

muscles relax, blood is forced through ostia into the heart. Heart and aorta contract peristaltically from behind forwards driving blood into head sinuses and then backwards into the perivisceral and sternal sinuses. The rate of heart beat in *Periplaneta* is 49/min.

From head sinuses, haemolymph is also sent into antennae by the pumping activity of two small ampullae, located in head. In case of wings, small pulsatile organs at their bases cause haemolymph to flow through the veins of fore and hindwings.

Respiratory System

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.

(b) *Tracheoles*. The profusely branching tracheae 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

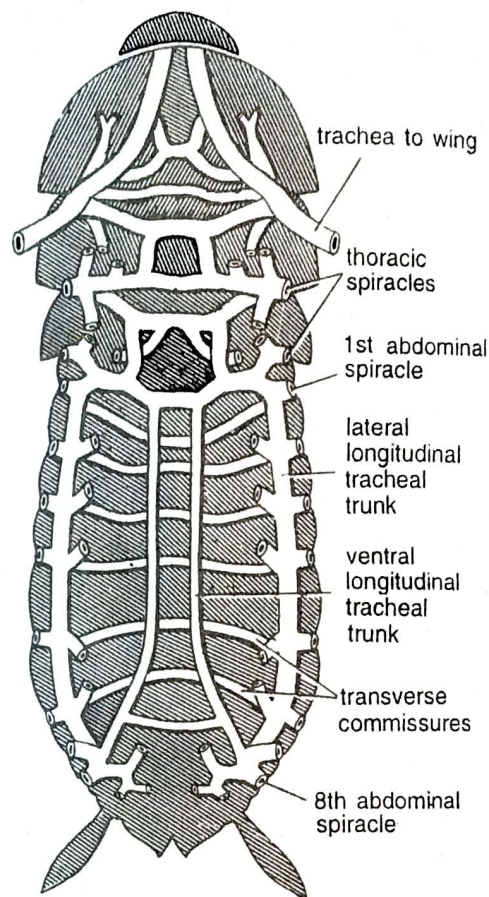


Fig. 15. *P. americana*. Tracheal system in dorsal view.

well compensates for the inability of blood to transport oxygen due to absence of a respiratory pigment.

(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.

2. Respiratory mechanism and gaseous exchange. Alternate contraction and relaxation of

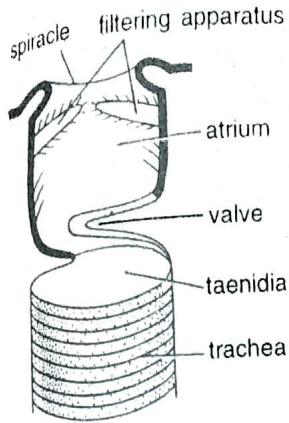


Fig. 16. A spiracle with atrium, filtering apparatus and valve.

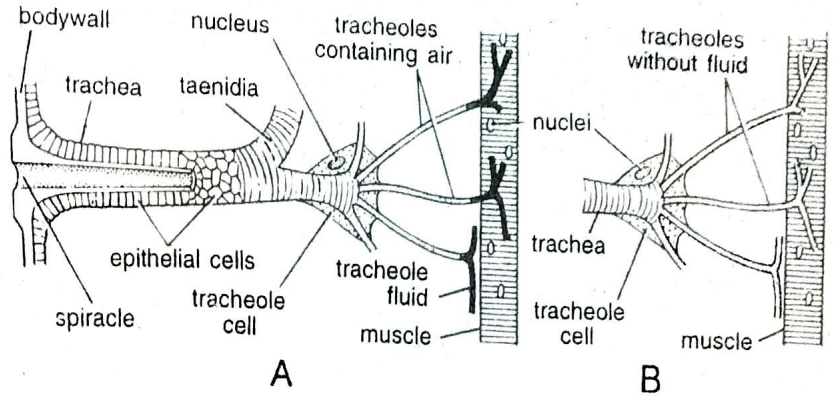


Fig. 17. *Periplaneta*. Role of tracheoles in gaseous exchange. A-Tracheoles with fluid at rest. B-Tracheoles without fluid after work.

the abdominal muscles (tergo-sternal muscles) cause rhythmic contraction and expansions of abdomen. Such movements cause change in diameter of tracheae and force air in and out of tracheal tubes through spiracles. 1st and 3rd pairs of spiracles always remain open while the remaining eight pairs open only during inspiration. Respiratory movements depend on the activity of insect and temperature. Greater the muscular activity, the more vigorous is the pumping in-and-out of air. Respiratory movements are coordinated and regulated by nerve centres in thoracic ganglia which are stimulated by low O_2 and higher CO_2 concentrations in tissue fluids.

Gaseous exchange occurs by simple diffusion between air in tracheae and dissolved gases in blood or tracheolar fluid which has been shown to rise and fall. When insect is resting, the tips of tracheoles remain filled with fluid so that O_2 diffuses slowly through fluid into body cells and tissues. When the metabolic activity is greater, fluid from tracheoles is withdrawn into surrounding tissue due to a rise in osmotic pressure of cells. This exposes more surface walls of tracheoles to oxygen, so that more oxygen is supplied to the surrounding tissues. O_2 entering the tissues brings about oxidation of energy-rich food molecules with the release of energy and production of CO_2 and water. Some of the CO_2 leaves the body through tracheae and spiracles. But major part of CO_2 leaves through the cuticular covering of body because it can diffuse more readily through chitin than O_2 .

Excretory System

Excretory system regulates the amounts of nitrogenous material, inorganic salts and water in blood or haemolymph. As a result of the protein metabolism, nitrogen is produced in excess which is excreted as uric acid. The main structures that play the role of excretion are – (i) *Malpighian tubules*, (ii) *fat body cells*, (iii) *uricose glands*, and (iv) *cuticle*.

1. Malpighian tubules. These are attached to the alimentary canal at the extreme anterior end of hindgut. These are fine, long, unbranched, yellowish and blind tubules lying freely in the haemolymph. These are between 60 to 150 in number and are arranged in 6-8 bundles. Each tubule is about 16 mm long and 0.5 mm in diameter and is lined by glandular epithelium with a characteristic *brush border*.

A Malpighian tubule has two functional parts. Glandular cells of *distal secretory part* extract nitrogenous wastes (mostly in the form of salts of uric acid, e.g. potassium urate) and water from haemolymph forming a solution called *urine*. The urine flows towards the *proximal absorptive part* of tubule which reabsorbs certain salts, such as potassium bicarbonate, and some water resulting in precipitation of uric acid. Uric acid already present in haemolymph combines with reabsorbed potassium bicarbonate and water to form the relatively soluble potassium urate which again becomes available to be actively transported from haemolymph into the lumen of distal portion of Malpighian tubule. Fro

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Definition of Respiration.

⇒ Terrestrial Respiration:- (Fellow Koppal)

Sujata

(Terrestrial + rignent)
typical.

Land-inhabiting Arthropods use the atmospheric O_2 directly either by trachea or book-lung or by some other means & carry the atmospheric O_2 either directly to the tissues or depend on the blood for the transport of the O_2 to the tissues.

Let's consider the terrestrial arthropod is

Cockroach (Periplaneta sp.)

It has well developed & elaborate respiratory system to compensate the absence of respiratory pigment in the blood. Respiratory system consist of -

↳ Spiracle:-

i) There are ten pairs of spiracles or stigmata arranged segmentally, 2 pairs in the thorax & 8 pairs in the abdomen.

ii) Each spiracle is slit-like aperture in an oval sclerotised area guarded by hairs to prevent dirt.

iii) The spiracle is bordered by an annular sclerite called peritreme.

iv) The spiracle are ~~closed~~ ^{opened} & closed by valves by sphincter or spiracular muscle, which regulates the flow of the air through them.

v) The aperture leads into a short chamber called atrium from which arises the main trachea of trunk.

Function:- The environment air enters & escapes from the trachea through spiracle.



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v v v

2) Tracheae

i) The haemocoel of cockroach contains a system of network of elastic, closed, branching & silvery white tubes called tracheae.

ii) They formed by the impingement of the ectoderm

iii) Its wall consists of - a) taenidia
b) basement membrane & epithelium

iv) The taenidia is cuticular prevents the tracheae from collapsing.

v) There are 3 pairs of large longitudinal tracheal trunks - one ^{pair} dorsal, one ^{pair} ventral & one ^{pair} lateral connected by transverse commissures.

vi) The ultimate branches of tracheae end in tracheole cells from which arise very fine tubes called tracheoles, end blindly in the tissue cells.

vii) In resting condition tracheoles are filled with tissue fluid with dissolved O_2

viii) By means of this system of tracheae here the cells of body are in direct contact with the environmental air.

ix) Thoracic spiracles leads into tracheal trunk, abdominal spiracles leads into lateral longitudinal trunks.

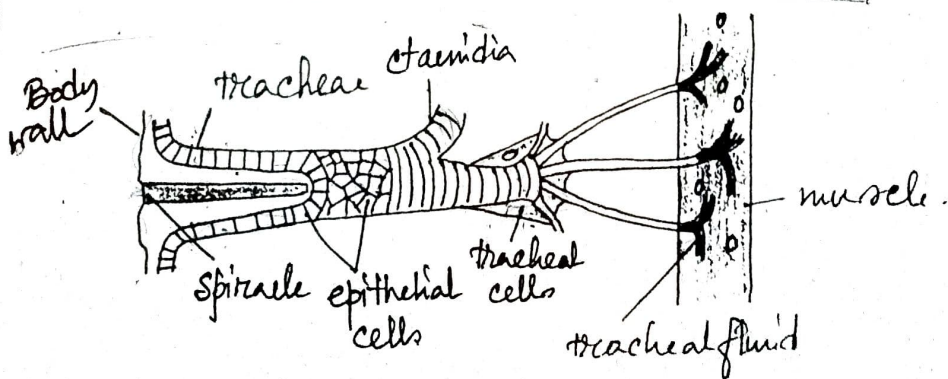


Fig. Respiratory System of Periplaneta

Mechanism of respiration:-

i) Inspiration (active process) & expiration (passive process) take place through spiracles.

ii) In cockroach 1st thoracic & 1st abdominal spiracles open all the time.

iii) 2nd thoracic & seventh abdominal spiracles open during inspiration & close during expiration.

iv) During inspiration air enters the spiracle, come to the trachea & tracheole contain fluids. O_2 get dissolved & reaches the tissue cell.

v) Opening of spiracles & subsequent diffusion of air occur due to the stimulation of spiracles by CO_2 .

vi) In expiration since CO_2 pass out through spiracle.

vii) Major part of CO_2 dissolved in the plasma & reaches the body surface which is permeable and allow CO_2 to pass out.

During active movement:-

1) During running or flying, metabolic rate is high & the osmotic pressure of tissues increase.

2) Then the fluid is withdrawn from the tracheoles into the blood cells with a column of air.

3) O_2 is taken by the fluid of cells.

4) In active movement abdominal segments expand & relax, these movement termed as respiratory movement.

5) Respiratory movements are co-ordinated by nerve in each segment receive impulse from thoracic ganglia controlling all respiratory activities.

6) The co-ordinated centers responds in lack of O_2 & excess of CO_2 .