



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.

Bigger animals, particularly active ones have small the surface to volume ratio which is inadequate to supply enough oxygen to satisfy their metabolic needs. They have overcome this problem developing special **respiratory surface** which increases efficiency of gaseous exchange. In addition, their blood contains respiratory pigment to increase oxygen carrying capacity of blood.

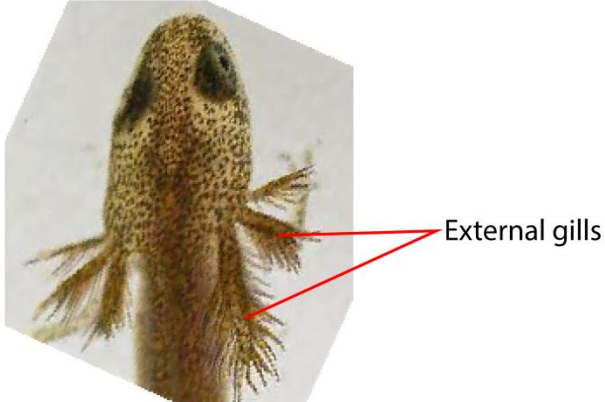
Specialised gaseous exchange surfaces

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

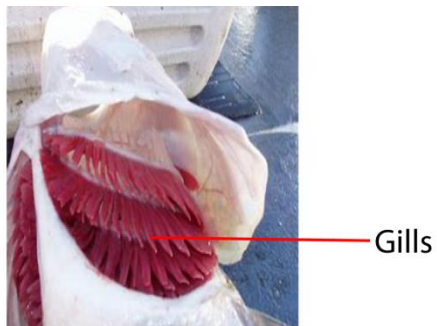
Examples

1. Body surface is usually sufficient gaseous exchange surface for small animals such as protozoa, earthworm, flatworms with large 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

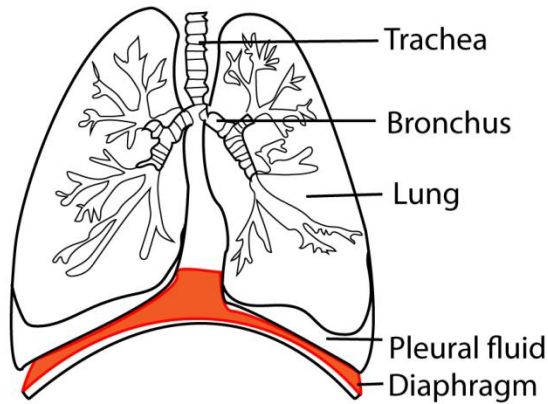


3. Fish use internal gills which are enclosed within the body and protected from damage.



4. Air-breathing 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.

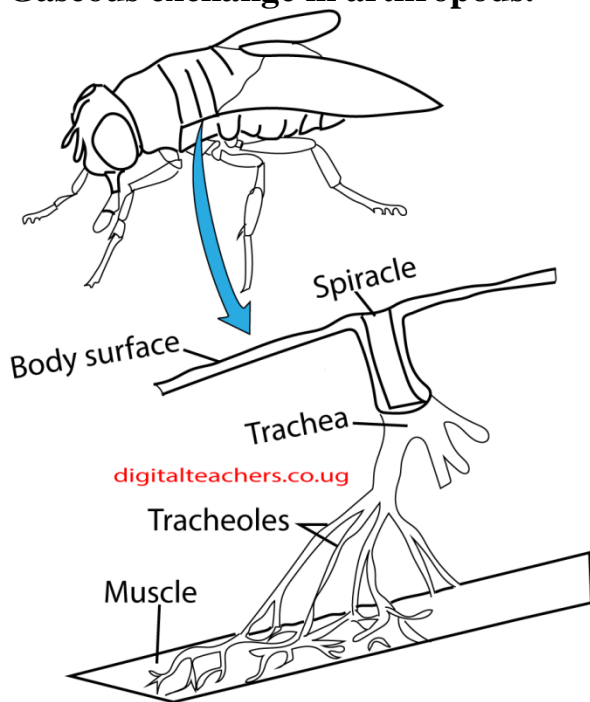
Respiratory system



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.

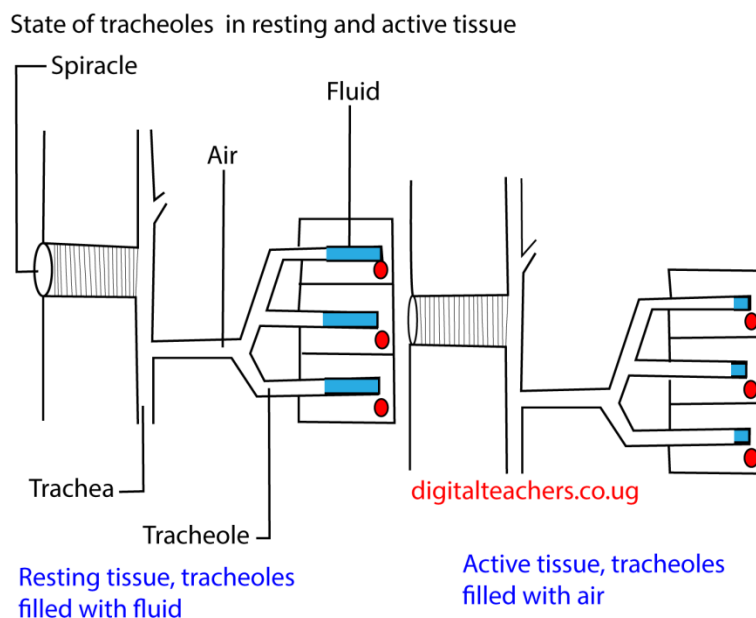
Gaseous exchange then occurs directly between the air in the tracheoles and the tissues and blood is not required to carry the gases. Tracheoles lack chitin moreover the degree of their branching may be adjusted according to metabolic needs of individual tissues.

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.

Control of ventilation rate in insects

Insects control the rate at which oxygen is delivered to the tissues by

1. Regulating the opening of the spiracles by the tiny muscles controlled by chemoreceptors. When the spiracles are open air enters the tracheal system and is able to reach the cells
2. The ends of tracheoles are fluid filled. At rest the tissues have a lower solute concentration than the fluid in tracheoles. As activity increases the muscles respire anaerobically and lactic acid accumulates. This raised the solute concentration of these cells above that of fluids in the tracheoles. Water therefore moves out of the tracheoles into the muscle cells by osmosis allowing more air to reach the cell. When the activity ceases the metabolites are oxidised, the solute concentration of the muscle is lowered and water re-enters the tracheoles reducing the amount of air reaching the cell.



3. Ventilation is increase 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

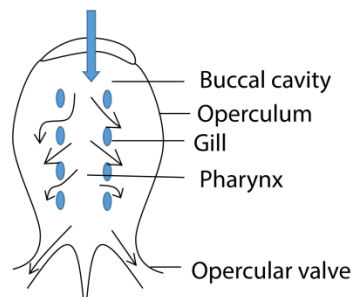
It limits the size of insect because it relies entirely on diffusion for the gases to move from environment to the respiring cells.

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

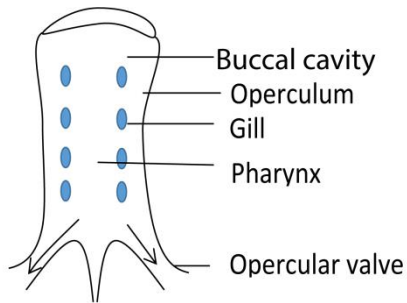
Inspiration

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.



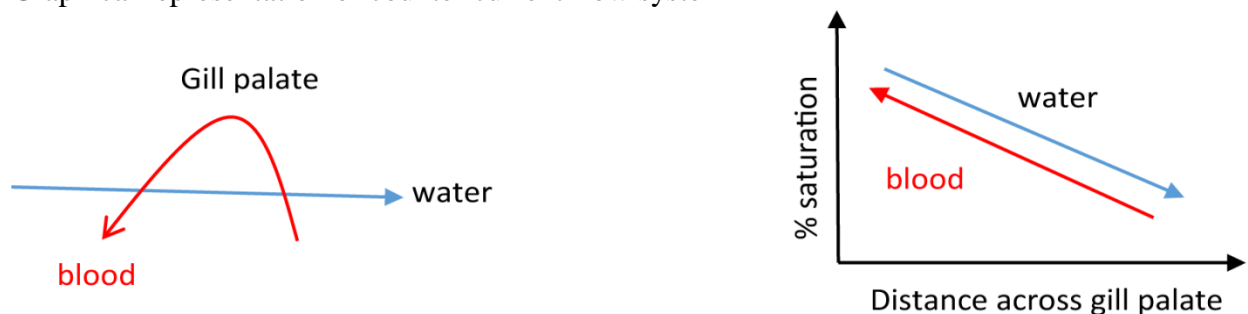
As water passes over the gills, gaseous exchange (oxygen into blood and carbon dioxide outside) occur between water and blood. The ventilation cycle maintains a continuous stream of water over the gills at all times. This ensures their efficiency.

The counter current flow system

This is a system developed by the fish in order to achieve maximum gaseous exchange. In this system blood and water flow in opposite direction along any gill lamellae. This means that as blood flows across the respiratory surface, it approaches water which has more and more oxygen available for exchange.

The advantage of counter current flow system is that a stiff diffusion gradient is maintained throughout the gaseous exchange surface.

Graphical representation of counter current flow system



Parallel flow system

Here water and blood flow in the same **direction at the same speed**. The concentration gradient will be great at first, however, it will steadily decrease as blood flow together with blood long the distance of the gill lamellae.



Parallel flow is not therefore a very efficient because blood leaves the gill less saturated than it would in the counter current flow. It can however be improved when the speed of water is faster than the speed of blood.

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

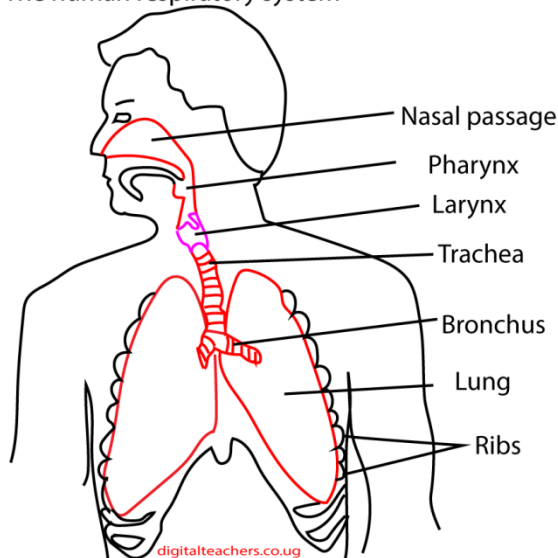
Gaseous exchange in amphibians.

A frog is able to exchange gases in three different ways

- a. Through the skin by **cutaneous respiration**
- b. Via the epithelium of 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.

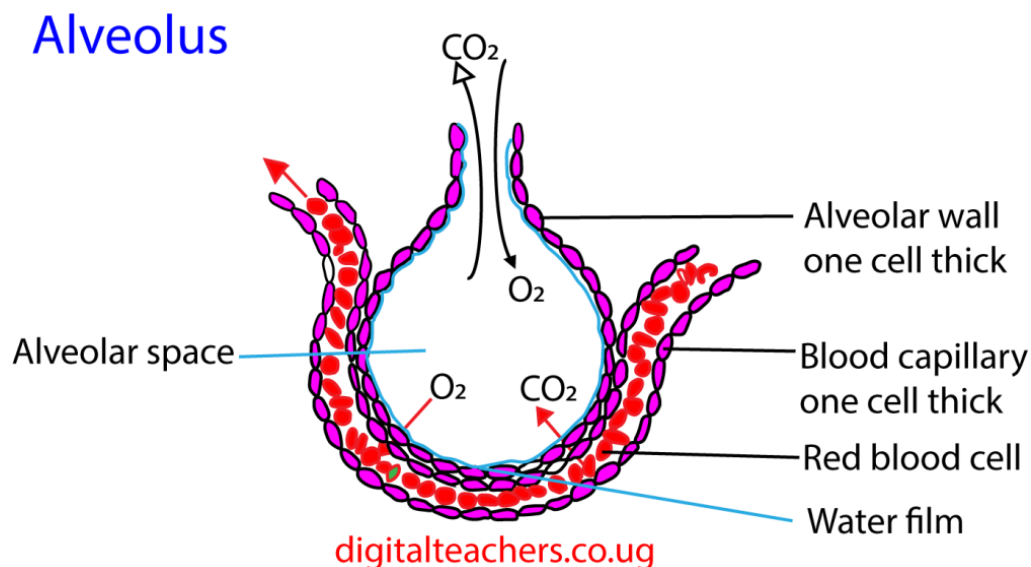
Alveoli.

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.

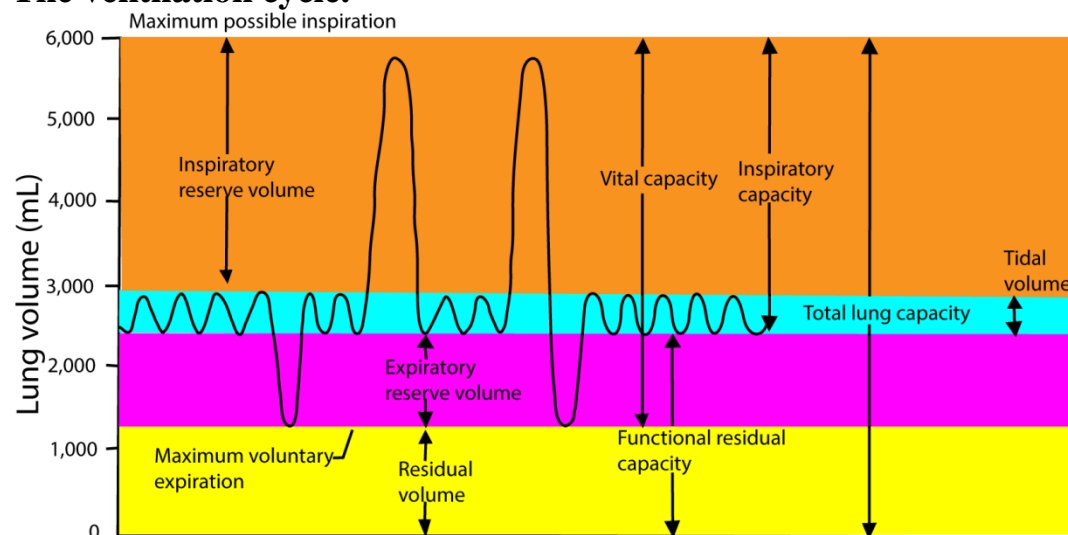
Diagram of alveolus showing intimate association between alveoli and blood capillaries.



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.

The ventilation cycle.



Pulmonary ventilation is accomplished by expansion and contraction of lungs.

Description of lung volumes

1. **tidal volume**; is the volume of air breathes in and out at rest. It about 0.5L.
2. **Ventilation rate**; is the volume of air breathed per minute. It can be obtained by multiplying the tidal volume with the number air is breathed in and out per minutes
3. **Inspiration reserve volume**; is the extra volume of air that can be inspired over and beyond the normal tidal volume, and it is usually equal to approximately 300ml in the young male adult.
4. **Expiratory reserve volume** is the amount of air that can still be expired by forced expiration after the end of a normal tidal expiration; this normally amounts to about 1100ml in young male adult.
5. **Residual volume**; is the volume of air remaining in the lungs even after the most forceful expiration. This volume averages about 1200ml in young male adult.
6. **Dead space**; this is the amount of air that remains in the tracheal and bronchioles. There is no gaseous exchange in the tube.

7. The **inspiratory capacity** equals the **tidal volume** plus the **inspiratory reserve volume**. This is the amount of air (about 3,500ml) that a person can breathe beginning at the normal expiratory level and distending his lungs to the maximum amount
8. The **functional residual capacity** equals the **expiratory reserve volume** plus the **residual volume**. This is the amount of air remaining in the lungs at the end of normal expiration (about 2300ml).
9. The **vital capacity** equals the **inspiratory reserve** volume plus the **tidal volume** plus the **expiratory reserve volume**. This is the maximum amount of air that a person can expel in the lungs after first filling his lungs to their maximum extent and then expiring to the maximum extent (about 4,600 ml).

The effect of fluctuation in oxygen and carbon dioxide

A deficient of oxygen (hypoxia) deprives the tissue of the vital requirement for metabolism. The consequence is that the sense organs are impaired, unconsciousness occurs suddenly, followed by paralysis and death.

Breathing pure oxygen at atmospheric pressure present no problems. However, if breathed at pressures greater than atmospheric as in diving, excess oxygen can be dangerous. At first, the tissues metabolise very rapidly, to keep pace with the oxygen supply. As the oxygen build up, however, it inhibits certain enzymes involved in the Krebs's cycle, the interfering with respiration.

Cells are more susceptible to changes in the levels of carbon dioxide. An accumulation of this gas increases the acidity of blood and tissue fluids, inhibits enzymes and stops essential metabolic process. This is why breathing air rich in carbon dioxide is very dangerous.

Control of lung ventilation

In human and other mammals, the overall control of ventilation involves a group of nerve cells comprising a ventilation centre in the posterior part of the brain called medulla oblongata.

The 'ventilation centre' responds to the levels of carbon dioxide and lesser extent oxygen in the blood stream.

If the partial pressure of carbon dioxide increases, the centre responds by increasing the ventilation rate and vice versa.

The partial pressure is detected by chemoreceptors found between the internal and external carotid arteries on each side of the neck where they form the carotid bodies and aortic bodies in the walls of the aorta close to the heart.

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

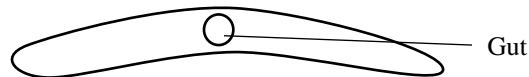
1. High haemoglobin concentration in blood
2. Have myoglobin that store oxygen
3. Fish e.g. trout store oxygen in swimming bladder
4. Have haemoglobin with high affinity for oxygen e.g. lungworm
5. Fish air breath: when oxygen in water is low fishes break the surface and trap air inside the mouth.
6. 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

- Which one of the following would be the immediate danger of fish when taken out of water?
 - Drying out of gills
 - Lack of oxygen around gills
 - Reduced surface area for gaseous exchange
 - Change in external temperature
- Which one of the following does not occur when the buccal cavity contracts during breathing in fish?
 - Mouth valve closes
 - Opercular valve closes
 - Mouth opens
 - Opercular volume increases
- Counter current flow in bony fish achieves a high level of gaseous exchange because
 - Increase in concentration gradient
 - Decreases the distance across which gases diffuse
 - Increase the speed of water flow over the gills
 - Maintains a high concentration gradient.
- The disadvantage of parallel flow system during gaseous exchange in some fish is the
 - Slow speed of blood
 - Low blood volume
 - Low oxygen uptake by blood
 - Low water volume over the gill
- The air that remain in the lungs after maximum expiration is known as the
 - Dead air space
 - Residual air
 - Vital capacity
 - Expiratory reserve volume.
- Men going up into space carry breathing kits similarly men into deep water carry breathing kits. What is the difference in the contents between divers and space men's kits.
 - There is no difference
 - Kits for spacemen have oxygen and nitrogen in equal quantities
 - Kits for divers contains much less oxygen than is found in the air.
 - Kits for spacemen's have more nitrogen than those for dive
- Which one of the following is a respiratory surface for mammalian foetus?
 - Alveolus
 - Placenta
 - Chorionic villi
 - Amnion
- Which one of the following is correct about the counter current mechanism in teleosts?
 - Blood with low oxygen concentration flows in the same direction with water of high oxygen concentration
 - Water of low oxygen concentration flows near blood of high oxygen concentration
 - Blood with high oxygen concentration flows in opposite direction to water of high oxygen concentration

- D. Water of high oxygen concentration flows in opposite direction to blood of low oxygen concentration.
9. Cartilaginous fish extract less oxygen from water than bony fish because the former
- A. Live in sea water
 - B. Are relatively bigger in size
 - C. Employ parallel flow system of gaseous exchange
 - D. Possess large gills with small surface area to volume ratio.
10. A cockroach has a respiratory system while an earthworm does not because
- A. Earthworm do not need much oxygen
 - B. The surface area volume ratio of a cockroach is small
 - C. Earthworm is parasitic
 - D. The respiratory system provides shape in a cockroach.
11. An organism living in an oxygen deficient environment has
- A. Haemoglobin that easily picks oxygen
 - B. Its oxygen dissociation curve lies to the right
 - C. Haemoglobin easily releases oxygen
 - D. Haemoglobin that less readily picks up oxygen
12. Which one of the following pairs of adjustment at a respiratory surface would increase its efficiency?
- A. Decreasing the rate of ventilation and increasing blood supply
 - B. Increasing the rate of blood flow and the rate of ventilation
 - C. Increasing the rate of ventilation and distance of diffusion of molecules
 - D. Decreasing the blood supply and the distance of diffusion of molecules.
13. Which of the following is a disadvantage of a trachea system for gaseous exchange in insects?
- A. Ventilation is limited
 - B. Tracheoles are impermeable
 - C. Spiracles are too small
 - D. The system does not supply all the body parts
14. In higher plants, the problem of obtaining oxygen for respiration is solved by leaves possessing
- A. Large intercellular space
 - B. Compact palisade layer
 - C. Thin lower epidermis
 - D. Numerous stomata on lower epidermis
15. Which of the following animals have the most efficient system of gaseous exchange?
- A. Insects
 - B. Bony fish
 - C. Mammal
 - D. Amphibians
16. The increase in supply of blood in heavily respiring tissues, is caused by high
- A. Ventilation rate
 - B. Concentration of oxygen in the inhaled air
 - C. Carbon dioxide concentration in blood
 - D. Carbon dioxide concentration in the tissues

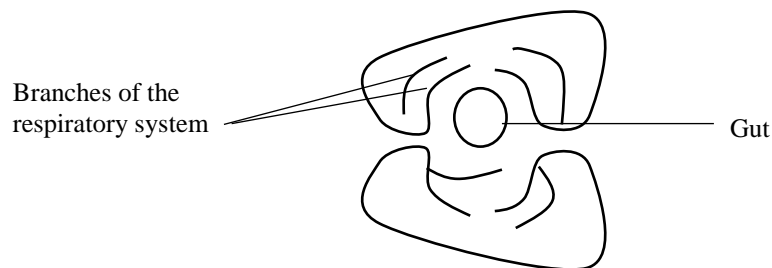
17. Which one of the following may act as a respiratory surface in animals?
- Spiracles
 - Bronchus
 - Skin
 - Trachea
18. Contraction of the intercostal muscles results into
- Increased pressure in the chest cavity
 - Ribs moving inwards and downwards
 - Increased volume of the chest cavity
 - Flattening of the diaphragm
19. The circulatory system in insects plays a role in all the following body system except
- Excretory
 - Respiratory
 - Digestive
 - reproductive
20. Which one of the following blood conditions would cause the least ventilation rate in human?
- Low carbon dioxide and high oxygen concentrations
 - High carbon dioxide and oxygen concentration
 - Low carbon dioxide and oxygen concentrations
 - High carbon dioxide and low oxygen concentrations.
21. The figure below shows a cross section of an organism



Which of the following means of gaseous exchange would be most suitable for the organism?

- Diffusion over the body
 - Use of trachea
 - Use of lungs
 - Use of gills
22. Which of the following would be the immediate danger to a fish taken out of water?
- Drying out of gills
 - Lack of oxygen around the gills
 - Reduced surface area for gaseous exchange
 - Change in external temperature
23. Many small animals use their skin as the only respiratory organ because they
- Are too small to have other respiratory organs
 - Have large surface area to volume ration
 - Use less energy and therefore use less oxygen
 - Are less active than big animals

24. Climbing the Rwenzori mountain rapidly may result in altitude sickness. This is will be due to
- Reduced partial pressure of oxygen in the air
 - Reduced quantities of haemoglobin in erythrocytes
 - Nitrogen bubbles forming in the blood stream
 - Increased carbon dioxide content of the blood.
25. One problem faced by terrestrial organism with lungs is that
- Breathing requires much energy
 - Oxygen diffuses very slowly in the air
 - Gas exchange involves water loss
 - Lung are deep in the chest thus increasing diffusion distance
26. Which one of the following would be the immediate problem to fish when taken out of water?
- Insufficient oxygen supply
 - Lack of support
 - Drying of gills
 - Lack of food
27. Which one of the following activities would decrease the ventilation rate in mammalian lung?
- Secretion of adrenaline into the blood
 - Accumulation of lactic acid in the body
 - Increase in the level of glucose in the blood
 - Increase in the production of acetylcholine in the body
28. Which one is the use of respiratory system of an organism whose section is shown in the figures below



The system requires

- A transport and ventilation mechanism
 - Ventilation mechanism and no transport system
 - A transport system and no ventilation mechanism
 - Neither transport mechanism nor a ventilation mechanism
29. Which one of the following concentration in blood would produce the highest frequency of impulses from the carotid nerve?
- Low carbon dioxide and high oxygen
 - High carbon dioxide and high oxygen
 - Low carbon dioxide and low oxygen

- D. High carbon dioxide and low oxygen
30. 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. Opercular volume increases
 - D. Mouth opens.
31. Which of the following features is not essential for gaseous exchange in lungs?
- A. Pleural fluid
 - B. Dense network of capillaries
 - C. Thin epithelium
 - D. Presence of moisture
32. Which of the following event will immediately result in an increase in ventilation rate?
- A. Increased level of oxygen
 - B. Increased levels of carbon dioxide
 - C. Accumulation of lactic acid in the body
 - D. Increased levels of oxygen and carbon dioxide
33. Possession of lungs in amphibian is an adaptation to live
- A. Both in water and land
 - B. In moist area
 - C. On dry land
 - D. In water
34. Which of the following events will cause inspiration in humans?
- A. Internal intercostal muscles and diaphragm contract
 - B. External intercostal muscles contract and diaphragm relax
 - C. Internal intercostal muscles relax and diaphragm contract.
 - D. External intercostal muscles contract and diaphragm contract
35. Which one of the following pairs of events occur together to increase the oxygen concentration in the alveoli of the lungs?
- A. Contraction of diaphragm muscles and internal intercostal muscle
 - B. Relaxation of diaphragm muscle and internal intercoastal muscle
 - C. Contraction of the diaphragm muscle and external intercostal muscle
 - D. Relaxation of the diaphragm muscles and external intercostal muscles
36. The disadvantage of parallel flow system during gaseous exchange in some fish is the
- A. Slow speed of blood
 - B. Low blood volume
 - C. Low oxygen uptake by blood
 - D. Low water volume over the gills
37. Which of the following events will cause inspiration in human?
- A. Internal intercostal muscle and diaphragm contract
 - B. Internal intercostal muscles and diaphragm relax
 - C. Internal intercostal muscles relax and diaphragm contract
 - D. Internal intercostal muscles contract and the diaphragm assumes a dome shape

38. Which one of the following is **not** correct about parallel flow of water across the gills?
- A. Water has a higher oxygen concentration at each point of contact
 - B. Low oxygen concentration is attained
 - C. Diffusion occurs over the whole region of the gill filament
 - D. High blood oxygen concentration is achieved.
39. The following are characteristics of amphibian
- (i) Have moist skin
 - (ii) Carry out external fertilization
 - (iii) Use gills at early for respiration
 - (iv) Use lungs for respiration
- Which of the following pairs of characteristics limit them from inhabiting a totally terrestrial environment?
- A. (i) and (ii)
 - B. (ii) and (iii)
 - C. (iii) and (iv)
 - D. (i) and (iv)
40. Which one of the following activities would decrease the ventilation rate in mammalian lungs?
- A. Secretion of adrenaline into the blood
 - B. Accumulation of lactic acid in the body
 - C. Increase in the level of glucose in blood
 - D. Increase in the production of acetylcholine in the body
41. Which of the following conditions in the human blood would stimulate the highest rates of ventilation and heart beat?
- A. Little carbon dioxide
 - B. Little oxygen
 - C. Much carbon dioxide
 - D. Much oxygen
42. Which part of the brain is responsible for controlling breathing in mammals?
- A. Thalamus
 - B. Pineal body
 - C. Medulla oblongata
 - D. cerebellum
43. Changes in the level of carbon dioxide in mammalian blood is detected by the
- A. Carotid and aortic bodies
 - B. Medulla oblongata
 - C. Cardio-vascular centres
 - D. Hypothalamus
44. Which of the following are adaptations of reptile for terrestrial environment?
- A. Lungs and shelled eggs
 - B. Lungs and scales
 - C. Ability to regulate body temperature and body shape
 - D. Ability to climb trees and lack of parental care.

45. Which of the following change may lead to increase in lung pressure in man?
- (i) Contraction of abdominal muscles
 - (ii) Relaxation of outer intercostal muscle
 - (iii) Contraction of the diaphragm
 - (iv) Relaxation of inner intercostal muscle
- A. (i) and (ii)
 - B. (i) and (iii)
 - C. (iii) and (iv)
 - D. (ii) and (iv)
46. Contraction of intercostal muscles in mammals to cause inspiration is comparable to
- A. Contraction of muscles of the buccal cavity in fish to cause water uptake
 - B. Contraction of circular muscles in insect during inspiration
 - C. Swelling of the guard cell in green plants during oxygen uptake
 - D. Opening of operculum in fishes
47. Which of the following is adaptation of fish to water?
- A. Lungs and gills
 - B. Body shape and gills
 - C. Lungs and body shape
 - D. Fins and scales
48. Men going up the space carry breathing kits, similarly men into deep water carry breathing kits. What is the difference in the contents between divers and spacemen's kits?
- A. There is no difference
 - B. Kits for spacemen have oxygen and nitrogen in equal quantities
 - C. Kits for divers contain much less oxygen than found in air
 - D. Kits for spacemen has more nitrogen than those of divers
49. Most of the carbon dioxide from human tissue travel to the lungs in form of
- A. Carbon dioxide solution
 - B. Bicarbonate ion HCO_3^- , H^+
 - C. Carboxy haemoglobin
 - D. Carbonic acid
50. Which of the following normally lowers the rate of heart beat?
- A. Secretion of adrenaline
 - B. Anaerobic respiration
 - C. Blood O_2 content becoming high and CO_2 low
 - D. O_2 content in blood becoming low and CO_2 high
51. A grasshopper whose head is completely immersed in water for an hour may not die because
- A. It does not drink water
 - B. Water contain enough nutrients on which it feeds
 - C. It continues absorbing oxygen required for its respiratory needs from water
 - D. The spiracles are still in position to perform their functions.

52. The factor which tropical forests do not compete for
- Carbon dioxide
 - Mineral salts
 - Light
 - Water
53. The air that remain in the lungs after maximum expiration is known as
- Dead space
 - Residual air
 - Vital capacity
 - Expiratory reserve volume
54. Which of the following structures is a gaseous exchange surface?
- Trachea
 - Tracheoles
 - bronchus
 - Bronchiole
55. In human, inhalation is stimulated by
- The carbon dioxide content in blood
 - Lack of oxygen in the blood
 - Stimuli from the carotid body
 - Stimuli from carotid sinus
56. During an exercise, the breathing rate of an individual was 20 breaths per minute while the tidal volume was 0.5dm^3 . The ventilation rate in $\text{dm}^3 \text{ minute}^{-1}$ of the individual during the exercise was:
- 40
 - 20.5
 - 19.5
 - 10

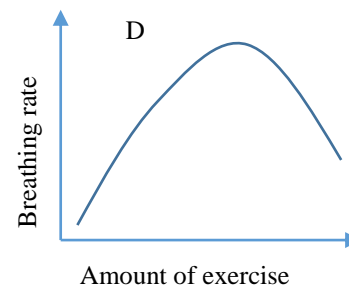
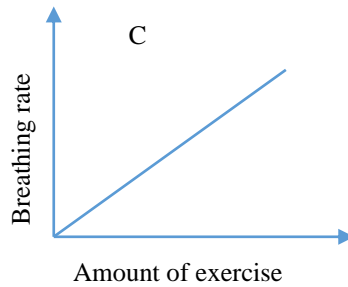
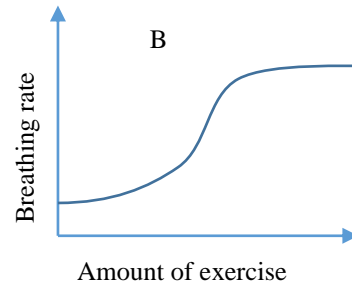
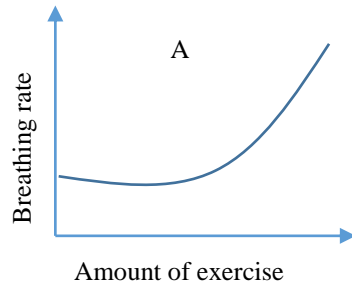
57. The table below shows the rate of breathing and volume of air exchanged with each breath for a person at rest and during exercise

State of individual	Breath per minute	Volume of each breath (cm^3)
Rest	12	500
During exercise	24	1000

The increase in volume of air exchanged per minute when an individual does exercise from rest is

- 500cm^3
- 600cm^3
- 15000cm^3
- 18000cm^3

58. Which of the following curves in the figures below correctly represent the breathing rate of an athlete under increasing sustainable exercise?



59. The volume and surface area of four animals A, B, C, and D are shown in the following table

Animal	Volume cm^3	Surface area cm^2
A	1	6
B	8	24
C	64	96
D	64	28

Which of the organism would most need a specialised respiratory surface?

60. Which one of the following would be the effect of increasing the partial pressure of carbon dioxide in the blood?

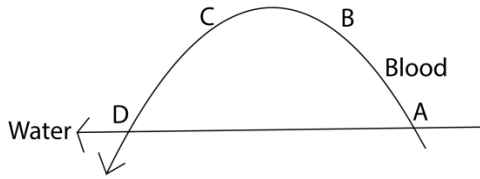
- A. Increase in the ventilation rate
- B. Variation of ventilation rate
- C. Reduction in ventilation rate
- D. Cessation of ventilation

61. Which one of the following is the role of capillary network around the alveoli in mammals?

- A. Makes alveoli more permeable
- B. Increase surface area of alveoli

- C. Maintains a steep diffusion gradient
- D. Makes the alveoli cell thinner

62. The figure below shows parallel flow across a gill in a fish



Which one of the points on the figure would have the highest diffusion gradient?

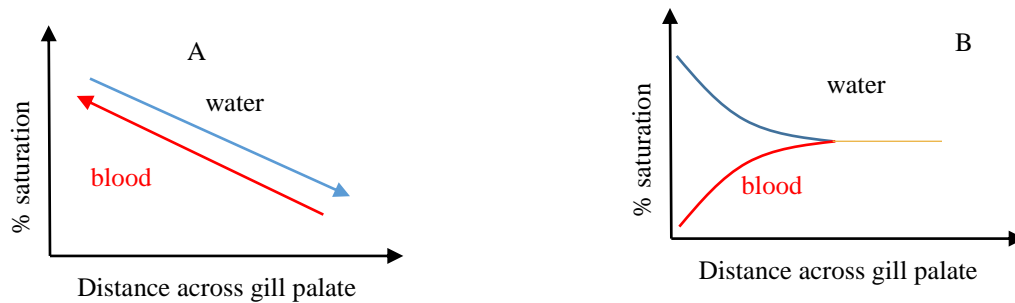
Paper 1 Section B:

63. Explain the following

- (i) Breathing in pure oxygen at higher pressure than atmospheric is dangerous? (4marks)
- (ii) Breathing in air rich in carbon dioxide is dangerous (3marks)

(b) outline three adaptations of animals that live in environment of low oxygen tensions (3marks)

64. The figure below illustrates two different mechanisms of gaseous exchange in fish A and B



(a) State two differences between the two systems of oxygen concentration (2marks)

.....

.....

.....

(b) Explain the physiological advantage of fish A over B(2marks)

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.....

.....

(c) Describe how a gill is structurally adapted as a respiratory surface (4marks)

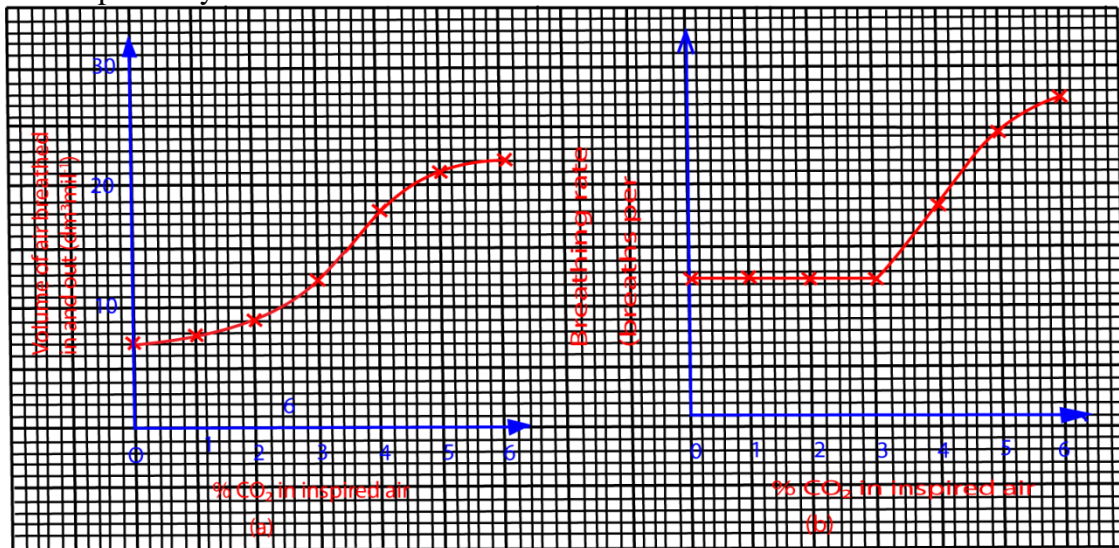
Assay questions

Paper 2

65. (2008/2/1) The table show percentage by volume of some gases in inspired air, expired air and alveolar air, in a resting human being

Gas	Percentage volume (%)		
	Inspired	Expired	Alveolar
Oxygen	20.90	15.30	13.39
Nitrogen	78.60	74.90	No data
Carbon dioxide	0.03	3.60	4.90
Water vapor	0.47	6.20	No data

The figure 1 (a) and (b) show effects of increasing carbon dioxide concentration in inspired air, on the volume of air breathed in and out per minute and on the breathing rate respectively.

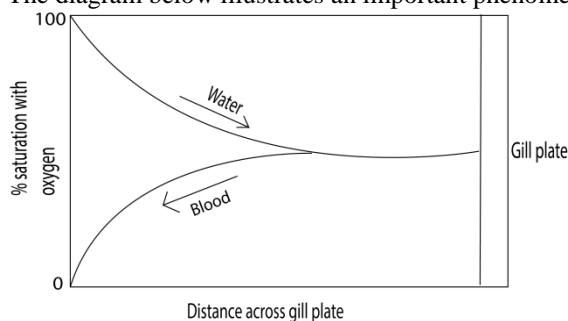


- (a) Explain why
- the percentage volume of oxygen in expired air is intermediate between the inspired and alveolar values. (4marks)
 - There is a difference in the percentage volume of nitrogen between inspired and expired air (4marks)
- (b) (i) Using the information in figure 1, calculate the mean volumes of a single breath in and out at different carbon dioxide concentration in inspired air, indicated in table 2 (3 ½ marks)

Table 2

Percentage concentration of CO ₂ in inspired air	0	1	2	3	4	5	6
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- (ii) Plot a graph showing the mean volume of a single breath against concentration of carbon dioxide in inspired air. (5 ½ marks)
- (c) Describe the effect of increase in carbon dioxide concentration in inspired air on
- Volume of air breathed in and out per minute (03marks)
 - Breathing rate (3marks)
 - Mean volume of a single breath in and out (3marks)
- (d) Explain the effect of increase in carbon dioxide concentration in inspired air on
- Volume of air breathed in and out per minute (02marks)
 - Breathing rate (02marks)
 - Mean volume of a single breath in and out (02marks)
- (e) Outline the physiological effects in the body, of breathing in excess
- Carbon dioxide (04marks)
 - Oxygen (04marks)
66. Giving examples in each case, explain how large surface area: volume ratio, has been achieved in organisms, for exchange of gases and food material.
67. (a) What are the qualities of respiratory surface
(b) how is each of the following organism adapted for efficient gaseous exchange
- insect
 - a terrestrial flowering plant
 - An amoeba
68. (a) What is meant by the term lung ventilation?
(b) Describe how lung ventilation and heart rate can be increased or decreases.
69. (a) Outline the various kinds of respiratory surfaces in animals.
(b) Describe the site of gaseous exchange in human
70. The diagram below illustrates an important phenomenon in gaseous exchange in bony fish such as tilapia.



- (a) (i) what phenomenon is illustrated
(ii) what advantage does this phenomenon have for the fish.
(iii) How is the advantage you have mentioned is achieved
(iv) What happened if water and blood flowed in the same direction and at the same speed?
(v) How could the arrangement be improved for benefit of the fish?
(vi) What is the relationship between the distance across the gill plate and percentage saturation with oxygen of this blood
(vii) Comment on the speed and oxygen capacity of blood and water at 50% saturation of blood.
- (b) Briefly describe the mechanism of drawing water over the gills in a gill fish
71. (a) Explain the need for special respiratory surface and transport system pigment in higher animals
(b) How is gaseous exchange occurring adequately in higher animals?
72. (a) (i) discuss the factors that affect the rate of diffusion at respiratory surface (6marks)
(ii) How are the conditions for efficient gaseous exchange fulfilled in mammalian lungs (8marks)
(b) the diameter of a capillary is smaller than the diameter of a red blood cell passing through them. How does this relationship help in gaseous exchange in the lungs? (6marks)
73. Explain
- the need for special respiratory surfaces and transport system pigment in higher animals (10marks)
 - how gaseous exchange occurs adequately in higher plants without transport system pigments.

74. (1988/2/5) (a) How are gaseous exchange surfaces adapted in terrestrial mammal
(b) Give an account for the gaseous exchange mechanism in a bony fish such as tilapia.
(c) How do these mechanisms differ from those of terrestrial mammals?

Answers to objective type questions

1	C	21	A	41	C	61	C		
2	C	22	C	42	C	62	A		
3	D	23	B	43	A				
4	C	24	A	44	B				
5	B	25	A	45	A				
6	C	26	A	46	C				
7	B	27	D	47	B				
8	D	28	B	48	C				
9	C	29	D	49	B				
10	B	30	D	50	C				
11	A	31	A	51	D				
12	B	32	B	52	A				
13	A	33	C	53	B				
14	D	34	C	54	B				
15	D	35	C	55	A				
16	D	36	C	56	D				
17	C	37	C	57	D				
18	C	38	D	58	B				
19	B	39	B	59	D				
20	A	40	D	60	A				

63. (a) Explain the following

- (i) Breathing in pure oxygen at higher pressures than atmospheric is dangerous
- (ii) Breathing in air rich in carbon dioxide is dangerous.

(b). Outline three adaptations of animals that live in environments of low oxygen tension

Solution

(a) (i) The tissue metabolizes rapidly at first to keep with the oxygen supply. As oxygen builds up, it inhibits certain enzymes involved in the Krebs cycle, thus interfering with cell respiration. This often leads to muscle twitching followed by impaired vision breathing difficulties. Confusion and lack of coordination and finally convulsion and death.

- (i) It increases the acidity of the blood and tissue fluids, inhibiting enzymes and stopping essential metabolic processes.

It also reduces the affinity of haemoglobin for oxygen so that little oxygen is delivered to the tissue from the lungs

Accumulation of carbon dioxide also interferes with respiration at the cellular level by inhibiting respiratory enzymes.

This may eventually cause tissue death as a result of lack of enough oxygen

(b) Adaption of animals that live in environments of low oxygen tensions include

- Increased affinity of their haemoglobin for oxygen.
- Increased haemoglobin concentration in their blood.
- Increased number of red blood cells in their blood.

Other

- Increased force and rate of heart contraction.
- Increased rate of breathing.

64. Solution

(a) Differences

Fish A	Fish B
-oxygen concentration of blood is above 50% at the end of the gill plate.	-oxygen concentration of the blood is about 50% at the end of the gill plate.
- water always has a higher oxygen concentration than blood	Initially water has a higher oxygen concentration, but at the end of the gill plate, the oxygen concentration blood and water are the same.
Other	Oxygen concentration of the blood increase first rapidly then decreases gradually and reaches a constant value at 50%
Oxygen concentration of the blood increase linearly along the gill plate.	

(b) Fish A maximizes gaseous exchange than fish B

Fish A maintains a steep concentration gradient between the water and blood that the fish picks up enough oxygen from the water and deposits sufficient quantities of excess carbon dioxide in it.

(c) Highly folded into filaments to increase surface area gaseous exchange

- It is covered with a thin highly permeable membrane to reduce the diffusion distance.
- It has a rich blood to increase the efficiency of gaseous exchange.
- It's wet in order to increase the chance of picking up gases readily dissolved in the moisture.
- Numerous filaments increase the surface area

65. Solution

(a) (i) The amount of oxygen in inspired air is equivalent to that in atmospheric.

- Some oxygen in inspired air is absorbed into the blood stream in the alveoli thus alveolar air contains less oxygen than inspired air.
- During transit, some air does not reach the respiratory surface in the alveoli. It is trapped in the respiratory air ways (inspired) air.
- The air expelled from the alveoli mixes with the air in the dead spaces, this increases the oxygen content in expired air to a value above alveolar air though less than atmospheric (inspired) air.

(ii) Percentage composition of a particular gas in the air depends on the number and amount of components in the air.

Although nitrogen is not used in the body and does not take part in the gaseous exchange, its percentage in the inspired air is greater than in expired air. This is because expired air contains an increased amount of components such as water vapour and carbon dioxide. This reduces the proportion per unit volume occupied by nitrogen in expired air.

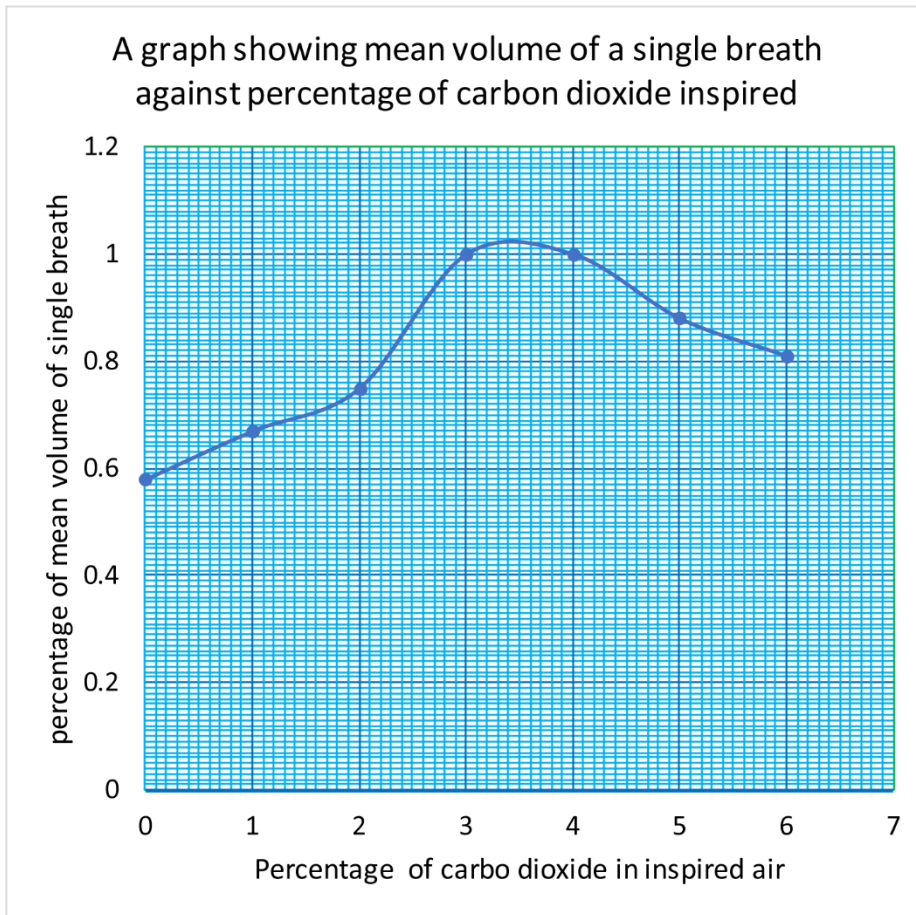
(b) (i) mean volume of breath = $\frac{\text{volume breathed in and out per minute}}{\text{breathing rate}} \text{ dm}^3/\text{breath}$

% of CO ₂ in inspired air	0	1	2	3	4	5	6
Mean volume of single breath/dm ³	0.58	0.67	0.75	1.00	1.00	0.88	0.81

Note: the values in the table are obtained using the formula above. For example, when the percentage of CO₂ in inspired air is zero (0), the mean volume per breath is given by

$$\text{Mean volume per breath} = \frac{7 \text{ dm}^3 \text{ min}^{-1}}{12 \text{ breaths min}^{-1}} = 0.58 \text{ dm}^3 / \text{breath}$$

(ii)



(c). (i) When percentage of carbon dioxide increases from 0-2%, the volume of air breathed in and out increases gradually from 7-9dm³.

From 2.4% carbon dioxide, volume of the air breathed in and out increases rapidly from 9-18dm³.

From 4-6% carbon dioxide, volume of air breathed in and out increases gradually from 18-22dm³.

(ii) Breathing rate is constant at 12 breathes/minute when carbon content increases from 0-3%.

Breathing rate increases rapidly linearly to 18 breaths/min when carbon dioxide content increase from 3-4%.

Breathing rate then increases gradually up to 27 breaths/min when carbon dioxide content increases from 4-6%.

(iii) Mean volume per breath increases gradually for carbon dioxide increase from 0-2%. It increase more rapidly from 2-3% and then becomes constant in 1.0dm^3 /breath of carbon dioxide from 3-4%.

The mean volume per breath then reduces gradually to 0.81dm^3 /breath for carbon dioxide increase from 4-6%

(d) (i)

- Increase in carbon dioxide concentration in inspired air cause an increase a depth of breathing, increasing the volume of air breathed in and out. This is so in order to enhance removal of excess carbon dioxide.
- Very high carbon dioxide content is inhibitory to respiratory muscle contraction as a result of anaerobic accumulation of lactic acid in them. When this occurs, the muscles are fatigued and no longer able to expand the chest further and the volume of air breathed in and out increases gradually at a decelerating rate.

(ii)

- High Carbon dioxide content in blood stimulates to the respiratory centre to get rid of excess carbon dioxide

(iii). Mean volume per breath increase with percentage of carbon dioxide in inspired air as a result of respiratory stimulation. However, the capacity of the lungs is so fixed that the mean volume increases up to a maximum and becomes constant.

At very high carbon dioxide percentages in inspired air, the breathing rate is so high rate time is not allowed for the volume per breath to accumulate to lung capacity. Thus the mean volume per breath decreases subsequently.

(e).

(i) Carbon dioxide reacts with water in the blood stream to form carbonic acid under the action of the enzyme carbonic anhydrase. This produces hydrogen ions which lower the blood pH and this has the following physiological effects.

It decreases hemoglobin affinity for oxygen, making it more efficient at picking up carbon dioxide and releasing oxygen. This reduces the oxygen carrying capacity of the blood.

When detected by chemoreceptors in the carotid sinus and aortic arch, there is a reflex stimulation of the respiratory center leading to increase in breathing rate.

It inhibits enzymes and hence stops essential metabolic processes.

If the pH becomes very low it can denature proteins in the body thus impairing their action.

(ii) In the tissue, oxygen acts as the final electron in the electron transport system in mitochondria, leading to formation of ATP, in this process, energy is lost in the form of heat that increases the body temperature.

In excess of oxygen, therefore, there is excessive production of heat which elevates body temperature. Elevated body temperature enhances the respiratory process further, creating a vicious cycle of events (positive feedback) that may eventually burn out the body cells (oxygen poisoning)

Excess oxygen also inhibits certain enzymes involved in the Krebs's cycle thus interfering with cell respiration.

66. Solution

(a) For exchange of gases, a large area to volume ratio has been achieved in the following ways among different organisms.

- Use of the cell surface membrane for gaseous exchange in unicellular organisms such as amoeba. Such organisms naturally have a large area to volume ratio because of their small size so that diffusion across the cell surface membrane can suffice their respiratory needs.
- In mammals, the respiratory surface is thrown into numerous spherical folds, called

alveoli. These greatly increase the surface area over which exchange of gases can occur.

- In aquatic organisms such as fish, the respiratory surface is formed of highly folded lamellate structures called gills. This also increases the surface area over which gaseous exchange can take place.
- In insects, a highly branched system of tubes, called trachea ramifies through all the body tissues so as to increase the surface area over which gaseous exchange between the tissues and the respiratory surface
- In plants, leaves are numerous, flattened and bear numerous pores, called stomata, in their epidermis. This greatly increases the surface area over which gaseous exchange can take place.
- Tadpoles have got external gills to increase surface area for gaseous exchange.

For absorption of food materials, a large surface area to volume ratio has been achieved in the following ways in different organisms.

- In planarian worms, the gut gives off numerous blind-ending branches which ramify throughout the body, penetrating into the tissues. Digested food is forced into these branches by muscular action and is thus conveyed to the cells.
- In mammals, such as man, the small intestine (the site of food absorption) is highly elongated and the absorptive surface is thrown into finger-like folds called villi. On the surface of the absorptive cells, the membrane is further highly folded into microvilli. As a result, a large area is presented for the absorption of digested food products.

67. (a) Qualities of gaseous exchange surface

- Has large surface area
- Moist
- Thin to reduce distance for diffusion
- Freely permeable to respiratory gases
- Has good blood supply
- Has good ventilation

(b) (i) adaptation of an insect for efficient gaseous exchange

- Has highly branched tracheal system that ramify the whole body up to individual cells
- Tubules open to atmosphere to receive oxygen through spiracles
- Tracheoles have thin walls to facilitate diffusion of gases
- Tracheal system is ventilated by contraction of abdominal and thoracic muscles.

(ii) Adaptations of flowering plants to gaseous exchange

- Has many stomata on leaves and lenticel to allow gaseous exchange

- Broad leaves give provide large surface area for gaseous exchange
- Cells in mesophyll layer are loosely packed to allow spaces for gaseous exchange
- Leaves have thin cuticle

(iii) Adaptation of amoeba for gaseous exchange

- Has large surface area to volume ratio
- Has thin membrane

68. (a) the meaning of lung ventilation

This is the renewal of air supply to the lung in which oxygen is continuously supplied and carbon dioxide removed.

(b) (i) variation of ventilation rate

- increased tissue respiration causes accumulation of carbon dioxides and depletion of oxygen
- the high carbon dioxide content in blood is detected by carotid body and aortic bodies.
- These send impulses to and stimulate the respiratory centre in medulla oblongata
- The respiratory centre send impulses to the intercostal muscle and diaphragm muscles to contract more vigorously to increase ventilation.
- When there is enough oxygen and less carbon dioxide the aortic and carotid bodies are less stimulated
- The frequency and depth of contraction of intercostal and diaphragm muscles reduce. This reduces the ventilation rate.

(ii) Variation of heart rate

- Cardiac muscles are myogenic, therefore heart beats at regular basis while the body is at rest
- When there is a need for more energy, the sympathetic nerves stimulate the sino-arterial to increase the rate of heart beat to increase blood supply to the body.
- When the need for energy decreases the Vagus nerve sends impulse to the heart to reduce heart rate.

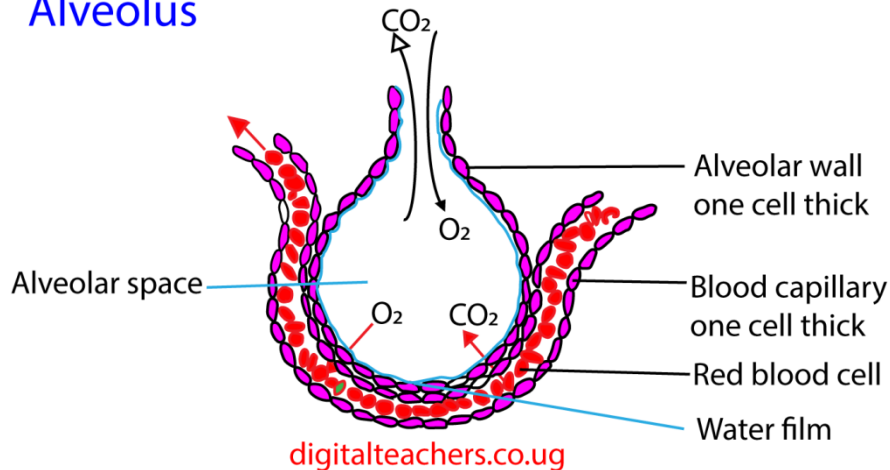
69. (a) Respiratory surfaces are: -

- Entire body such as flat worms a big surface area to volume ratio
- Moist skin e.g. in amoeba
- Tracheal system ramify the whole body of an insect and deliver oxygen directly to cells.
- External gills in tadpole
- Internal gills in fish
- Lungs in mammals

(b) Gaseous exchange surface in man is composed of alveoli in the lungs

- the alveolus is a single celled air bag with intimate association with blood capillaries

Alveolus



Adaptation of alveoli for gaseous exchange

- (i) They are very numerous that they offer a big surface area for gaseous exchange
- (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.

70. (a) (i) counter current flow of fluid in gaseous exchange

- (ii) Achieves high oxygen saturation in blood
- (iii) maintains high diffusion gradient between water and blood
- (iv) the concentration gradient between oxygen and water would be high initially and then drops as water and blood move together along the gill plate
- (v) by increase the speed of water relative to that of blood
- (vi) the percentage saturation of blood with oxygen increases with distance across the gill plate, gradually to 50% saturation by the end of end gill plate
- (vii) the speed of blood and water are equal while the capacity of water is higher than that of blood.

(b) Ventilation in fish

- Water is sucked in through the mouth by expansion of the buccal cavity.
- Water then enters the opercula cavity and over the gills by outward movement of operculum accompanied by contraction of buccal cavity.
-