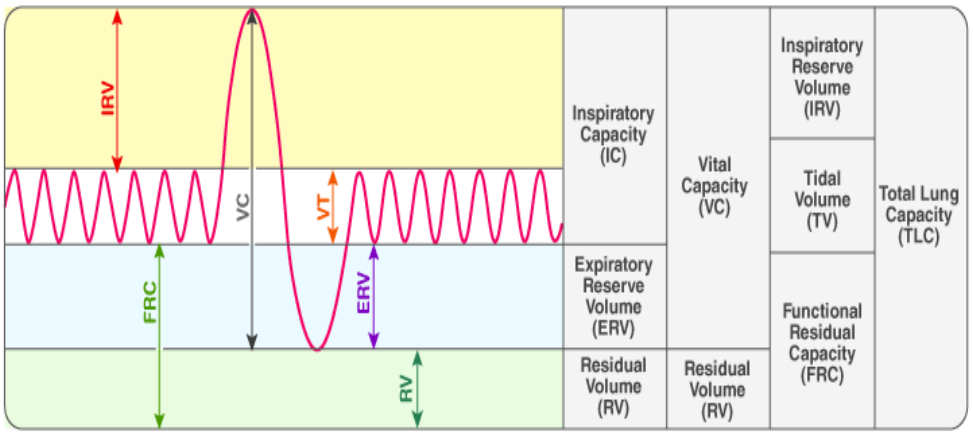
Respiratory Volumes and Capacities

1) **Tidal volume (TV)-**The volume of air inspired or expired normally. It is total 500 ml i.e. 150 mL of dead space and 350 mL of alveolar volume. A Healthy man have 6000-8000 mL/min.
   In infants it is 15 ml approx and in fetus it is 0 ml.
2) **Inspiratory reserve volume (IRV)-** 2500 to 3000 ml, Additional amount of air a person inspire forcible after a normal inspiration.
3) **Expiratory reserve volume (ERV)-** 1000 to 1100 ml, Additional amount of air a person expire forcible after a normal expiration.
4) **Residual volume (RV)-** 1100 to 1200 ml, The amount of air remain in the lungs after forcible expiration.
5) **Inspiratory Capacity (IC) -** Total volume of air a person can inspire after a normal expiration i.e. TV + IRV
6) **Expiratory Capacity (EC)-** Total volume of air a person can expire after a normal inspiration i.e. TV + ERV
7) **Functional residual capacity (FRC),** The air remaining in the lungs after normal expiration (ERV + RV)
8) **Vital capacity (VC)-** The maximum volume of air that can be breathed in or out after forced expiration or inspiration (IRV + ERV + TV). It is 3400-4800ml
9) **Total Lung capacity (TLC)-** Total volume of air present in the lungs after a forced (maximum) inspiration. (VC + RV) or (RV+ ERV+ TV+ IRV)
10) **Dead space**: Portion of tracheobronchial tree where gaseous exchange does not occur is called dead space. It is also called conductive zone. Dead space is 150 ml.



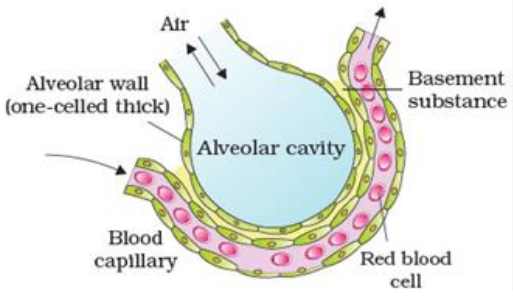
Note:

- Vital capacity is higher in athletes, mountain dwellers than in plain dwellers, in men than women & in young ones than old persons.
- All pulmonary volumes and capacities are about 20-25% less in women than in men and they are greater in tall persons and atheletes than in small and asthenic people.
- During respiration, the lungs and the respiratory tract are never devoid of air. Instead, there is a tidal volume of air.

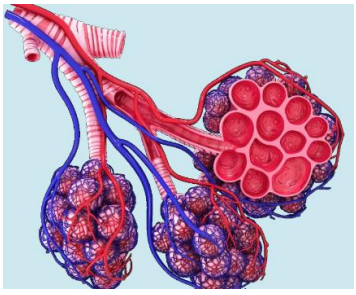
Exchange of Gases- takes place at two sites by simple diffusion due to pressure/ concentration gradient, solubility of the gases, thickness of membrane & surface area of respiratory surface (total 80m^2)

1. Alveoli to blood
2. Between blood and tissues.

- **Partial pressure**- Pressure contributed by individual gas in a mixture of gas represented by pCO_2 and pO_2 . Gases diffuses through higher partial pressure to lower partial pressure.
- **Solubility** of CO_2 is 20-25 times more than solubility of O_2 , so CO_2 diffuse much faster through membrane.
- Diffusion at alveoli takes place through **three membranes**. i.e. 0.5mm.
  1) Squamous epithelium- Alveoli
  2) Endothelium- capillaries
  3) Basement- space between them

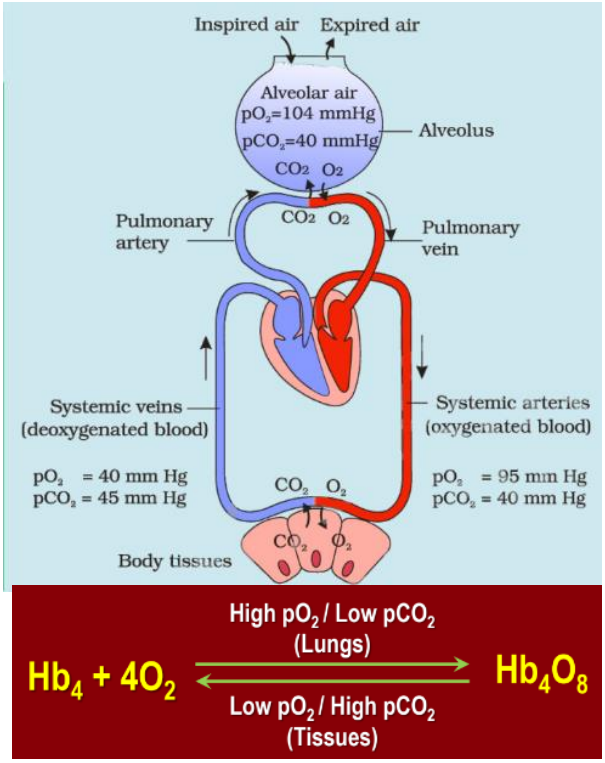


Respiratory gas	pO_2 (mm Hg)	pCO_2 (mm Hg)
Atmospheric air	159	0.3
Alveoli	104	40
Deoxygenated blood	40	45
Oxygenated blood	95	40
Tissues	40	45



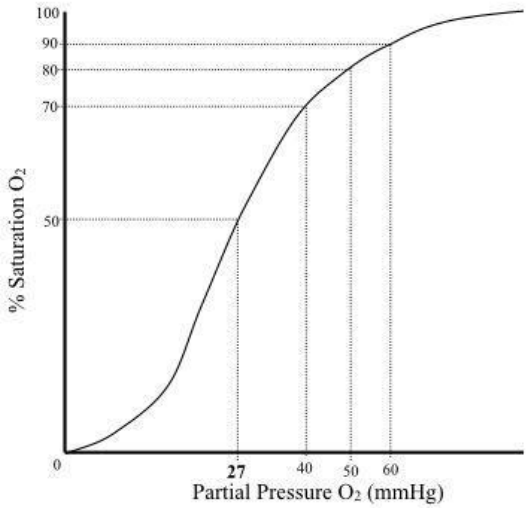
Transport of Gases- Blood is medium of transport for CO_2 and O_2 .

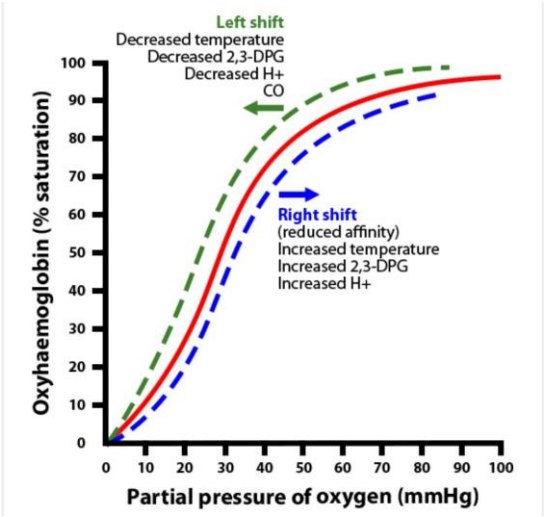
- 97% of oxygen is carried by RBCs as **Oxyhaemoglobin** and remaining 3% by blood plasma in diffused form.
- Each molecule of Haemoglobin molecule can bind to 4 molecules of oxygen forming **oxyhaemoglobin. (Fe++** in haemoglobin binds to O_2).
- Binding of O_2 & CO_2 is related with partial pressure of O_2 & CO_2 ,H+ ion concentration, pH and temperature.
- In the alveoli, oxyhaemoglobin formation is favoured due to higher pO_2 , low temperature , low pCO_2 , high PH and H^+ concentration.
- In tissues, oxyhaemoglobin dissociates due to low pO_2
- Every 100mL of oxygenated blood can deliver about 5mL of O_2 to the tissues.



Oxygen Dissociation Curve

A sigmoid curve (S–shaped) is obtained when percentage saturation of haemoglobin with oxygen is plotted against pO_2.



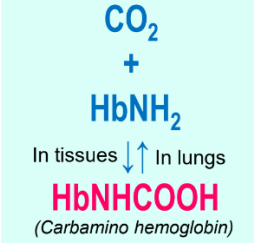


Bhor Effect- An increase in carbon di-oxide in the blood causes oxygen to displaced from the haemoglobin.
Haldane Effect-Binding of oxygen with haemoglobin tends to displace carbon di-oxide from blood.

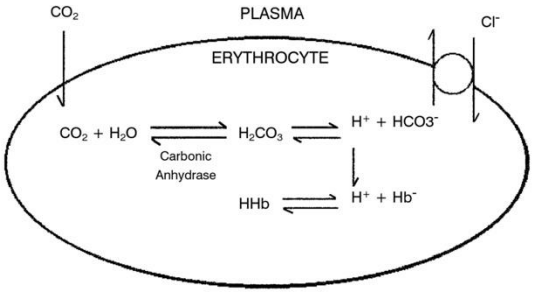
Left Shift – Haldane Effect (Association of O_2)	**Right Shift- Bhor Effect** (Dissociation of O_2)
• Association of O2 by Haemoglobin • Increase in pO2 • Decrease H+ ions and High PH (alkalosis) • Decrease in pCO2 • Decrease in temperature • Decrease in 2, 3 -diphosphoglycerate.	• Dissociation of O2 by Haemoglobin • Decrease in pO2 • Increase in H+ ions and Low PH (acidosis) • Increase in pCO2 • Increase in temperature • Increase 2,3-diphosphoglycerate:

Carbon dioxide Transport

- About 7% of CO_2 is transported in **dissolved form (in plasma)**
- As **carbaminohaemoglobin** in RBC- 20 – 25%
- About 70% as bicarbonate ions (HCO3-).



- RBCs contain high concentration of the enzyme, carbonic anhydrase & minute quantities of it is present in the plasma too.
- At tissue PCO2 is high due to catabolism, CO_2 diffuses into the RBCs, & combines with water forming carbonic acid (H_2CO_3) catalyzed by carbonic anhydrase. Carbonic acid is unstable and dissociates into H+ and bicarbonate ions (HCO3-).
- The HCO_3^- diffuses from the RBCs to plasma, where it is carried to the lungs.
- At the alveoli pCO_2 is low, the reaction is reversed leading to the formation of CO_2 and water.
- **Chloride Shift (Hamburger's Phenomenon) –** HCO3- formed in RBCs leaves RBCs in exchange to Cl- to plasma.
- Every 100mL of deoxygenated blood delivers 4mL of CO_2 to the alveoli for elimination.

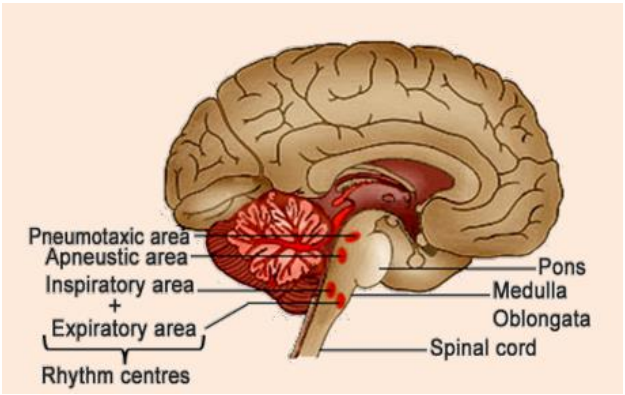


Regulation of Respiration- **Hind Brain**

- **Respiratory rhythm centre**- **Medulla** region.

Inspiratory Area- Actively controlled by **Dorsal Medulla**
(Expiration is passive process)

Expiratory Area – Forceful Expiration is controlled actively by Ventral Medulla.



- **Pneumotaxic centre** in pons moderate the function of respiratory rhythm centre.
- **Apneustic Centre-** in pons is responsible for slow & deep breathing.
- **Chemo-sensitive area** near rhythm centre is highly sensitive to CO_2 and H+ ions that ultimately control the respiratory rate.
- **Receptors in Aortic Arch & Carotid Artery** recognize changes in CO_2 and H+ ions concentration and send signal to rhythm centre.
- Oxygen do not play major role in controlling rate of respiration.

Function of Respiration -Energy production, Maintenance of acid-base balance, Maintenance of temperature, Return of blood and lymph.

Disorders Of Respiratory System

Asthma: is a difficulty in breathing causing wheezing due to inflammation of bronchi and bronchioles.

Emphysema: is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. Major reason Smoking. There is shortness of breath even at rest.

Occupational respiratory disorder: Workers, who are exposed to a lot of dust are prone to get long term inflammation and leading to fibrosis and lung damage.

Pneumonia– it is acute infection or inflammation of the alveoli of the lungs due to bacterium *streptococcus pneumoniae.* Alveoli become acutely inflamed and most of air space of the alveoli is filled with fluid and dead white blood corpuscles limiting gaseous exchange.

Mountain Sickness is the condition characterised by the ill effect of hypoxia (shortage of oxygen) in the tissues at high altitude commonly to person going to high altitude for the first time.

Symptoms- Loss of appetite, nausea, & vomiting occurs due to expansion of gases in digestive system. Breathlessness occurs because of pulmonary oedema, Headache, depression, disorientation, lack of sleep, weakness and fatigue.

Carbon monoxide poisoning-(CO has **200** times more efficiency than O2). **It** occurs when CO binds up with Haemoglobin. When too much CO is in the air, your body replaces the oxygen in your RBCs with CO. This can lead to serious tissue damage, or even death.