Respiration in Arthropods

Respiratory Organs in Arthropoda

Structures adapted to facilitate the passage of oxygen or air from the environment across the body surface are included in respiratory system. In many arthropods these organs are protected in the pouches, and in aquatic animals, irrigated by water currents produced by the associated appendages.

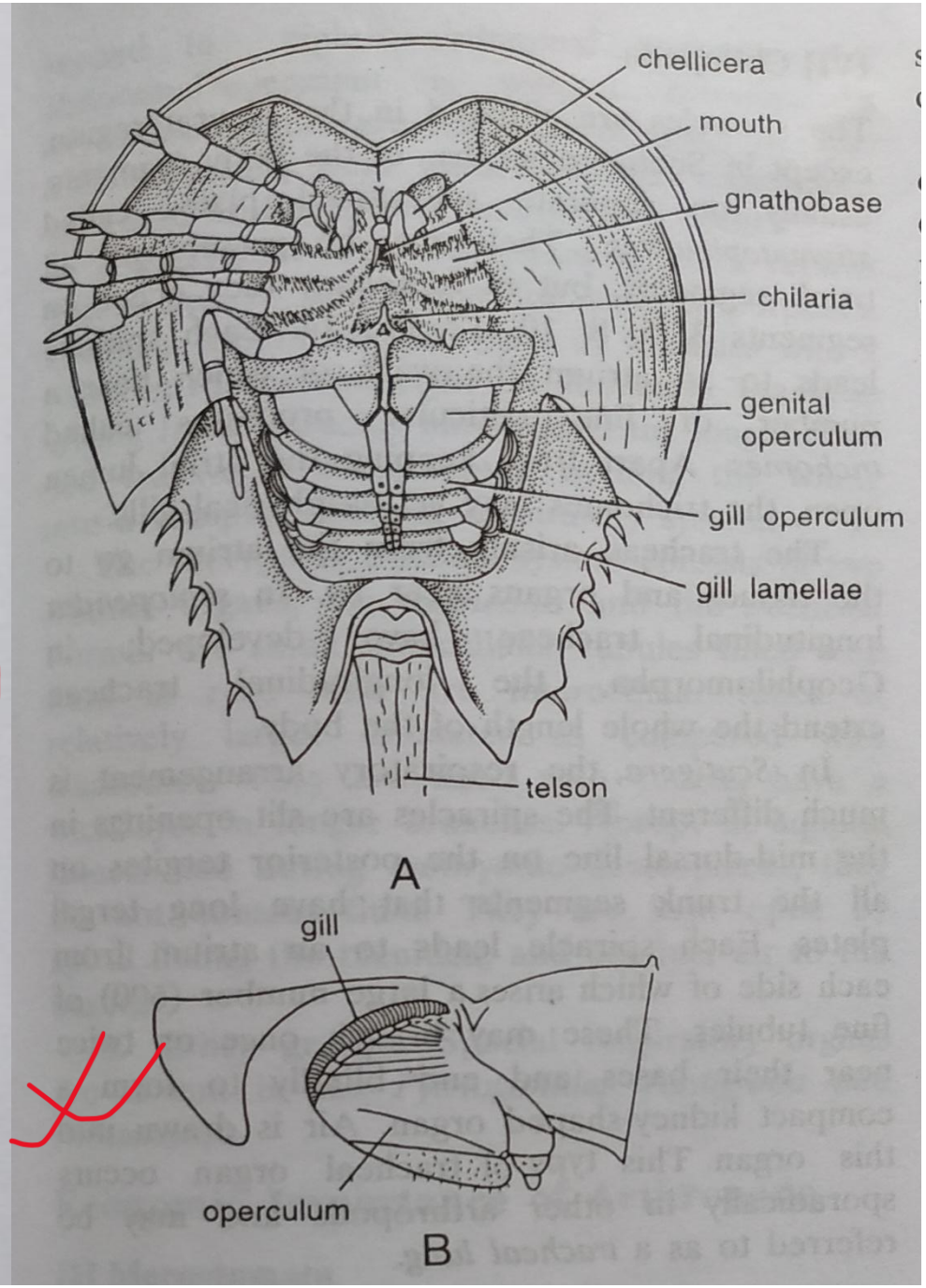
There are arthropods which lack specialized respiratory structures and the diffusion of gases in such cases, across their body surfaces become adequate for their requirements.

Different types of respiratory organs found in different groups of Arthropoda are as follows :

Chelicerata

1. Merostomata. In xiphosuran, *Limulus,* the respiratory organs are *book-gills* which occur on the posterior wall of the plate like appendages of five posterior segments of mesosoma. They become modified as gills. On each appendage are found, some 1,500 thin-walled lamellae formed by folding of posterior integument. The lamellae project from the surface and since they lie parallel to each other resembling the pages of a book, they are characteristically known as *book-gills*. The beating of the appendages causes a current of water to pass over the book gills. The coxa of the last pair of legs bears a short spatulate flabellum which cleans the gills and also serves to sense the oxygen content of the water current. The respiratory pigment is haemocyanin.

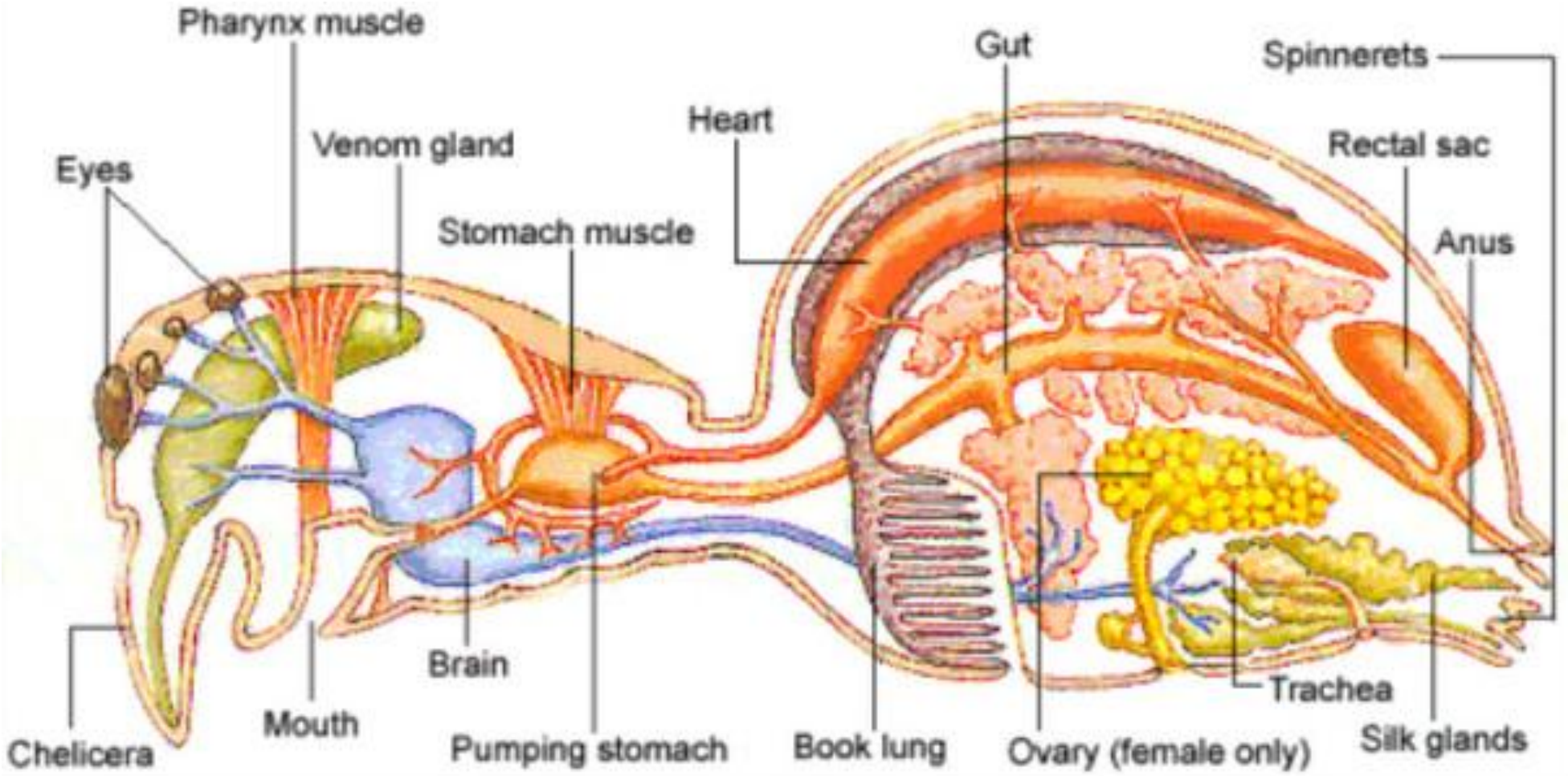
In eurypteridan genus *Slimonia,* the gills are not borne on the genital operculum or mesosomal plates, but are represented by a highly vascularised area on the ventral body wall (Moore, 1941).

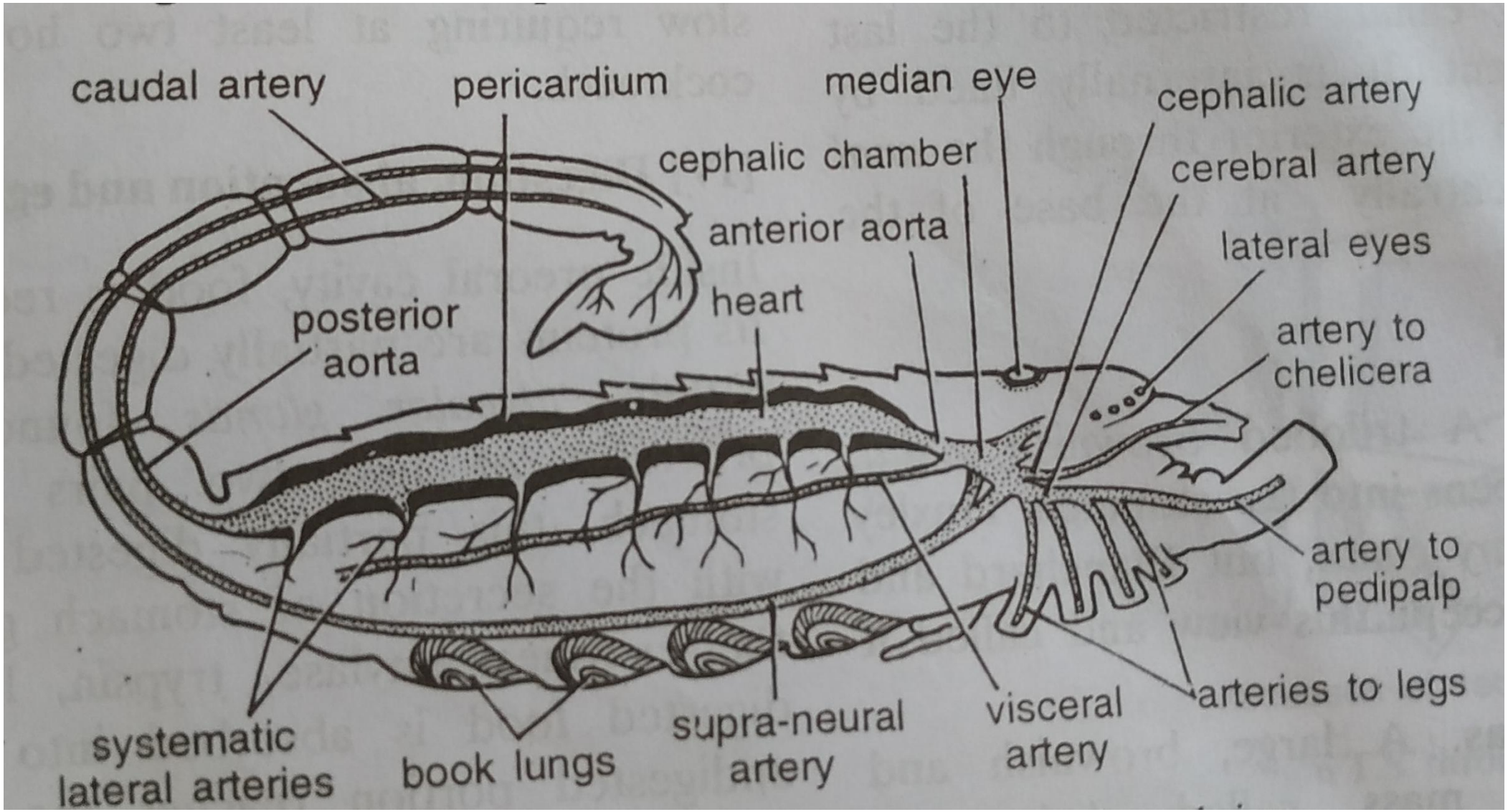


2. Arachnida. Organs of respiration are either book-lungs or tracheae or both. *Book-lungs* are modified book-gills due to migration of arachnids to a terrestrial environment. Unlike book gills the book-lungs are internal. There are four pairs of book-lungs each pair being located inside each mesosomatic segments from 3 to 6.

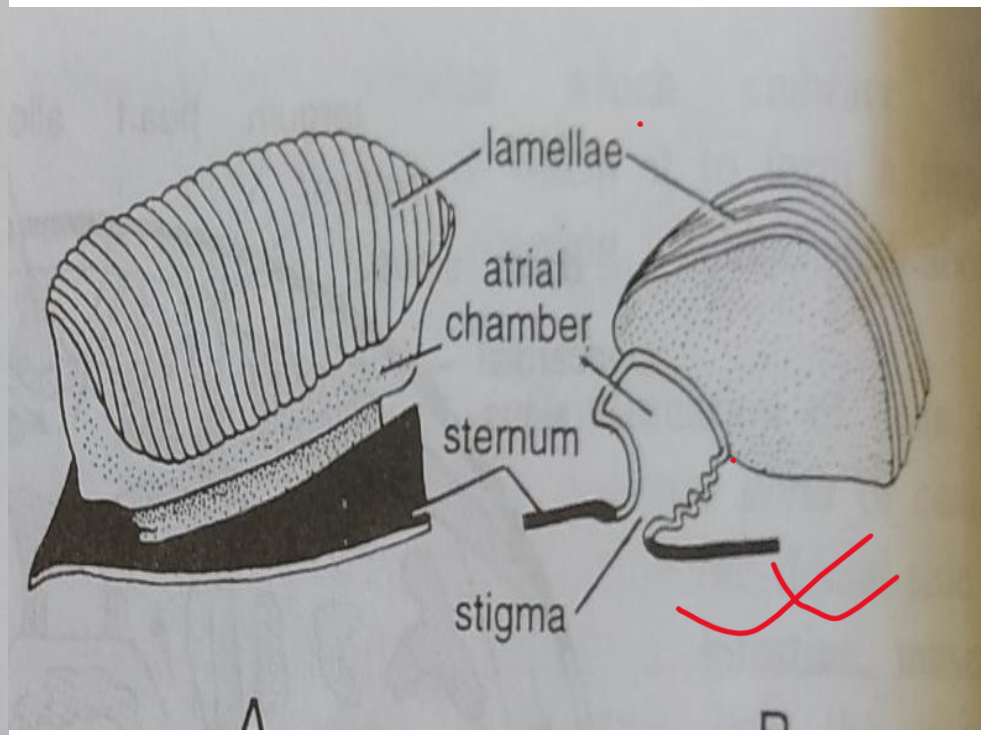
In Amblypygida and Uropygida book-lungs are found on the third and fourth segments of the opisthosoma (mesosoma). In Araneae book-lungs occur on 3rd and 4th segments also in the listomorph and mygalomorph spiders. *Tracheae* also forms the respiratory organ of some arachnids. It is very much like the tracheae of insects except their independent evolution. In some cases the tracheal system seems to be derived from book-lungs. This type of tracheal system is found in spiders. In two small groups of spiders book-lungs are replaced by tracheae.

In Araneae the spiracles lead to a small atrial cavity from which four primary tracheal tubes extend anteriorly. The spiracles may migrate posteriorly and fuse across the mid-ventral line to form simple opening lying just infront of the spinnerets.


Pharynx muscle
Gut
Spinnerets
Heart
Venom gland
Rectal sac
Eyes
Stomach muscle
Anus
Brain
Trachea
Mouth
Chelicera
Pumping stomach
Book lung
Ovary (female only)
Silk glands

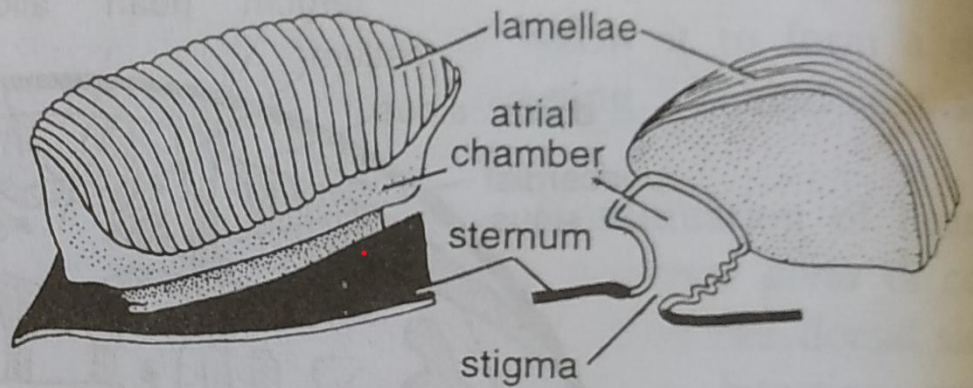

caudal artery
pericardium
median eye
cephalic artery
cephalic chamber
cerebral artery
anterior aorta
lateral eyes
heart
posterior aorta
artery to chelicera
artery to pedipalp
arteries to legs
visceral artery
supra-neural artery
book lungs
systematic lateral arteries

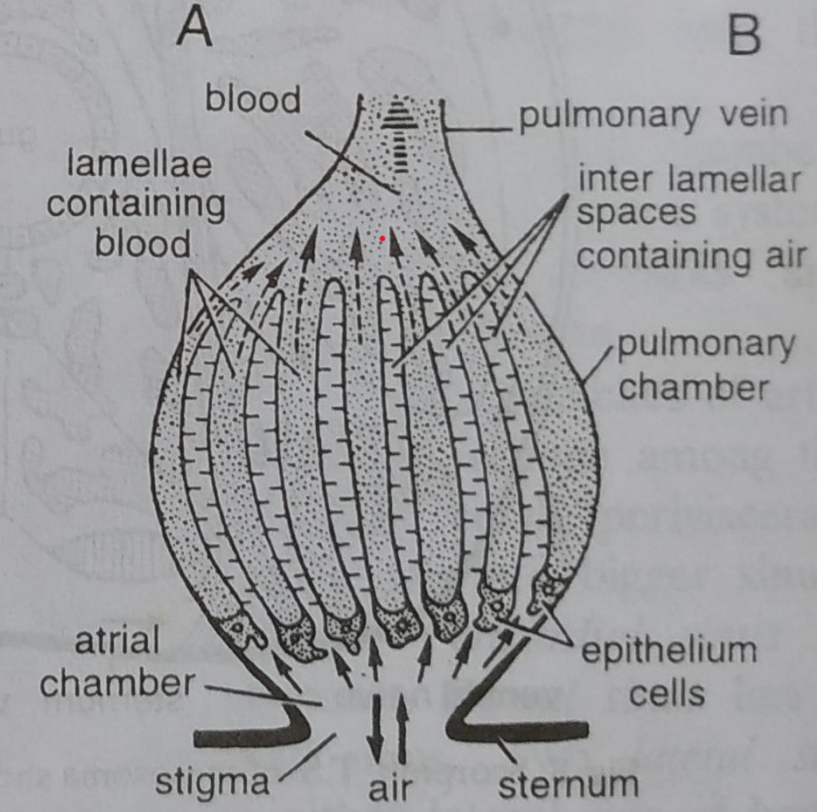
1. Structure of book lungs. Respiratory system consists of 4 pairs of cuticular *pulmonary sacs* or *book-lungs*. One pair of them lies inside each mesosomatic segment from 3rd to 6th. Book lungs are formed by invaginations of cuticle at the bases of rudimentary appendages. They are peculiar to the terrestrial arachnides. Each book-lung consists of two parts. Proximal or ventral part is in the form of a small compressed air cavity, called *atrial chamber*. It communicates with the outer air by a slit-like opening, the *spiracle* or *stigma*, placed obliquely on the ventro-lateral side of sternum. Dorsal part is made of nearly 150 vertical folds or *lamellae*, running parallel and arranged like leaves of a book. Each lamella is a hollow structure, made of two thin layers of cuticle united at their edges. A thin *air-space* is bounded in between two adjacent lamellae. Roof of atrial chamber is perforated by many linear, slit-like openings. The atrial chamber communicates with the inter lamellar air-spaces through these openings. Internal spaces of lamellae are continuous with body cavity and thus filled with blood.



3. Mechanism of respiration. Inflow and outflow of air in book-lungs seems to be controlled by the action of *dorso-ventral* and *atrial muscles*. On contraction of these muscles, book-lungs are compressed and air of inter-lamellar spaces is forced out into atrial chamber and then to exterior through *stigmata*. When the muscles relax the book-lungs resume their normal shape so that fresh air enters through stigmata, first into the artrial chamber and then into the inter-lamellar spaces.

Exchange of gases takes place between air of interlamellar spaces and venous blood through the thin membranous walls of lamellae. Blood becomes oxygenated and its CO_2 is passed out into air.





Mandibulata

[II] Crustacea

Gills are the organs of respiration in most crustaceans but in primitive crustaceans the gaseous exchange takes place over the general body surface. In many crustaceans *carapace* is present as their characteristic feature, the inner thin lining acts as gill as in Malacostraca, Myscidacea, Tanaidacea, and Decapoda. It is highly vascularised enabling the exchange of gases from the water current passing over it. Cephalocarida and Mystacocarida, the primitive crustaceans groups however either lack carapce or it is poorly developed. In Cirripedia, the *mantle* is thought to be the main site of gaseous exchange.

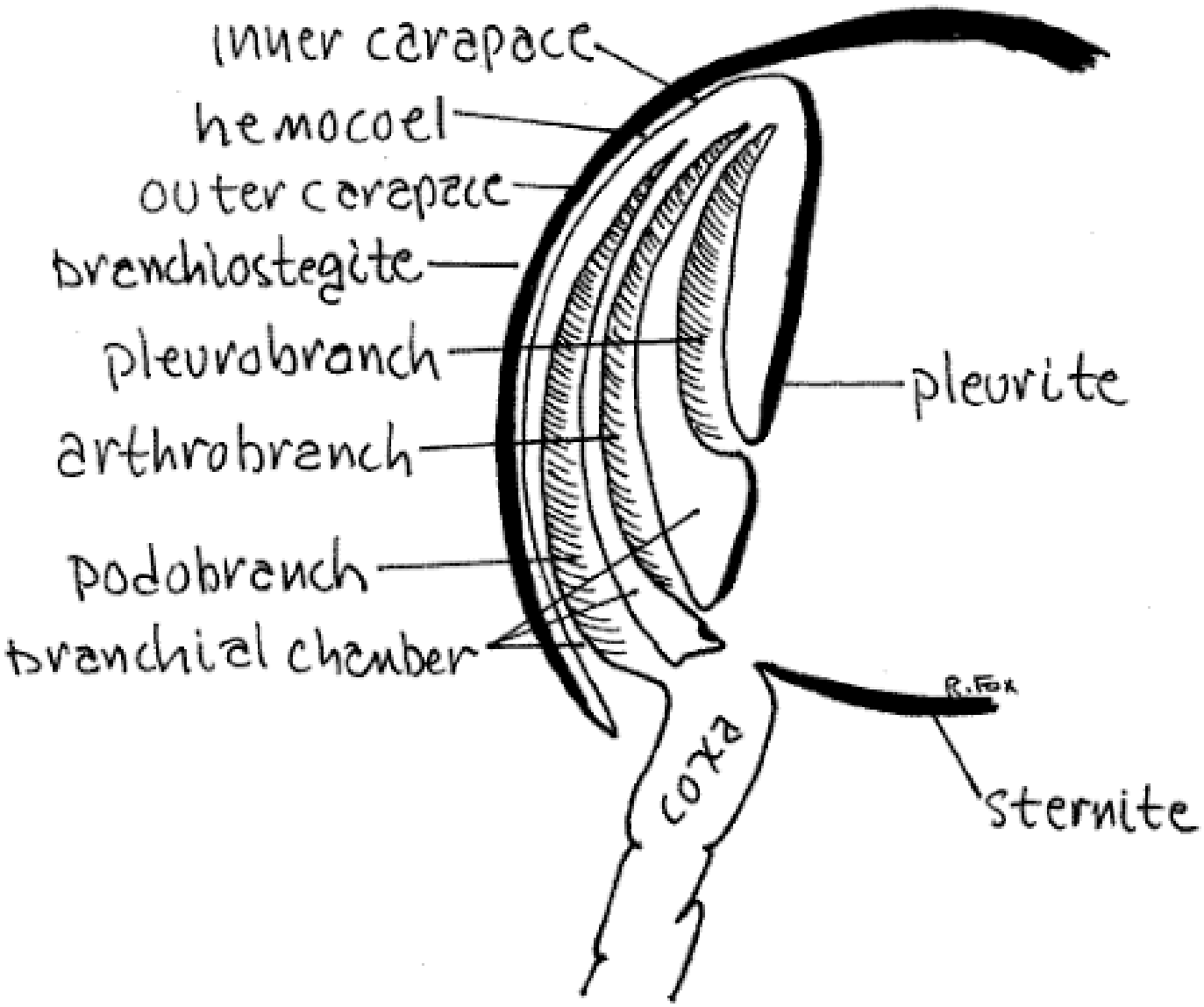
In Malacostraca *gills* are found as well defined set of respiratory organs. Primitive malacostracan *Nebalia* and anapsides. gills are *epipodites* found on thoracic limbs. In stomatopod, *squilla,* besides epipodites on thoracic limbs, large branching *gills* develop on the exopodites of the pleopods. In Cumacea the epipodites are filamentous. In Isopoda, the epipodites are lacking and the abdominal pleopods become modified for respiration. In Amphipoda simple plate like epipodites on thoracic limbs act as gills. It is in Decapoda that the fully developed gills are found. For instance in Palaemon, there are 8 gills present

Crustacea

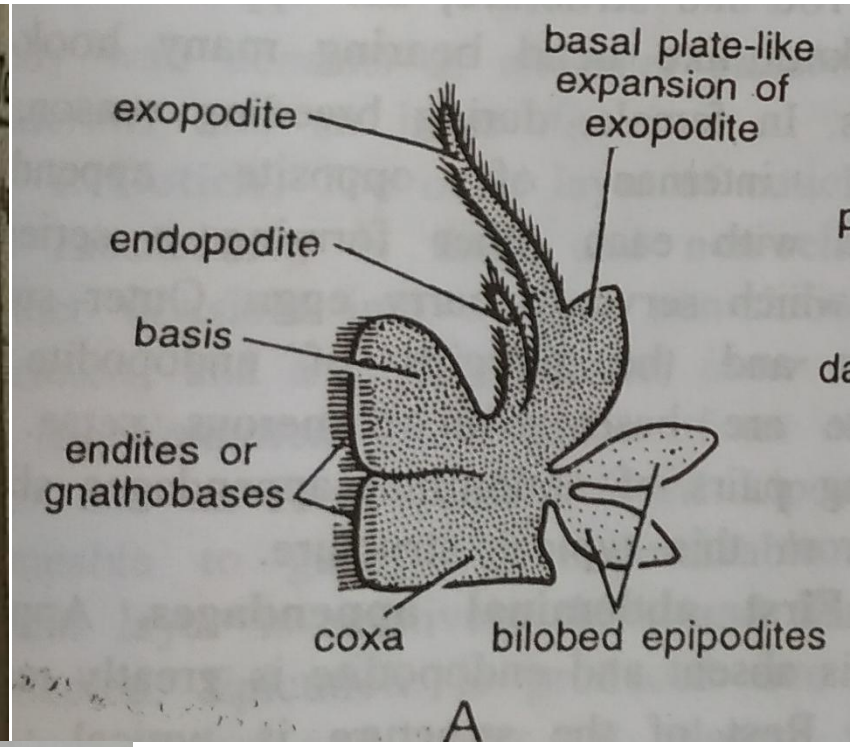
[I] Respiratory organs

Respiratory system is well developed and consists of : (i) *lining of branchiostegites* or gill covers, (ii) three pairs of *epipodites*, and (iii) eight pairs of *gills* or *branchiae*. These are sheltered in two large and compressed *gill-chambers*, one on either side of thorax. Each gill-chamber is bounded internally by *epimeron* or lateral wall of thorax, and externally by the curving pleural side of carapace or *branchiostegite*. The gill-chambers open on the anterior, ventral and posterior sides.

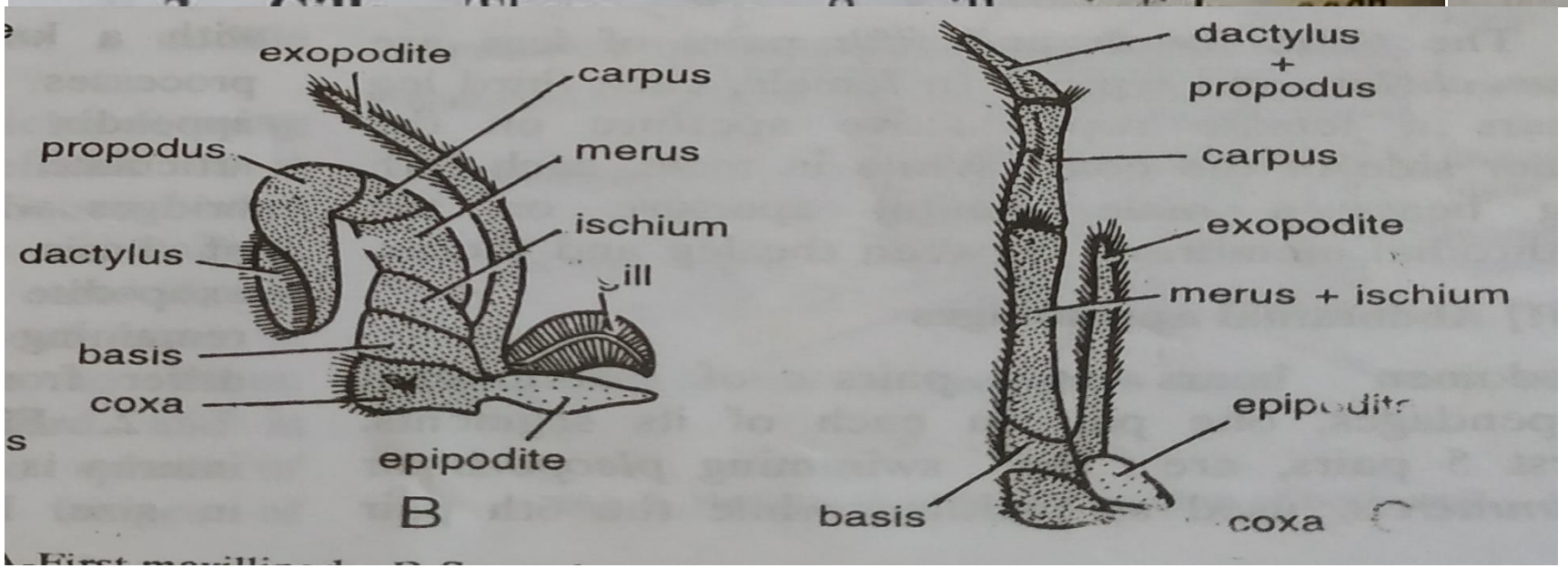
1. Lining of branchiostegites. Inner lining of branchiostegites or gill-covers is thin, membranous and highly vascular containing minute blood lacunae. These form large respiratory surfaces which absorb oxygen (O_2) dissolved in water and give out carbon dioxide (CO_2).


inner carapace
hemocoel
outer carapace
branchiostegite
pleurobranch
arthrobranch
podobranch
branchial chamber
pleurite
coxa
sternite
R. Fox

2. Epipodites. These are 3 pairs of simple, foliaceous and highly vascular outgrowths of integument, given out from the coxal segments of 3 pairs of maxillipedes. They occupy the anterior part of gill-chambers beneath the scaphognathites of maxillae. Epipodites of Ist pair are bilobed and larger than others. Epipodites also serve as respiratory organs like primitive gills.



A



B

C

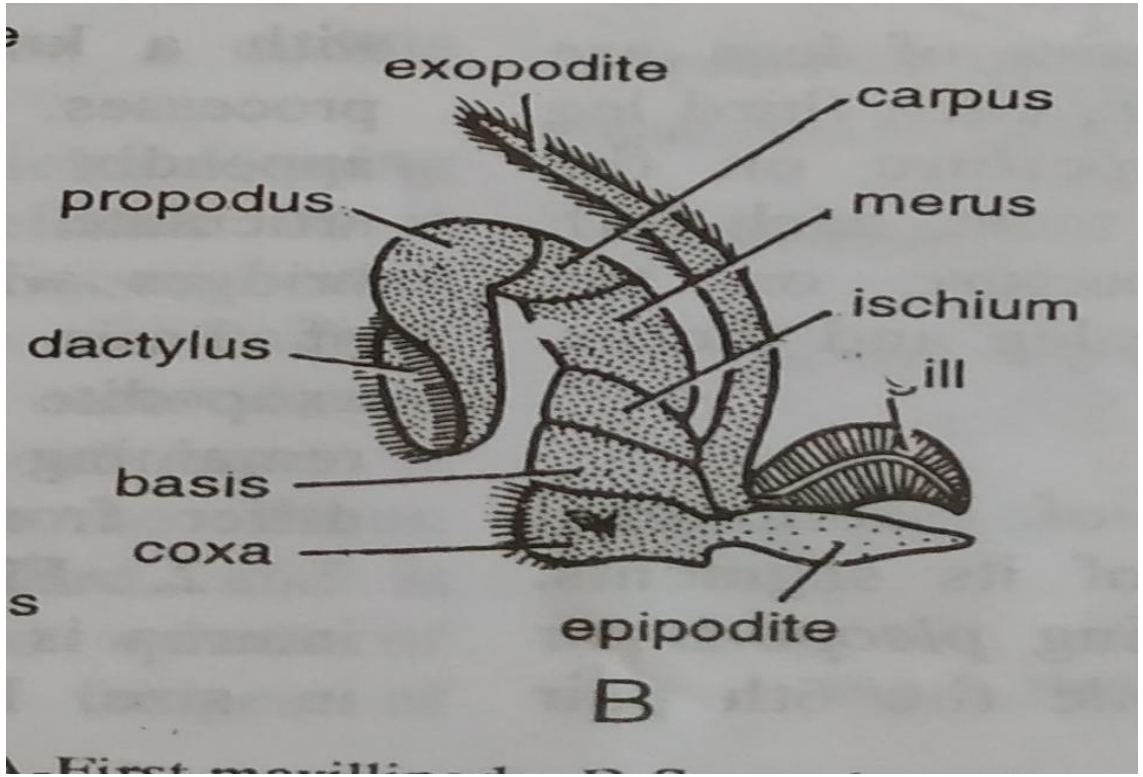
3. Gills. There are 8 gills inside each gill-chamber. Only 7 of them are exposed on removing the gill-cover as the 8th gill lies concealed beneath the dorsal part of the 2nd gill.

(a) Types of gills. Gills are of three kinds according to their place of origin and attachment.

(i) Podobranch or foot-gill. It is attached to the coxa of an appendage. In *Palaemon,* one podobranch is carried by the coxa of each second maxillipede.

(ii) Arthrobranch or joint-gill. It is attached to the arthrodial membrane joining a limb with the body. Each third maxillipede bears two arthrobranchs. Second arthrobranch is the smallest and remains concealed beneath the first arthrobranch.

(iii) Pleurobranch or side gill. It is attached to the lateral wall of segment bearing the limb. Last 5 gills on each side are pleurobranchs, attached to the lateral wall of thoracic segments bearing the 5 walking legs.



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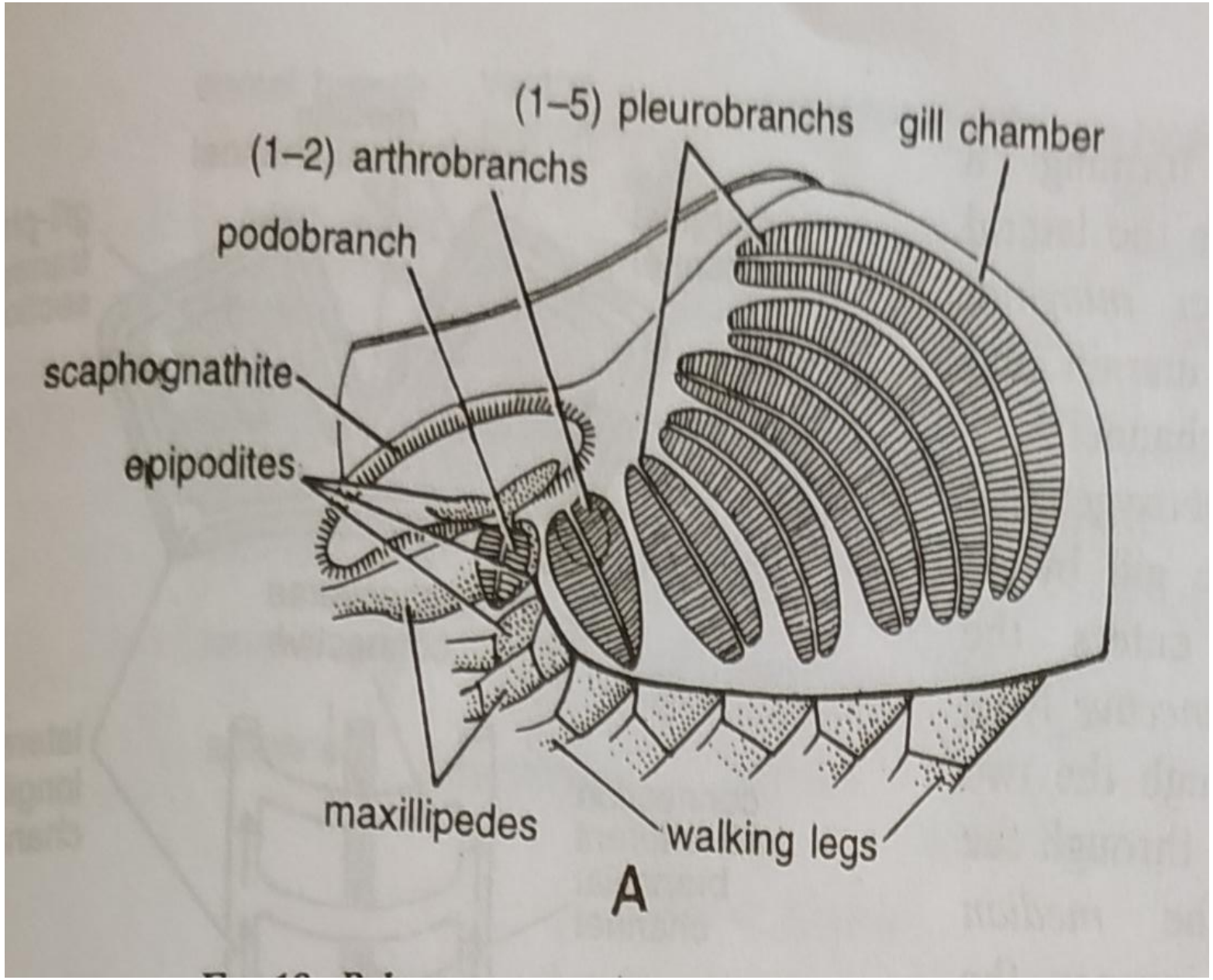
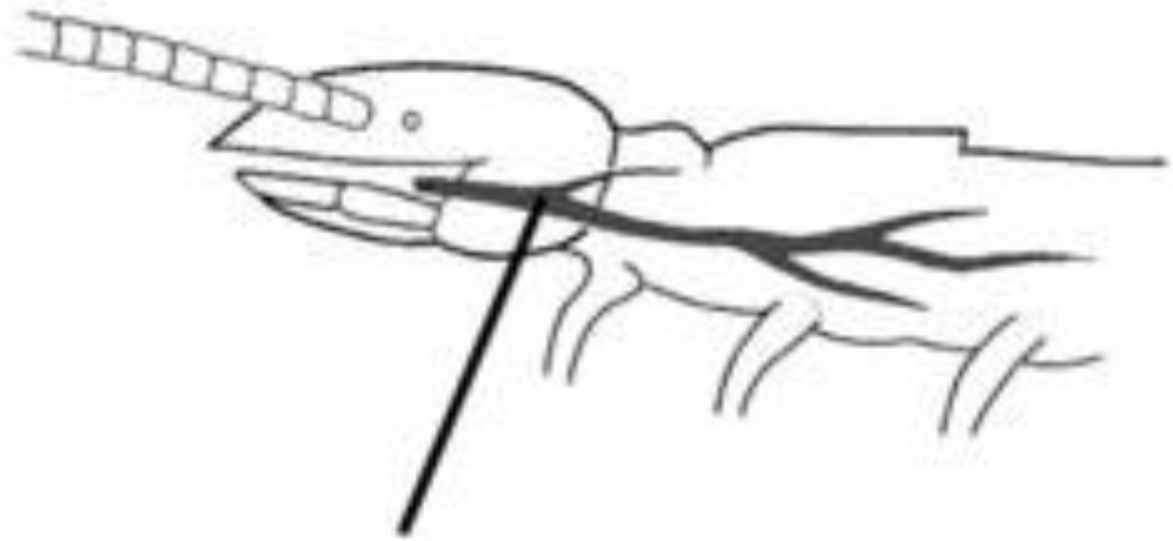

(1–5) pleurobranchs
gill chamber
(1–2) arthrobranchs
podobranch
scaphognathite
epipodites
maxillipedes
walking legs
A

[III] Pauropoda

Majority of pauropods lack special respiratory organs. A few have a very short tracheae, the spiracles are situated on the coxae of the walking legs.

[IV] Symphyla

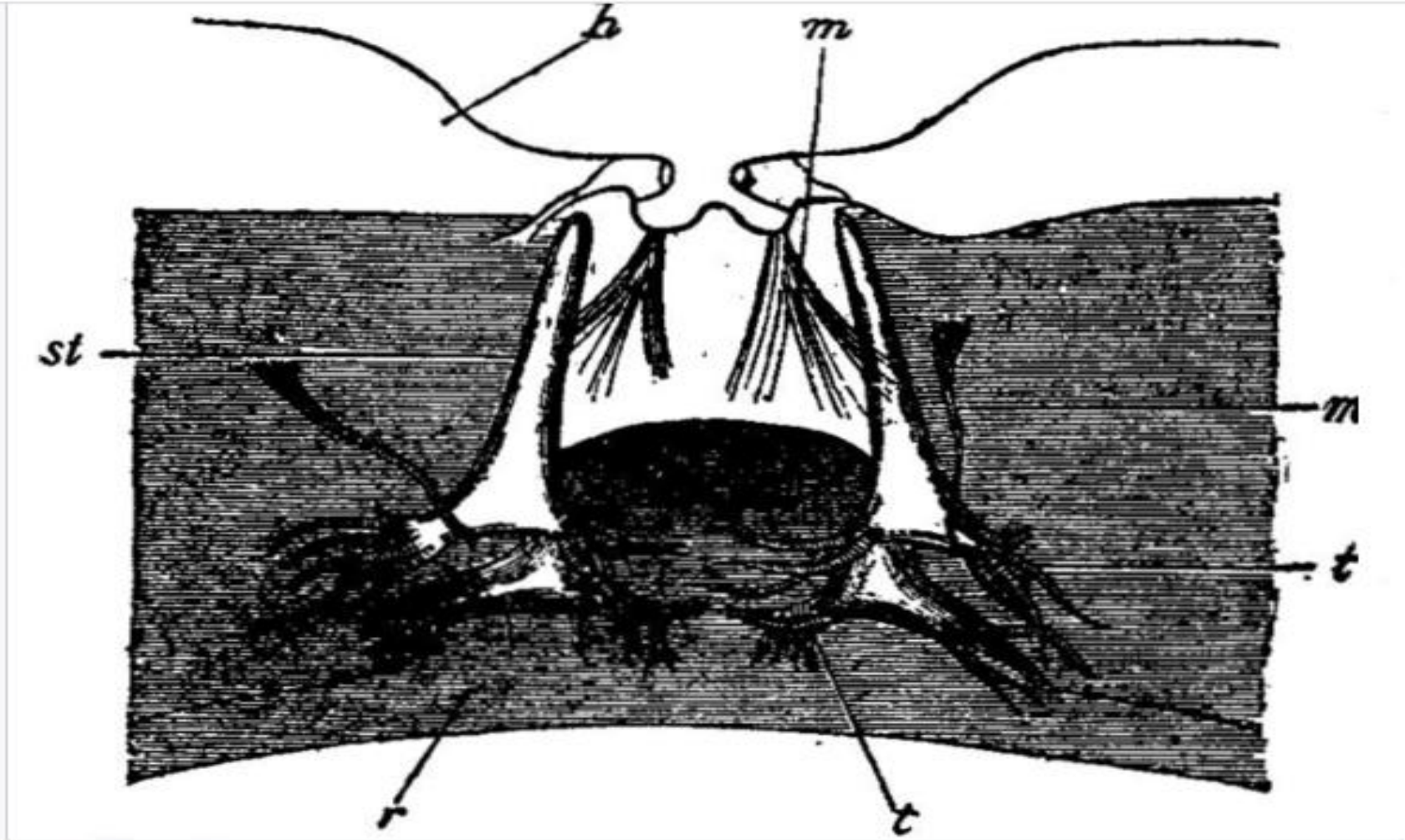
There is only a single pair of spiracle situated on the head just above the base of the mandibles. A few branches of tracheae from head pass to the anterior trunk segments.



(B)

[V] Diplopoda

Each trunk segment has a pair of spiracles and two pairs per diplo-segment. They are situated on sternites anterior and lateral to each pair of walking legs. They open to an atrial cavity which



After Voges.

FIG. 3.—Inner view of ventral area of a single segment of *Julus*, much enlarged to show the structure and arrangement of the tracheal organs. The two pairs of tracheae are seen *in situ*, the posterior pair overlapping the anterior.

h, Posterior margin of the body-ring (tergum).
r, Anterior border
st, Tubular chamber of tracheae
t, Fine tracheae given off from it.
ms, Respiratory muscle attached to tracheal sac.
m, Ventral body muscle

[VII] Insecta

1. Apterygota. Tracheal system constitutes the main organs of respiration found in various degrees of development in different orders.

In *Protura* no tracheae occur in Acerentomidae (*Acerentulus*) but they are present in Eosentomidae. In *Eosentomon* two pairs of spiracles are present, one pair each on mesothorax and metathorax. Tracheae arising from each do not interconnect. Abdominal spiracles are absent.

In *Collembola*, no tracheae are indicated in majority of them. Cuticle forms the respiratory source. Tracheae are found only in the species of the family Sminthuridae where there is only a single pair of spiracle situated between head and thorax.

In *Thysanura*, nine pairs of spiracles in the Machilidae of which one pair is on mesothorax, one pair on metathorax and seven pairs on the second to eighth abdominal segments. 1st abdominal segment is without spiracle. In Lepismidae, there are ten pairs of spiracles. The tracheae arising from spiracle do not anastomose but those in Lepismidae anastomoses occurs.

but those

2. Pterygota. Tracheal system varies in various orders due to adaptation for various purposes. Primitive orders have 10 pairs of spiracles with 2 pairs on thorax and eight on abdomen. Tracheae arising from spiracles have numerous longitudinal and transverse anastomoses welding the whole into a complex efficient respiratory system.

The pterygotes tracheal system consists of two distinct organs, the *tracheoles* and the *tracheae*. Former are small intracellular tubules filled with fluid at rest, later are intercellular tubes of relatively larger diameter as compared with tracheoles. They are lined with cuticle, have a wax layer in longer branches. Accept in aquatic insects and during embryonic development, they do not contain fluid. They are kept open by spiral lining, the taenidea, and conduct air to the tissues.

Special respiratory organs

1. Respiratory organs. Respiratory system of cockroach is well-developed to compensate the poorly developed circulatory system. It consists, as in other insects, of *tracheae, tracheoles* and *spiracles*.

(a) Tracheae. Haemocoel contains a network of elastic, closed and branching air tubes or *tracheae*. There are three pairs of large, parallel, longitudinal *tracheal trunks*, one dorsal, one ventral and one lateral in position, which are connected together by transverse commissures. Tracheae are formed as invaginations of outer integument, hence they are made of an outer epithelial wall lined by an inner chitinous cuticle. The cuticular lining is spirally thickened forming *intima* or *taenidia* which prevents the tracheal tubes from collapsing. When cockroach is dissected under water, the tracheae, filled with air, presents a glistening appearance.

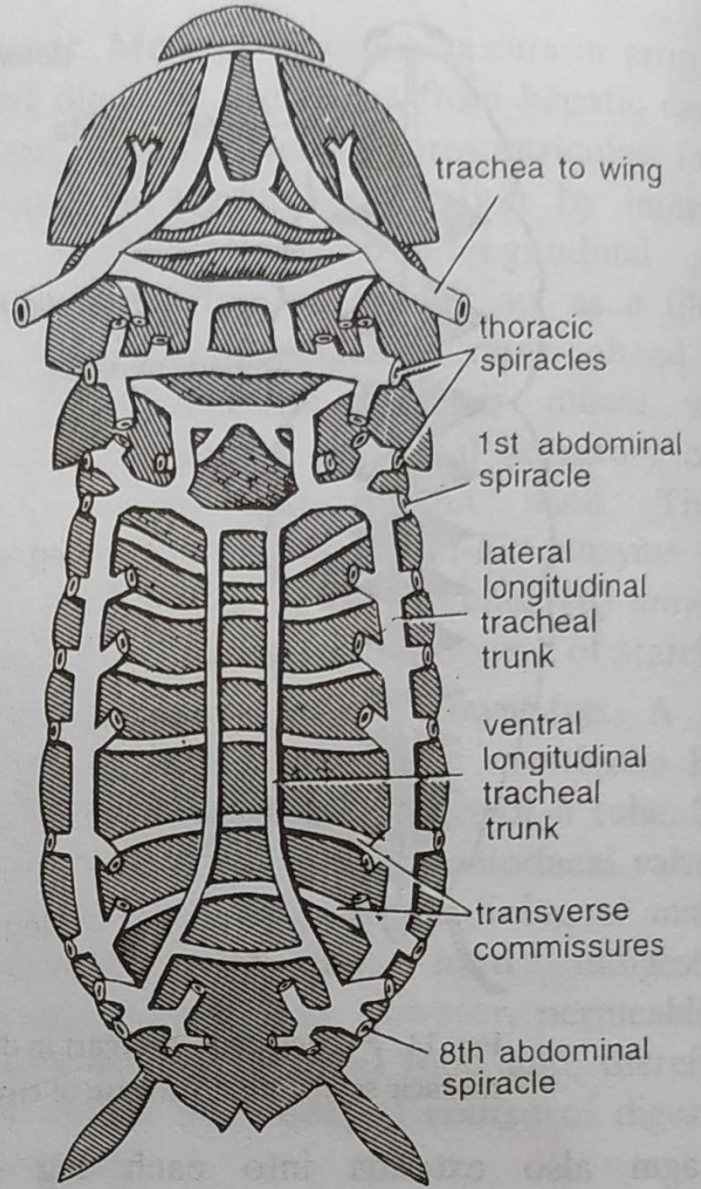
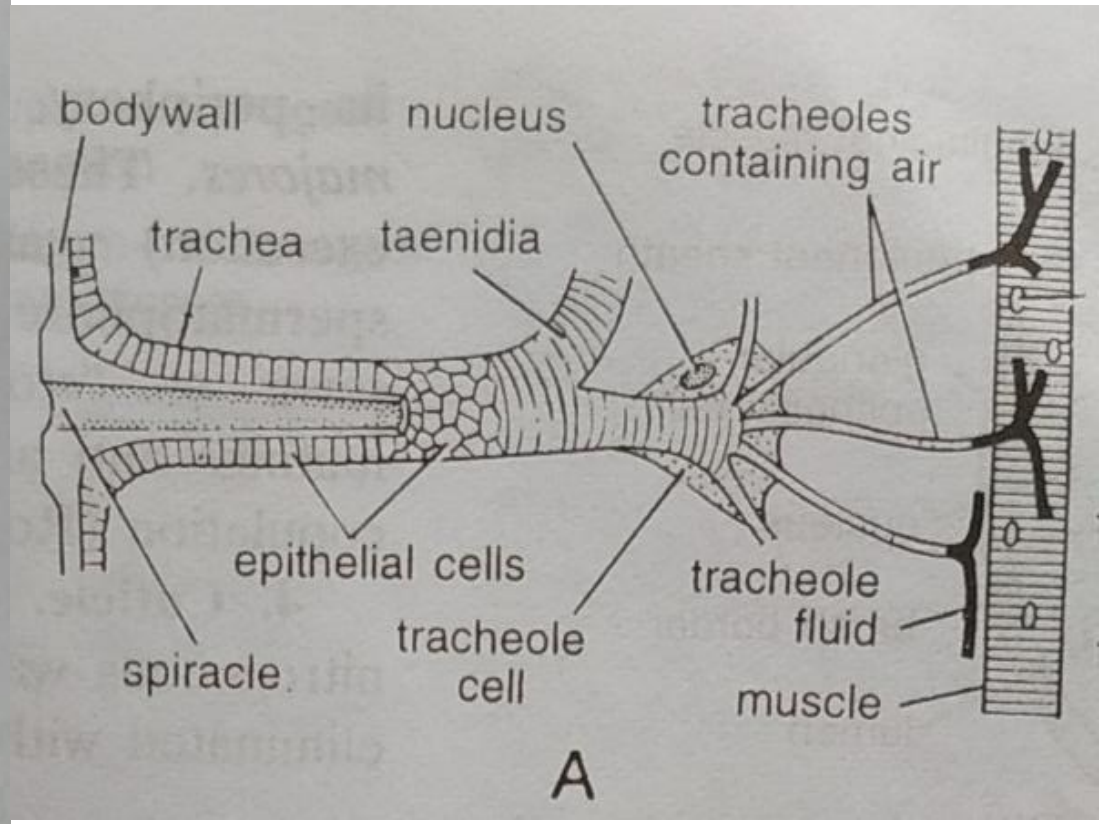


Fig. 15. *P. americana*. Tracheal system in dorsal view.

(b) Tracheoles. The profusely branching trachae anastomose and penetrate to all parts of body. The ultimate finer branches of tracheae are called *tracheoles* which come in contact with the individual body cells. They have a diameter of only 1 micron. Their cavities are intracellular, that is, each tracheole is made of a single cell. Their walls are very thin and devoid of cuticular spiral thickening, instead they are lined by a protein called *trachein*. They are permeable to water. Their tips are usually filled with a fluid in which oxygen dissolves and diffuses to the tissues. However, some zoologists think that tracheoles end blindly and remain without fluid. Thus, the elaborate tracheal system carries oxygen directly to all the body cells. This very well compensates for the inability of blood to transport oxygen due to absence of a respiratory pigment.



A

(c) ***Spiracles.*** The main tracheal trunks open to the exterior on body surface through 10 pairs of segmentally arranged apertures termed *spiracles* or *stigmata*. Two pairs of spiracles are thoracic, one between pro- and mesothorax and the other between meso- and metathorax. Eight pairs of spiracles are abdominal, one pair in each of the first eight abdominal segments. They are present laterally in the soft cuticle between terga and sterna. A spiracle is guarded by bristles or hair to keep out dirt. It is surrounded by an annular sclerite, the *peritreme*. It has a closing device in the form of a simple *valve* which prevents undue loss of water and can be closed or opened to regulate the flow of air. Each spiracle internally leads into a short tracheal chamber or *atrium* from which arises a main tracheal trunk.

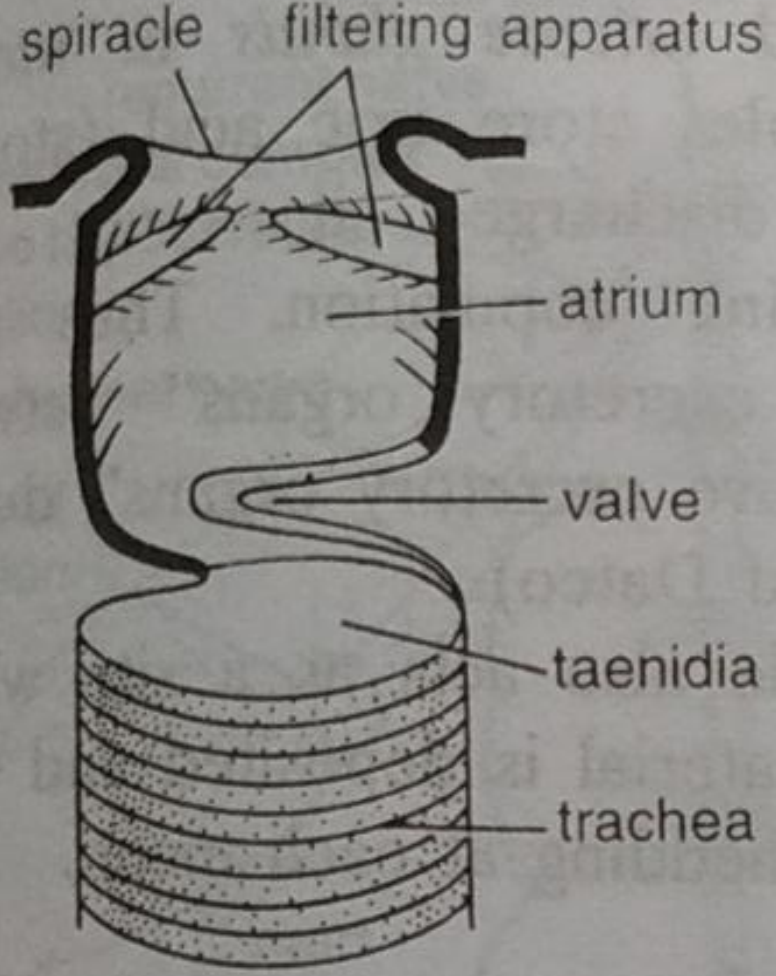


Fig. 16. A spiracle with atrium, filtering apparatus and valve.

4. Air sacs. In grasshopper and certain other insects (Honey bee), some of the tracheae become expanded into large thin-walled *air sacs*, which serve for storage and better circulation of air. Air sacs are devoid of taenidia.

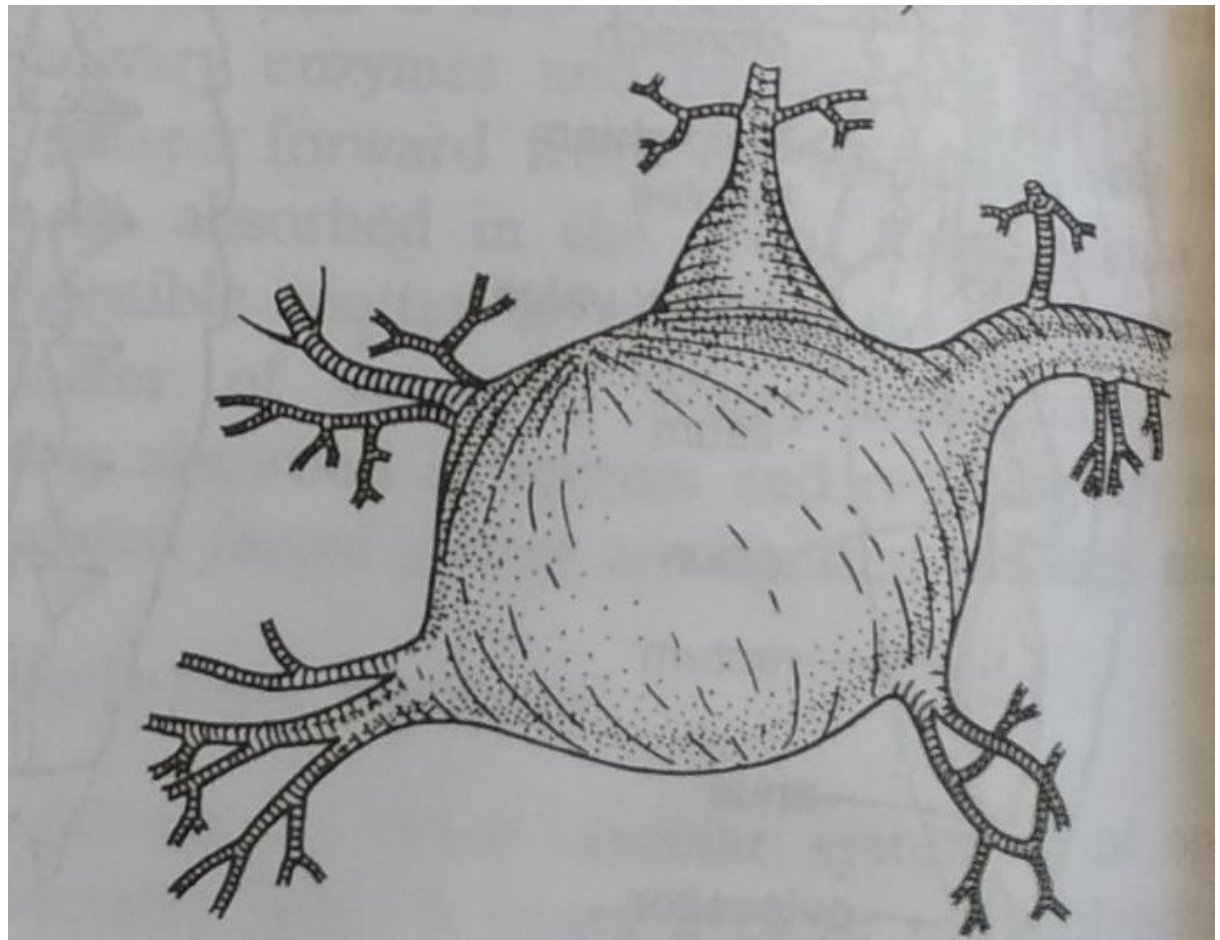
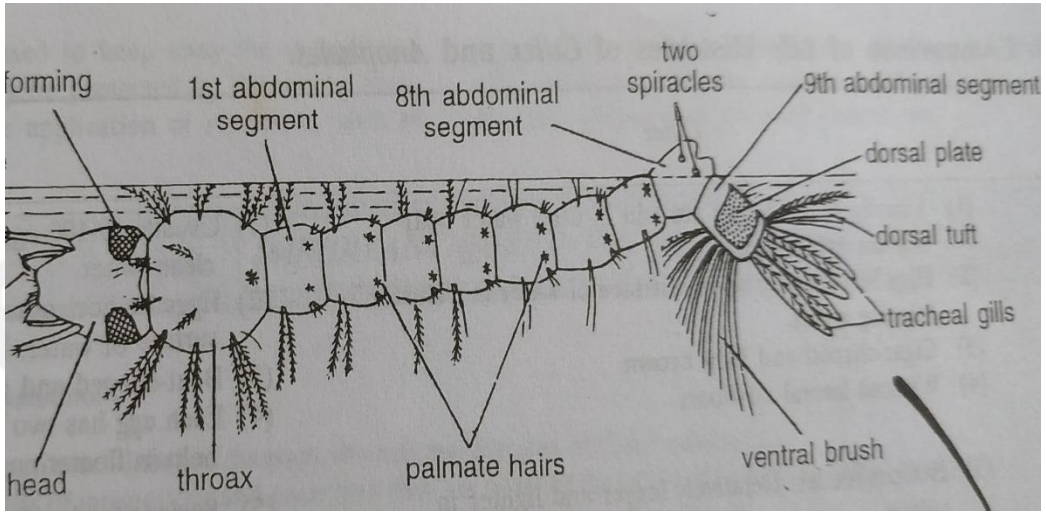
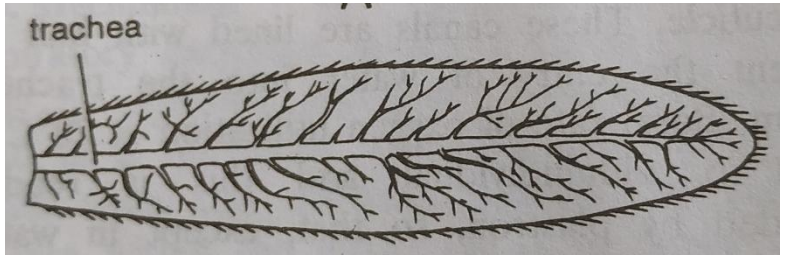


Fig. 10. An air sac.

3. Rectal gills: The rectal gills are located in the inner surface of rectum. They are a form of soft lamellae. Water is drawn in and expelled out via for respiration. Rectal gills occur in the naiads of dragonfly.

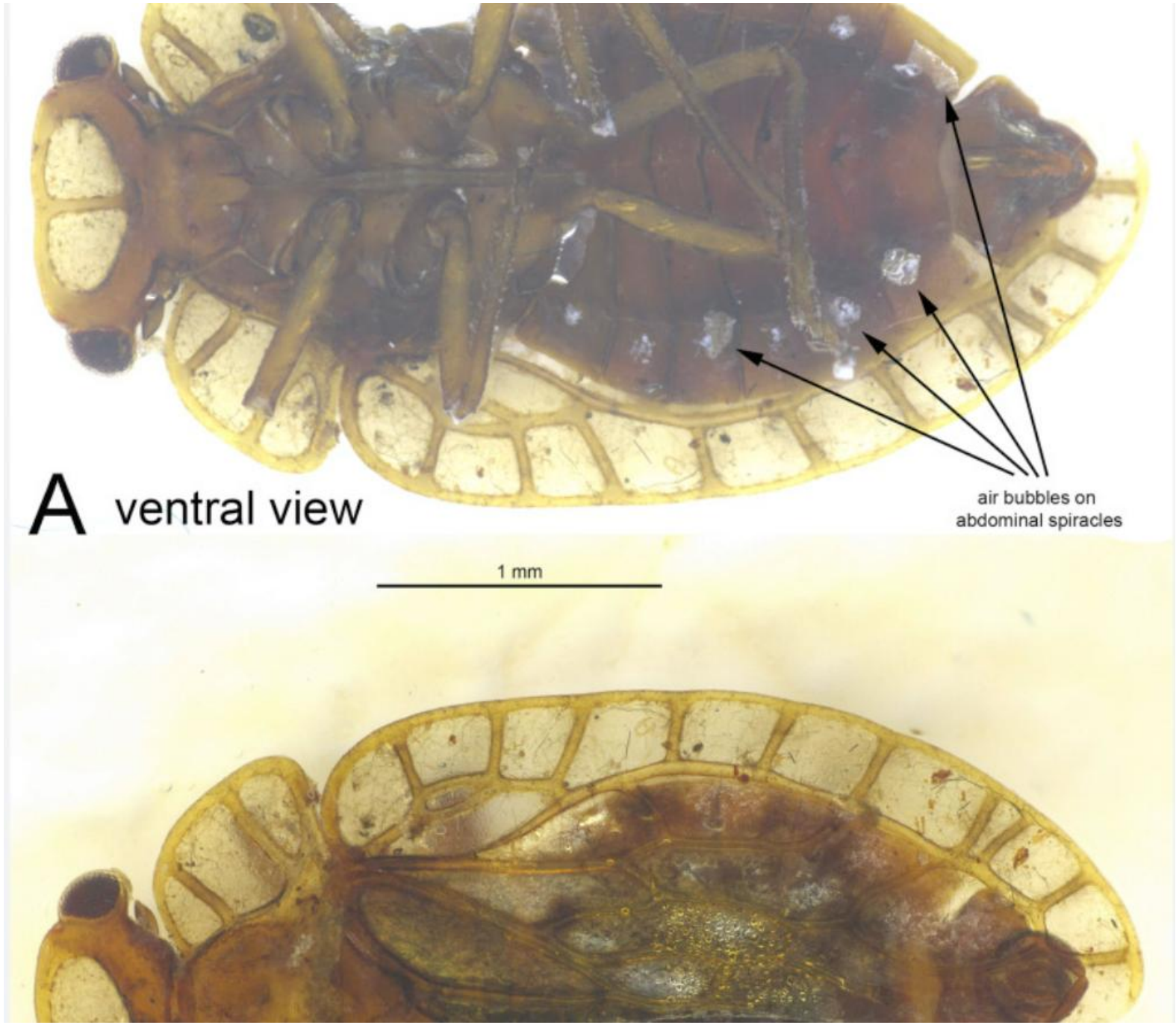


5. Tracheal gills: These are the outgrowths of the body wall. They are finger-shaped or leaf-shaped. They contain a system of tracheae. The naiads of mayfly contain 7 pairs of leaf-like tracheal gills on the sides of abdomen. The naiad of damselfly has three leaf like tracheal gills attached to the posterior end of the abdomen. Mosquito larvae possess 2 pairs of tracheal gill at last abdominal segment.



for considerable distance.

6. Plastron respiration. Some insects have specialized structures which hold a permanent thin films of air on the outside of the body in such a way that an extensive air water interface is present for gaseous exchange. Such a film of gas is called *plastron* (Thorpe, 1950). The tracheae opens into the plastron so that oxygen can pass directly to the tissue. The volume of


A ventral view
air bubbles on
abdominal spiracles
1 mm

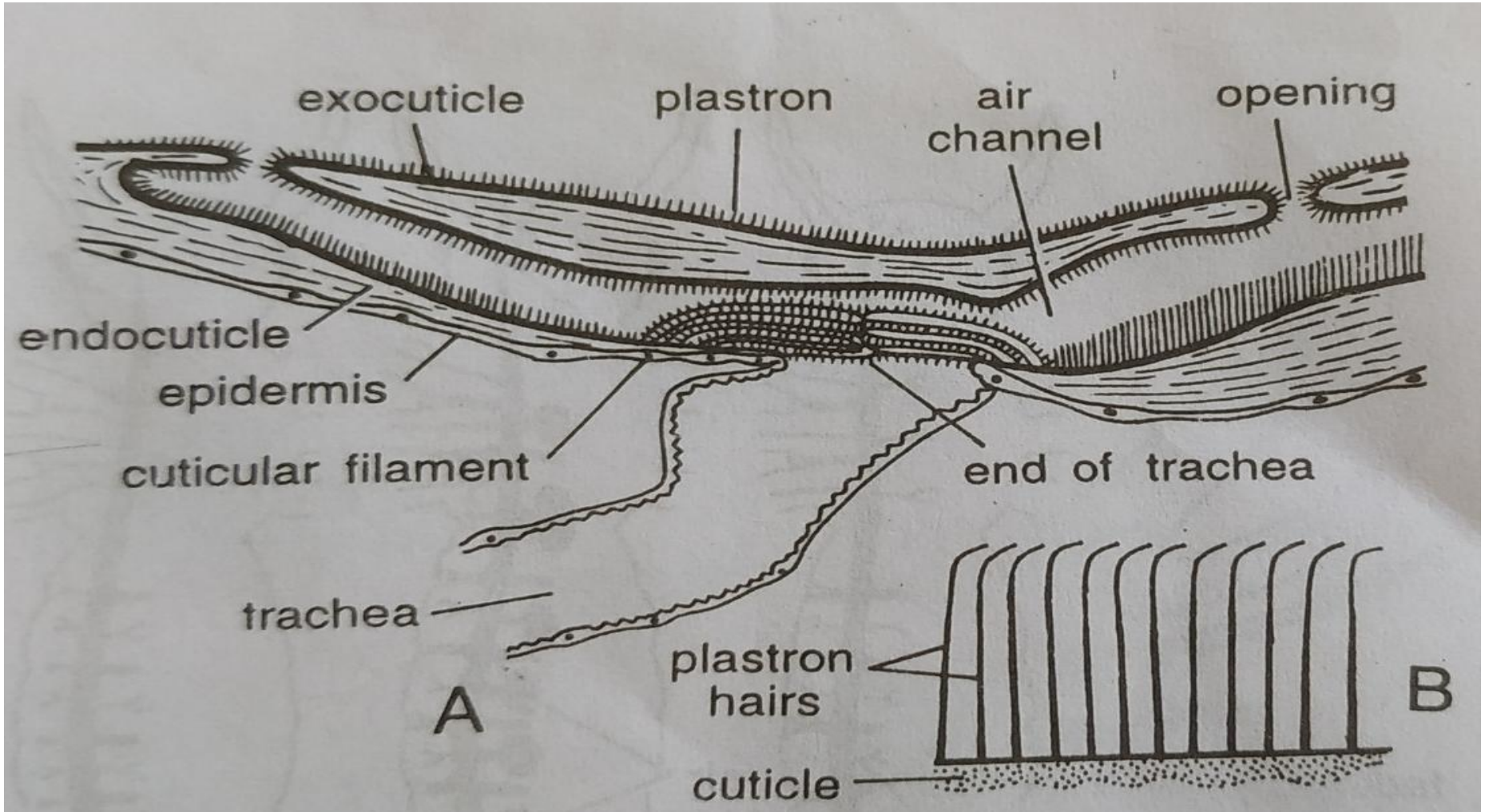


Fig. 14. *Aphelocheirus.* **A** — Junction of trachea with system of channels in the cuticle. **B** — Part of plastron magnified to show hairs.

Reference:

- Modern Textbook of Zoology, INVERTEBRATE, RL Kotpal
- Internet