Respiration in Arthropoda

- Arthropoda is the largest phylum of the animal kingdom which comprises 75-80% of animals.
- They live in diverse kinds of habitats and have, thus, developed a variety of structures and organs for breathing.
- Some of these organs include book gills, book lungs and tracheal organs.
- In fact, a few arthropods species have very soft skin and they can exchange gases with the external environment through skin.

Book Gills-Organs of Respiration in Aquatic Arthropods

- characteristic respiratory organs of aquatic arthropods, especially crustaceans; though these can also be observed in some arachnids, such as *Limulus*.

These are present at different places of the body, based on which they can be of various kinds.

(a) Podobranchs: These are also called foot gills as they are attached to the coxa of an appendage.

(b) Arthrobranchs: These gills are attached to the arthrodial membrane which joins the leg to the body of a crustacean. These are also called joint gills.

(c) Pleurobranchs: The side gills attached to the pleural membrane of the body segment bearing the limb are termed as pleurobranchs.

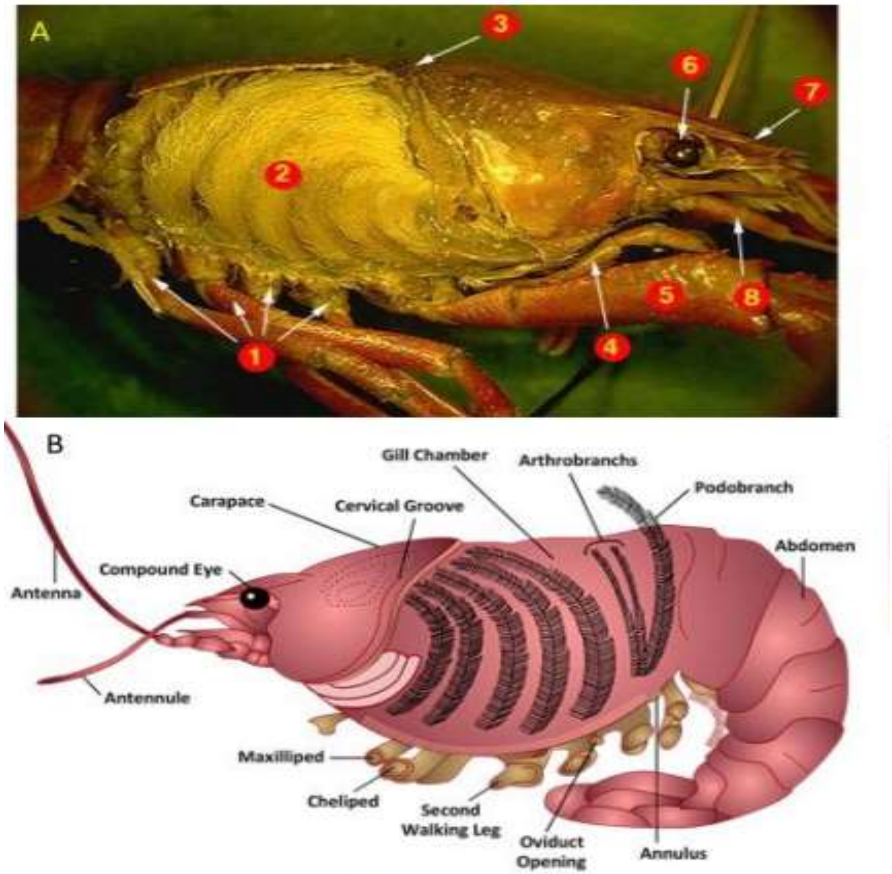


Fig. 1: Different Kinds of gills in a crayfish based on their location
A. 1. Walking legs, 2. Gills 3. Carapace 4. Cheliped 5. Maxilliped 6. Compound eye 7. Antennule 8. Antenna

Structure of a book gill

The book gills are often flap-like or crescentic in shape. They are called so because they resemble a book. Each gill is made up of a number of thin structures, called gill lamellae or gill plates. These are arranged like the leaves/pages of a book at right angle to the gill base which is also called gill axis. The gill lamellae of a book gill are of diverse shapes. Based on their structure, the book gills in arthropods are of three types:

(a) Phyllobranch: The gill lamellae are leaf-like, for example in *Palaemon*.

(b) Trichobranch: These gills have hair-like lamellae, e.g. in *Astacus*

(c) Dendrobranch: These are the gills with lamellae divided into arborescent bundles.

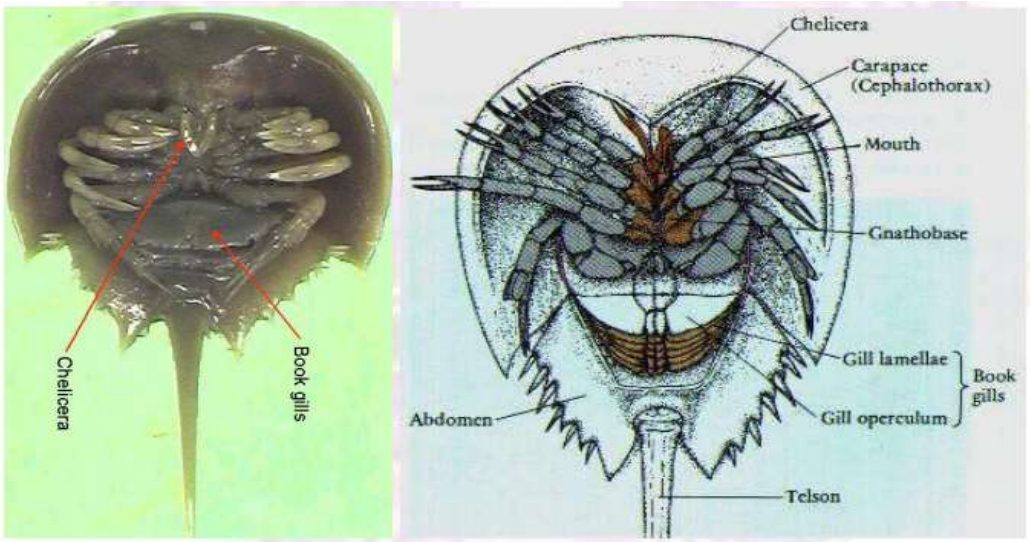
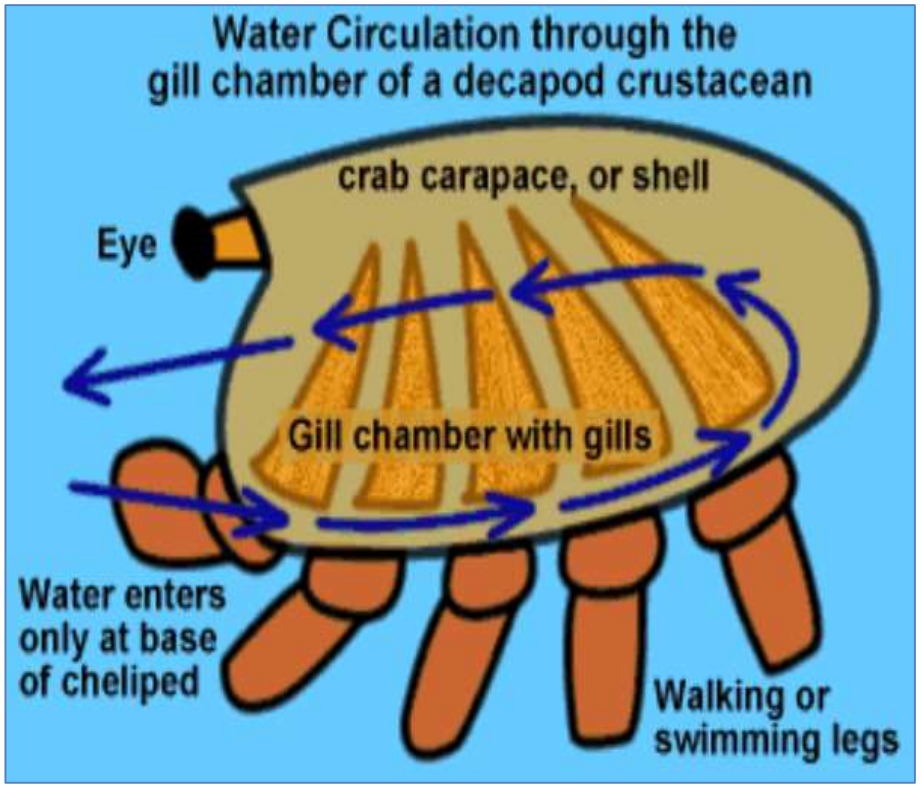


Fig. 2: Location of book gills in horseshoe crab

Mechanism of respiration through book gills

Book gills, like fish gills are bathed in water and supplied with blood vessels. The exchange of respiratory gases takes place between water and blood flowing through the gill lamellae.



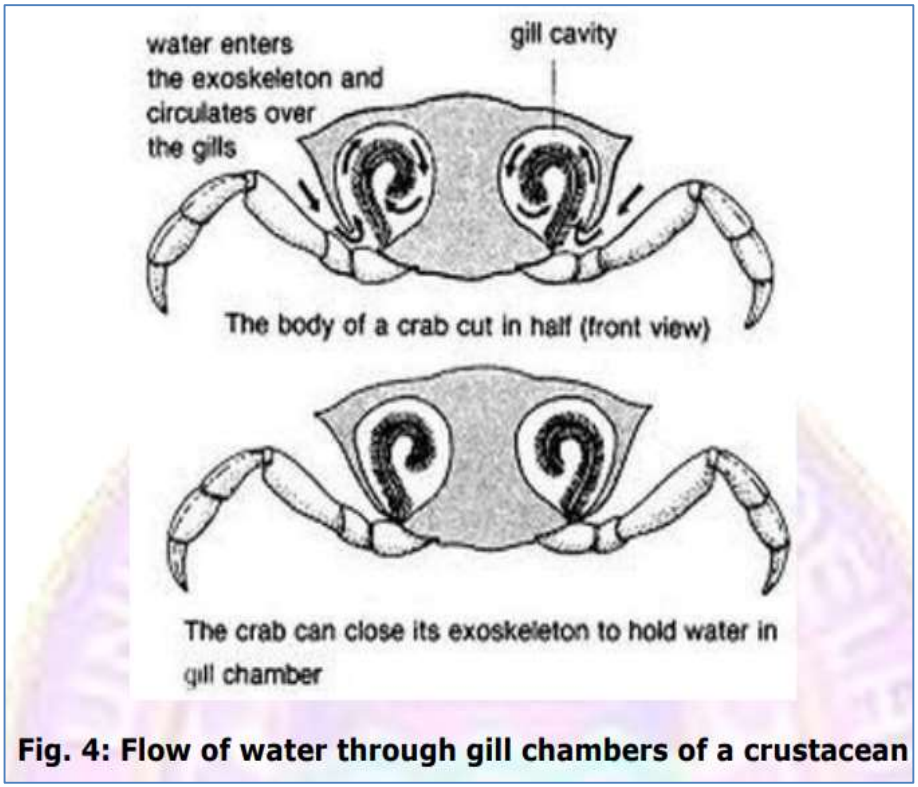


Fig. 4: Flow of water through gill chambers of a crustacean

Book Lungs-Organs of Respiration in Terrestrial Arthropods

- Book lungs are the characteristic respiratory organs of terrestrial arthropods; arachnids.
- These are always in pairs and considered to be evolved from book gills as an adaptation of terrestrial mode of life.
- Book lungs are often located in the abdominal segments of the arachnids; for example, in scorpion, there are four pairs of book lungs located in 3-6th abdominal segments.

Structure of a book lung

A book lung is consists of two parts:

(a) Dorsal Chamber

- It is also called pulmonary chamber and is formed by the invagination of ventral abdominal wall.
- It consists of approximately 150 leaf-like lamellae, each of which is lined with the cuticle.
- The lamellae lie parallel to each other like the leaves of a book.
- The thin space between two lamellae is filled with the air.

(a) Ventral Chamber

- The ventral chamber, also called atrial chamber is the non-folded part of the book lung and is filled with the air.
- On one side, it is continuous with the interlamellar spaces of pulmonary chamber and on the other side it opens to the outside through a slit-like opening, called stigma or spiracles.

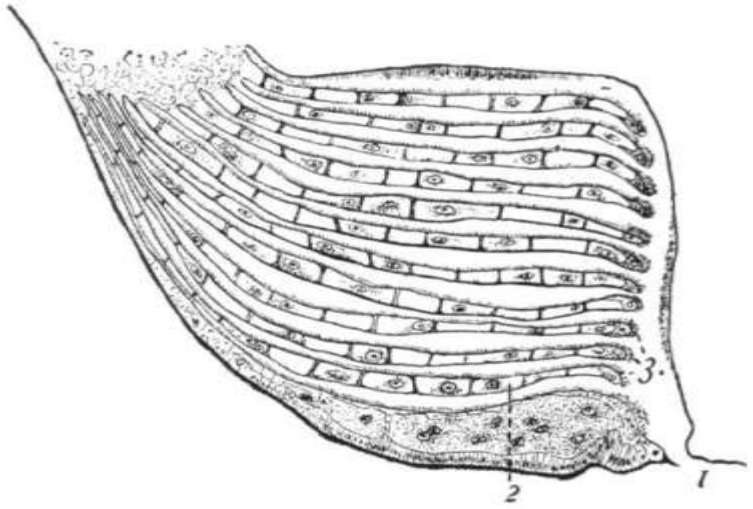
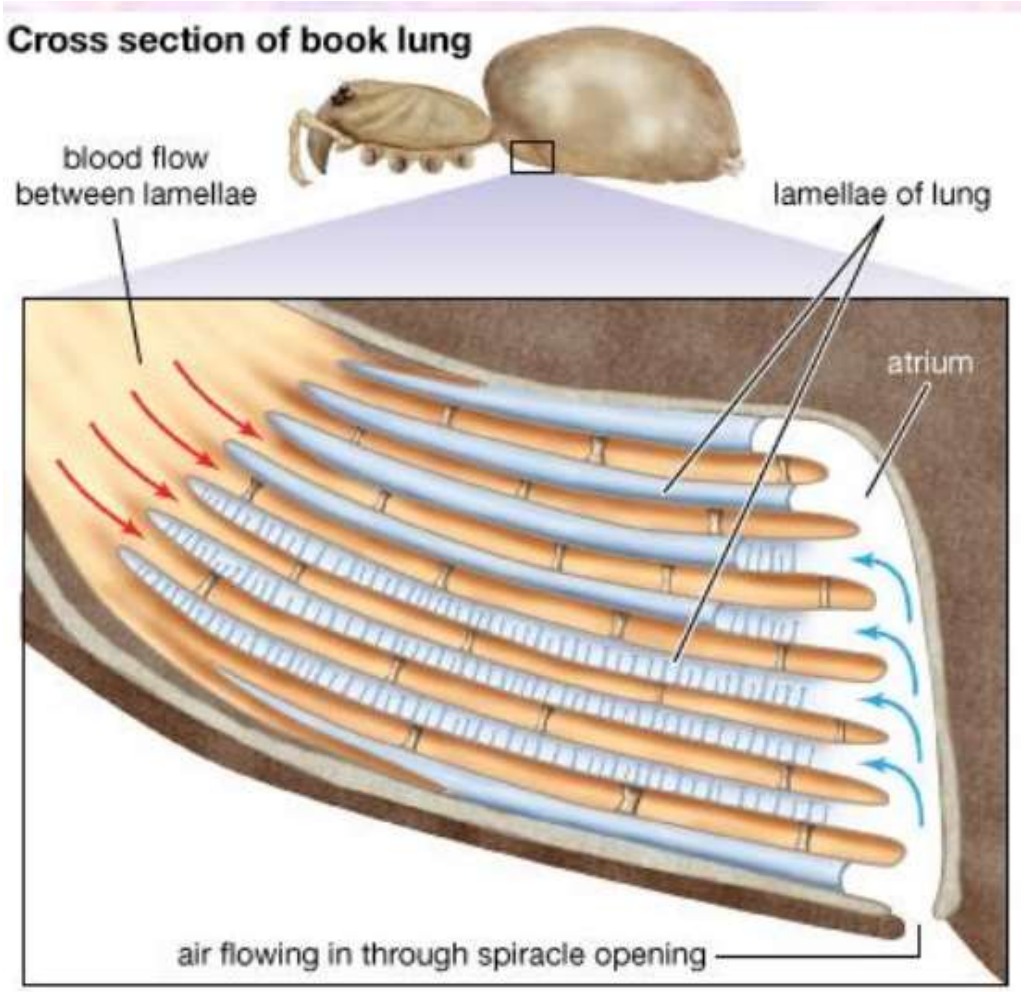


Fig. 6: Structure of a book lung

Mechanism of respiration through book lungs

The movement of air in the book lungs is controlled by certain muscles attached to them. These include; atrial muscles and dorso-ventral muscles.



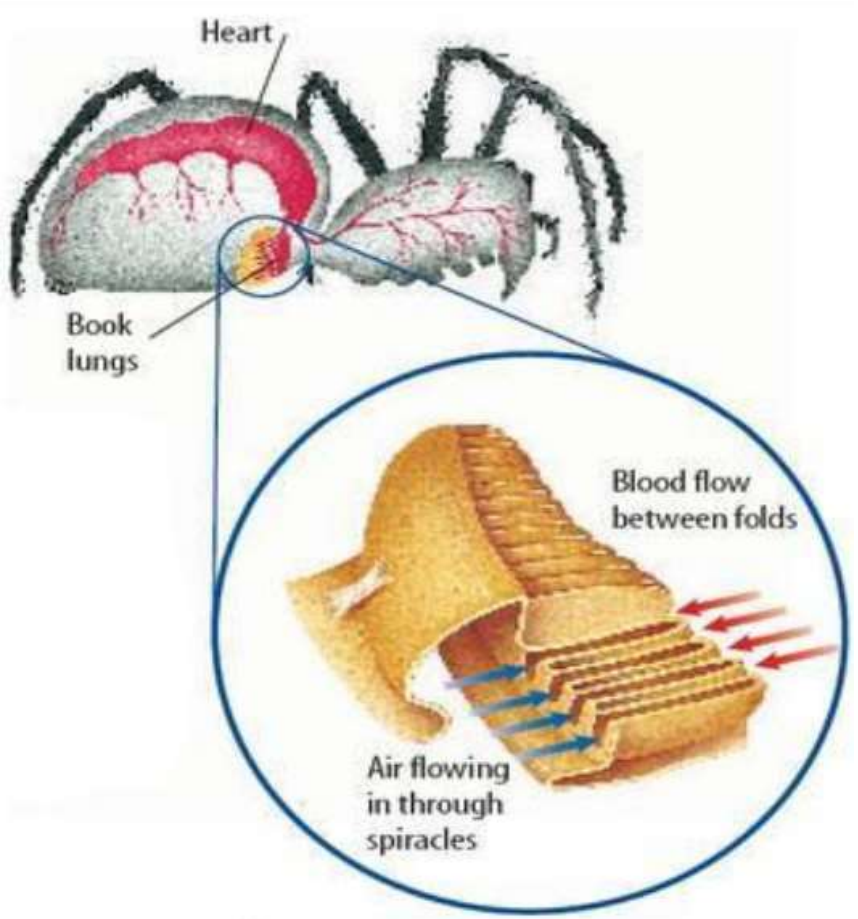


Fig. 9: Exchange of gases in a book lung

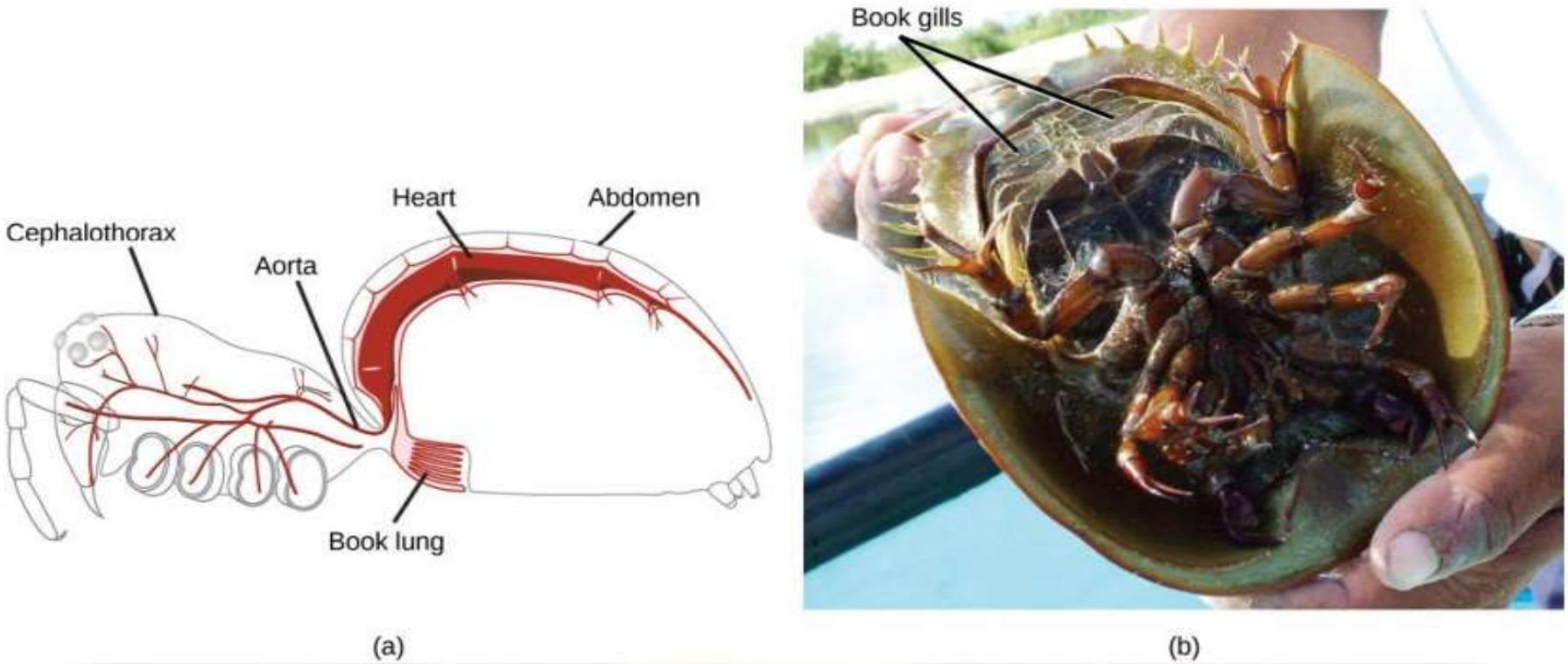


Fig. 10: Comparison between book lungs and book gills

The book lungs of (a) arachnids are made up of alternating air pockets and hemocoel tissue shaped like a stack of books. The book gills of (b) crustaceans are similar to book lungs but are external so that gas exchange can occur with the surrounding water.

Tracheal System-Respiratory System in Insects

Insects, unlike other arthropods, do not have any respiratory pigment and thus have inefficient circulatory system to meet their respiratory demands. Consequently, they have evolved a tracheal system which comprises of a large number of small tubes that carry oxygen to each and every body cell for oxidation of food.

The insect tracheal system consists of the following parts:

(a) Tracheae

(b) Tracheoles

(c) Spiracles

(d) Air Sacs

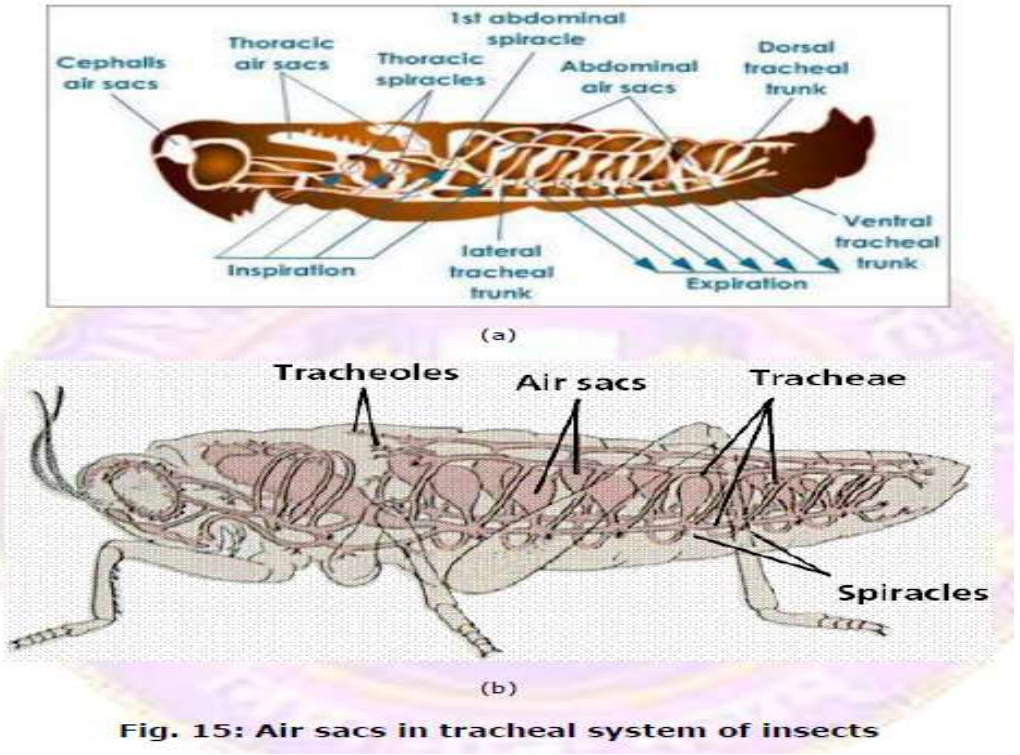


Fig. 15: Air sacs in tracheal system of insects

(a)Tracheae

The tracheal system constitutes of special tubes called tracheae, formed by the invagination of cuticle. These tubes form an extensive network which spread throughout the insect body and supply oxygen. Generally, insects have a pair or more of longitudinal tracheal trunks which are cross-connected to each other by horizontal tracheae. The tracheal tubes are lined internally by a chitinous layer, called intima. The intima forms ring-like spiral thickenings, called taenidia, which provide them support and elasticity preventing their collapse.

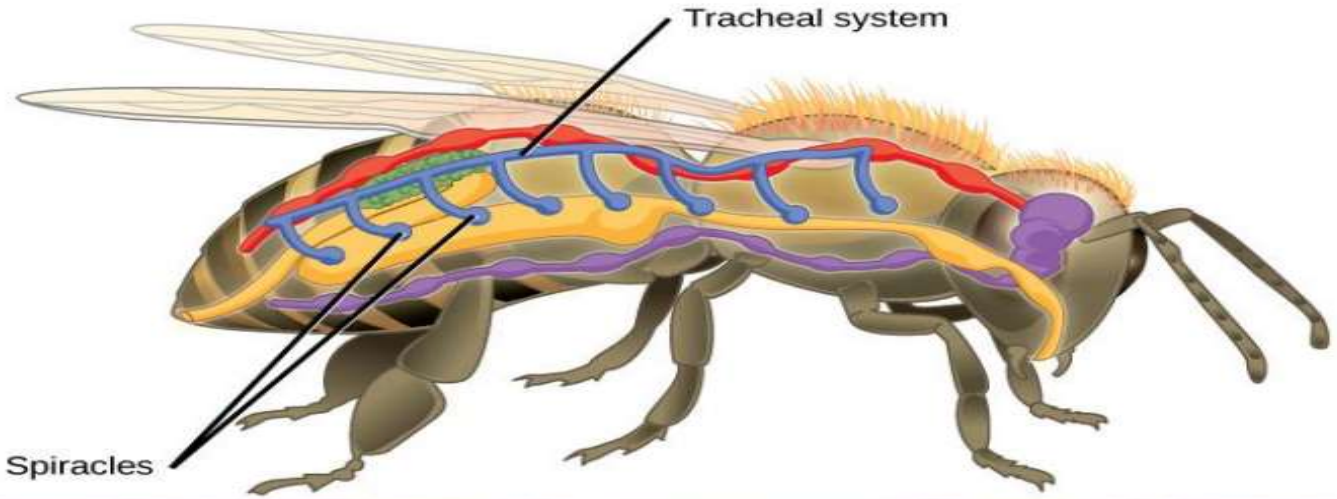


Fig. 11: Outline of insect tracheal system

(b) Tracheoles

The tracheae branch repeatedly into smaller tubes, called tracheoles. These are devoid of cuticular thickenings and are lined with a proteinaceous layer formed of trachein. The tracheoles finally enter and terminate into each body cell. The distal ends of these tracheoles are closed and are filled up with tracheole fluid. The fluid-filled parts of tracheoles are termed as tracheole end cells.

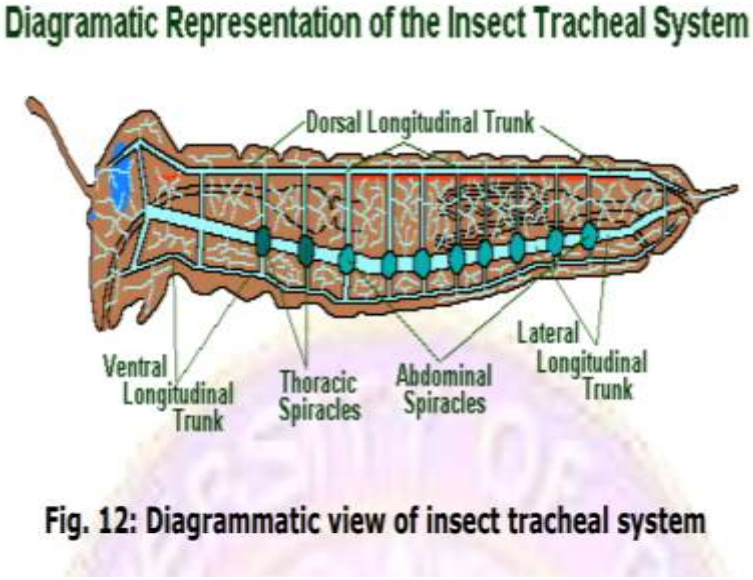


Fig. 12: Diagrammatic view of insect tracheal system

(c) Spiracles

The prime tracheal trunks open to the exterior by segmentally arranged apertures present in the lateral region of the body wall; spiracles or stigmata. There are often ten pairs of spiracles in the insects; two pairs present in the thoracic region and eight pairs in the abdominal region.

Fig. 13: Spiracles in an insect tracheal system

(a)Air Sacs

In many insects, such as bees, grasshoppers, butterflies, etc., the tracheae lack the spiral thickenings and dilate at certain places. These are called **air sacs** which permit increased oxygen supply leading to more efficient respiration and enhanced release of energy.

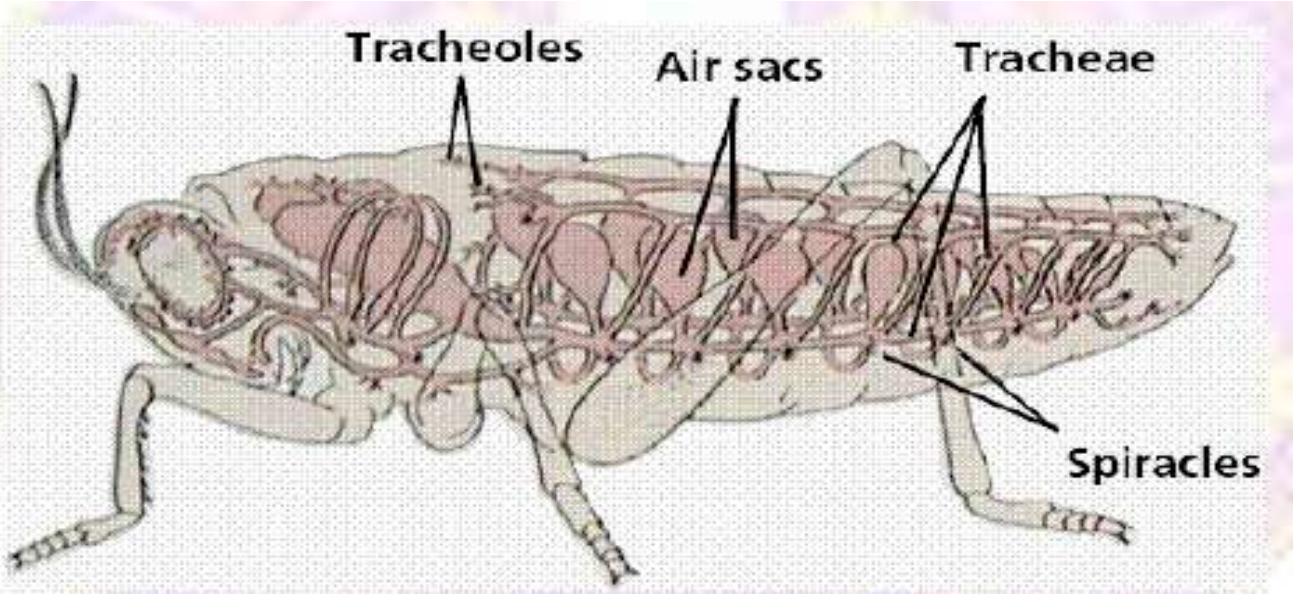
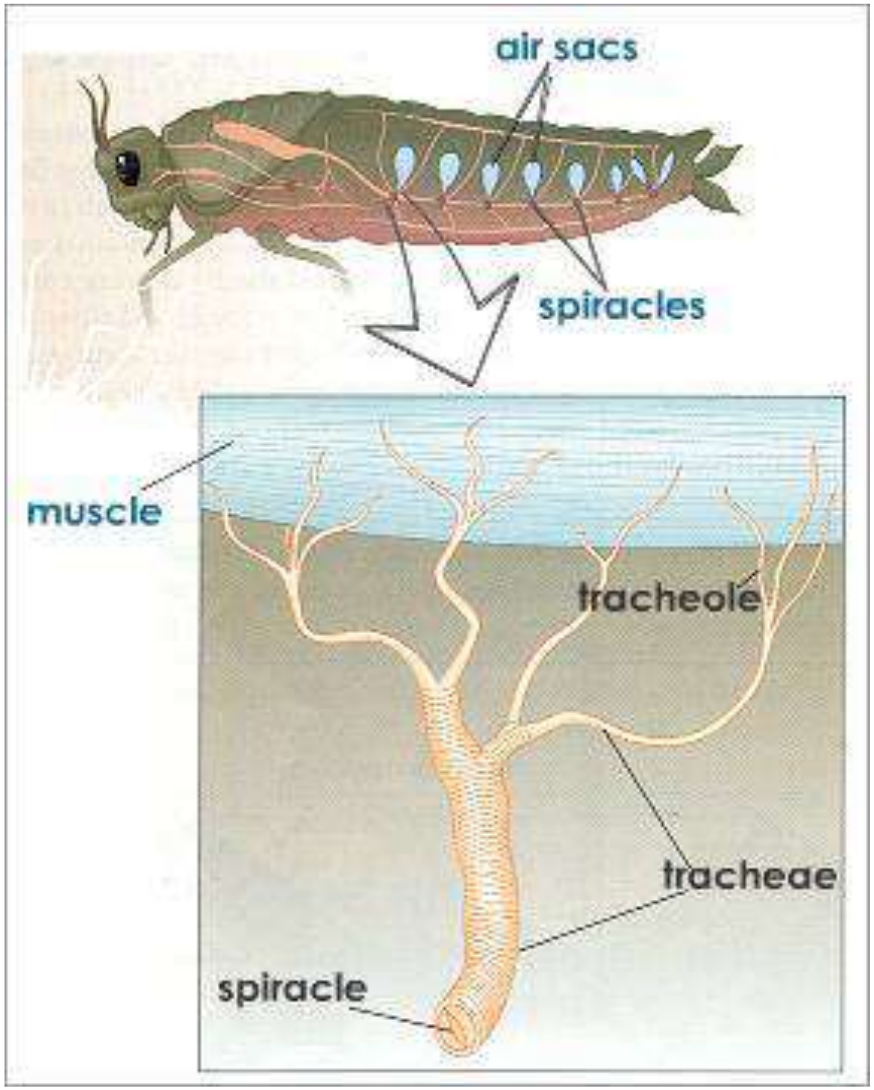
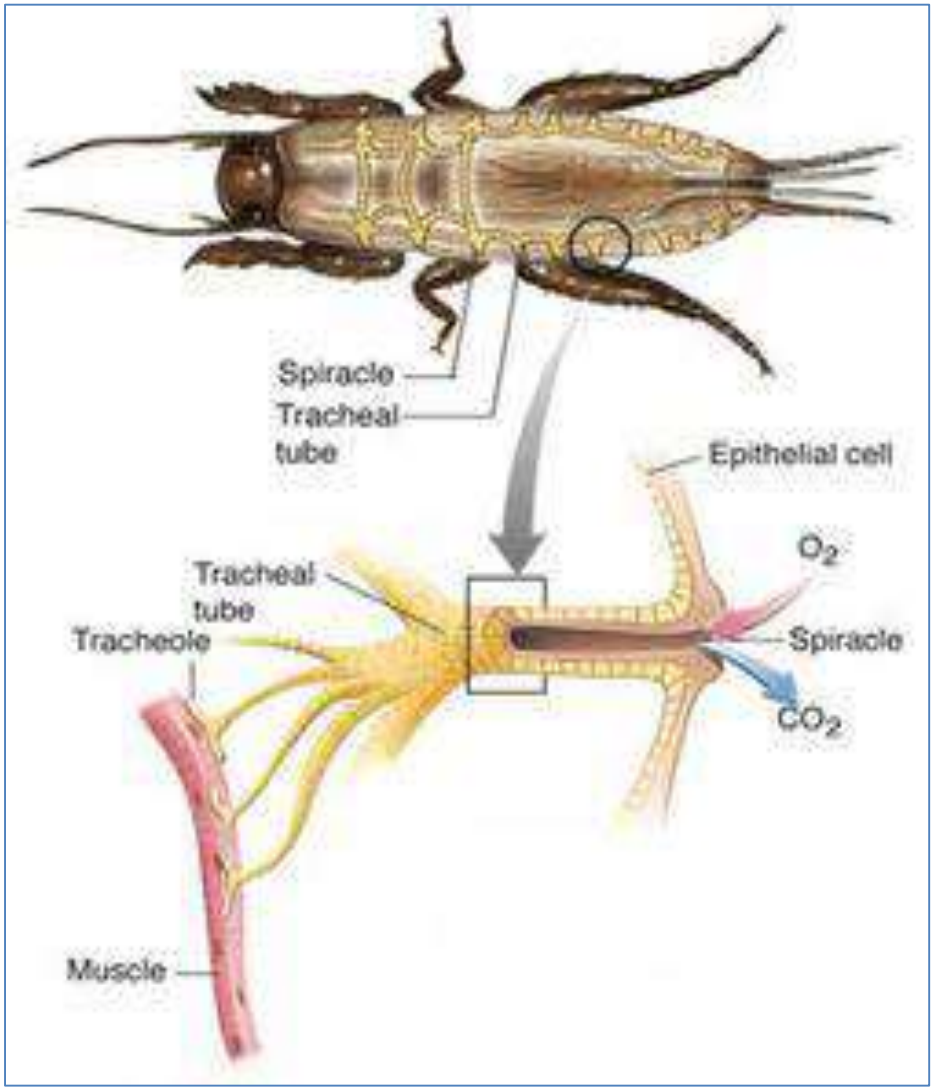


Fig. 15: Air sacs in tracheal system of insects

Gaseous exchange *via* tracheal system

The gaseous exchange in the tracheal system is primarily by diffusion and ventilation.





Respiration in Aquatic Insects

Aquatic insects have developed diverse structures and mechanisms for respiration.

A few of such structures are discussed below.

Fig. 19: A giant water bug, *Abedus heberti*, breathing using plastron

A. Plastron Respiration

Certain aquatic insects with tracheal respiration carry an air bubble or a thin gaseous layer restricted mostly to their ventral surface. This is called **plastron** which is actually a 'gas store' which communicates with the tracheal system.

B. Tracheal Gills

The immature stages of many aquatic insects have developed tracheal gills. These are thin plates or filaments-like structures with abundant tracheal supply but only a very small blood cavity. The tracheae present in these gills exchange gases with the water and help in respiration.

Fig. 20: Tracheal gills in the sub-imago of May fly, *Cloeon dipterum*

The tracheal gills commonly occur on the abdomen, but can also be observed on the thorax. Depending on the position of these gills, these can be of the following types:

a) Abdominal tracheal gills: The naiads of mayfly (Ephemeroptera) have 7 pairs of leaf-like tracheal gills on the abdominal segments. The larvae of trichopterans, caddis flies also possess leaf-like abdominal gills for respiration.

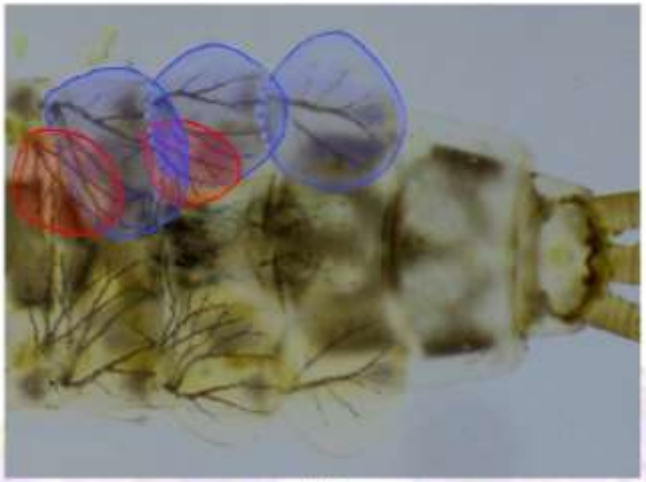
b) Thoracic tracheal gills: The larvae of a few species of stone fly (Plecoptera) have tracheal gills on their thorax.

c) Caudal tracheal gills: These are characteristics of the damselfly naiads which have 3 flattened or leaf-like respiratory gills at the end of abdomen. The abdominal end of mosquito larvae also has four leaf-like tracheal gills. However, they are believed to help in ionic balance instead of respiration.

d) Rectal tracheal gills: These are internal tracheal folds found in the rectum of dragonfly naiads. Water enters in the rectum through anus and passes over these folds resulting in exchange of gases.

e) Coxal tracheal gills: These can be found originating from the coxae certain stoneflies. However, these probably function in osmoregulation rather than respiration.

Fig. 21: Filamentous tracheal gills on the abdominal segments of *Hydropsyche* (Trichoptera: Caddis fly)



(b)

Fig. 22: Enlarged view of abdominal Tracheal Gills in the naiads of Mayfly, *Cloeon dipterum*

(b)

Fig. 23: Caudal Tracheal Gills in the naiads of a damselfly

C. Blood Gills

A few aquatic insects contain gills which have a spacious lumen but are either devoid of tracheae or tracheae are poorly developed in these gills. Their lumen is filled with the blood and thus, these are called blood gills.

For example, the ventral and anal gills of *Chironomus*.

D. Spiracular Gills

These gills are ectodermal and filament-like which are covered by a thin layer of cuticle. The cuticle has thin air spaces which are connected to the tracheae and help in breathing. These gills can be observed in the pupae of black fly, *Simulium*.

Fig. 24: Spiracular Gills in the pupa of a black fly, *Simulium aureum* Fries

E. Breathing Tube:

A few aquatic insects are unable to breathe oxygen dissolved in the water and are dependent on the atmospheric air for respiration. They have developed certain structures for taking in atmospheric air. A few of these are as follows:

a) Caudal tube:

Certain adult aquatic insects, such as water scorpion *Nepa*, have a pair of caudal breathing tubes at the end of abdomen to form a siphon.

b) Respiratory siphon:

Mosquito larvae have a tube-like respiratory siphon at the end of their abdomen which serves as a breathing tube.

Fig. 25: Larvae of *Culex* sp. hanging from the water surface by respiratory siphons

c) Respiratory trumpets:

The pupae of mosquito and midges have a pair of breathing tubes, called respiratory trumpets, which are located dorsally on the thoracic region. They are structurally and functionally similar to the respiratory siphons present in the larvae and help in breathing.

Fig. 26: Pupa of *Culex pipiens* hanging from the water surface by respiratory trumpets

Points to recall

- ✓ Arthropods have developed a variety of structures and organs for breathing, which include book gills, book lungs, tracheae, etc.
- ✓ Book gills are characteristic respiratory organs of aquatic arthropods, especially crustaceans.
- ✓ Book gills are of various kinds depending upon their location and structure.
- ✓ Each book gill is made up of a number of thin gill lamellae arranged like the leaves/pages of a book at right angle to the gill base.
- ✓ In a book gill, the exchange of respiratory gases takes place between water and blood flowing through the gill lamellae.
- ✓ Book lungs are the characteristic abdominal respiratory organs of terrestrial arthropods; arachnids.
- ✓ A book lung is consists of a dorsal pulmonary chamber consisting of approximately 150 leaf-like lamellae arranged like the leaves of a book and a ventral atrial chamber filled with the air.
- ✓ In a book lung, the gaseous exchange takes place between blood and the air present in the interlamellar spaces through the thin membranous walls of lamellae.

- ✓ Insects are devoid of any respiratory pigment and thus have evolved a tracheal system comprising of a large number of small tubes that carry oxygen to each and every body cell for oxidation of food.
- ✓ The tracheae, formed by the invagination of cuticle, possess spirally thickened taenidia and form an extensive network throughout the insect body.
- ✓ The tracheae branch into smaller tracheoles which are lined with proteinaceous trachein. Their distal ends terminating into body cells are filled up with tracheole fluid.
- ✓ The tracheal trunks open to the exterior by segementally arranged lateral spiracles which helps to regulate the flow of air and prevents the loss of moisture from the body.
- ✓ The tracheae of a few insects dilate at certain places into air sacs which permit increased oxygen supply leading to more efficient respiration.
- ✓ Air enters the tracheal system during inspiration and oxygen diffuses from the tracheoles into the body cells whereas CO_2 diffuses from the cells into the tracheoles. The CO_2-rich air is released outside the body during expiration.

- ✓ Certain aquatic insects with tracheal respiration carry an air bubble, plastron on their ventral surface which communicates with the tracheal system and helps in respiration.
- ✓ The immature stages of many aquatic insects have thin tracheal gills with abundant tracheal supply which exchange gases with the water and help in respiration. These may be located at various places of the insect body.
- ✓ A few aquatic insects contain blood gills which have a spacious lumen but are either devoid of tracheae or poorly developed tracheae the lumen of which is filled with the blood.
- ✓ The spiracular gills are ectodermal, filament-like and are covered by a thin layer of cuticle with has thin air spaces connected to the tracheae.
- ✓ A few aquatic insects are unable to breathe oxygen dissolved in the water and draw in atmospheric air for respiration with the help of certain structures.
- ✓ Mosquito larvae have a tube-like respiratory siphon at the end of their abdomen which serves as a breathing tube.