Insect Respiratory System

Tracheal system

Spiracles
Tracheal system

- In insects, exchange of gases takes place through tubular structures, called **trachea** distributed throughout the body collectively forming **tracheal system**.
- Open outside on the body wall through small openings called **spiracles**.
- Spiracles occur on the **pleural surfaces** of the body, one on either side of each segment.
- Trachea are divided into very fine branches known as **tracheoles**.
- They **supply oxygen** to the body tissues.
- Trachea are fine elastic tubular structures and **ectodermal** in origin.
- Consist of cuticle, epidermis, basement membrane.
- But arranged in **reverse manner**, i.e. **basement membrane forms the outermost** coat of trachea.
  - The **inner cuticular lining forms the intima** inside.

![Diagram of tracheal system](image)

**Spiracle tracheae and tracheoles**
• ‘Taenidia’ - cuticular lining appear as a spiral thickening throughout the length trachea
• give support to the trachea without being collapsed when there is no air
• It consists of chitin, resilin in protein-chitin matrix.
• ramify into very fine branches known as ‘tracheoles’ about 0.1 – 1 µm in diameter
• formed in to cells called ‘tracheoblast’ or tracheolar end cell
• derived from epidermal cells, lining the trachea
• form a network over the visceral organs including the alimentary canal,
• become intracellular and supply oxygen directly to the tissues

The tracheal system is of 2 types
1. with functional spiracles is called the open tracheal system
2. with non-functional spiracles is called closed tracheal system
### Differences between trachea and tracheoles:

<table>
<thead>
<tr>
<th></th>
<th>Trachea</th>
<th>Tracheoles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>These are large tubes running from spiracles</td>
<td>Fine tubes arising <strong>distally</strong> from trachea</td>
</tr>
<tr>
<td>2</td>
<td>Taenidia <strong>present</strong></td>
<td><strong>Absent</strong></td>
</tr>
<tr>
<td>3</td>
<td>Intima layer is <strong>shed</strong> during moulting</td>
<td>Intima layer is <strong>retained</strong>, <strong>unchanged</strong> during moulting</td>
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<tr>
<td>4</td>
<td>Never become intracellular</td>
<td>Intracellular</td>
</tr>
<tr>
<td>5</td>
<td>The intima layer consist of protein – chitin matrix <strong>with resilin</strong></td>
<td>Chitin – protein matrix present, <strong>resilin absent</strong></td>
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</table>
Tracheal trunks

- Trachea coming from spiracles join with neighbouring ones form ‘longitudinal trunks’
- Trachea combine with others coming from dorsal, lateral and ventral sides of the body fuse to form transverse commissures and longitudinal connectives
- All these in total form into dorsal trunk, 2 lateral trunks and ventral trunk
- The dorsal trunk supply oxygen to proximal part of the body as well as to heart
- The ventral supplies to the central nervous system
- The two lateral longitudinal trunks spreads tracheoles to gut, legs, gonads and wings
- The head do not contain spiracles
- Air is supplied through the first pair of spiracles by two main branches of dorsal trunk
- One branch supply O2 to eyes, antenna, brain
- Other branch to mouthparts and muscles of the head

Diagramatic Representation of the Insect Tracheal System
• Spiracles: openings of the internal tubular trachea
• Except in Diplura, spiracles are **absent in prothorax** and distributed in meso, metathorax and abdomen
• A total of **10 pairs** are present in general, **2 pairs in thorax and 8 pairs in abdomen**
• Spiracles are situated on **pleural surface**
• Consists small ring like sclerite at opening, ‘**peritreme**’ leading to a cavity, ‘**atrium**’
• The closing and opening of spiracles is accompanied by **atrial valve**
• Lined with fibrous processes and form a felt chamber which reduces water loss

• In some **dipterans, coleopterans, lepidopterans**, spiracles consists of **sieve plate** containing large number of small apertures
• **Gas exchange** takes place and prevent entry of water especially in aquatic forms
• In **terrestrial insects**, water loss through spiracles is controlled by the **closing mechanism**
  consists of **one or two valves** or a **constriction** from the trachea or by muscular activity
• Hydrophobic nature of spiracles is also due to the presence of modified epidermal glands known as **peristigmatic glands**
• They secrete a **hydrophobe** material preventing the wetting of these organs
Classification of tracheal system

In most of the insects, **10 pairs of spiracles** are present based on number and arrangement of functional spiracles.

I. **Holopneustic**: primitive type with 2 pairs of spiracles on thorax and 8 pairs on abdomen.
   All the spiracles are functional
   \[1 + 1 + 8\]
   e.g. dragonflies, grasshoppers and cockroach

II. **Hemipneustic**: One or more pairs of spiracles become non-functional. They are
   a) **Peripneustic**: Metathoracic spiracle is closed
      \[1 + 0 + 8\]
      e.g.: larvae of Lepidoptera, Hymenoptera, Coleoptera
   b) **Amphipneustic**: Only mesothoracic and last pair of abdominal spiracles are open
      \[1 + 0 + 1\]
      e.g.: larva of cyclorrhaphan Diptera
   C) **Propneustic**: Only one pair i.e. mesothoracic spiracles are open
      \[1 + 0 + 0\]
      e.g.: mosquito pupa
   d) **Metapneustic**: Only last pair of abdominal spiracles are open
      \[0 + 0 + 1\]
      e.g.: mosquito larvae
   e) **Apneustic**: No functional spiracles
      e.g.: mayfly larva, nymph of Odonata

III. **Hypopneustic**: 1 or 2 pairs of spiracles may completely disappear or absent
    e.g.: Siphunculata, Mallophaga

IV. **Hyperpneustic**: More than 10 pairs of spiracles are present
    e.g.: Japyx sps. (dipluran)
Other types of respiration

1. Cutaneous respiration: through **body wall** e.g.: Protura, Collembola and endoparasites

2. Tracheal gills / abdominal gills: e.g.: larva of Trichoptera, nymphs of Ephemeroptera
   - outgrowths of the trachea in the form of gills
   - on the lateral sides of the body
   - Absorbs dissolved oxygen
   - vary in shape as lamellate or filamentous

3. Spiracular gills: E.g.: aquatic pupae
   - Peritreme or atrium is drawn out in to a long filament
   - adapted for both aquatic and aerial respiration
   - enables the insect to live in air, moist places, completely in water

4. Blood gills:
   - Tubular/digitiform or eversible structures at the anal end 4-6 in larva of Trichoptera
   - In chironomid larva, 2 pairs on penultimate segment and 4 shorter anal gills are present
   - Called blood gills as they contain blood but some times have trachea
   - absorption of water and inorganic ions rather than respiration
5. Rectal gills: e.g.: dragonfly nymphs (naids)
   - rectum modifies into a barrel-like chamber
   - rectal wall forms basal **thick pads** and distal **gill filaments**
   - which are richly supplied with **tracheoles**

6. Air sacs: e.g.: winged insects
   - **trachea dilated** to form thin walled air sacs
   - **do not contain the taenidia**
   - seen as glistening sac-like structures
   - function as **storage structures of air**
   - change their volume with respiratory movement

7. Plastron respiration: e.g.: aquatic beetles
   - special type of air store in the form of a **thin film**
   - held by a system of **hydrofuge** hairs, scales
   - **volume remains constant**
   - If there is adequate oxygen, it acts as a **physical gill**
   - The trachea opens into **plastron**