Respiratory system

The primary function of the lungs is gas exchange. The respiratory system consists of the nasal cavity, the pharynx, larynx, the trachea, the bronchi, and the lungs. The term **upper respiratory tract** refers to the nasal cavity, the pharynx, and associated structures; and the **lower respiratory tract** includes the larynx, trachea, bronchi, and lungs.

Respiratory function of the nose:

[1] **Warming the air** by the extensive surfaces of the conchae and septum.
[2] The air is almost completely **humidified**.
[3] The air is **filtered**.

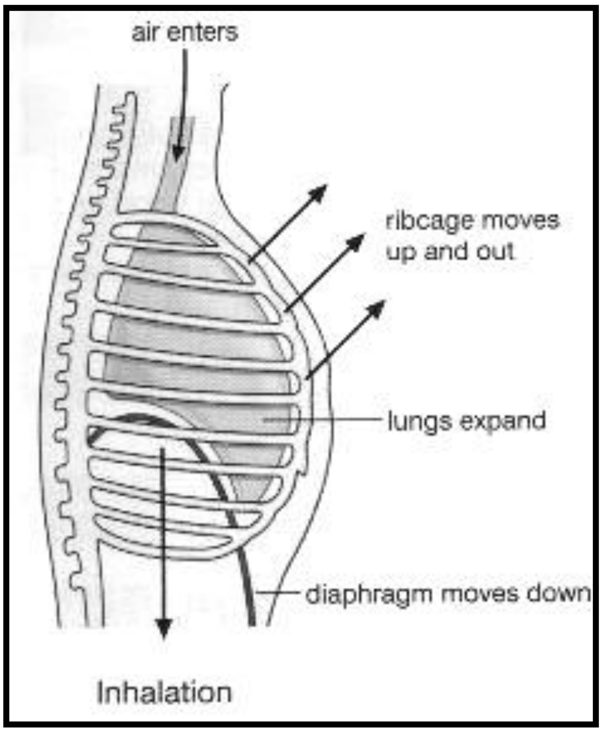
The process of respiration can be divided into four major events:

[1] Pulmonary ventilation which means the inflow and outflow of air between the atmosphere and the lung alveoli.
[2] Diffusion of oxygen and carbon dioxide between the alveoli and the blood.
[3] Transport of oxygen and carbon dioxide in the blood and body fluids to and from the cells.
[4] Regulation of ventilation.

Pulmonary ventilation: Which includes *inspiration* and *expiration.*

[A] Inspiration: Normal inspiration is an active process. The lungs can be expand in two ways:

[1] By **downward and upward movement of the muscles of**
[2] By **raising the rib cage**



[B] Expiration: Normal expiration is a passive process. The lungs can be shrinked or contracted by two ways:

[1] Relaxation of diaphragm and the inspiratory muscles
[2] Elastic recoil tendency (retractive force or elastance) of the lung

Types of Breathing:

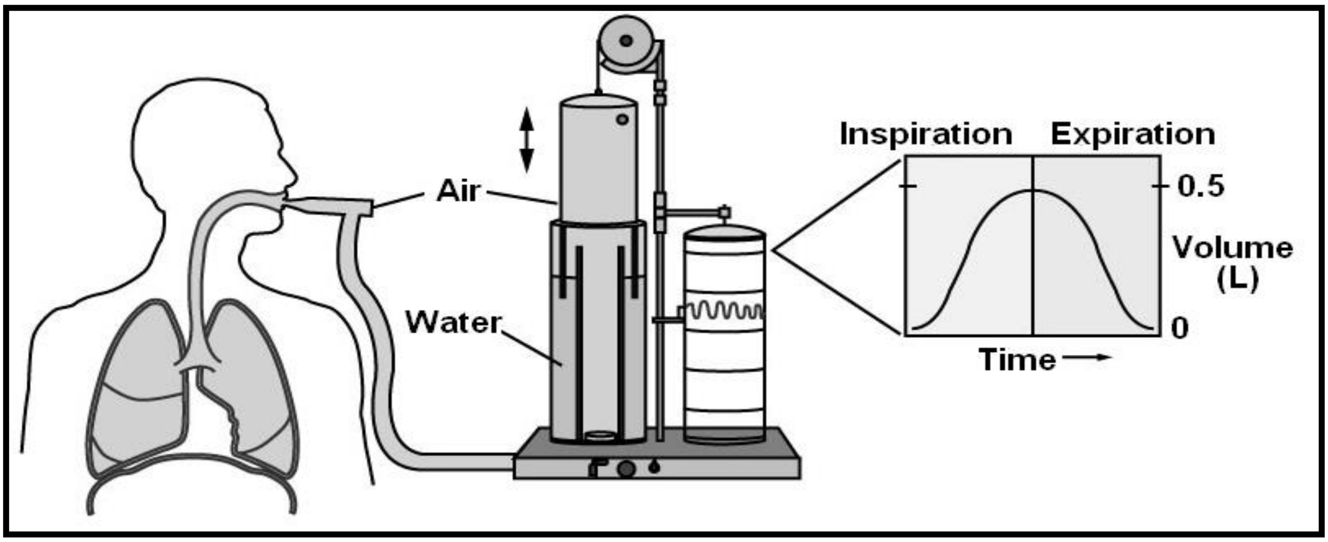
[A]. Diaphragmatic Breathing(=Abdominal Breathing):
B. Costal Breathing:

The role of surfactant: A substance known as surfactant, which is a lipoprotein, and its main constituent is the phospholipids dipalmitoyl phosphatidylcholine, and it is secreted from type II alveolar epithelium.

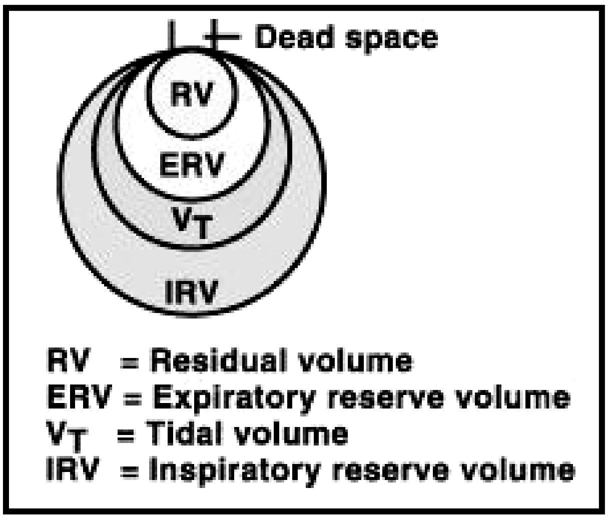
[1] It reduces the surface tension of the fluid lining the alveoli by decreasing the forces between the surface molecules of the alveolar fluid, and therefore, allowing the lungs to expand. **[2] It stabilizes the sizes of the alveoli:** Surfactant also plays an important role in stabilizing the sizes of the alveoli.

[3] It prevents accumulation of edema fluid in the alveoli: Surfactant is also playing a role in preventing accumulation of edema fluid in the alveoli.

The pulmonary volumes and capacities: Pulmonary ventilation can be recorded by using the **spirometer** and the process called spirometry by which



volume of air that is moved in and out of the lung can be recorded. The volumes and capacities of lungs are:

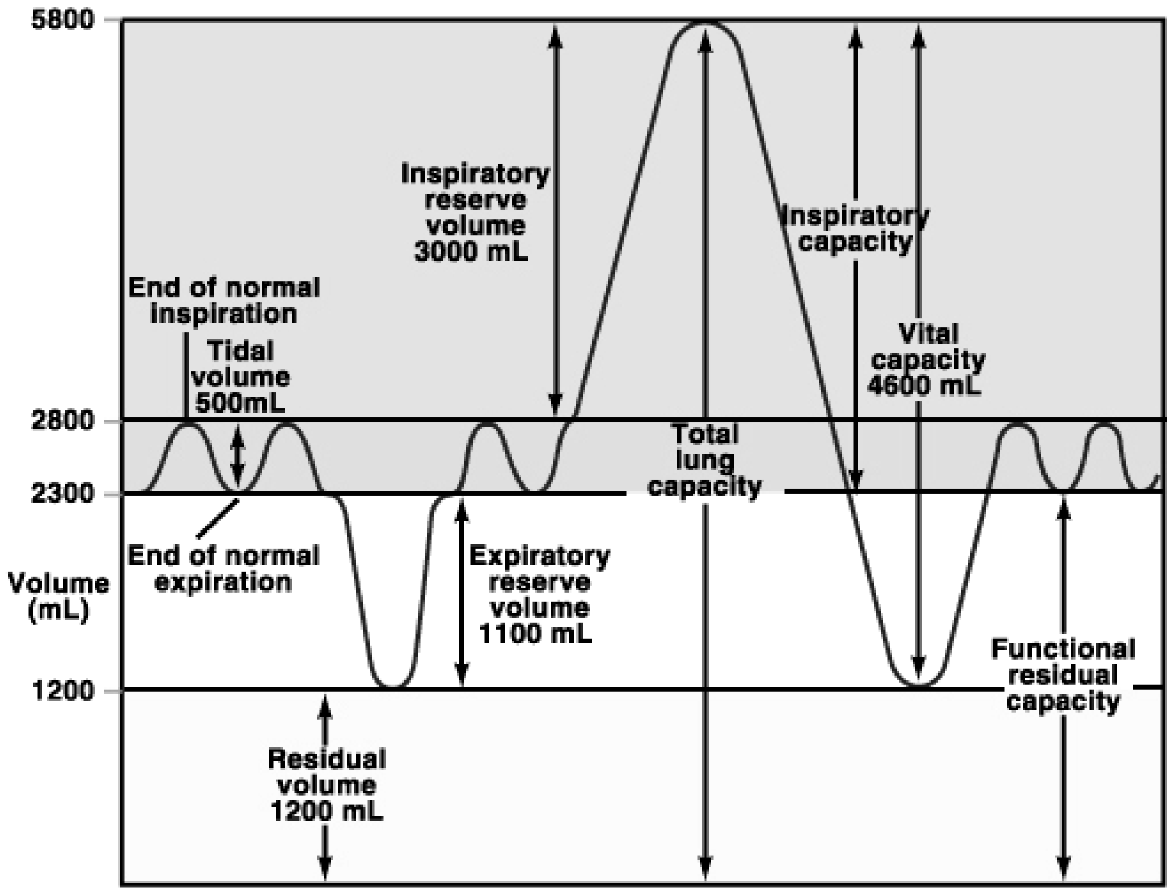


[1] The tidal volume (TV): Is the volume of air inspired or expired with each normal breath and it is about **500 ml** in average young adult man.

[2] The inspiratory reserve volume (IRV): Is the extra volume of air that can be inspired over and beyond tidal volume and it is about **3000 ml**.

[3] The expiratory reserve volume (ERV): Is the amount of air that can be expired after the normal tidal expiration, which is about **1100 ml.**

[4] The residual volume (RV): Is the volume of air still remaining in the lungs after the most forceful expiration, which is about **1200 ml**. This is important because it provides air in the alveoli to aerate the blood even between breaths which otherwise the concentration of oxygen and carbon dioxide in the blood would rise and fall markedly with each respiration, which would certainly be disadvantageous to the respiratory process.



The other way for determination of lung RV is by plethysmographic method.

[5] The inspiratory capacity (IC) = TV +IRV = 500 +3000 = **3500 ml**. This is the amount of air that a person cans breath beginning at the normal expiratory level and distending the lungs to the maximum amount.

[6] The functional residual capacity (**FRC**)= ERV + RV = 1100 + 1200 = **2300 ml**. This is the amount of air remaining in the lungs at the end of normal expiration.

[7] The vital capacity (VC) = IRV + TV + ERV = 3000 + 500 + 1100 = **4600 ml**. This is the maximum amount of air that a person can expel from the lungs after filling the lungs first to their maximum extent, and then expiring to the maximum extent.

[8] The total lung capacity (TLC) = VC + RV = 4600 + 1200 = **5800 ml**. This is the maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort.

Peak expiratory flow (PEF): It is the maximum airflow obtained during maximum expiratory effort after maximum inspiration. When a person expires with great force through *Wright peak flow meter,*

Forced vital capacity (FVC): It is the maximum volume of air expired forcefully following maximum inspiration. In a normal subject this is accomplished in 3-4 sec.

Timed vital capacity (forced expiratory volume-1 sec, FEV1): It is the volume of air expired during the first second of forceful expiration.

Percent vital capacity (FEV1%): It is equal to [FEV_1/VC] x 100. In normal subject, the FEV1% is at least 80%. However, in obstructive lung diseases like asthma, FEV_1% is markedly reduced while normal in restrictive lung diseases.

The dead space: It is the space in which the gas exchange is not taking place. Some of the air that a person breathes never reaches the gas exchange areas but instead goes to fill the respiratory passages. The respiratory passages where no gas exchange takes place is called the **anatomical dead space** (which consist of nose, pharynx, larynx, trachea, bronchi, bronchioles). The normal anatomical dead space air in the young adult is about **150 ml** There is another type of dead space and is called **physiological dead space**. This is

due to some alveoli are not functional or are only partially functional because of absent or poor blood flow through adjacent pulmonary capillaries.
Total dead space = anatomical D.S. + physiological D.S.
= 150 + 0 = 150 ml. i.e. equal to anatomical dead space.

Respiratory system passageways: They consist of **nose**, **pharynx**, **larynx**, **trachea**, **bronchi** (decrease in diameter and length with each successive branching but the sum of their cross-sectional areas actually increases), **bronchioles** (about 1 mm in diameter), **terminal bronchioles**, **respiratory bronchioles**, **alveolar ducts**, **alveolar sacs**, and **alveoli**. From trachea to the end of the terminal bronchiole is called the conducting

These smooth muscles are under nervous and humoral control:

[A] Nervous control of the bronchioles: parasympathetic cause mild to moderate constriction of the bronchioles.

[B] Humoral control of the bronchioles: histamine and the substance called slow reactive substance of anaphylaxis (SRA). causing the airway obstruction that occurs in allergic asthma. epinephrine and norepinephrine, relax the bronchioles (by activation of β_2 receptors).

Factor	**Effect**
Parasympathetic stimulation	Bronchoconstriction
Histamine and SRA	Bronchoconstriction
Low blood PCO_2	Bronchoconstriction
High blood PCO_2	Bronchodilatation
Sympathetic stimulation to the adrenal glands (epinephrine and norepinephrine)	Bronchodilatation

The cough reflex: The trachea, bronchi, respiratory bronchioles, and alveoli are very sensitive to irritation and touch. the following effects:
[1] About 2.5 liters of air is inspired.
[2] The epiglottis closes, and the vocal cords shut tightly to entrap the air within the lungs.
[3] The abdominal muscles contract forcefully, pushing against the diaphragm while other expiratory muscles also contract forcefully. [4] The vocal cords and the epiglottis suddenly open widely so that air under pressure in the lungs

The sneeze reflex: The sneeze reflex is very much similar to cough reflex except that it applies to the nasal passageways instead of to the lower respiratory passages.

<u>Exchange of gases in alveoli and tissues:</u> After the alveoli are ventilated with fresh air, the next step in the respiratory process is <u>diffusion</u> *<u>of oxygen from the alveoli into the pulmonary blood and transported by the blood to the tissue capillaries and then leave the tissue capillaries and cross cell membrane to gain entry into cells. Diffusion of CO_2 in the opposite direction, from the pulmonary blood into the alveoli.</u>*

<u>Composition of alveolar air</u>:

		Inspired air	Alveolar air	Expired air
	Atmospheric air (mm Hg)	Humidified air (mm Hg)	Alveolar air (mm Hg)	Expired air (mm Hg)
N_2	597	563.7	569	566
O_2	159	149	104	120
CO_2	0.3	0.3	40	27
H_2O	37	47	47	47
Total	760	760	760	760

respiratory membrane (pulmonary membrane) which consist of the following layers:

[1] A layer of fluid lining the alveolus and containing surfactant.
[2] The alveolar epithelium.
[3] The epithelial basement membrane.
[4] A very thin interstitial space.
[5] A capillary basement membrane
[6] The capillary endothelial membrane.

<u>Factors that affect rate of gas diffusion through the respiratory membrane</u>:

[1] The thickness of the membrane:

[2] The surface area of respiratory membrane:

[3] The diffusion coefficient of the gas in the substance of the membrane, which is the water of the membrane:

[4] The pressure difference between the two sides of the membrane,

O_2-Hb dissociation curve:

Factors that cause shifting of the O_2-Hb dissociation curve:

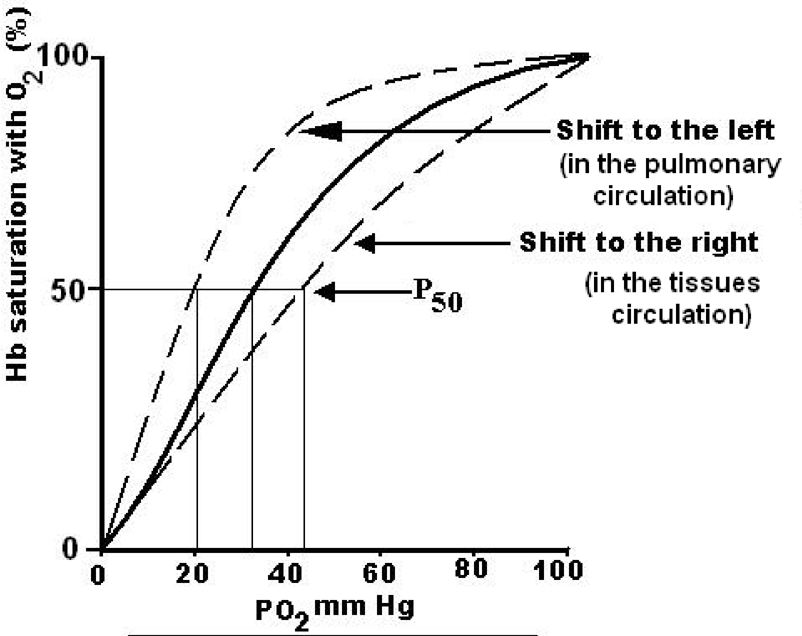
The factors that displace the curve to the right, which means that at any given PO_2, Hb has less affinity for O_2 (higher P_{50}), are:

[1] Increased $[H^+]$ with pH decreasing from 7.4 to 7.2.

[2] Increased CO_2 concentration.

[3] Increased 2,3-diphosphoglycerate (2,3-DPG).

[4] Increased blood temperature.



Hb-O_2 dissociation curve

The factors that shift the curve to the left, which means that at any given pO_2, Hb has more affinity for O_2, are:

[1] Decrease in $[H^+]$ with an increase in pH from 7.4 to 7.6.

[2] Decreased CO_2 concentration.

[3] The presence of large amount of Hb-F.

[4] Decreased blood temperature.

Shift of the O_2-Hb dissociation curve by changes in the blood CO_2 and $[H^+]$ is important to enhance oxygenation of the blood in the lungs and also to enhance release of oxygen from the blood in the tissues. This is called **Bohr effect**

The control of respiration: The respiration is controlled by the respiratory center in the brain which is composed of three major groups of neurons located bilaterally within the reticular formation of the medulla oblongata and pons and these are:

[1] The dorsal group of neurons: They are responsible for the basic rhythm of respiration by autonomous repetitive bursts of inspiratory action potentials.

[2] The pneumotaxic group: The primary effect of these is to control the switch off point of the inspiratory ramp, thus controlling the duration of the filling phase of the lung cycle.

[3] The ventral group

[A] The neurons of the ventral respiratory group remain inactive during normal quiet respiration.

[B] respiratory signals then spell over into the ventral respiratory neurons from the dorsal respiratory area.

[C] These neurons contribute to both inspiration and expiration..

Hypoxia: Hypoxia is cellular deficiency of O_2. Brain is the most sensitive tissue to hypoxia: complete lack of oxygen can cause unconsciousness in 15 sec and irreversible damage within 2 min. Traditionally hypoxia has been divided into 4 types:

[1] Hypoxic hypoxia: Inadequate ventilation of the alveoli or insufficient diffusion of O_2 through the respiratory membrane.

[2] Anaemic hypoxia: In which the arterial PO_2 is normal but the amount of Hb available to carry O_2 is reduced.

[3] Stagnant or ischaemic hypoxia: In which the blood flow to a tissue is so low that adequate O_2 is not delivered to it despite a normal PO_2 and Hb concentration.

[4] Histotoxic hypoxia: In which the amount of O_2 delivered to a tissue is adequate because of the action of a toxic agent such as in cyanide poisoning,