1) Mechanism and mechanics of breathing (respiration) :-

Definition → Respiration means the entry of atmospheric air into the lungs and after gaseous exchange, the exist of CO_2 enriched air to the atmosphere

Respiration is of two types —

(1) Inspiration and (2) Expiration.

(1) Inspiration → (entry of atmospheric air into the lungs) It is an active process, since it is caused by the contraction of certain muscles and that process needs energy.

Inspiration is of two types —

(i) Normal inspiration — during quiet time and (ii) Forceful inspiration — during hard work.

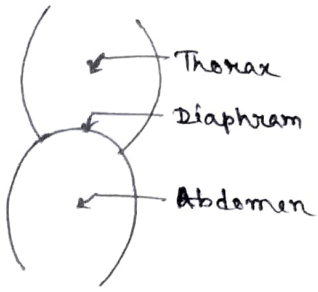
(2) Expiration → It is an inactive process since it needs no energy. Expiration is the exist of CO_2 enriched air from lungs to the atmosphere.

Mechanism → Two sets of muscles work together so as to increase the thoracic volume. These muscles are known as 'respiratory muscle'.

Respiratory muscles are of two types —

(1) Diaphragm and (2) External intercostal muscle.

(1) Diaphram → It is the principal respiratory muscle and almost 75% of the total volume change of ~~thora~~ thorax is executed by the diaphram alone. This muscle remains as the separating membrane between thorax and abdomen. It is dome shaped. It has 3 parts, ie (i) costal portion - remain attached with ribs, (ii) crural portion and (iii) central tendon - where costal and crural muscles remain inserted. Diaphram is connected by phrenic nerves which have originated from C_3–C_5 segments of spinal cord. The right half of the diaphram is connecte by the right phrenic nerves and the left half is connected by left phrenic nerves.



When the phrenic nerves get signal from the brain, the diaphram descends down to about 1.5 cm at the time of normal inspiration and about 7 cm during forceful inspiration.

This movement of diaphram pushes the lower ribs externally and the volume of thorax is increased.

(2) External intercostal muscle →

The muscles present in between the ribs are known as intercostal muscles.

The external intercostal muscles remain externally and in oblique fashion. This muscles contract during respiration. They are supplied by intercostal nerves which originate from thoracic segments. As a whole, all these muscles move up and forward.

These due to contraction of the two muscles, the volume of thoracic cage, is increased in all dimentions.

Pulmonary surfactant

Surfactant is a chemical secreted by the type II alveolar cells. It is composed of dipalmitoyl lecithin, phosphatidyl glycine, other phospholipids, neutral lipids, proteins and some carbo-hydrates. It is a surface tension lowering agent*. It reduces surface tension of the thin film of fluid lining the alveoli and makes it easier to inflate the lungs. The main constituents of surfactant are as follows;—

[* present in the inner wall of the alveoli.]

(1) Lipids —

- i) Dipalmitoyl phosphatidyl cholin
- ii) Phosphatidyl glycine
- iii) Phosphatidyl ethanol amines
- iv) Neutral lipids (5%)
- v) Glycolipids (5-10%)

(2) Proteins —

- (i) SPA — This is produced in the alveoli type II and clara cells in the lungs, regulates the surfactant turn over, immunoregulation in the lungs and in the formation of tubular myelin which is a precursor stage of surfactant.
- (ii) SPB — It controls the tubular myelin formation, involved in the surfactant activity of the surfactant by stabilizing the phospholipid there.
- (iii) SPC — It is involved in the surface activity of the surfactant by stabilizing the phospholipid there.
- (iv) SPD — It is a glycoprotein having a molecular weight of 43 KDa. Its function is unknown.

Surface tension is a force generated by the inter-molecular attraction of the surface molecules of a liquid. This layer of molecules together behaves as a stretched rubber membrane on the surface of the liquid. In a bubble, this surface tension between the molecules (of the liquid) forming the bubble wall, acts centrally and tends to collapse the bubble. A suitable pressure is to be maintained

inside the bubble to make it stable. The relationship increase of a sphere, is given by the Laplace's law, as follows;-

$P = \frac{2T}{R}$ where, P = transmural pressure (i.e intraluminal pressure – outside pressure)

T = Surface tension

R = radius of the sphere.

If T is decreased by the surfactant as stated above, the value of P needed to distend the alveoli will also decrease.

Suppose, there are two alveoli, one small with radius R_1 and the another larger with radius R_2, both are ~~connected with~~ normally inter connected with airways. T in both the alveoli will be equal as the same alveolar fluid is responsible for this. Now, the P for the smaller alveolues will be more as the ratio $T/R_1 > T/R_2$ (as $R_1 < R_2$ and T = constant). So, the smaller alveolues will blow into the larger one and itself will collapse. The pulmonary surfactant prevents this.

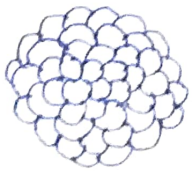
This is due to the reason that the surfactant is to spread over a larger area in a large alveolues but in a smaller area when the alveolues ~~become~~ is smaller. So, when the alveolues becomes smaller during expiration, the concentration of the surfactant increases per unit area. Therefore, the value of T for the smaller alveolues decreases and hence the value of P does not increases though the R decreases ($P = \frac{2T}{R}$) so, When an alveolues becomes smaller during expiration, it will not collapse by blowing into a larger alveolues.

During inspiration the size of the alveolues becomes larger and the same amount of surfactant is spread over the large surface of the expanded alveolues which is helped by the proteins present in it. It cannot exert its full action due to its low concentration. But during expiration the alveolues becomes smaller and relative concentration of the surfactant rises, so it can decrease the surface tension. This way it prevents collapse of the smaller alveolues (after expiration) which would otherwise blow into the comperatively larger alveoli as per Laplace's law. In this way the surfactant stabilises the alveoli.

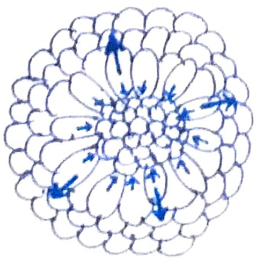
Interdependence

Interdependence is a phenomenon by which a zone of collapsing alveoli is subjected to radial traction by the surrounding normal alveoli and the collapse is prevented. It is due to attachment of the alveoli ~~and~~ with one another. This prevents atelectasis (= collapse of parts of the lungs) and also open up the collapsed alveoli, thus plays an important role in maintaining stability of the alveoli. It can be explained as follows;—

Suppose there is a row of boys, each holding the hands of the adjacent boy. The gap between them is sufficient to keep their arms just taut. Now, if a boy wants to bring his hands closer, can he do it? No, because this act creats a pull on the hands of the adjacent boys which does not allow the boy in the middle to close his hands. Similarly, an alveolus if wants to collapse the adjacent alveoli prevents it as these are connected anatomically and collapse of one stretches the adjacent alveoli.



Normal alveoli



Expanding force on the collapsed area

0.2 radius of the alveoli

Surfactant :- It is surfactant tension lowering agent, present in the innerwall of alveoli.
Surfactants consists of lipid (85-90%) and proteins (10-15%).

(1) Lipids (85-90%)

- Dipalmityl phosphatidyl cholin
- Phosphatidyl glycin
- Phosphatidyl ethanol amin
- Nutral lipid (5%)
- Glycolipid (5-10%)

② Proteins

→ SPA :— This is produced in the alveoli type II and clara cells in the lungs, regulates the surfactant turn over, immunoregulation in the lungs and in the formation of tubular myelin which is a precursor stage of surfactant.

→ SPB :— It controls the tubular myelin formation, involved in the surface activity of the surfactant by stabilizing the phospholipid there.

→ SPC :— It is involved in the surface activity of the surfactant by stabilizing the phospho-lipid there.

→ SPD :— It is a glycoprotein.

Molecular weight → 43 K.Da, function is unknown.

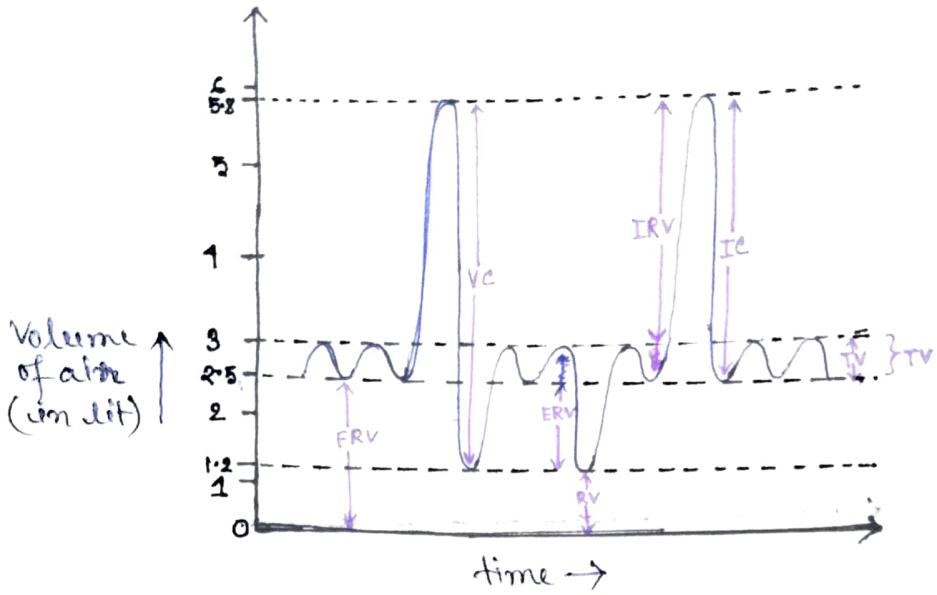
■ Significance of surfactant :—

1) It reduces the work of breathing by reducing surfacetension.
2) Preventing collapse and sticking of alveoli during expiration with antisticking property.
3) Stabilizing alveoli.

* 3) Pulmonary volumes :—

Instrument → spirometer

the record is known as spirogram



- **Tidal volume (TV)** → The amount of air which is breathed in or out during normal quiet respiration constitutes the tidal volume.
  It is about 0.5 lit

- **Inspiratory reserve volume** → The amount of air which can be breathed in forcefully after normal inspiration.

  IRV = 2.8 lit

- **Inspiratory capacity** → The total amount of air taken in the lungs during normal inspiration and during forceful inspiration after normal inspiration, constitutes the inspiratory capacity.

  IC = TV + IRV
  = 0.5 + 2.8
  = 3.3 lit.

- **Expiratory reserve volume** → The amount of air which can be breathed out forcefully after normal expiration is known as expiratory reserve volume.

  ERV = 1.3 lit

  ERV = 1.3 lit

☒ **Residual volume →** The amount of air remains in the lungs after forceful expiration, that can not be breathed out, is known as residual volume.

☒ **Functional residual volume →** The total amount of air remains in the lungs after normal quite expiration is called functional residual volume.

FRV = 2·5 lit

2005

☒ **Vital capacity →** The maximum amount of air remains in the lungs from forceful inspiration to forceful expiration, is known as vital capacity.

VC = 4·6 lit

☒ **Timed vital capacity →** The amount of air which can be breathed out forcefully in the first second of the vital capacity constitutes the timed vital capacity. In normal individual it is about 83% of total vital capacity.

(TVC)

It has great physiological importance. In case of asthma the vital capacity remains unaltered, but timed vital capacity becomes less than 83%.

☒ **Maximum breathing capacity :–** The maximum amount of air which can be breathed in or out in the first minute of breathing, is known as maximum breathing capacity. Normally it varies between 125 to 170 ml.

☒ **Total lung capacity →** After forceful inspiration the maximum amount of air remain in the lungs constitutes the total lung capacity.

TLC

Dead space → The amount of air which remains locked up in the air passage and do not take part in gaseous exchange constitutes the dead space. This air remains locked up in the first 16 generations of branching of trachea, ie, the conducting zone.

DS = 150 ml

(350 ml takes part in gaseous exchange, out of 500 ml.)

Dead space is of two types –

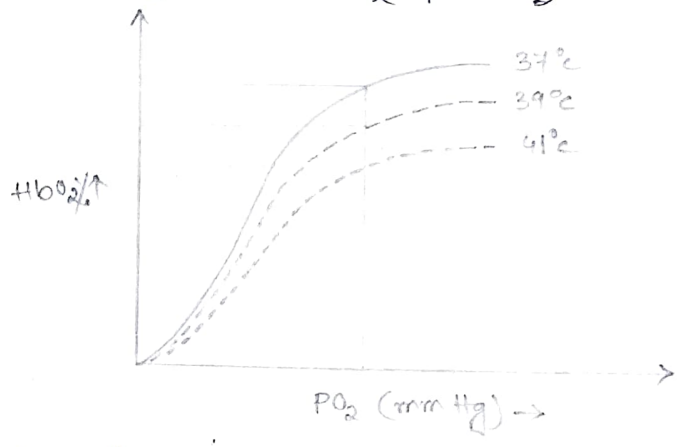
1) Anatomical dead space → (The conducting zone)

2) Physiological dead space → Anatomical dead space + the volume of air packed up in those alveolies that don't take part in gaseous exchange + those alveolies which are over ventilated.

:: Factors influencing the O_2-dissociation curve ::

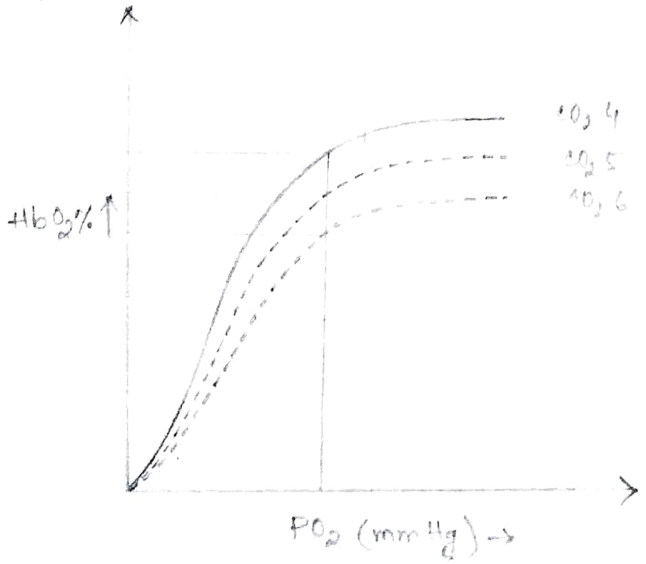
i) **Temperature** :— Temperature has a defenitive effect on O_2 dissociation curve. When the temperature rises O_2 dissociation curve shifts to the right.

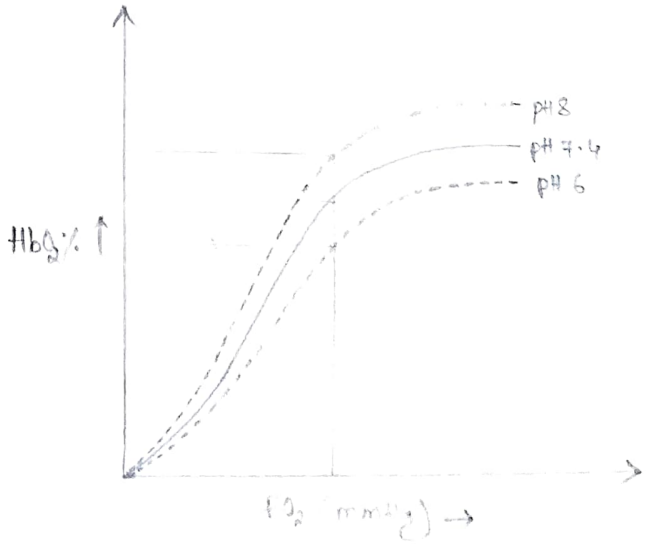
This phenomenon happens during exercise, when the muscle contracts, its metabolic pattern is changed and it needs more oxygen than normal. Mean while heat is generated and Hb looses its affinity for O_2. So, O_2 is easily liberated and those exercising muscles get more O_2 quickly.



(ii) **Lower pH and higher pCO_2** :—

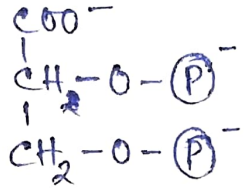
In rapidly metabolizing tissues, such as contracting muscles, much CO_2 is generated which intern increases H^+ concentration (H^+ comes from H_2CO_3). So, the pH in those muscle is decreased due to the accumulation of acid, ~~i.e H^+ level increased~~. This promotes the release of O_2 from oxyhemoglobin. So, O_2 dissociation curve is shifted to the right. This phenomenon was first discovered by C. Bohr in 1904 and is also known as **Bohr's effect**.





iii) **Concentration of 2,3-DPG** :— 2,3-DPG is very plentiful in red cells and it has got a significant effect on O_2-dissociation curve. 2,3-diphosphoglycerate (2,3-DPG) is produced during glycolysis.

When glucose is broken down to 1,3-diphosphoglycerate, then 1,3-DPG mutase enzyme converts it into 2,3-DPG. Another enzyme, called 2,3-DPG phosphatase converts 2,3-DPG into. This 1,3-DPG mutase enzyme is only found in the RBCs. 2,3-DPG is a highly anaionic particle i,e it has got many negetive charges.



$\Rightarrow$ 2,3-DPG

This 2,3-DPG binds with the β chains of the hemoglobin. These β-chains possess high positive charges due to presence of histidine, lysine, arginine etc. amino acids. As the 2,3-DPG binds with β-chains, those chains then move closure and looser their affinity for O_2 and thus the O_2 is liberated from the oxyhemoglobin. So, a higher concentration of 2,3-DPG in the cells moves the following reaction to the right. and forcilitates the unloading of O_2 from HbO_2. Thus the O_2 dissociation curve is shifted to the right.

Concentration of 2,3-DPG rises during heavy exercise or in high altitude and cells then need more O_2 supply than the normal. Higher conc. of 2,3-DPG then forcilitates the supply of O_2 to the cells.

$$HbO_2 + 2,3\text{-DPG} \rightleftharpoons Hb\text{-}2,3\text{-DPG} + O_2$$