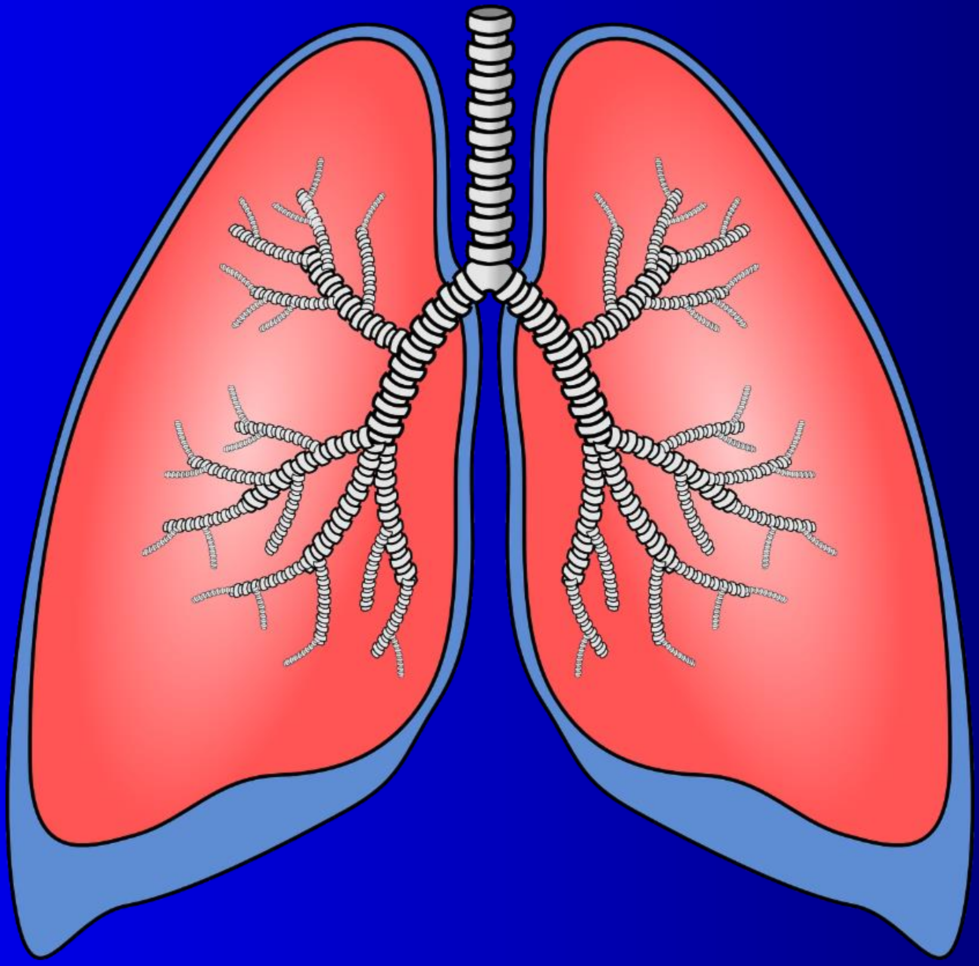
Breathing and Exchange of gases

Breathing



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Breathing

Respiration

Respiration is the process of release of energy from the breakdown of organic substances.

Breathing : (External respiration)

The process of exchange of Oxygen from the atmosphere with carbon dioxide produced in the body is called breathing.

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Breathing Organs

Body surface	Sponges, coelenterates, etc.
Moist Skin	Example: Earthworm, frogs.
Tracheal tubes	Insects
Gills	Aquatic arthropods and fishes
Lungs	Terrestrial animals (Reptiles, Birds, and Mammals)

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Human Respiratory System

Human Respiratory system includes

A pair of nostrils of nose

Nasopharynx

Trachea

Bronchi

Bronchioles

A pair of lungs.

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Organs of Respiratory System

Nasopharynx:

It acts as a common passage for food and air. It opens through glottis into the trachea.

Epiglottis:

Epiglottis is the covering of glottis which prevents the entry of food into the larynx.

Larynx (sound box) is a cartilaginous structure located at the top of trachea. It helps in sound production.

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Organs of Respiratory System

Trachea:

Trachea is a straight tube which is divided into right and left primary bronchi.

Bronchioles:

Each bronchi undergoes repeated divisions to form the secondary and tertiary bronchi and bronchioles ending up in very thin terminal **bronchioles**.

Cartilaginous rings:

The tracheae, primary, secondary and tertiary bronchi, and initial bronchioles are supported by incomplete cartilaginous rings.

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Organs of Respiratory System

Alveoli:

Each terminal bronchiole gives rise to a number of very thin, irregular walled and vascularised bag-like structures called **alveoli**.

A pair of Lungs:

The branching network of bronchi, bronchioles and alveoli comprise a pair of lungs.

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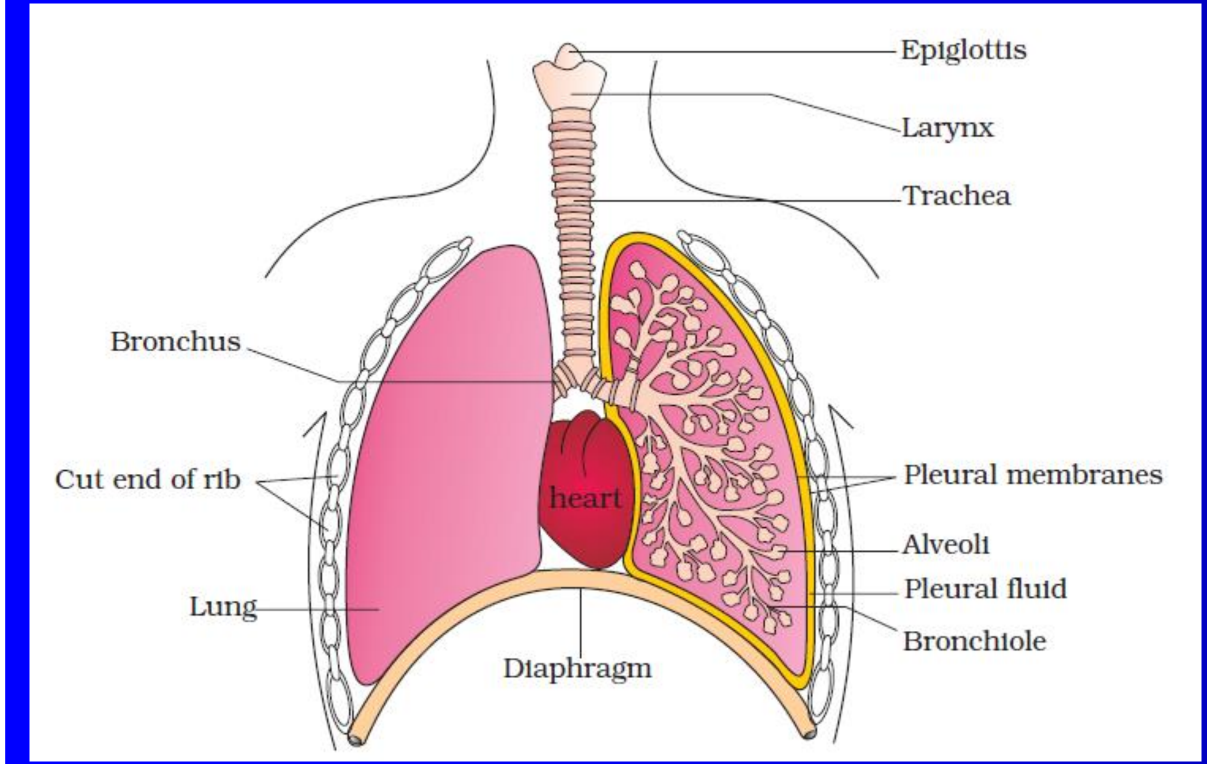
Lungs



Lungs are covered by a double layered pleura, with pleural fluid between them.

It reduces friction on the lung surface.

The outer pleural membrane is in close contact with the thoracic lining whereas the inner pleural membrane is in contact with the lung surface.

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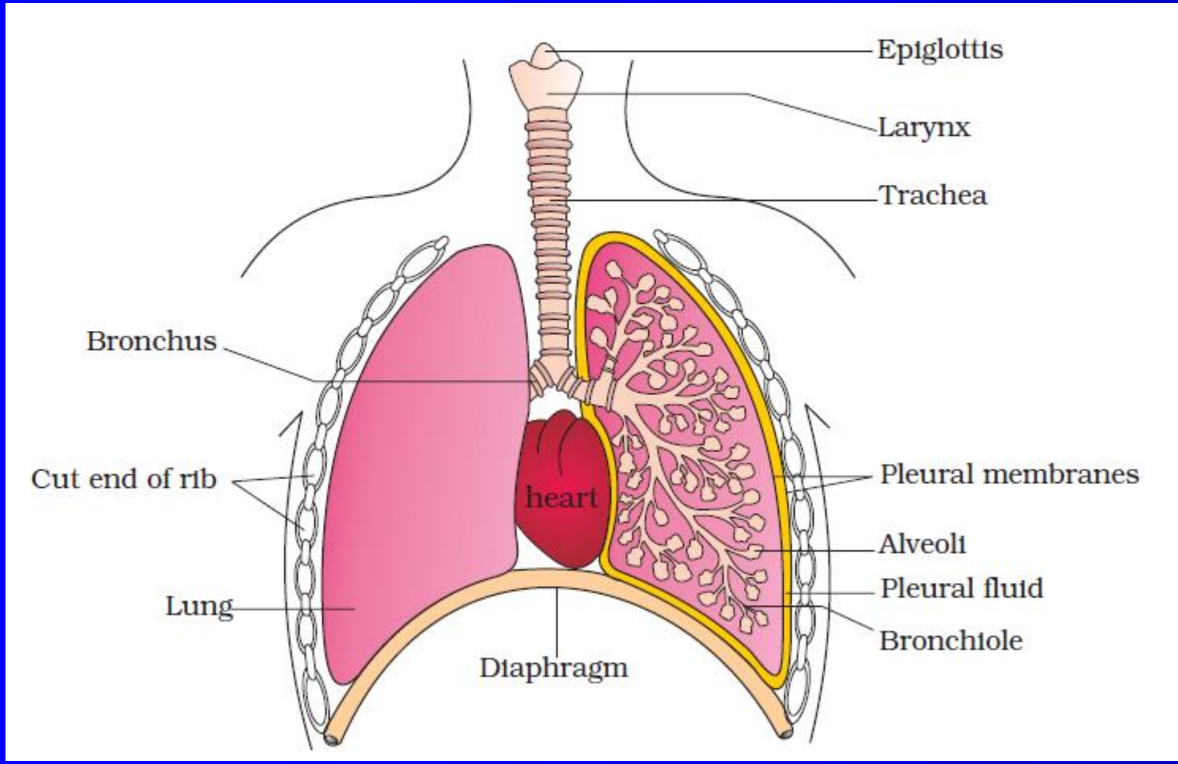
Lungs



The part starting with the external nostrils up to the terminal bronchioles form the conducting part.

The alveoli and their ducts form the respiratory or exchange part of the respiratory system.

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Lungs

The conducting part transports the atmospheric air to the alveoli, clears it from foreign particles, humidifies and also brings the air to body temperature.

Exchange part is the site of actual diffusion of O_2 and CO_2 between blood and atmospheric air.

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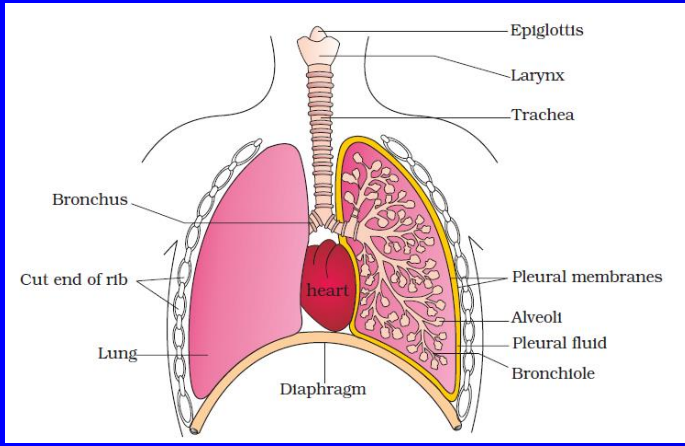
Lungs



The lungs are situated in the thoracic chamber which is anatomically an air-tight chamber.

The thoracic chamber is formed dorsally by the vertebral column, ventrally by the sternum, laterally by the ribs and on the lower side by the dome-shaped diaphragm.

The anatomical setup of lungs in thorax is such that any change in the volume of the thoracic cavity will be reflected in the lung (pulmonary) cavity.

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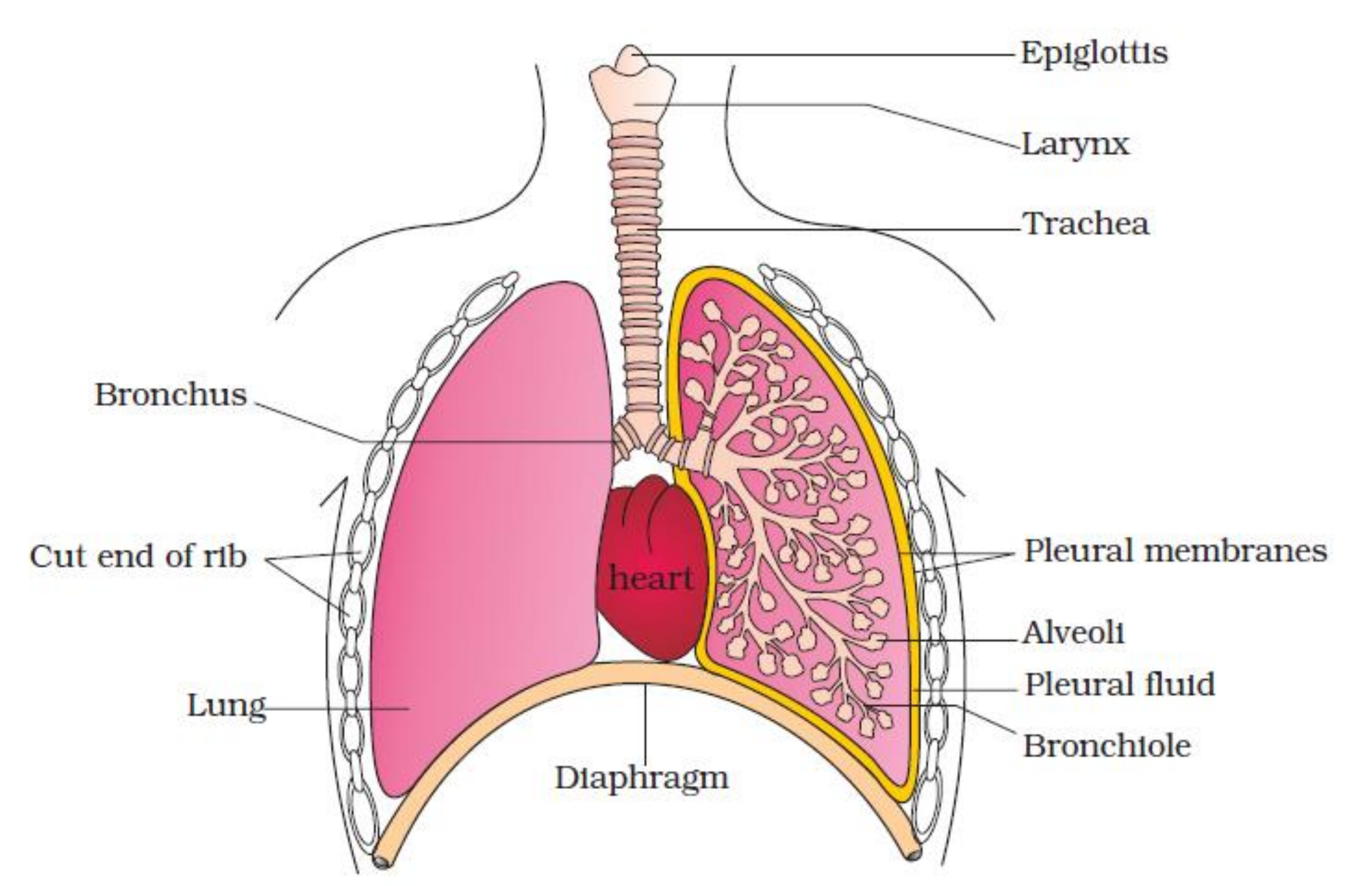
Lungs



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Steps of Respiration

Respiration involves the following five steps:

- Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.
- Diffusion of gases (O_2 and CO_2) across alveolar membrane.
- Transport of gases by the blood.
- Diffusion of O_2 and CO_2 between blood and tissues.
- Utilisation of O_2 by the cells for catabolic reactions and resultant release of CO_2.

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Mechanism of Breathing

The process of breathing involves taking in of atmospheric air **(inspiration)** and giving out of alveolar air **(expiration).**

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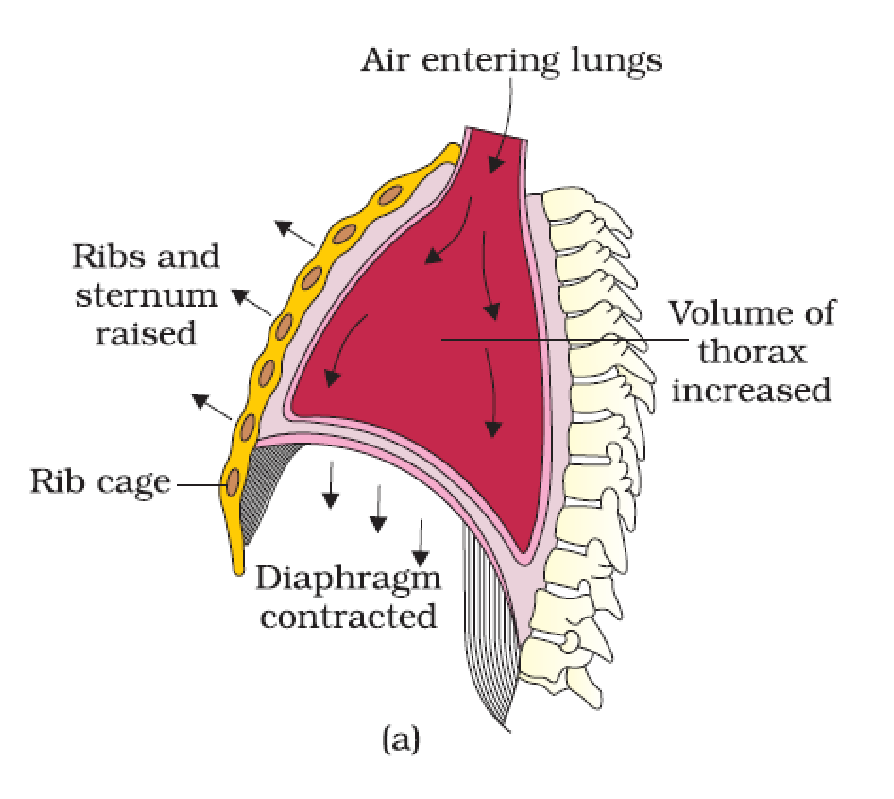
Inspiration



- It occurs when intra-pulmonary pressure is lower than atmospheric pressure, which means there is negative pressure in lungs.
- Diaphragm moves down and ribs move upwards and outwards, thereby leading the movement of air into the lungs.
- The volume of air in the thoracic chamber increases.

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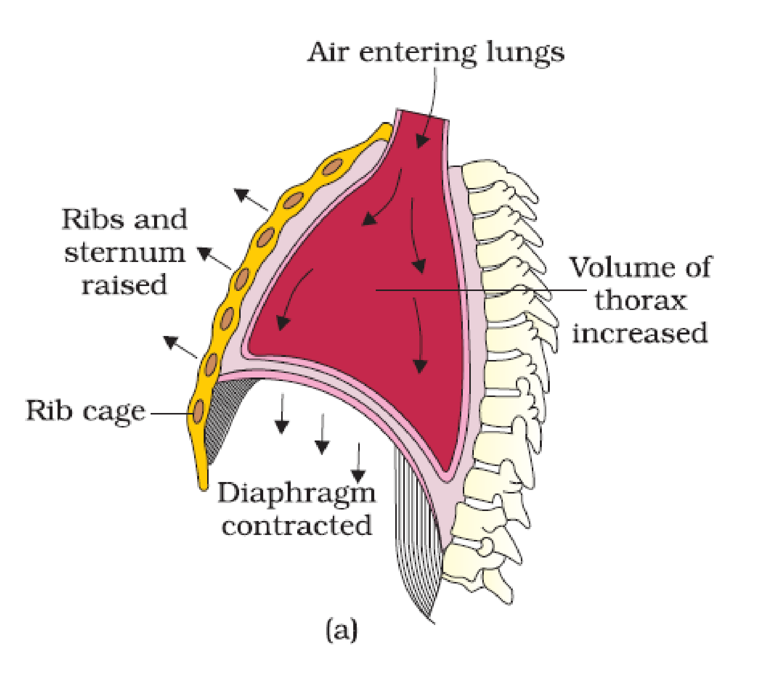
Expiration



- Expiration occurs when intra-pulmonary pressure is higher than atmospheric pressure, which means that there is positive pressure in lungs.
- Diaphragm moves up and the ribs move downward and inward.
- This reduces the size of chest cavity and leads to the movement of air out of lungs.
- The volume of air in the thoracic chamber decreases.

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Expiration

An adult human respires at the rate of 12-16 times/minute.

Spirometer helps in clinical assessment of pulmonary function.

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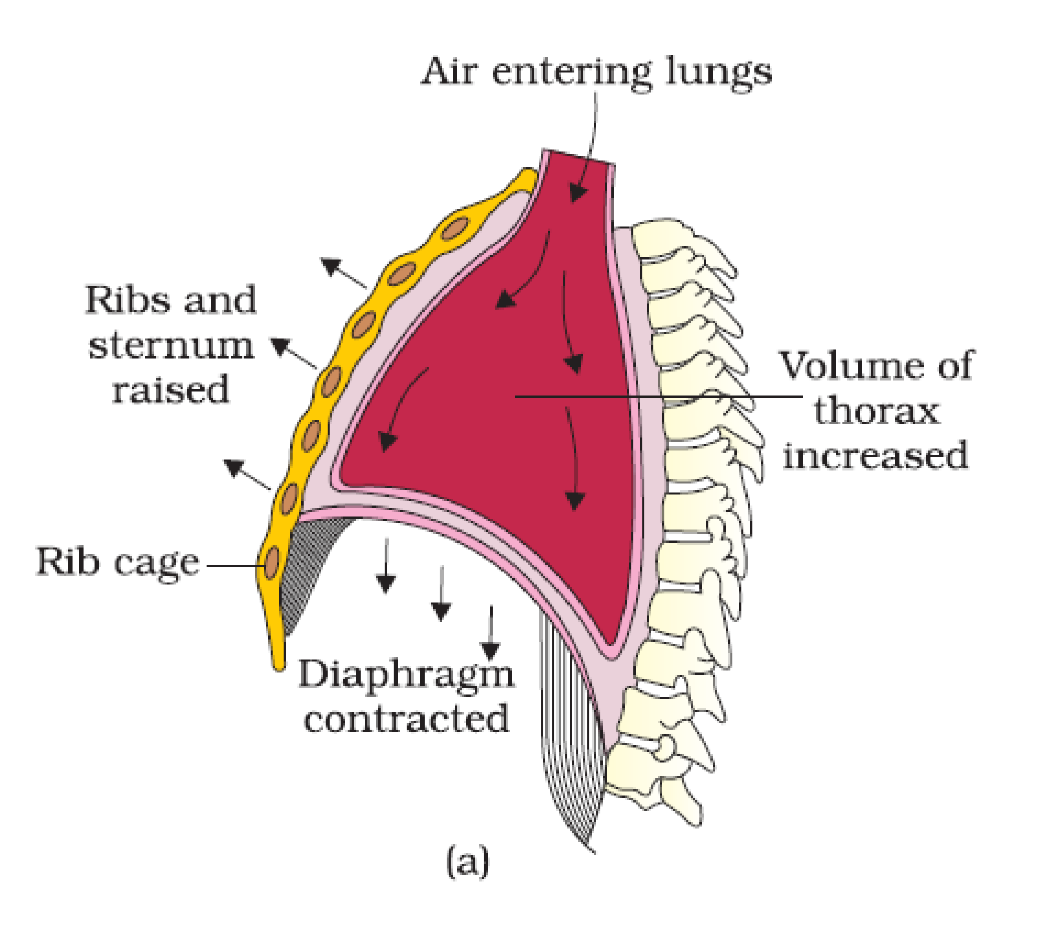
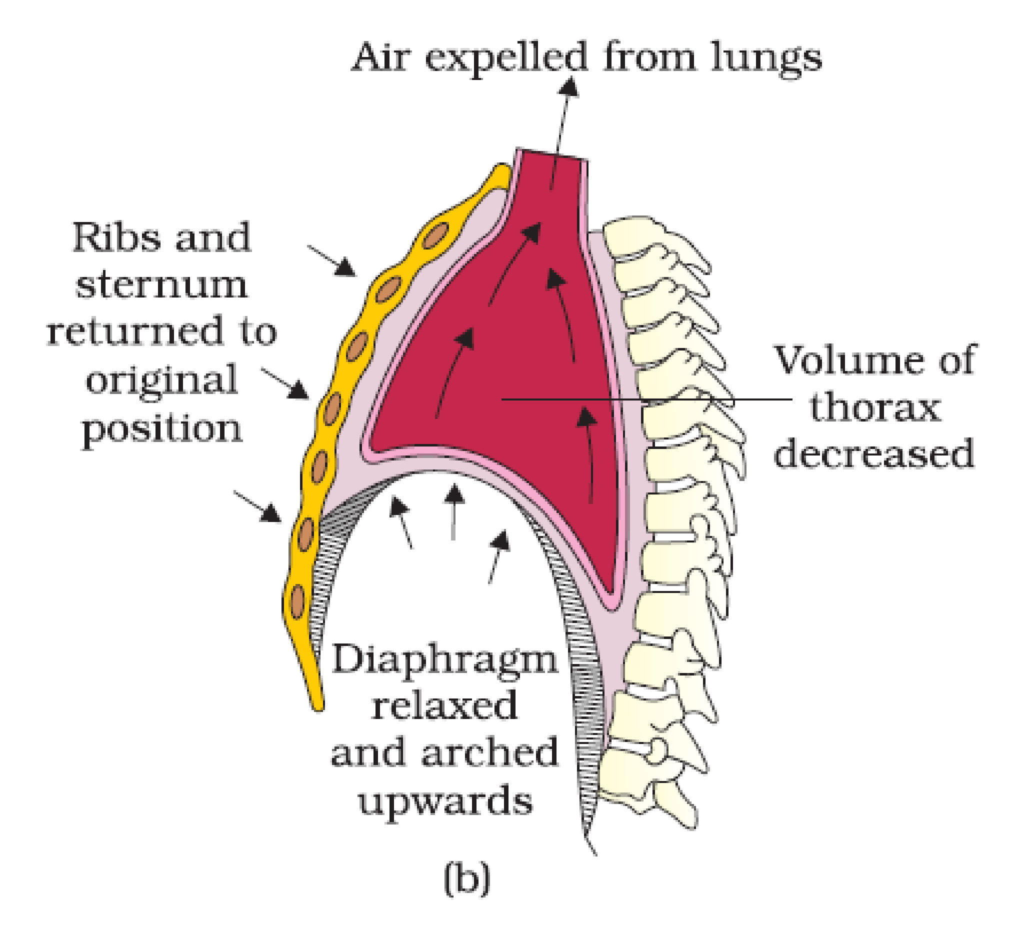
Inspiration

Expiration





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Respiratory Volume

Tidal Volume (TV):

It is the volume of air that is inspired or expired in a single breath during regular breathing. Its value is about 500 mL.

A healthy man can inspire or expire about 6000 to 8000 mL of air/minute.

Inspiratory Reserve Volume (IRV)

It is the additional volume of air that can be inspired by a person in a forcible inspiration. It is about 2500 – 3000 mL.

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Respiratory Volume

Expiratory Reserve Volume (ERV)

It is the maximum volume of air that can be expired by a person in a forcible expiration. It is about 1000 – 1100 mL.

Residual Volume (RV)

It is the amount of air remaining in the lungs after maximum expiratory effort. It is about 1100 – 1200 mL.

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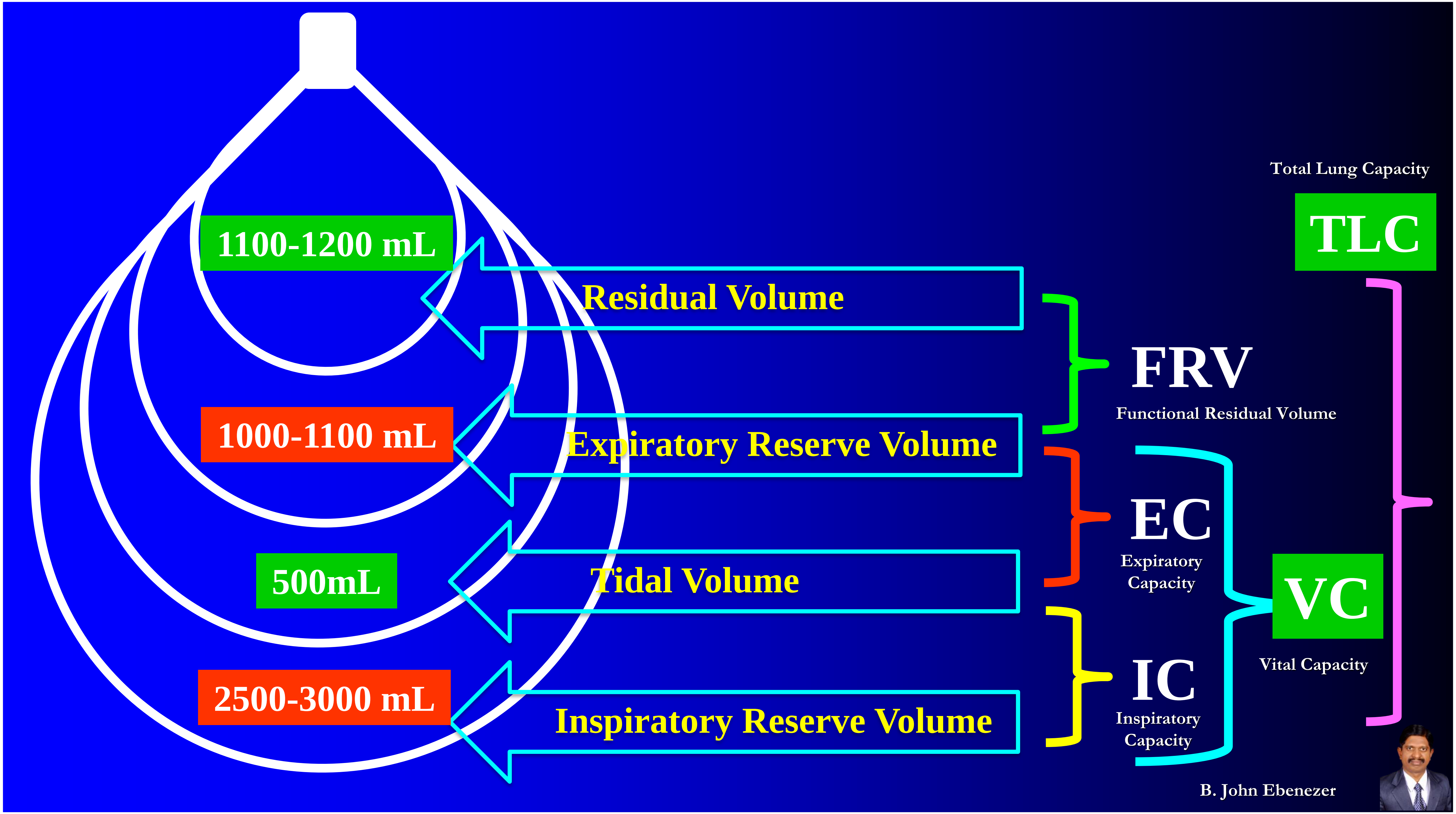

1100-1200 mL
Residual Volume
1000-1100 mL
Expiratory Reserve Volume
500mL
Tidal Volume
2500-3000 mL
Inspiratory Reserve Volume
FRV
Functional Residual Volume
EC
Expiratory Capacity
IC
Inspiratory Capacity
VC
Vital Capacity
Total Lung Capacity
TLC
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Respiratory Capacities

By adding up a few respiratory volumes described above, one can derive various pulmonary capacities, which can be used in clinical diagnosis.

Inspiratory Capacity (IC)

It is the amount of air that can be inhaled by a person after normal exhalation. It includes **Tidal Volume** and **Inspiratory Reserve Volume.**

TV + IRV.

Expiratory Capacity (EC)

It is the amount of air that can be exhaled by a person after normal inhalation. It includes **Tidal Volume** and **Expiratory Reserve Volume.**

TV + ERV.

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Respiratory Capacities

Functional Residual Volume (FRV)

It is the amount of air that remains in lungs after normal exhalation.

It includes **Expiratory Reserve Volume** and **Residual Volume**.

Expiratory Reserve Volume + Residual Volume

ERV + RV.

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Respiratory Capacities

Vital Capacity (VC)

It is the maximum volume of air that a person can breathe in after maximum exhalation. It is equal to **Expiratory Reserve Volume**, **Tidal Volume** and **Inspiratory Reserve Volume.**

Expiratory Reserve Volume + Tidal Volume + Inspiratory Reserve Volume.

ERV+TV+IRV

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Respiratory Capacities

Total lung capacity (TLC)

It is the total amount of air accommodated in lungs after forced inhalation.

It includes **Vital Capacity** and **Residual Volume.**

Vital Capacity + Residual Volume

VC + RV

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Exchange of Gases

The primary sites of exchange of gases are **Alveoli**.

Exchange of gases also occurs between **blood and tissues** by simple diffusion.

The factors involved in diffusion are;

- **Pressure/concentration gradient**
- **Solubility of the gases**
- **The thickness of the membranes involved in diffusion.**

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Partial Pressure

Pressure contributed by an individual gas is called partial pressure and is represented as pO_2 for oxygen and pCO_2 for carbon dioxide.

The partial pressures of O_2 and CO_2 in the atmospheric air and the two sites of diffusion are given in the following Table.

TABLE 17.1 Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

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The gradient for CO_2 is in the opposite direction, i.e., from tissues to blood and blood to alveoli.

As the solubility of CO_2 is 20-25 times higher than that of O_2, the amount of CO_2 that can diffuses through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2.

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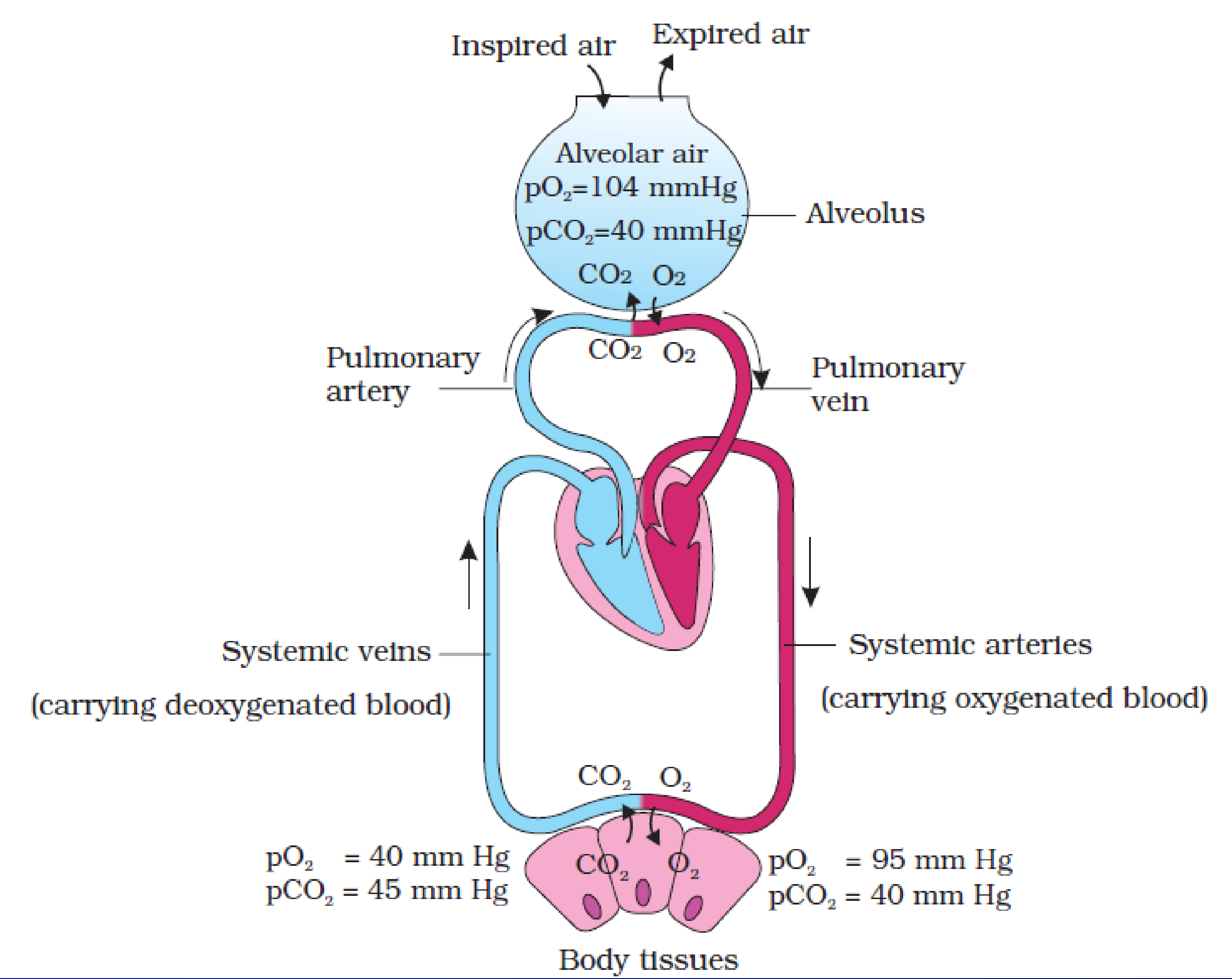
Exchange of Gases



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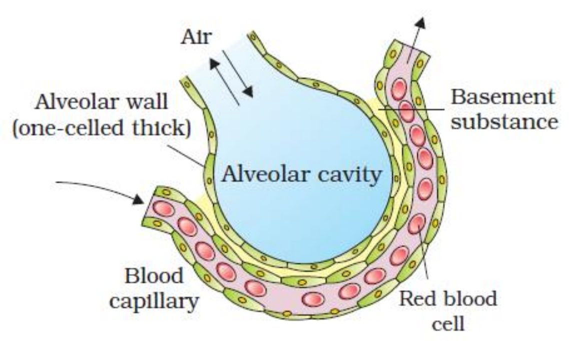
Diffusion Membrane



The diffusion membrane is made up of three major layers.

- Thin **squamous epithelium of alveoli**
- The **endothelium of alveolar capillaries**
- The **basement substance** in between them.

However, its total thickness is much **less than a millimetre**.

Therefore, all the factors in our body are favourable for diffusion of O_2 from alveoli to tissues and CO_2 from tissues to alveoli.

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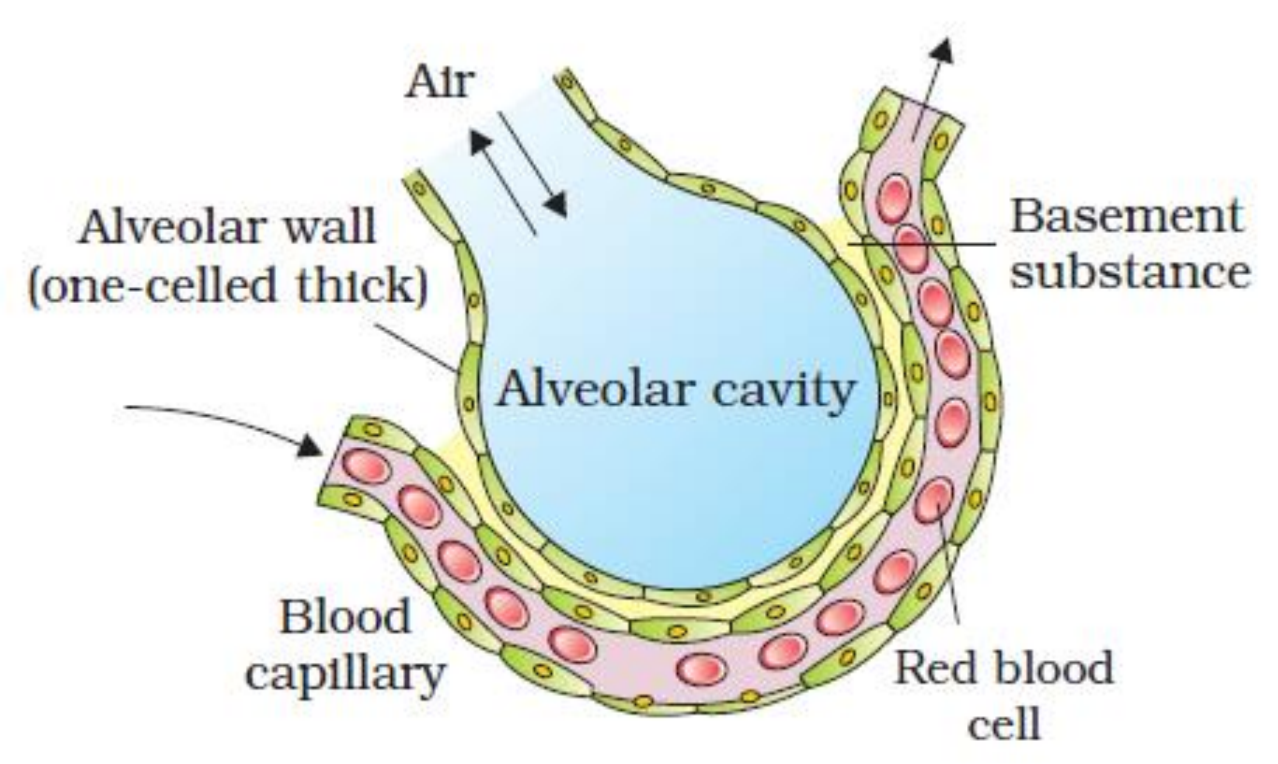
Diffusion Membrane



Transport of Gases

Blood is the medium of transport for O_2 and CO_2.

O_2 transported by RBCs in the blood is about 97 per cent .

O_2 transported by Plasma in a dissolved state is about 3 per cent.

CO_2 transported as bicarbonate ions is 70 per cent.

CO_2 transported as Carbaminohaemoglobin by RBC is 20-25 percent.

CO_2 transported by plasma in a dissolved state is about 7 percent.

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Partial Pressure of O_2

Haemoglobin is a red coloured iron containing pigment present in the RBC.

O_2 can bind with haemoglobin to form **oxyhaemoglobin**.

Each haemoglobin molecule can carry a maximum of four molecules of O_2.

The factors affecting the binding of oxygen with haemoglobin are;

- Partial pressure of O_2
- Partial pressure of CO_2
- Hydrogen ion concentration
- Temperature

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Partial Pressure of O_2

Exchange of gases (O_2 and CO_2) at alveolar and tissues occurs by **diffusion.**

The partial pressure of O_2 in atmospheric air is higher than that of oxygen in alveolar air.

The pO_2 in atmospheric air is about 159 mm Hg.

The pO_2 in alveolar air is about 104 mm Hg.

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Sigmoid Curve

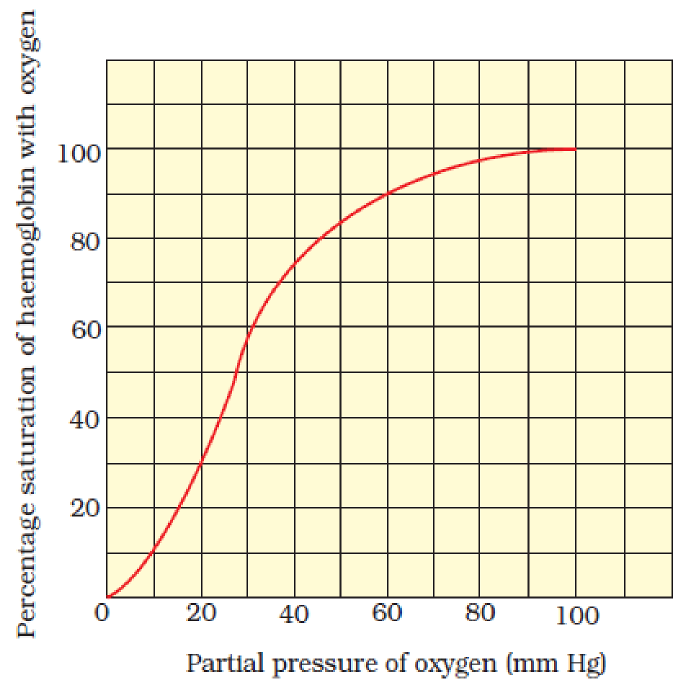

Figure 17.5 Oxygen dissociation curve

A sigmoid curve is obtained when percentage saturation of haemoglobin with O_2 is plotted against the pO_2.

This curve is called the Oxygen dissociation curve and is highly useful in studying the effect of factors like pCO_2, H^+ concentration, etc., on binding of O_2 with haemoglobin.

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Sigmoid Curve

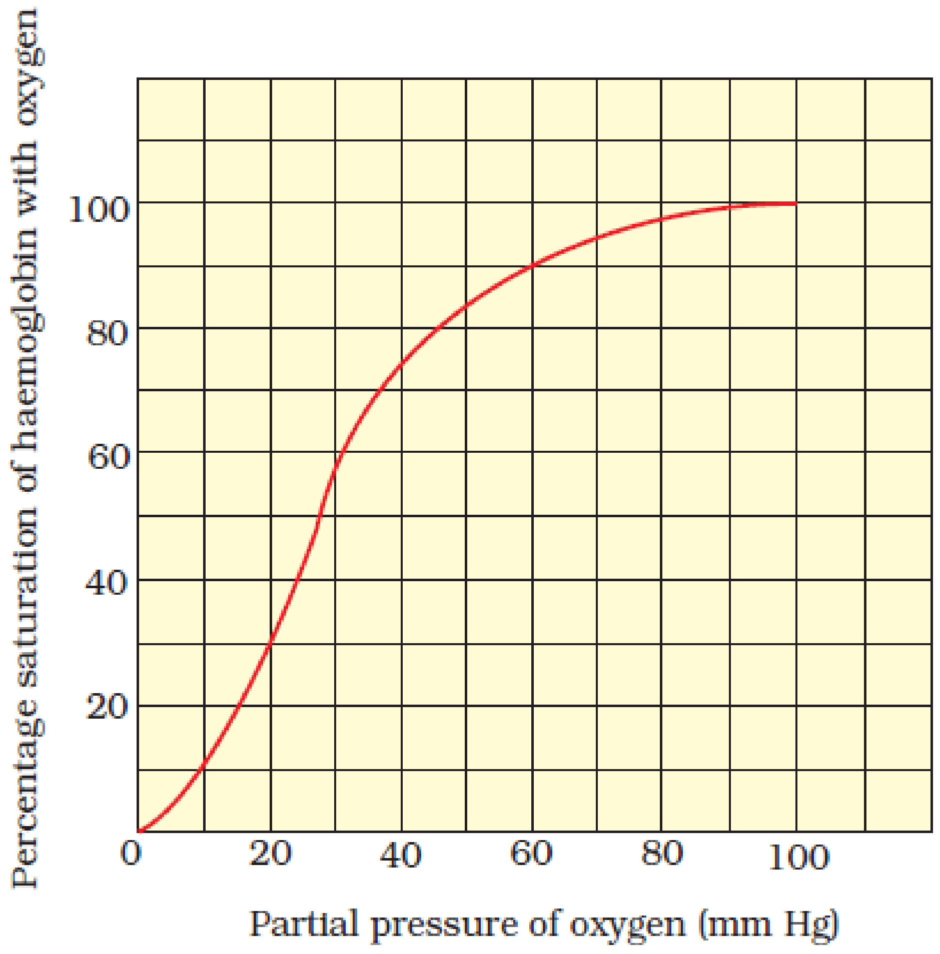

Figure 17.5 Oxygen dissociation curve

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Formation of Oxyhaemoglobin in Alveoli

The factors necessary for the formation of oxyhaemoglobin in the alveoli are;

High pO_2

Low pCO_2

Low H^+ concentration

Low Temperature

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Dissociation of Oxygen in Tissues

The factors necessary for the dissociation of oxygen from oxyhaemoglobin in tissues are;

Low pO_2

High pCO_2

High H^+ concentration

High temperature

Every 100 ml of oxygenated blood can deliver around 5 ml of O_2 to the tissues under normal physiological conditions.

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Transport of Carbon dioxide

The CO_2 carried as **carbamino-haemoglobin** by haemoglobin is about 20-25 per cent.

The factors necessary for this binding in the tissues is

High pCO_2

Low pO_2

The factors necessary for this dissociation in the alveoli is;

Low pCO_2

High pO_2

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RBCs contain a very high concentration of the enzyme, carbonic anhydrase,

Minute quantities of carbonic anhydrase is present in the plasma too.

This enzyme facilitates the following reaction in both the directions.

$$CO_2 + H_2O \underset{}{\overset{\text{Carbonic anhydrase}}{\rightleftharpoons}} H_2CO_3 \underset{}{\overset{\text{Carbonic anhydrase}}{\rightleftharpoons}} HCO_3^- + H^+$$

Carbonic acid

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Partial Pressure of CO_2

The partial pressure of CO_2 in atmospheric air is lower than that of CO_2 in alveolar air.

The pCO_2 in atmospheric air is about 0.3 mm Hg.

The pCO_2 in alveolar air is about 40 mm Hg.

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Transport of Carbon dioxide

CO2 transported as Sodium bicarbonate is about 70%.

CO2 transported as Carbaminohaemoglobin by RBC is 20-25%

CO2 transported in dissolved state by plasma is about 7%

CO_2 trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2.

Every 100 ml of deoxygenated blood delivers approximately 4 ml of CO_2 to the alveoli.

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Regulation of Respiration

Neural System

Rhythm Centre of Medulla

Controls Respiratory Rhythm

Pneumotaxic Centre of Pons

Moderate the functions of Rhythm Centre

Neural Signal

Reduce Duration of Inspiration and Alter Respiratory Rate

Chemotaxic Centre

Sense changes in CO_2 & H^+ ion Concentration

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Regulation of Respiration

Human beings have a significant ability to maintain and moderate the respiratory rhythm to suit the demands of the body tissues.

This is done by the neural system.

Respiratory rhythm centre present in the medulla region of the brain responsible for this regulation.

Pneumotaxic centre in the pons region of the brain can moderate the functions of the respiratory rhythm centre.

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Regulation of Respiration

Neural signal from the Pneumotaxic centre can reduce the duration of inspiration and thereby alter the respiratory rate.

A chemosensitive area is situated adjacent to the rhythm centre which is highly sensitive to CO_2 and Hydrogen ions.

Increase in these substances can activate this centre, which in turn can signal the rhythm centre to make necessary adjustments in the respiratory process by which these substances can be eliminated.

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Regulation of Respiration

Receptors associated with aortic arch and carotid artery also can recognise changes in CO_2 and H^+ concentration and send signals to the rhythm centre for remedial actions.

The role of oxygen in the regulation of respiratory rhythm is quite insignificant.

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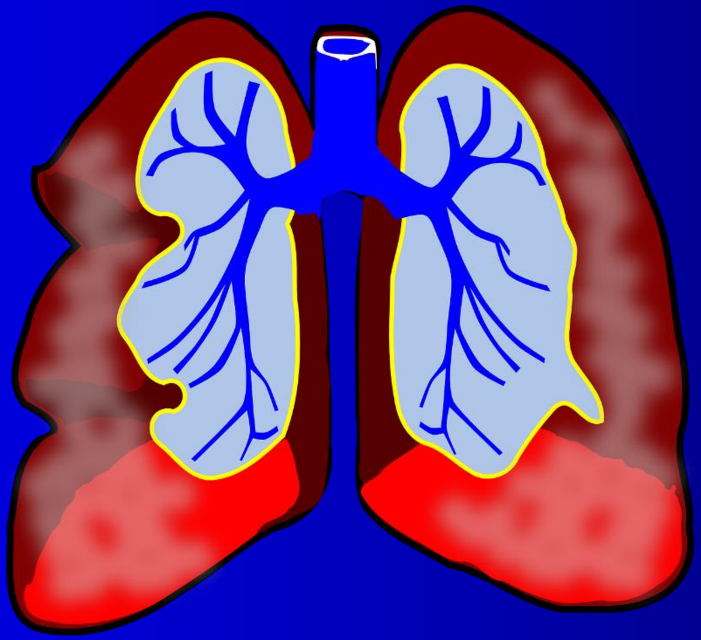
Respiratory Disorders

Asthma is a lung disorder causes difficulty in breathing leading to wheezing due to inflammation of bronchi and bronchioles.



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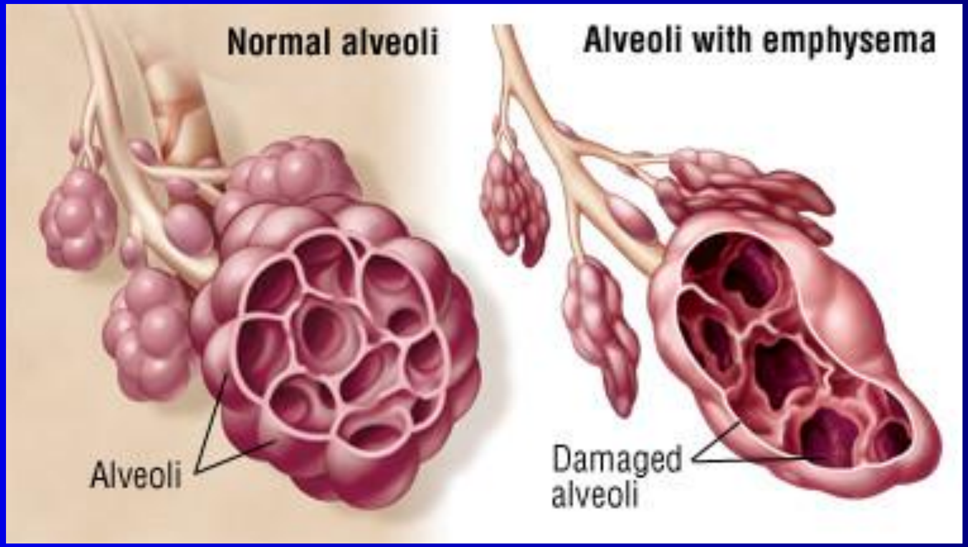
Emphysema

Emphysema is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased.

One of the major causes of this is cigarette smoking.



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Occupational Respiratory Disorders

Industries which involve in grinding or stone breaking, produce so much of dust that the immune system of the body cannot manage the situation.

This causes inflammation leading to fibrosis (proliferation of fibrous tissues) and thus causing serious lung damage.

Workers in such industries should wear protective masks.

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God Bless You!