Dr. Bbosa Science

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Gaseous exchange

Whether aerobic or anaerobic respiration is occurring the constant passage to gases between organism and their environment has to be maintained. Aerobes require oxygen for oxidation of foodstuffs to release energy whilst aerobes and most anaerobe must expel carbon dioxide, a waste product of respiration. Exchange of carbon dioxide and oxygen between the environment and the organism is termed gaseous exchanges, and the area where gaseous exchange actually takes place is called the **respiratory surface.**

Adaptations of a respiratory surface.

- It must be **permeable,** so that gases can pass through.
- It must be **thin,** because diffusion is only efficient over distances of 1mm or less.
- It should possess **a large surface area** so that sufficient amounts of gases are able to be exchanged according to the organisms need.
- It must be **moist to ease diffusion** of gases across the respiratory surface.

In small animals, the surface to volume ratio is large enough for diffusion across the external surface to satisfy their respiratory need. But in larger animals, particularly active ones, the surface to volume ratio is too small for this to be so, and special **respiratory surface** has been developed.

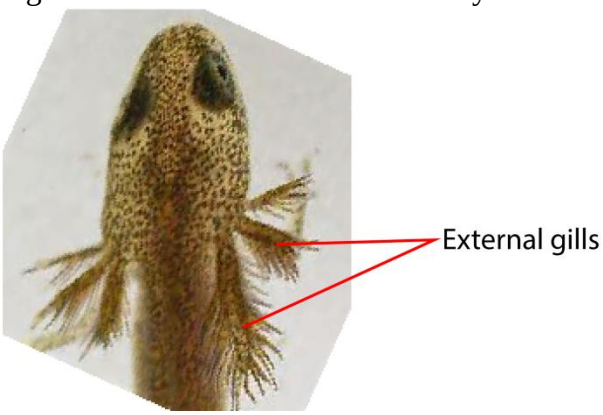
Specialised gaseous exchange surfaces

The specialised gaseous exchange surfaces provide large surface area by developing flaps, sac or tubes.

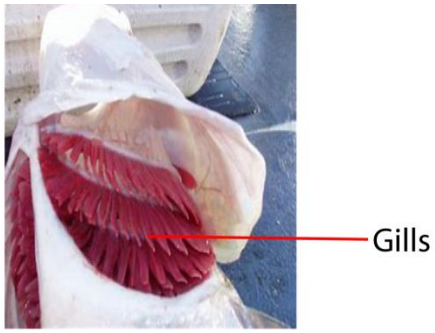
Examples

1. Body surface is usually sufficient gaseous exchange surface for small animals such as protozoa, earthworm, flatworms with larges surface-volume ratio.

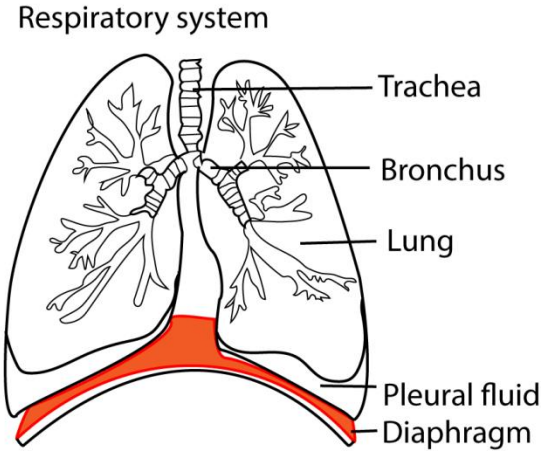
2. Aquatic organism such as Lung worm and tadpole use external gill which are epidermal outgrowth from the surface of the body



3. Fish use internal gills which are enclosed within the body and protected from damage.



4. Air-breaking vertebrates have developed **lungs** which develop as sac-like outgrowth of the pharynx in which air is brought close to the blood to allow gaseous exchange.

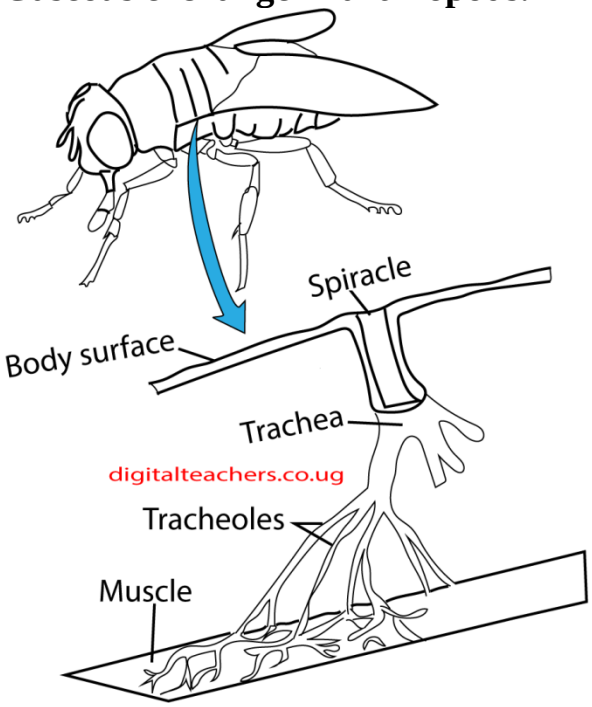


The biggest problem of gaseous exchange through by the lung is that energy is required for ventilation especially during inspiration and leads to water loss.

5. Insects have developed a tracheal system, penetrating and ramifying and delivering oxygen to tissue cell

6. The frog and other amphibians use the skin and buccal cavity in addition the lungs

Gaseous exchange in arthropods.



Gas exchange in insects takes place through **trachea**, the air tubes, which terminally branch in tracheoles. Each tracheole delivers oxygen and removes carbon dioxide from each cell. Air enters and leaves the tracheal system through the spiracles.

Some insects can ventilate the tracheal system with body movements.

Gaseous exchange then occurs directly between the air in the tracheoles and the tissues and blood is not required to carry the gases. Tracheoles lack chitin moreover the degree of their branching may be adjusted according to metabolic needs of individual tissues.

In some insects such as grasshopper are ventilated by rhythmic movements of the thorax and abdomen and in all flying insects, ventilation is aided by muscular movement during flight.

Adaptations of insects to effective gaseous exchange

- It has got tracheal system that ramify the whole body delivering oxygen to each cells.
- The extent of this ramification is adjusted to meet the tissues' need.
- Insects have control mechanism that supply the right amount of air to the cell as required from time to time.
- Insects are small and flattened to ease diffusion of gases.

Disadvantage of the tracheal system

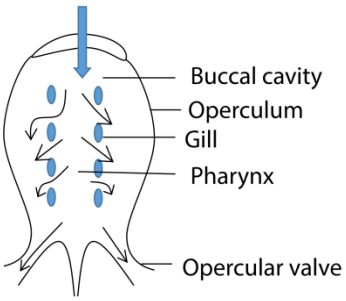
It limits the size of insect because it relies entirely on diffusion for the gases to move from environment to the respiring cells.

Gaseous exchange in Bony fish

Gaseous exchange between fish and water occurs over the gills located in opercular cavity which is enclosed by muscular flap, the operculum. Water is drawn into and pumped out of the pharynx by movement of the operculum

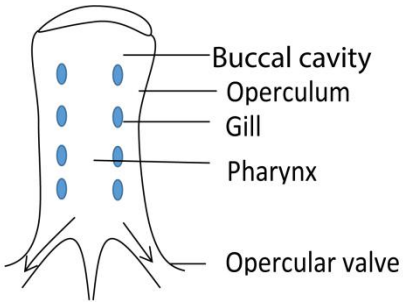
Inspiration

Water is sucked through the mouth by expansion of buccal cavity and then into the opercular cavity by outward movement of the operculum accompanied by contraction of the buccal cavity



Expiration

Water is expelled through the opercular opening by inward movement of operculum together with continued contraction of buccal cavity. The mouth closes and operculum valve opens.



As water passes over the gills, gaseous exchange (oxygen into blood and carbon dioxide outside) occur between water and blood. The ventilation cycle maintains a continuous stream of water over the gills at all times. This ensures their efficiency.

Adaptations of fish gill to gaseous exchange

1. Gills are red- rich blood supply
2. many tiny gill filaments increase surface area for gaseous exchange
3. Gill lamellae is flat to help increase their surface area for oxygen exchange
4. Water enters the mouth and comes out through operculum
5. Water passes over the gills
6. Epithelium covering gills is only one cell thick reducing diffusion gradient.
7. Gill filaments are protected from damage by operculum

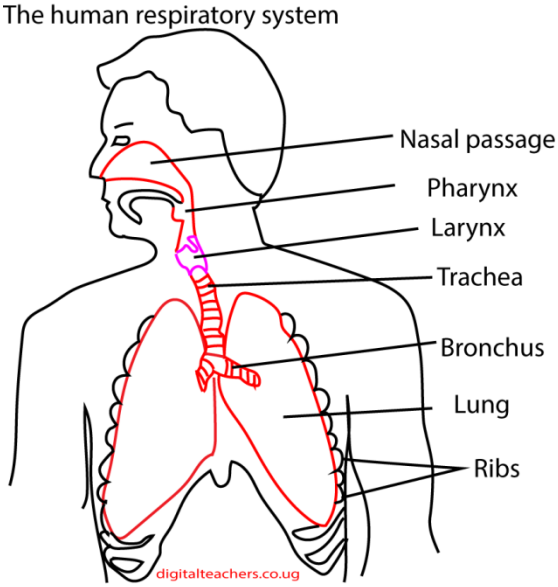
Gaseous exchange in amphibians.

A frog is able to exchange gases in three different ways

a. Through the skin by **cutaneous respiration**
b. Via the epithelium if the buccal cavity: **buccal respiration** and
c. In the lungs: **pulmonary respiration**.

Gaseous exchange in man

The human respiratory system



The human lungs and associated structure are shown in figure above. The **lungs** are situated in the **thorax,** the walls of which are formed by the **ribs** and **intercostal muscles** and the floor of the **diaphragm.** The lungs are surrounded by a very narrow **pleural cavity** lined by **pleural membranes.** The pleural cavity contains a thin layer of lubricating which allows the pleural membranes to slide easily over each other as the thorax expands and contracts during breathing.

Inspiration.

Air is drawn into the lungs via the **trachea** and bronchi**.**

1. External intercostal muscles contract and rise the ribs upwards and outwards.
2. The radial and circular muscles of the diaphragm contract and diaphragm flattens.

3. There is an increase in volume of the thoracic cavity and a decrease in pressure in the lungs.
4. Air is drawn into the lungs to equalise the pressure to atmospheric pressure.

Expiration.

- This is a reverse of the inspiration process; air being expelled from lungs.
- It is mainly a passive process resulting from elastic recoil of the tissues that have been stretched during inspiration.
- However, in forced breathing or when breathing tubes are blocked, expiration is aided by contraction of the internal intercostal muscles and **abdominal muscles.**
- Contraction of the latter raises the pressure in the abdominal cavity, forcing the diaphragm upwards.

- Comparison Chart inhalation and exhalation

BASIS FOR COMPARISON	INHALATION	EXHALATION
Meaning	Inhalation is the process of intake of air into lungs.	Exhalation is the process of letting air out from lungs.
Type of process	Inhalation is an active process.	Exhalation is a passive process.
The role of diaphragm	They contract during the inhalation and get flattens by moving down.	They relax during exhalation and turned into dome-shaped by moving up.
The role of intercostal muscle	Internal intercostal muscles relaxes and external costal muscles contract.	Internal intercostal muscles contract and external intercostal muscles relax.
The volume of lungs	It increases during inhalation means it get inflated.	It decreases during exhalation means it gets deflated.
The size of chest cavity	Increases.	Decreases.

BASIS FOR COMPARISON	INHALATION	EXHALATION
It results	Air rich in oxygen is taken into the blood.	Carbon dioxide is pushed out.
Effect of intercostal muscles	Due to the effect of intercostal muscles rib cage moves upward and outward.	Due to the effect of intercostal muscles the rib cage moves downward.
The composition of air	The air which is inhaled is oxygen and nitrogen mix.	The air which is exhaled is carbon dioxide and nitrogen mix.
Air pressure	Decrease in air pressure (below atmospheric pressure).	Increase in air pressure.

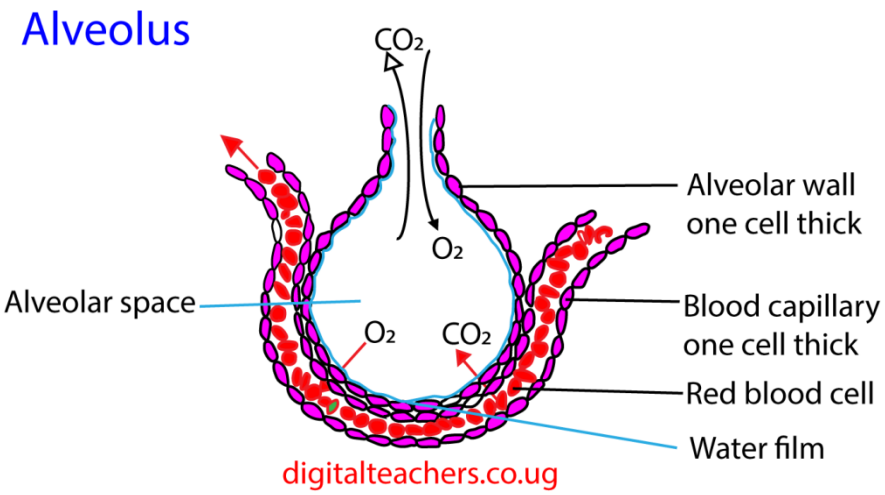
Alveoli.

Alveoli (singular alveolus) are numerous hollow, lobed air sacs that form the gaseous exchange surface in the lungs.

They occur at the terminal end of the tracheal branching and come in close association with extensive capillary system.

This makes them efficient apparatus for gaseous exchange.

Diagram of alveolus showing intimate association between alveoli and blood capillaries.



Adaptations of the alveolus to efficient gaseous exchange

1. They are very numerous that they offer a big surface area for gaseous exchange
2. Alveolar epithelium is covered internally with a thin layer of fluids in which oxygen dissolves before diffusing into the blood which create high diffusion gradient.
3. Alveolar fluid contains surfactants that prevent alveolar form collapsing
4. Alveolus is separated form blood capillaries by thin membrane that offer minimum resistance to diffusion of gases.
5. The blood capillaries of the alveolus are smaller than the red blood cells such that when cell squeeze through the capillaries, they make intimate contact with capillary membranes that ease gaseous diffusion.

Gaseous exchange in plants

Plants have numerous stomata (pore) on their leaves and on the green stems or if the stem are woody, through cracks in the bark and via lenticel.

These provide effective way of gaseous exchange in and out of the plant. H.P Brown and F. Escombe, discovered that a greater volume of gas will pass through numerous small holes in a given time than through a single hole of the same total area. This is because diffusion is faster at the perimeter than in the centre of a hole and the combined perimeter of tiny small holes is greater than the perimeter of a few large ones.

The stomata are therefore ideal for gaseous exchange.

Secondly the spongy mesophyll cell has large air spaces and thus little resistance to the air in the leaves. The opening and closing of stomata can be controlled as need arises.

Adaptation of animals to low oxygen tension

1. High haemoglobin concentration in blood
2. Have myoglobin that store oxygen

3. Fish e.g. trout store oxygen in swimming bladder
4. Have haemoglobin with high affinity for oxygen e.g. lungworm
5. Fish air breath: when oxygen in water is low fishes break the surface and trap air inside the mouth.
6. Decreased activities. Animals tend to be sluggish
7. Increased ventilation rate i.e. fast and deep breathing to reduce oxygen requirement
8. Aquatic surface respiration: fish stay on the surface leave snout at air water surface taking in water richer in oxygen.

Exercise

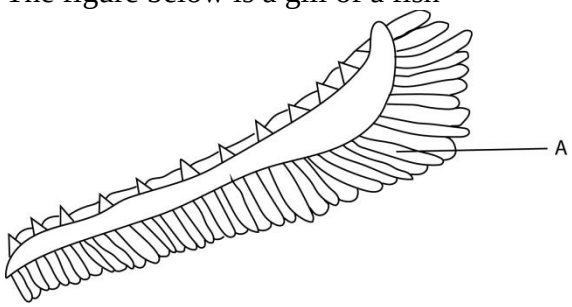
1. Which one of the following would be the immediate danger of fish when taken out of water?
   A. Drying out of gills
   B. Lack of oxygen around gills
   C. Reduced surface area for gaseous exchange
   D. Change in external temperature
2. Which one of the following does not occur when the buccal cavity contracts during breathing in fish?
   A. Mouth valve closes
   B. Opercular valve closes
   C. Mouth opens
   D. Opercular volume increases
3. Which of the following occur during expiration in human? The diaphragm
   A. Flatten and intercostal muscles contract
   B. Flatten and intercostal muscles relax
   C. Became dome shaped and intercostal muscles contract
   D. Became dome shaped and intercostal muscles relax
4. Which of the following statements is true of a person who lives at sea level compared to one who lives at high altitude? The one at sea level
   A. Breathes more slowly when both are at high altitude
   B. Has more blood vessels
   C. Breath faster when both are at high altitude
   D. Has more red blood cells
5. Which one of the following occurs during exhalation in an animal
   A. Diaphragm flattens
   B. Volume of the thorax increases
   C. External intercostal muscles relax
   D. Diaphragm contract
6. During gaseous exchange in fish, oxygen diffuses into the blood through the
   A. Operculum
   B. Gill rackers
   C. Gill filament
   D. Gill bar
7. The site of gaseous exchange in insect and mammals are
   A. Spiracles and lungs
   B. Trachea and bronchioles
   C. Tracheoles and alveoli
   D. Spiracles and trachea
8. Which one of the following structures adapts vertebrates to survive on land?
   A. Legs
   B. Wings
   C. Lungs
   D. Scales

9. Which of the following organisms does not transport oxygen by blood?
   A. Cockroach
   B. Frog
   C. Bird
   D. fish
10. Under which of the following conditions will air enter the mammalian lung? When the
   A. Pressure in the thorax is increased
   B. Ribs are lowered
   C. Diaphragm is raised
   D. Volume of the thorax is increased
11. Which one of the following is not used for gaseous exchange in amphibian?
   A. Lungs
   B. Skin
   C. Mouth
   D. Nostril
12. In plants, large surface area to volume ratio for gaseous exchange is achieved by
   A. Presence of numerous stomata on the eaves
   B. Flatness of leaves
   C. Presence of air spaces in the mesophyll
   D. Presence of lenticels
13. Which one of the following is a correct route taken by carbon dioxide from a body of cell of an insect to atmosphere?
   A. Trachea – Tracheoles – spiracles
   B. Spiracles – trachea – spiracles
   C. Tracheoles – trachea – spiracles
   D. Spiracles – Tracheoles – trachea
14. Which one of the following is not an adaption of a leaf for absorption of carbon dioxide?
   A. Its exposure in the air
   B. Presence of air spaces in the mesophyll layer
   C. Presence of chloroplast
   D. Presence of stomata
15. An insects' respiratory system consists of
   A. Trachea, Tracheoles and bronchioles
   B. Spiracles, trachea, Tracheoles
   C. Spiracles, trachea and bronchioles
   D. Trachea, bronchioles and Tracheoles
16. People living at high altitude have more red blood cells than those at lower altitudes in order to
   A. Breathe more quickly
   B. Keep the body warm
   C. Pump more blood
   D. Absorb enough oxygen

17. Which of the following is not a characteristic of a respiratory surface?
    A. Thin wall
    B. Moist surface
    C. Densely supplied with capillaries
    D. Rough surface
18. A good mammalian respiratory surface should be
    A. Dry with large surface area
    B. Moist with reduced surface area
    C. Dry with many blood vessels
    D. Moist with many blood vessels

19. In which of the following animals does expired air take a different route from that of inspired air
    A. Birds
    B. Reptiles
    C. Boy fish
    D. Mammals
20. Which of the following groups of animals uses gills, skin, buccal cavity and lungs for gaseous exchange at some stage in their life cycle?
    A. Fish
    B. Amphibians
    C. Reptiles
    D. Mammals

21. The figure below is a gill of a fish



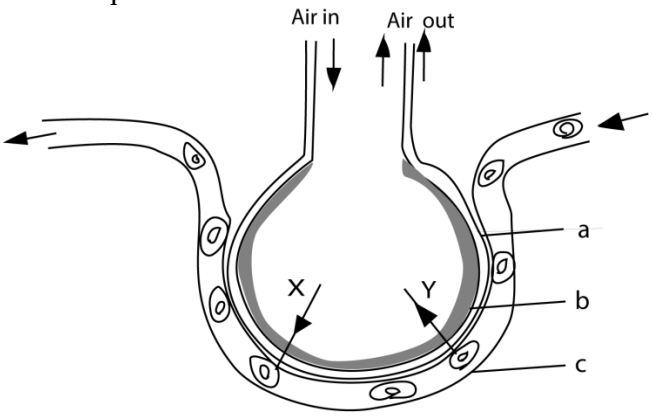
    The name and function of part labelled A is
    A. Gill filament for gaseous exchange
    B. Gill racker for filtering food
    C. Gill bar for support
    D. Gill arch for increasing surface area
22. Which of the following is adaptation of reptiles for terrestrial environment?
    A. Limbs
    B. Lungs
    C. Scales
    D. Elongated body

23. Which one of the following structures is not essential in the life of a tadpole
    A. Lungs
    B. Horny jaws
    C. Gills
    D. Tail

Structure questions

24. How does each of the following characteristics of a respiratory surface aid diffusion of gases at the surface
    (a) Thin epithelium
    (b) Dense network of capillaries
    (c) Moist surface
    (d) Large surface area

25. The figure below shows a structure in the mammalian lung, study the figure and use it to answer questions that follow:



    (a) Name
        (i) Parts a, b, and c. (1 ½ marks)
        (ii) Gases indicated by arrows x and y (01marks)
    (b) Explain how features shown in the figure, enable the structure to function efficiently (5 ½ marks)
    (c) State four differences between the air that goes into the structure and that which goes out of the structure (03mark)

26. (a) Explain how lungs are adapted to their functions as respiratory organs (10marks)
    (b) Explain why amoeba does not have respiratory system

27. (a) Describe inhalation and exhalation in a bony fish. (11 marks)
    (b) How is the respiration surface in fish adapted for it functions? (04marks)
28. (a) Describe the breathing mechanism in a bony fish (11marks)
    (b) How are gills in a bony fish adapted to their function? (04marks)
29. (a) outline the mechanism of
        (i) Inspiration
        (ii) Expiration in bony fish

(b) How are gills adapted for gaseous exchange in a bony fish?

30. (a) how does gaseous exchange take place in an insect
(b) How does gaseous exchange in insect differ from that of mammals?

Marking guide

1	D	6	C	11	D	16	D	21	A
2	B	7	C	12	A	17	D	22	B
3	D	8	C	13	C	18	D	23	A
4	C	9	A	14	C	19	C		
5	C	10	D	15	B	20	B		

24. (a) thin epithelium reduces diffusion distance increasing the rate of diffusion
(b) dense network of capillaries supply the alveolus with deoxygenated blood and carry away oxygenated blood maintaining diffusion gradient across the membrane
(c) moisture dissolves gases and builds big diffusion gradient across the membrane
(d) large surface are increases the probability of gases to diffuse across the membrane.

25. (a) (i) a – thin alveolar membrane
b – water film
c – blood capillary

(ii) x - oxygen
y – carbon dioxide

(b) - thin alveolar membrane allows easy diffusion
- water film dissolves gases and builds big diffusion gradient across the membrane it also contains surface active agent that prevents the alveoli from collapsing
- blood capillary supplies the alveolus with deoxygenated blood and carry away oxygenated blood maintaining diffusion gradient across the membrane

(c) Differences between inhaled air x and exhaled air y

Inhaled air x	Exhaled air y
Contains more oxygen	Contains less oxygen
Contains little carbon dioxide	Contains much carbon dioxide
Contains little water	Contain much water vapour
cold	warm

26. (a) adaptations of lung for gaseous exchange
(i) Lungs contain numerous air sacs called alveoli that increase surface are for gaseous surface.
(ii) Alveolar epithelium is covered internally with a thin layer of fluids in which oxygen dissolves before diffusing into the blood which create high diffusion gradient.
(iii) Alveolar fluid contains surfactants that prevent alveolar form collapsing

(iv) Alveolus is separated form blood capillaries by thin membrane that offer minimum resistance to diffusion of gases.

(v) The blood capillaries of the alveolus are smaller than the red blood cells such that when cell squeeze through the capillaries, they make intimate contact with capillary membranes that ease gaseous diffusion.

(b) Amoeba lacks a gaseous exchange surface because

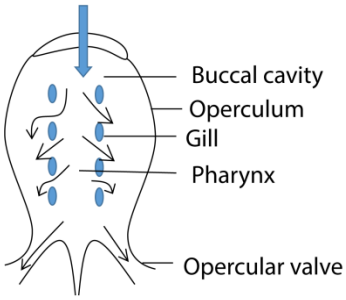
(i) has enough surface area to surface area to volume ratio to meet its gaseous exchange requirements

(ii) it is too small to carry gaseous exchange system

27, 28, 29 (a)

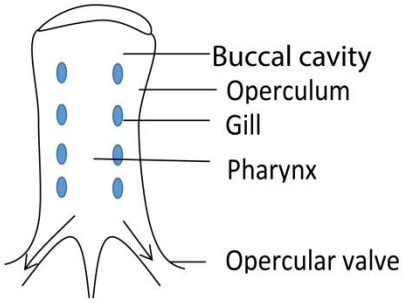
Inspiration

Water is sucked through the mouth by expansion of buccal cavity and then into the opercular cavity by outward movement of the operculum accompanied by contraction of the buccal cavity



Expiration

Water is expelled through the opercula opening by inward movement of operculum together with continued contraction of buccal cavity. The mouth closes and operculum valve opens.



27, 28, 29 (b) **Adaptations of fish gill to gaseous exchange**

(i) Gills are red- rich blood supply

(ii) many tiny gill filaments increase surface area for gaseous exchange

(iii) Gill lamellae is flat to help increase their surface area for oxygen exchange

(iv) Water enters the mouth and comes out through operculum

(v) Water passes over the gills

(vi) Epithelium covering gills is only one cell thick reducing diffusion gradient.

(vii) Gill filaments are protected from damage by operculum

31. (a) Gas exchange in insects takes place through **trachea**, the air tubes, which terminally branch in tracheoles. Each trachea delivers oxygen and removes carbon dioxide from each cell. Air enters and leaves the tracheal system through the spiracles. Some insects can ventilate the tracheal system with body movements.

(b) Difference between gaseous exchange in insect and that of mammals?

Insect circulation system	Mammal circulation
Oxygen delivered directly to cells	Oxygen is delivered by red blood cels
Has no blood pigment	Has blood pigment
Air enter through spiracles	Air enter through nose