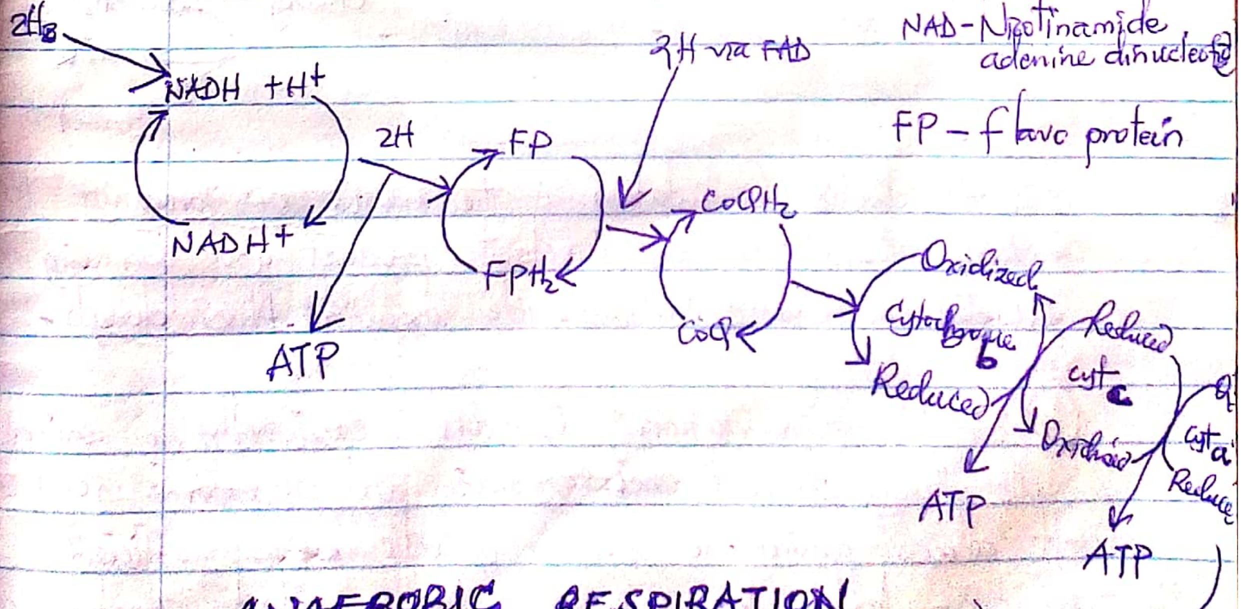
ELECTRON TRANSPORT CHAIN

It occurs in the membranes of the mitochondria. It is the means by which the energy, in the form of hydrogen atom, from Krebs cycle, is converted to ATP. The hydrogen atoms attached to a hydrogen carriers NAD and FAD are transferred to a chain of other carrier at progressively lower energy levels.

As the hydrogens pass from one carrier to the next, the energy released is used to produce ATP. The series of carrier is called Respiration chain. The carrier in the chain include NAD, Flavoprotein, Coenzyme Q and Iron-containing protein called Cytochrome.

Initially hydrogen atoms are passed along the chain but ~~later~~ latter split into their proton and electron and only the electron pass from carrier to carrier. For this reason, the pathway can be called electron or hydrogen transport system. At the end of the chain the protons and electrons recombine and the hydrogen atoms create a link with oxygen to form water. This formation of ATP through the oxidation of the hydrogen ~~of the hydrogen~~ atoms is called Oxidative phosphorylation. Oxygen acts as the final electron acceptor.



$2H + O_2$
$\downarrow$
H_2O

ANAEROBIC RESPIRATION

A variety of microorganisms (anaerobes) employs anaerobic respiration as their major ATP yielding process. Organisms that survive only in absence of Oxygen are termed as Obligate anaerobes eg

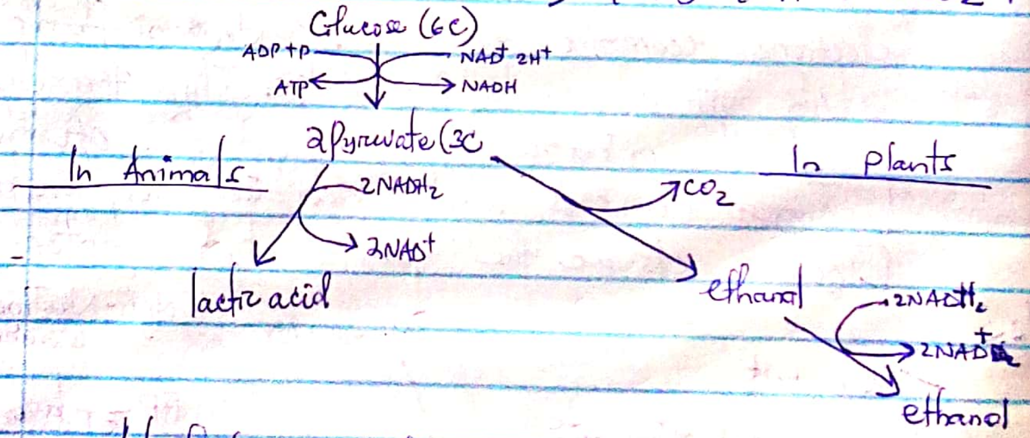
C. Brotulium and C. tetani). Obligate anaerobes find oxygen poisonous.

Other organisms such as yeast and alimentary canal parasites (Such as tape worms), can exist whether oxygen is available or not. These are called facultative anaerobes. Also some cells temporarily deprived of oxygen available to accept the hydrogen (such as Muscle cells) are able to respire anaerobically.

Pyruvate serves as an electron/hydrogen acceptor in absence of oxygen to accept the hydrogen atoms released during glycolysis; and depending on the metabolic pathways within the organism's cells, the end-products of anaerobic ~~respirat~~ respiration will either be ethanol and carbon dioxide (eg fermentation as in yeast) or lactate, for example lactate fermentation in muscle cells.

(a) In alcoholic fermentation, the glucose is converted to ethanol and carbondioxide.

$$C_6H_{12}O_6 \xrightarrow{\text{fermentation}} 2\,CH_3CH_2OH + 2CO_2 .$$



Alcoholic fermentation is the basis of brewing in which ethanol is an important product and baking industry in which carbondioxide expands the dough.

(b) Lactic fermentation: Occurs occasionally in animal cells during strenuous ~~exerss~~ exercise and oxygen is insufficient. It allows animal to survive periods of insufficient oxygen. When oxygen is later availed, lactic acid is oxidised to carbondioxide and water or can be turned into carbohydrates. The amount of oxygen required to oxidize lactic acid accumulated in muscles is called the Oxygen debt.

Alternative Respiratory Substances

Fats are oxidized after hydrolysis to glycerol and fatty acids. Glycerol is phosphorylated and converted into glyceraldehyde-3-phosphate which is incorporated into the glycolysis pathway. Fats produce more hydrogens than glucose/Carbohydrates and hence produce more energy.

Proteins are used only in cases of starvation. They are hydrolysed to constituent amino acids which are deaminated to form carbohydrates before converted to pyruvate.

Respiratory Quotients

The respiratory quotient (RQ) is the measure of the ratio of carbondioxide evolved by an organism to the oxygen consumed, over a short period.

$$RQ = \frac{CO_2 \text{ evolved}}{O_2 \text{ consumed}}$$

For hexose sugars like Glucose, the equation for complete oxidation is; $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$.

$$RQ = \frac{6CO_2}{6O_2} = 1.0$$

Importance

- Knowledge of respiratory quotient helps in determining respiratory substrate.
- It helps in knowing the type of respiration being performed.
- It provides some information about major transformation of food materials.

In fats and proteins, the ratio of CO_2 evolved to O_2 consumed is far smaller than in carbohydrates. A fat and proteins, therefore requires more O_2 for its complete oxidation than carbohydrates. The respiratory quotient of fats is 0.7 whereas that of proteins is 0.9. Organisms rarely respire one substrate at a time, but the respiratory quotients of an animal is between 0.8 and 0.9.

Low RQ may indicate that carbondioxide is used elsewhere for example;

- at compensation point during photosynthesis, carbondioxide produced is used in photosynthesis.
- during egg formation, carbon dioxide produced is used for shell formation. Carbon dioxide is the source of carbonate ions for formation of $CaCO_3$ in egg shells.
- RQ is less than one, when respiration is aerobic but the respiratory substance is either fat or protein. RQ is about 0.7 for most of the common fats. It occurs during germination of fatty seeds.

$$\underset{\text{(triolein)}}{C_{57}H_{104}O_6} + 80O_2 \longrightarrow 57CO_2 + 52H_2O$$

$$RQ = \frac{57CO_2}{80O_2} = 0.71$$

$$2\underset{\text{(tripalmitin)}}{(C_{51}H_{98}O_6)} + 145O_2 \longrightarrow 102CO_2 + 98H_2O.$$

$$RQ = \frac{102CO_2}{145O_2} = 0.7$$

RQ is almost 0.9 in case of proteins, peptones etc.

RQ zero

Succulents do not evolve carbon dioxide during night (when their stomata are open) as the same is used in carbon fixation. They also change carbohydrates to organic acids which utilize oxygen but do ~~not~~ not evolve ~~carbohydrate~~ carbon dioxide.

$$2C_6H_{12}O_6 + 3O_2 \longrightarrow 3C_4H_6O_5 + 3H_2O$$

$RQ = \text{Zero}\quad CO_2/3O_2 = \text{Zero}.$

High respiratory quotients occur;

- When carbohydrates are converted into fat eg when an animal is preparing to hibernate and in fattening livestock since during conversion of carbohydrates to fat, CO_2 is liberated when pyruvate is converted to AcetylCoA. AcetylCOA is then converted to fats without using O_2.
- During anaerobic respiration because carbon dioxide is given out but no oxygen used.

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2CO_2 + 2C_2H_5OH \quad RQ = 2CO_2/\text{zero} = \text{Inf}$$

Basal Metabolic Rate (BMR)

Is the minimum rate of energy expenditure per unit time by endothermic animals at rest.

Factors affecting the BMR

Body size. Metabolic rate increases as weight, height and surface area increase.

Body composition. Fat tissue has a lower metabolic activity than muscle. As ↑se in muscle mass ↑ses, BMR ↑se

Gender. 5-10% lower in females than men. Because they contain more body fat & less muscle mass than men.

Age. During adulthood lean muscle decreases hence decline in BMR after the age of 30. Avoided by training.

Climate and body temperature. BMR for people in tropic is 5-20% higher than in temperate, due to energy for cooling the body. In hot weather much exercise is perfor mo

Hormonal level. Thyroxine increase the rate of metabolism.

Health. Fever, illness, Injury may increase resting metabolic rate.

GASEOUS EXCHANGE

This is the exchange of respiratory gases between the cells of the organism and the environment. Aerobic organisms require oxygen for the respiration giving carbondioxide as the waste product. The area where gaseous exchange with the environment actually takes place is called the respiratory surface. It takes place in all organisms by the physical process called diffusion.

Properties of Respiratory surfaces

- It must be permeable, to allow passage of gases.
- It must be thin, because diffusion is only effecient over distances of 1mm or less.
- It should have a large surface area so that sufficient gase molecules are exchanged according to the organism's need.
- It should posses a good blood supply (& good ventilation mechanism) in large organisms to maintain a steep diffusion gradient.

brane: From Fick's law;

$$\text{The diffusion rate} = \frac{\text{Surface area} \times \text{difference in concentration}}{\text{Thickness}}$$

NB The fish are unable to achieve the higher metabolic rates of animals with lungs; due to;

- Water is more than 700 times denser than air and 100 times more viscous. Hence it requires more energy to pass water over the respiratory surface.
- It is harder to ~~kee~~ maintain a steep concentration gradient across a respiratory surface; in water or air; because air (diffuses) moves very ~~fast~~ slowly compared to water.

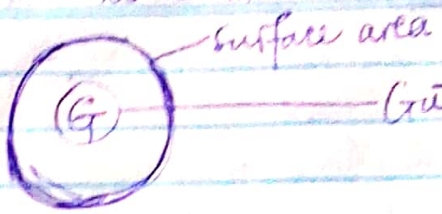
Terrestrial organisms (animals) rely almost entirely on air for their gaseous exchange.

Development of respiratory surfaces.

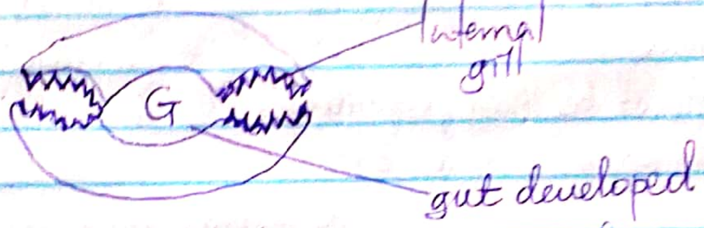
The development of respiratory surfaces in organisms became complicated with the increase in body size (reduction of body S.A:V ratio).

In very small (unicellular) organisms, gases can easily and effectively be exchanged across the whole (entire) body.

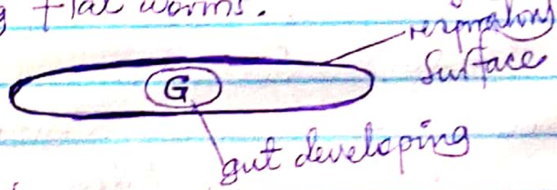
i) from protists to earthworms.



ii) Development of highly vascularized Internal gills. This is to draw water over the gill surfaces eg fishes and mature ~~young~~ tadpoles. Young tadpoles start with external gills.



iii) Flattening of the body surface, this increases the surface to volume ratio and also decreases the distances over which diffusion has to occur within the body eg flat worms.



iv) External gills. These ↑se the surface area but not protected hence easily damaged. Gaseous exchange takes place across the rest of body surface as well as the gills eg lugworm; and young tadpoles.

v) Highly Vascularized lungs. These are sacs connected to the pharynx. Air is drawn into them by a ventilation mechanism. They are found in all air-breathing Vertebrates.

vi) Gas exchange at the terminal ends of the tracheal ~~cavity~~ tubes. This is the tracheal system which ramify through the body and penetrate into all tissues. Found in insects and other arthropods.

Explain the need for a respiratory pigment.

MECHANISM OF GAS EXCHANGE

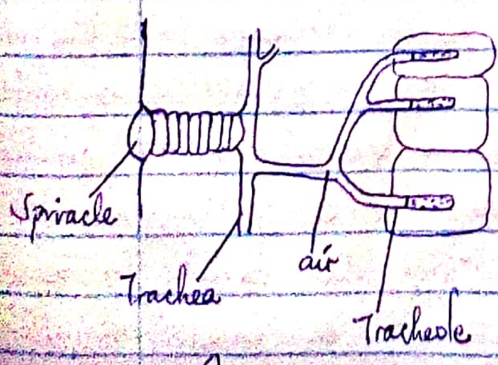
(a) INSECTS

Gaseous exchange occurs by means of a system of tubes called the tracheal system. This system allows oxygen to diffuse from the outside air directly into the tissues without need for blood. This allows higher metabolic rates.

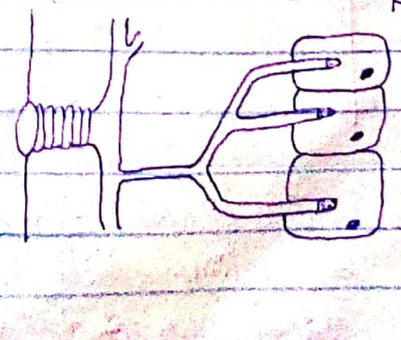
Pairs of holes called spiracles found on the second & third thoracic segments and first eight abdominal segments, lead into air filled sacs. Extending from these are branched tubes called tracheae and each secretes a thin layer of strong supporting chitinous material around its outer surface, further strengthened by spiral or circular patterns of thickening which maintain an open pipeline to reduce pressure.

In each body segment, the tracheae branch to form numerous smaller tubes called tracheoles, which are sites for gaseous exchange. Tracheoles lack a chitinous ~~ring~~ lining. At rest they are filled with watery fluid and the rate ~~of~~ at which oxygen diffuses through them, and carbon dioxide in the reverse direction, satisfies the insect's requirement.

During exercise, increased metabolic activity by the muscles leads to ~~maximum~~ accumulation of products such as lactic acid, hence making the insect's solute potential more negative. The water in the tracheoles leaves by osmosis into the tissues, cause more air and more oxygen to enter the tracheoles and come into close contact with tissues just when required.



a) Resting tissue



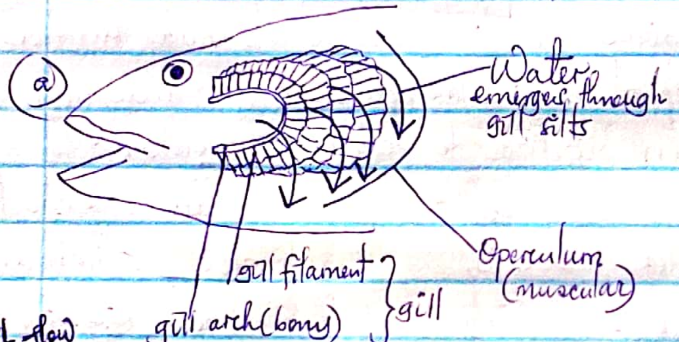
b) Active tissue

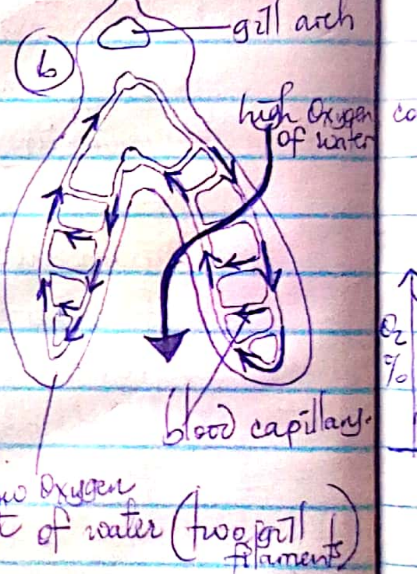
b) BONY FISH -eg Herring

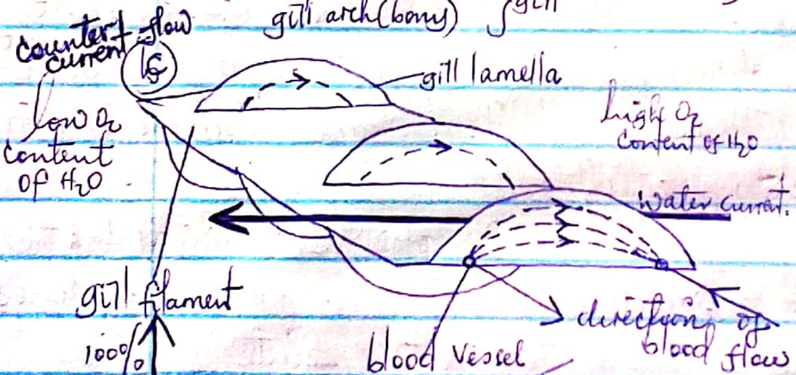
Fish possesses gill slits in the walls of the pharyngeal region of the gut (between buccal cavity and oesophagus). These connect with the outside env't, water.

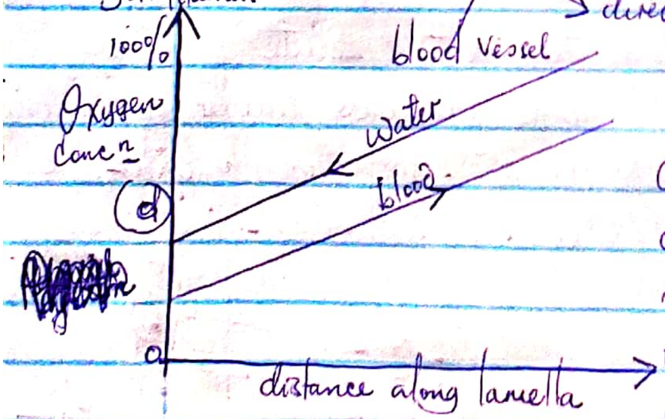
The tissues between the silts forms supports known as branchial arches or gill arches. In bony fish there are four pairs of gill arches separating five pairs of gill slits.

Each gill is made up of two rows of gill filaments arranged in the V shape. The filaments possess lamellae which are thin plates which have a rich supply of blood capillaries. These plates greatly ↑se the surface area of the respiratory surface. The barrier between blood and water is only several cells thick so diffusion between the two is rapid.







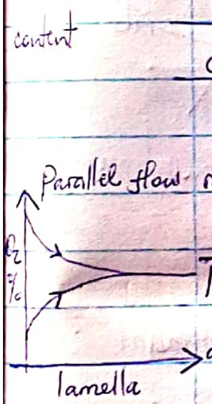


Ventilation Mechanism

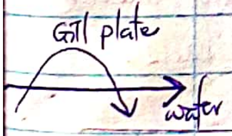
During Inspiration, the buccal cavity expands, decreasing the pressure causing water to draw in through the mouth. At the same time the outside water pressure presses the posterior (rear) end of the operculum shut, preventing entry of water from this region. The muscles in the operculum are also active which contract causing opercular cavity to be enlarged. The pressure in the opercular cavity is less than that in buccal cavity, hence water is drawn from the buccal cavity over the gills into opercular cavity. Theref gaseous exchange is able to continue even when the fish is taking a fresh supply of water.

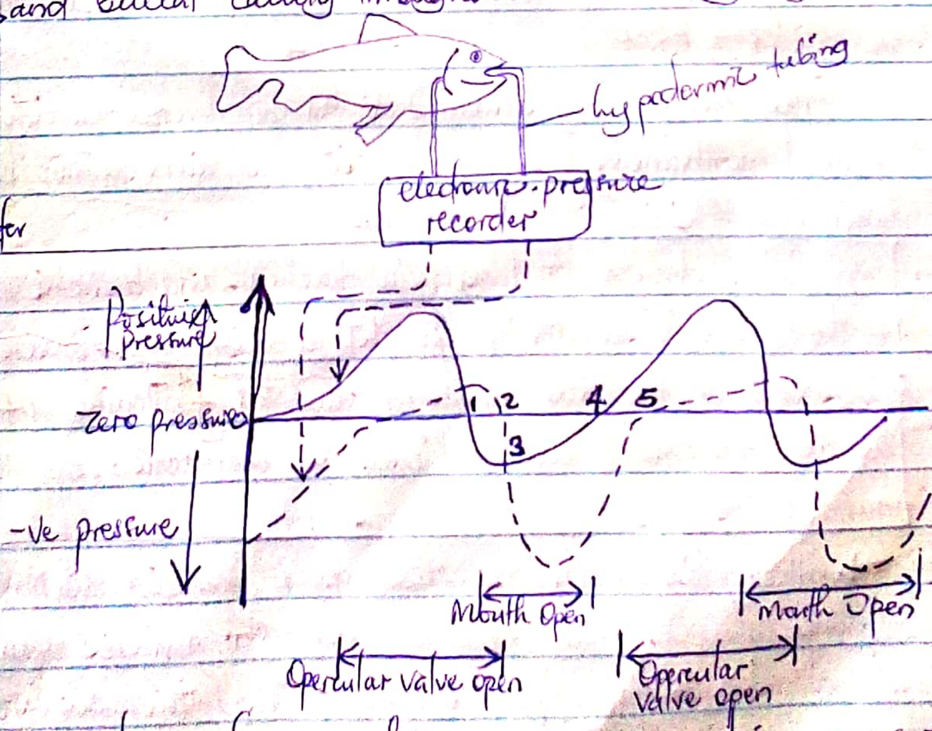
During expiration, the mouth closes, as does the entrance to the oesophagus and the floor of the buccal cavity is raised. This forces water over the gills, through the gill silts and into the opercular cavity where the fixed pressure forces ~~the~~ open the posterior end of the operculum. Water leaves to the outside environment. The coordinated activity of the buccal cavity and the opercular muscles ensures the continuous flow of water over the gills. This maintains a high concentration of Oxygen in water near gills and low concentration of carbondioxide.

Neighbouring gill filaments overlap at their tips, providing resistance to water flow. This slows down the passage of water ~~to~~ over the gill lamellae, thus fixing time for gaseous exchange to take place. The blood in the lamellae flows in opposite direction to that of water. This called Countercurrent system; and is more efficient than parallel current system in which two fluids travel in the same direction. In countercurrent system, a concentration gradient will be maintained between water and blood.



The graph below shows variation of pressure of Opercular and buccal cavity throughout the breathing cycle in bony fish





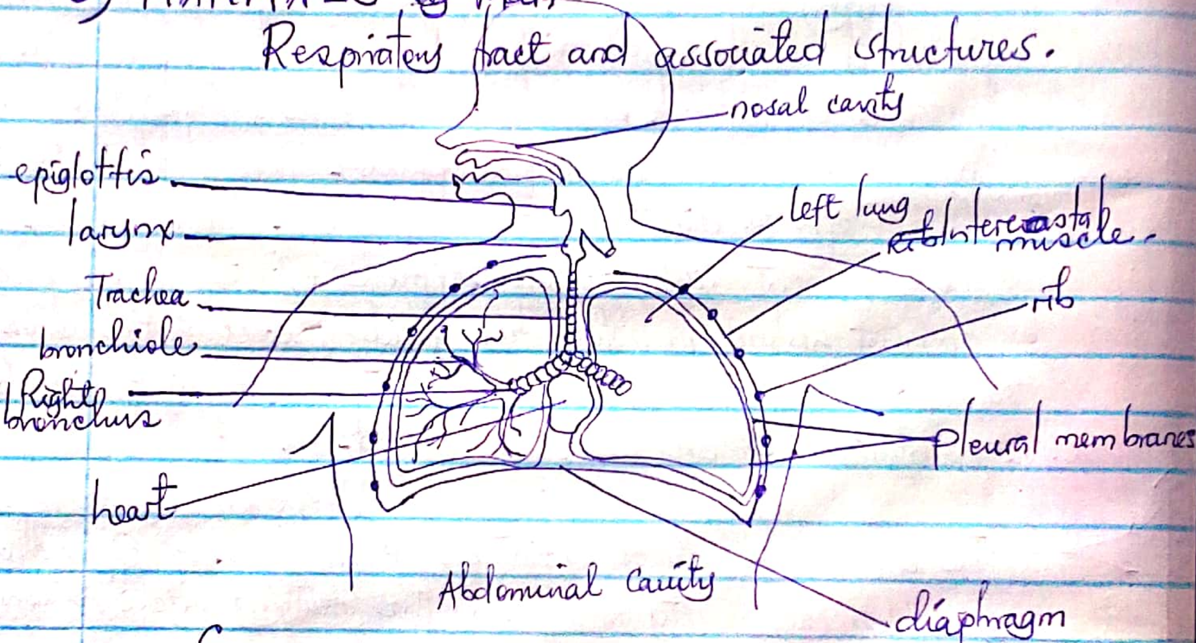
1 – Buccal Cavity expanding, acquires negative pressure; mouth valve opens and water enters from outside.

2 – Opercular cavity expanding, acquires negative pressure, opercular valve closes.

3- Negative pressure in Opercular cavity falls below that of buccal cavity which has begun to contract. Water is sucked into opercular cavity from buccal cavity.
4- Buccal cavity contracting, aquires positive pressure, mouth valve closes and water forced from Buccal cavity to Opercular cavity.
5- Opercular cavity contracting, acquires positive pressure opercular valve opens and water expelled.

c) MAMMALS eg Man

Respiratory tract and associated structures.

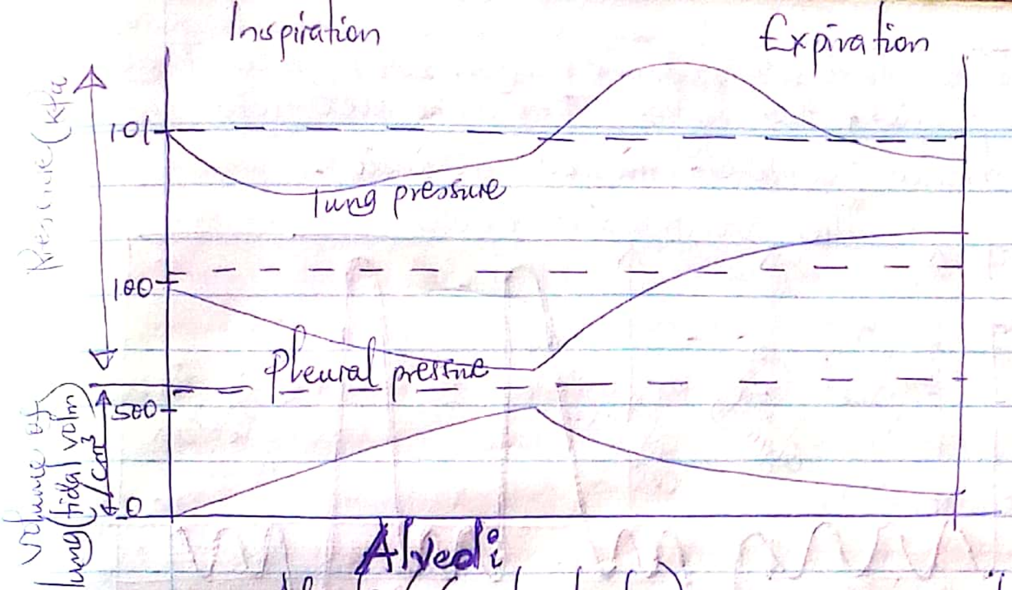


GAS EXCHANGE IN HUMANS

The lungs are surrounded by a pleural cavity lined by pleural membranes. The pleural cavity contains a thin layer of lubricating fluid.

Inspiration | Air is drawn into lungs via trachea and bronchi. The expansion of the thoracic cavity is brought about by Upward and outward movement of the ribs, accompanied by flattening of the diaphragm. The rib movements are achieved by contraction of the intercostal muscles

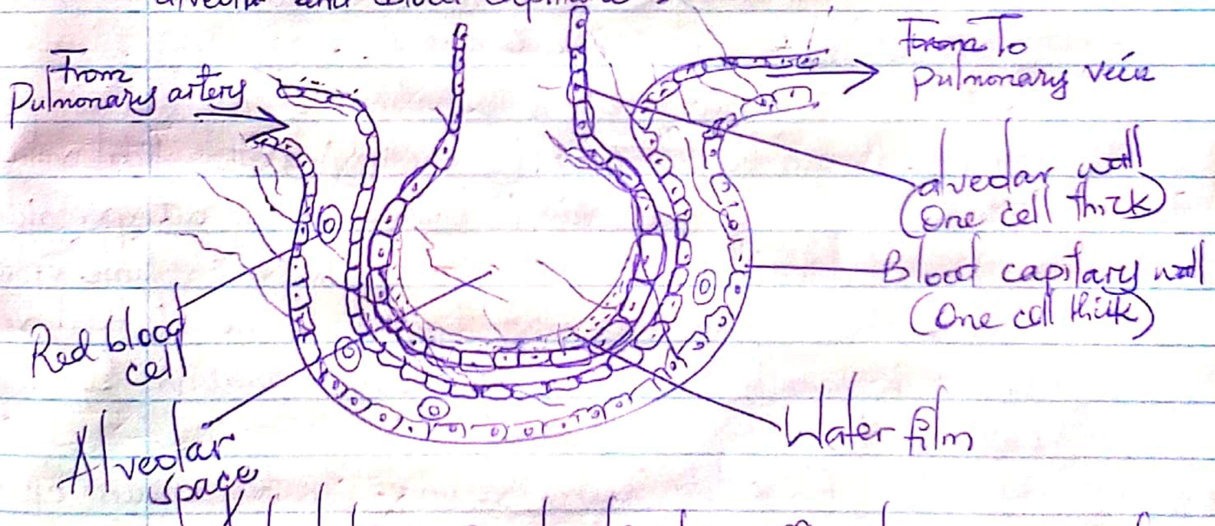
Expiration ⇒ The diaphragm muscles relax, making diaphragm raised (dome) shape. The external intercostal muscles relax and internal intercostal muscles contract; The thoracic cavity volume reduces and its pressure increases. This forces air out of the lungs through trachea, nasal cavity and externally through the nostrils.



Alveoli

Alveoli (Singula alveolus) are numerous hollow, lobed air sacs that form the gaseous exchange surface in the lungs. They occur at the terminal end of the ~~trachea~~ tracheal branching and come in close association with extensive capillary stem. This makes them efficient apparatus for gaseous exchange.

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

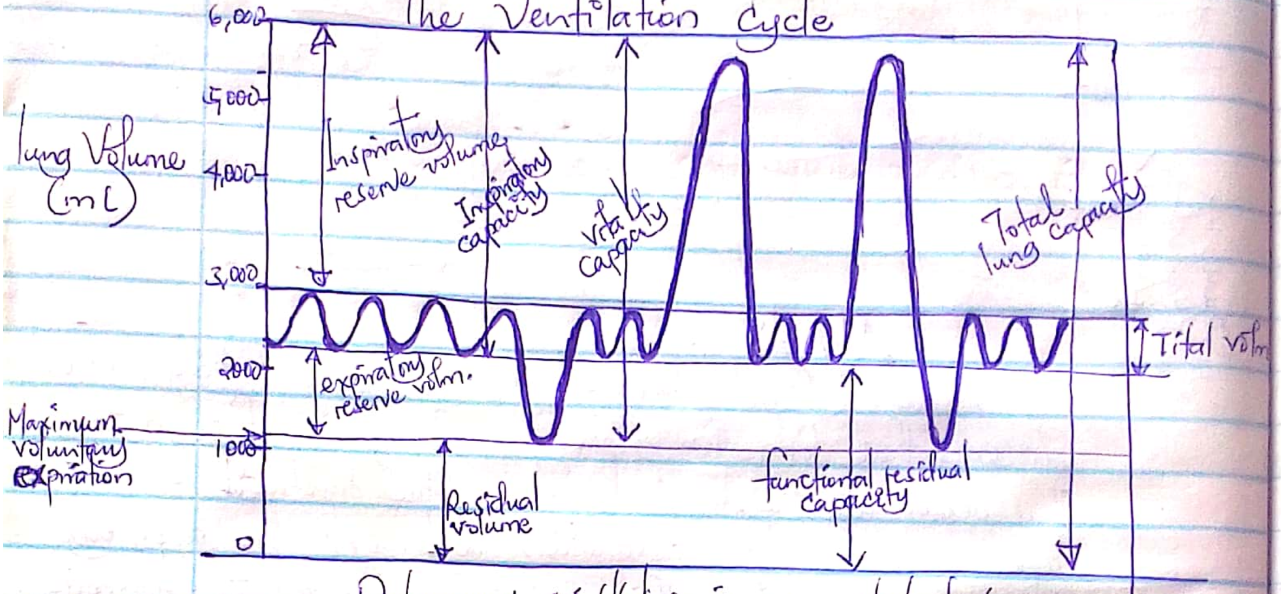


Adaptations of alveoli to efficient gaseous exchange

- They are very numerous, to offer high surface area for gaseous exchange.
- Alveolar epithelium is covered internally with a thin layer of fluids in which ~~oxy~~ oxygen dissolves before diffusing into the blood which creates high diffusion gradient.
- Alveolar fluids contain surfactants that prevent alveoli from collapsing.
- Alveolus is separated from blood capillaries by thin membrane that offer minimum resistance to diffusion of gases.

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

The Ventilation cycle



Pulmonary ~~circulation~~ Ventilation is accomplished by expansion & contraction of lungs.

Description of Lung Volumes

Tidal volume: Is the volume of air breathed in and out at rest. It is about 0.5 l.

Ventilation rate: Is the volume of air breathed per minute. It can be obtained by multiplying the tidal volume with the number of times, air is breathed in and out per minute.

Inspiratory 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 300 ml in the young male adult.

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 110 ml in young male adult.

Residual volume. Is the volume of air remaining in the lungs even after the most forceful expiration. This volume averages about 1200 ml in young male adult.

Dead Space This is the amount of air that remains in the tracheal and bronchioles. There is no gaseous exchange in the tube.

Inspiratory Capacity = Tidal volm + Inspiratory Reserve volm

I.C Is the amount of air (about 3,500 ml) that a person can breathe at the beginning of expiratory level and distending his lungs to the maximum amount.

Functional residual capacity = Expiratory reserve volm + Residual volume.

This is the amount of air remaining in the lungs at the end of normal expiration (about 2300 ml).

Vital capacity = Inspiratory Reserve Volume + Tidal volume + Expir Reser volm

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 CO_2

A deficient of oxygen is called Hypoxia. It deprives the tissues of the vital requirements for metabolism. The consequence is that the sense organs are impaired, unconsciousness occurs suddenly, followed by paralysis & 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 Krebs cycle, interfering with respiration.

Cells are more susceptible to changes in the levels of carbondioxide. An accumulation of this gas ↑ses 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 cells comprising a ventilation centre in the posterior part of the brain called Medulla Oblongata.

This centre responds to the levels of carbondioxide and lesser extent oxygen in the blood ~~dem~~ stream. If the partial pressure of carbondioxide increases, the centre responds by ↑ing 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.

Adaptations of animals to low O_2 tension

- High haemoglobin concentration in blood.
- Have myoglobin that store oxygen.
- Fish eg trout store O_2 in swimming bladder.
- Decreased activities. Animals tend to be sluggish.
- Have haemoglobin with high affinity for oxygen eg lugworm.
- Increased ventilation rate ie fast and deep breathing to reduced oxygen requirement.
- Aquatic surface requirement: fish stay on the surface leave snout at air water surface taking in water richer in oxygen.

Gaseous exchange in plants.

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

These provide provide effective way of gaseous exchange in and out the plant. H.P Brown and F. Escombe ~~distan~~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 ~~tiny small holes~~ a few large ones.

The stomata are therefore ideal for gaseous exchange.

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

Check in any other books for the homeostatic control of respiratory gases.