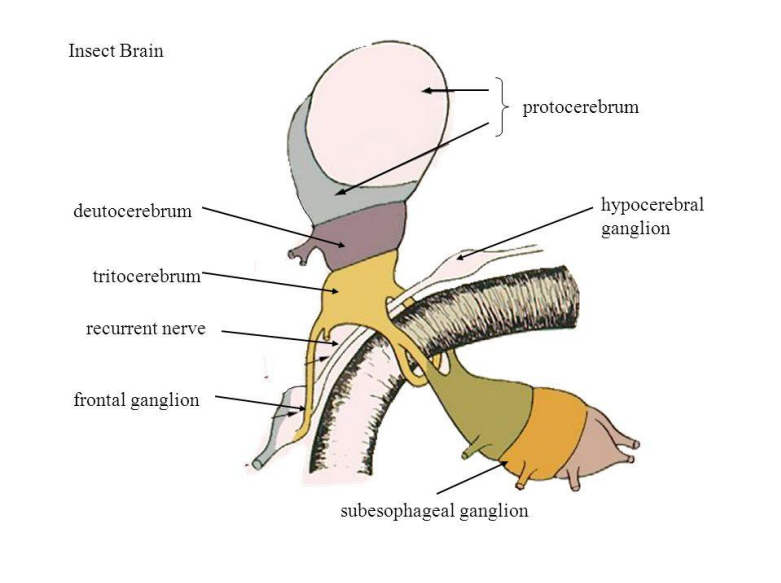
1- **Antennary nerves** : Sensory and motor ; one from the antennary and the other from the dorsal lobe .

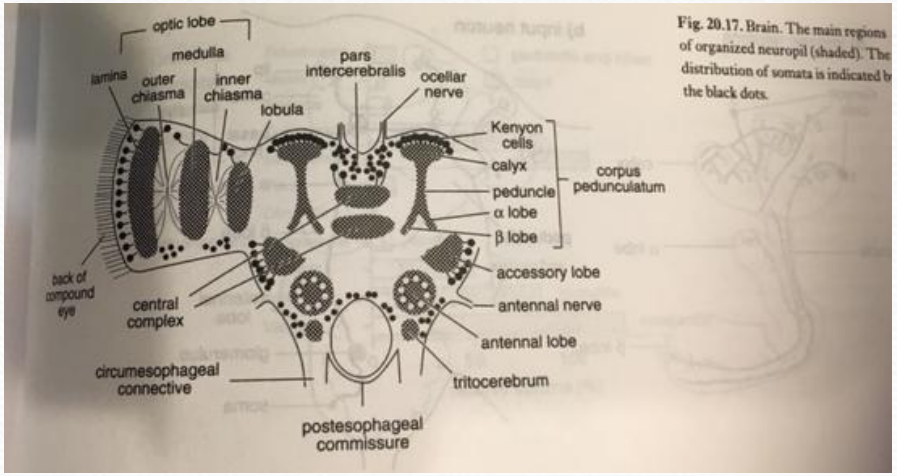
2- **Accessory antennal nerves** : issue from antennary lobes (motor nerves of appendages).

3- **Tegumentary nerves** : arising from dorsal lobes to vertex .

Tritocerebrum

- The third pair of ganglia innervate the labrum and integrate sensory inputs from proto- and deutocerebrums.
- They also link the brain with the rest of the ventral nerve cord and the stomodaeal nervous system that controls the internal organs.
- It is divided into two widely separated lobes beneath the deutocerebrum and connected by a commissure passing behind the esophagus.





- They are attached to the dorsal lobe of the deutocerebrum.
- Anteriorly, nerves containing sensory and motor elements connect with the frontal ganglion and the labrum.

2- Suboesophageal ganglion

- It is formed by : fusion of the ganglia of mandibular , maxillary and labial segments.
- It is the ventral ganglion center of the head.
- It gives of paired nerves supplying their appendages.

- Functions of the Suboesophageal Ganglion

  - It contains the motor centers for the mouth parts which it innervates.
  - It may influence the motor activity of the entire insect .
  - It does not contain essential coordination centers for movement , since normal walking may occur after its removal.

3- Ventral Nerve Cord

- It consists of series of ganglia lying on the floor of the thorax and abdomen.
- They are united by a pair of connectives.
- Thoracic ganglia : The first 3 – ganglia which are situated one in each of the thoracic segment .

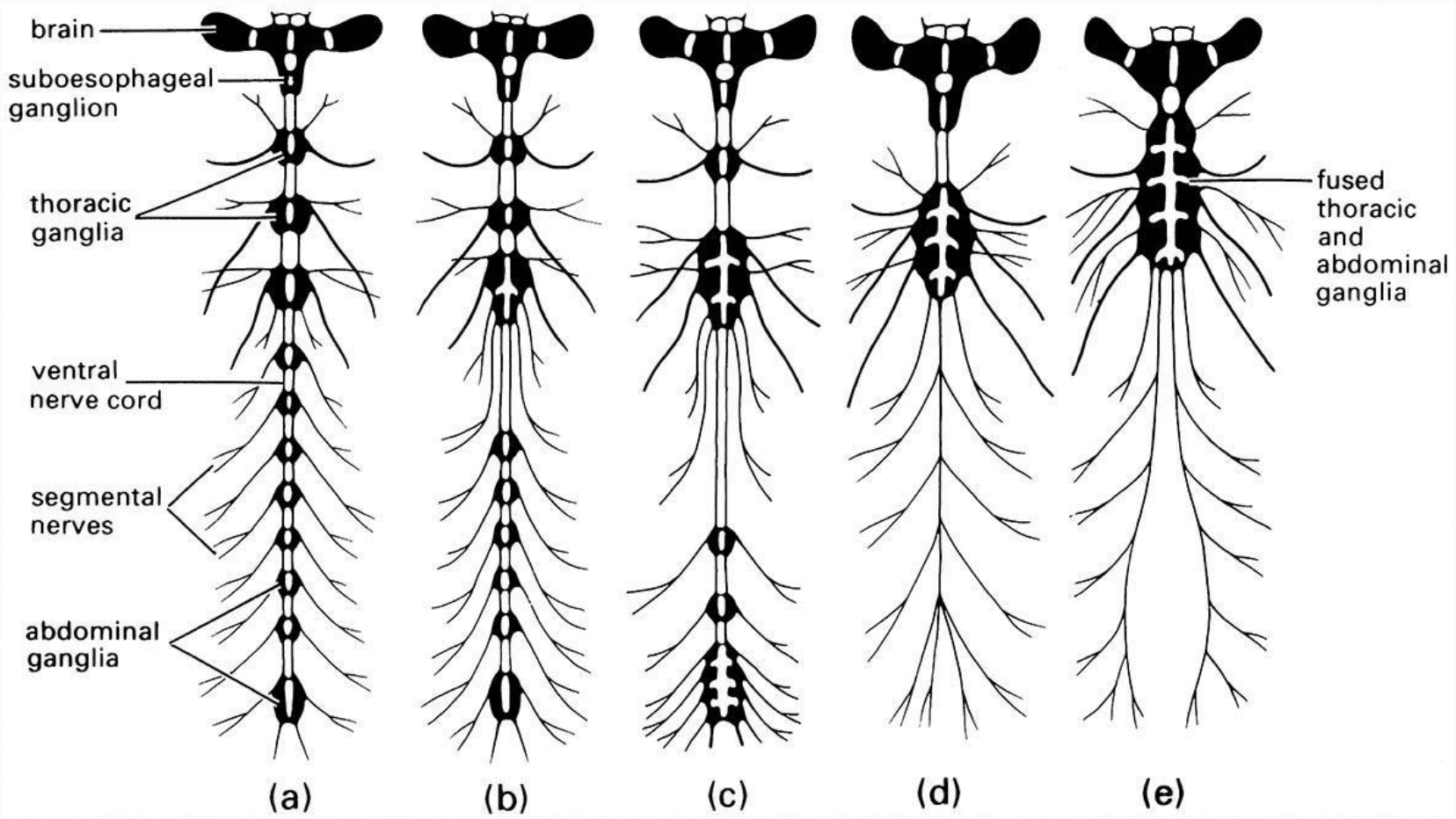
Function ; Control the locomotor organs ; it gives off

1) a pair of nerves supply the general muscles.

2) a pair innervates muscles of legs.

Meso – and Meta thoracic ganglion : They have the above 1) & 2) and a 3 rd pair controls movements of wings .

- Abdominal ganglia : They are variable in number .


brain
suboesophageal ganglion
thoracic ganglia
ventral nerve cord
segmental nerves
abdominal ganglia
fused thoracic and abdominal ganglia
(a)
(b)
(c)
(d)
(e)

Cerebral development

1- The volume of the brain is changed in different insects.

2 – The optic lobes :developed in proportional to the size of the eyes .

3 – The antennary lobes ; related to the development of senses and organs connected with them .

4 – Mushroom bodies : Attain their greatest size in Hymenoptera with elaborate behavior , as there exists structural differences in the brain of drone , worker and queen bees correlated with the degree of activities.

Ventral Nerve Cord

1 – **Primitive ; Thysanura & Dictyoptera:**

- Suboesophageal g.
- Thoracic g.
- Abdominal g.

Separate and visible { all the above ganglia are separate } .

- The most posterior being a compound centre.

2- Orthoptera & Hymenoptera:

- Suboesophageal , Pro - & Meso- thoracic g. { all are separate & visible }
- Metathoracic + 1 st (1- 3) abdominal are joined .
- The 7 th & the subsequent form a compound centre.

3 - Heteroptera:

- Suboesophageal & prothoracic ganglia { are separate }.
- All the others are fused .

4 - Higher Diptera , Homoptera:

- Suboesophageal , Single compound thoracic – abdominal ganglion.

5 – Coleoptera larva:

- Suboesophageal & all the ventral ganglia are fused.