Forms of Respiration among Arthropods

The following points highlight the two main forms of respiration among arthropods. The forms are: 1. Aquatic Respiration 2. Aerial Respiration.

1. Aquatic Respiration:

The organs associated with aquatic respi­ration are:

1. Gills or Branchiae

2. Tracheal gills

3. Blood gills

4. Rectal gills

5. Book gills

6. Branchiostegite or gill cover

7. Epipodite and

8. Branchial basket.

1. Gills or Branchiae:

(i) Occurrence: The gills are the respiratory organs of aquatic arthropods. These are best developed in crustaceans. In other aquatic arthropods, special types of gills are often encountered.

(ii) Location: Gills are situated within the gill chamber. The gill chamber is located on each lateral side of the cephalo-thorax and covered by the gill cover or branchiostegite.

(iii) Origin of gills in crustacean: Gills originate as out-pushings of the body wall. In Amphipoda, the gills are outgrowths of the thoracic limbs and in Isopods the endopodites of second and fifth pleapods are modified as gills.

(iv) Structure of gills in Crustacea: A typical gill is crescent shaped. It consists of a central axis or rod, on each side of which are arranged blade-like gill filaments, called lamellae. One end of each filament or lamella remains connected with the rod or central axis and the other end of the filament is blind. Through the central axis of each gill runs an afferent and an efferent branchial channel.

(v) Types of gills in Crustacea:

A. Based on the shape of the lamellae

1. Phyllobranchiate gill: In this type of gills the lamellae are flat, broad leaf-like and are arranged in two rows. It is found in crabs and prawns (Palaemon).

2. Trichobranchiate gill: In this type of gills, the gill filaments are tubular-shaped. It is found in cray­fish (e.g., Astacus) and rock lobsters. It consists of a central axis with numer­ous lateral filaments, formed from the sides of the body or from an out­growth of skin of the legs.

3. Dendrobranchiate gill: In this type of gills, the leaf-like lamel­lae are divided into fine branched fila­ments. It is found in Penaeus.

B. Based on the mode of attachment

1. Podobranch: Podobranch attached with the coxopodite of the thoracic appendage. In Macrobrachium (= Palaemon), Penaeus the podobranchs are one pair and re­main attached to the second maxillipedes.

2. Arthrobranch: Arthrobranch the gills are attached with the arthroidal membrane which connect the appendages of the thorax. In Palaemon the arthrobranchs are two, attached to the arthroidal membrane of third maxillipede. In Penaeus there are eleven pairs of arthrobranchs, start­ing from second maxilliped to third walking leg, two in each appendage and fourth walking legs contain single arthrobranch.

3. Pleurobranch: Pleurobranch—the gills are attached with the lateral wall of the thorax. In Palaemon there are five pleurobranchs, attached to the lateral side of the tho­rax. Is Penaeus there are six pairs of pleurobranchs attached to the last six pairs of thoracic appendages.

(vi) Number of gills in Crustacea:

Number varies in different groups. The Decapods which contain all the types of gills exhibit extreme variation—in the shrimp, Lucifer, gills are absent; penaeid shrimp has 24; Homarus has 20; Peacrab contains 6 gills. In Palaemon, there are 8 pairs of gills and the anterior gills are small and the size increases towards the posterior end.

(vii) Modification of gills in Arthropoda:

The gills are variously modified in Crus­taceans and other Arthropods. In Phyllocarida, broad epipodites of the tho­racic appendages work as gills. Similar gills are seen in Cumacea. Gills are plate-like in Amphipoda and flattened in a Decapod, Palinurus.

In Euphausiacea, the tufted podobranchs are not covered by carapace. The gills appear as a row of small branchial lamellae on each side of Cyprididae. In Phyllopoda, the leaf-like pleopods work as gills. Among the Crustaceans only Stomatopods and Isopods have abdominal gills.

2. Tracheal gills:

In the aqualtic larvae of many insects a series of simple and divided external pro­cesses are attached to the abdominal seg­ments. These are richly supplied with tra­cheae and are called the tracheal gills help in respiration.

3. Blood gills:

In certain aquatic insect larvae (mainly chironomidae) the tracheae are replaced by the branching tubular outgrowths contain­ing blood vessels and are called the blood gills.

4. Rectal gills:

In the nymphs of several insects the inner surface of the rectum bears gills. These gills are called the rectal gills.

5. Book gills:

The most specialised gills are seen in Xiphosurids, where the abdominal append­ages bear plate-like book gills. These gills are formed by the evagination of the posterior borders of opisthosoma in seg­ments from ninth to thirteenth. Each gill contains nearly 150 lamellae, which look like the delicate leaves of a book.

Mechanism of gill respiration:

In most Crustaceans, the gills are not covered within a special gill chamber. But in Decapods, the carapace extends laterally over the gills to house them in a special chamber.

In such forms with chamber, current of water enters through one end and after bathing the gills, passes out through another direction. In Crustaceans and Xiphosurids, gaseous exchange takes place in the gills between the blood and the water. But in Insects, after diffusion the oxygen passes to the tracheal tubes.

Branchial formula:

The number and arrangement of gills are presented in a form of formula on each side, called branchial formula. The branchial for­mula of a freshwater prawn (e.g., Macrobrachium sp. = Palaemon sp.) is repre­sented in Table 18.17.

Other devices of aquatic respiration:

6. Branchiostegites:

In Crustacea the gill-chamber is covered by the lateral extension of carapace, called gill cover or branchiostegite. The inner lin­ing of the branchiostegite is thin, membra­nous and richly supplied with blood. It is in direct contact with water current and ex­changes gases between the blood and the water.

7. Epipodites:

These are small highly vascularised leaf-­like membranous outgrowths of integument on the outer side of coxa of the maxillipeds in first three thoracic segments. These epipodites being present in the anterior part of each gill-chamber (e.g., Crustacea) carry out respiratory functions.

8. Branchial basket:

The immature Odonates (Insects) have their rectum modified into a branchial bas­ket. Its wall is contractile and richly supplied with the branches of tracheae. This kind of respiration is often referred to as anal respi­ration.

2. Aerial Respiration:

The aerial respiration takes place in ter­restrial arthropods.

The organs for respira­tion are the following:

1. Trachea

2. Lungs

3. Book-lungs

4. Pseudotracheae or air tubes

5. Anal respiration

6. Miscellaneous devices

1. Trachea:

This is the most important organ for aerial respiration. This chitin-lined tube is seen in almost all land arthropods, such as insects, centipedes, millipedes and many arachnids.

Two types of tracheae are seen:

(i) Ventila­tion trachea—oval in section and collapses after the exhalation of air and

(ii) Diffused trachea—rigid and does not collapse after the exhalation.

(a)Origin:

The tracheae originate as the in­vagination of the body wall.

(a) Structures of trachea and associated parts:

(i) Each trachea is a tube with walls made up of polygonal cells.

(ii) The wall of trachea is composed of three layers—these are the internal layer, called intima, a middle layer of epithelium and an outer layer of base­ment membrane.

(iii) The intima is lined by spiral cuticular ridges, called taenidea, that prevent collapse.

(iv) The tracheal cuticle contains the same layers as the surface cuticle except the cement layer and wax layer.

(v) The tracheae open externally by small openings, called spiracles or stigmata.

(vi) These spiracles are located along the sides of the body.

(vii) Each spiracle opens into a chamber, called atrium and the spiracle is placed on a plate, called penetrene.

(viii) Each spiracle has two lids for opening and closing.

(ix) Within the chamber foreign particles are eliminated by a filtering appara­tus, containing either special bundles of setae or a kind of sieve-like mem­brane.

(x) Some parts of tracheae are dilated to form air-sacs. They help as reservoirs of air.

(xi) The finer branches of tracheae are called tracheoles which are without inner taerridial ridges. A tracheole may be 1µ in diameter and reaches every cell of the body.

(xii) The end of a finer tracheae is im­mersed in a fluid through which gaseous exchange takes place.

(b) Classification of tracheae:

(i) In adult insects, the tracheal system is of one kind.

(ii) Two pairs thoracic and eight pairs abdominal spiracles are usually present in all adult insects. There are 12 pairs in primitive condition.

(iii) In certain forms some spiracles may be secondarily absent but they appear at least in some stages of develop­ment. For example, the queen termite has only six pairs abdominal spiracles instead of eight pairs. The metathoracic pair of spiracles is absent in Lepi­doptera, Hymenoptera, Coleoptera and a few others.

(iv) In millipedes, a pair of spiracles is present in each thoracic segment and two pairs of spiracles in each abdomi­nal segment.

(v) During development, spiracles ap­pear in varied ways in different in­sects.

Thus from the point of view of embryology the tracheal system is classified on the basis of the number of functional spiracles. This classifica­tion does not denote any special kind of tracheal system in the adult.

On the basis of functional spiracles the tracheal system in larvae may be classified as:

(i) Polypneustic: Tracheal system open­ings to the exterior by 8 or more pairs of functional spiracles. It may again be subdivided into:

(a) Holopneustic: When 2 pairs of tho­racic and 8 pairs of abdominal spiracles are functional. The term is used when 10 pairs of functional spiracles are present.

(b) Peripneustic:A respiratory system with 1 thoracic and 8 abdominal spiracles are present on each side of the body. The term is denoted when the abdominal spiracles occur on all the segments of the abdomen.

(c) Hemipneustic: A respiratory system with 1 thoracic and 7 abdominal spiracles are present on each side of the body. The term is used when one or more pairs of spiracles are non­functional.

(ii) Oligoneustic: Here, either one or two pairs of spiracles are functional.

It includes divisions like:

(a) Amphipneustic: When one pair of thoracic and one pair of post-abdominal spiracles are present. Such condition is found in the larva of the common house fly.

(b) Metapneustic: Only one pair of post abdominal spiracles is functional. This condition is seen in the mosquito larva.

(c) Propneustic: Only one pair of tho­racic spiracles is functional. This condition is seen in the pupae of certain Diptera.

(iii) Apneustic: No spiracle is present in functional state. Gaseous exchange takes place through the integument, seen among aquatic insect larvae.

(c) Mechanism of tracheal respiration:

The trachea ramifies into a number of fine networks of tracheoles which terminate into tissues where exchange of gases takes place by diffusion. Air is drawn in and forced out through the spiracles by the alternate con­traction and expansion of the body. The spiracles remain closed most of the time and exchange of gases is probably due to diffu­sion and ventilation.

Recent studies indicate that the spiracles open very briefly but not all at a time due to reduction of haemocoelomic pressure. The spiracles are closed by valves, thus control the water loss, and opening of the spiracles is related to the high CO2 concentration.

Gaseous exchange through the tracheae takes place by diffusion primarily and tracheoles are permeable to water and remain fluid-filled. This fluid is believed to be involved in the final O2 trans­port to the tissues.

Again it is reported that the movement of trachea is facilitated by the alternate contrac­tion and relaxation of the body sclerites. In the bed bugs, rigid and convex sternum does not take part in the respiratory move­ment, which is done only by the elastic tergum. In cockroaches the tergum and ster­num of the segments are separated by in­tersegmental membrane which bulges out during respiration.

(d) Modifications of the tracheae:

In most Collembola, the tracheae are absent and the respiration is largely cutane­ous. In Machiles, segmental tracheae origi­nate from spiracles but do not have trunks. In the larva of Musca, dorsal longitudinal trunk is provided with one pair of anterior and one pair of posterior apertures.

In the larvae of mosquito, a single spiracle is con­nected to the dorsal trunk. In the Myriapods, stigmata open within air chamber from where large numbers of tracheae are given off. The other peculiar features of this group are that in Diplopoda the tracheae are branched and in Symphyla only two tracheae are present on the head.

Other devices of aerial respiration:

1. Lungs:In the Crustacea, Birgus, the upper part of the gill-chamber is sepa­rated from the rest and forms a closed chamber within which vascular tufts project and perform aerial respiration.

2. Book-lungs:The book-lungs are best seen in Scorpionids and spiders. These are blind sacs which originate from the evaginations of opisthosoma. These are regarded as the modified abdominal appendages. Within the sac the inner lining is raised into numerous delicate folds, like the leaves of a book. These folds are richly vascularised and thus respiration in Scorpionids is circulation dependent. Each book-lung communicates to the exterior by a stigma.

3. Pseudotracheae or air tubes:The only land living Crustacea, Oniscus (wood lice), possess numerous minute tube­-like structures in the abdominal ap­pendages, called Pseudotracheae, help in respiration.

4. Anal respiration:Many crustaceans perform rhythmical contractions of intestine—taking in and expelling out water. Such anal respiration is com­mon in lower crustaceans and is espe­cially noticeable in Cyclops.

5. Miscellaneous devices:

A combina­tion of book-lung with trachea is seen in spiders. Some aquatic members of Colleoptera and Hemiptera (e.g., Nepa, Ranatra) carry respiratory tubes, lo­cated at the posterior end of the body which is formed by two cerci. While they dive inside the water, they cany air with them for respiration. In mos­quito larvae, a long siphon draws air from the surface of the water.

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