

## The Respiratory System

Most of the energy required by the cells of the body is derived from chemical reactions, which can only take place in the presence of oxygen (O<sub>2</sub>). The main waste product of these reactions is carbon dioxide (CO<sub>2</sub>). The respiratory system provides the route by which oxygen enters the body and carbon dioxide is excreted. The exchange of gases between the blood and the lungs and through to the cells is called external respiration and the utilisation of the oxygen within the cells is called internal (cellular) respiration.

Figure 1 - The Respiratory System

### The organs of the respiratory system are:

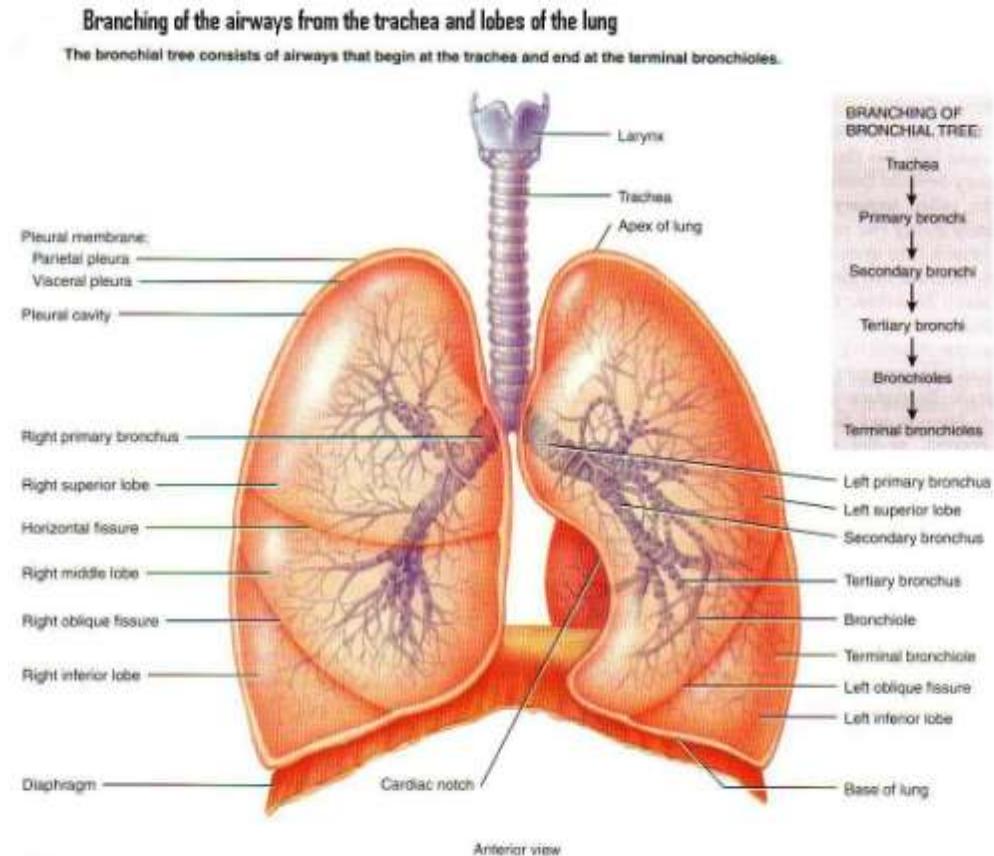
- Nose
- Pharynx
- Larynx
- Trachea
- Two bronchi (one bronchus to each lung)
- Bronchioles (smaller air passages)
- Alveoli (small air sacs where gaseous exchange takes place)
- Two lungs and their coverings (the pleura)
- Muscles of respiration – intercostal muscles and the diaphragm

The respiratory tract is divided into two: the upper and lower

### The Upper Respiratory Tract

The upper airway is formed by the nose, mouth, pharynx and larynx. It serves as a passageway for air being inspired and expired, filters, warms and moistens the inhaled air, and provides the protective reflexes of sneezing and the closing off of the larynx to prevent aspiration of fluids and solids (via the epiglottis).

**Nose:** The nose has a highly vascularised and ciliated mucous membrane lining which moistens, warms and filters inhaled air.



**Pharynx:** This is a muscular tube lined with mucous membrane extending from the base of the skull to the sixth cervical vertebra.

**Larynx:** The larynx is composed of muscle tissue and cartilage and is lined with mucous membrane. It functions as an air passage and contains the vocal cords.

## The Lower Respiratory Tract

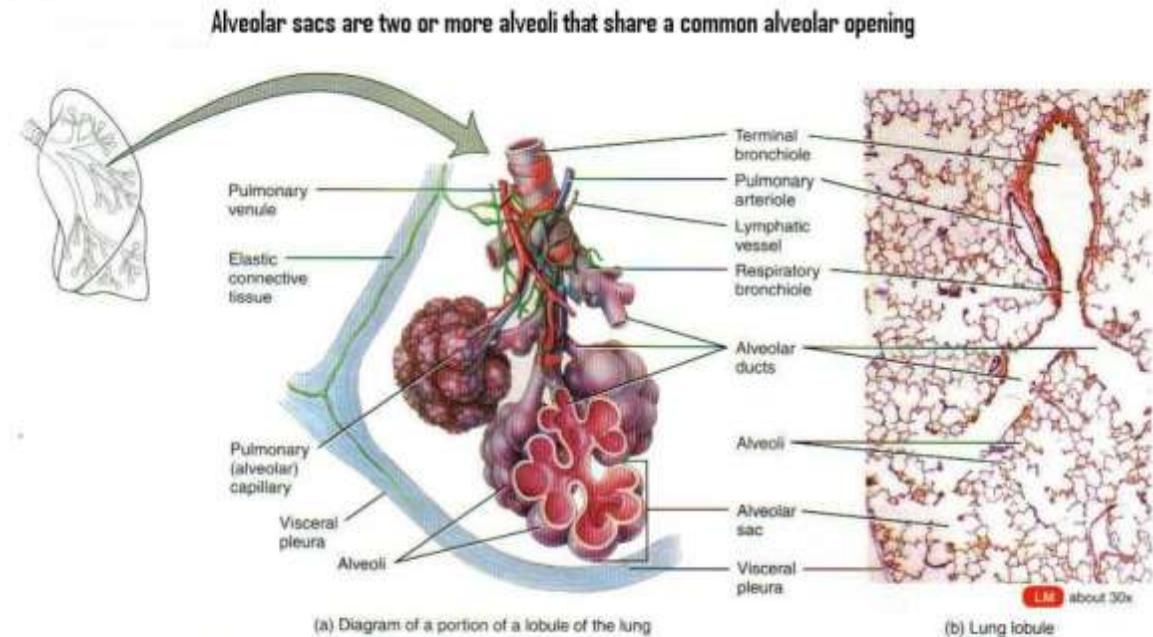
The lower tract consists of the trachea, bronchi and two lungs.

**Trachea:** The trachea continues from the larynx above and divides into the right and left bronchi below. The trachea, main bronchi and smaller bronchi are supported by C-shaped incomplete rings of cartilage with a gap behind. They are lined by ciliated epithelium containing goblet cells, which secrete mucus.

**Bronchi:** Each bronchus enters a lung where it branches like a tree to form the bronchial tubes. These in turn divide to form secondary and tertiary bronchi, and finally bronchioles, which are about 1mm in diameter. The **bronchioles** sub-divide, progressively becoming smaller. When no more branching takes place it becomes a terminal bronchiole, which gives rise to a spray of microscopic tubes known as alveolar ducts and each duct terminates in clusters of microscopic sacs called alveoli. **Alveoli** consist only of a thin layer of flattened epithelial cells, which are surrounded by blood capillaries, and here oxygen and carbon dioxide are exchanged by diffusion.

**The Lungs:** There are two lungs. Each lung is made up mainly of bronchial tubes with their successive branches, alveoli and many blood vessels. The right lung has three lobes and the left lung has two lobes. Each lung is enclosed in an adherent serous membrane called the visceral pleura. A second layer lines the thoracic wall and is called the parietal pleura.

Figure 2 - Alveoli



## The Mechanism of Respiration

This is the process by which the lungs expand to take in air and contract to expel it. The cycle of respiration, which occurs about 15 times a minute, consists of three phases:

- Inspiration
- Expiration
- Pause

Inspiration is the active phase during which air moves into the lungs. Expiration, in normal breathing, is a passive phase during which air moves out of the lungs. Inherent within this mechanism is the difference in pressures between the thoracic and abdominal cavities; the pressure of the abdominal cavity is greater than that of the thoracic. In inspiration the chest has to work against the pressure of the abdomen to pull air into the lungs, but uses this pressure in the process of exhalation.

## Muscles of Respiration

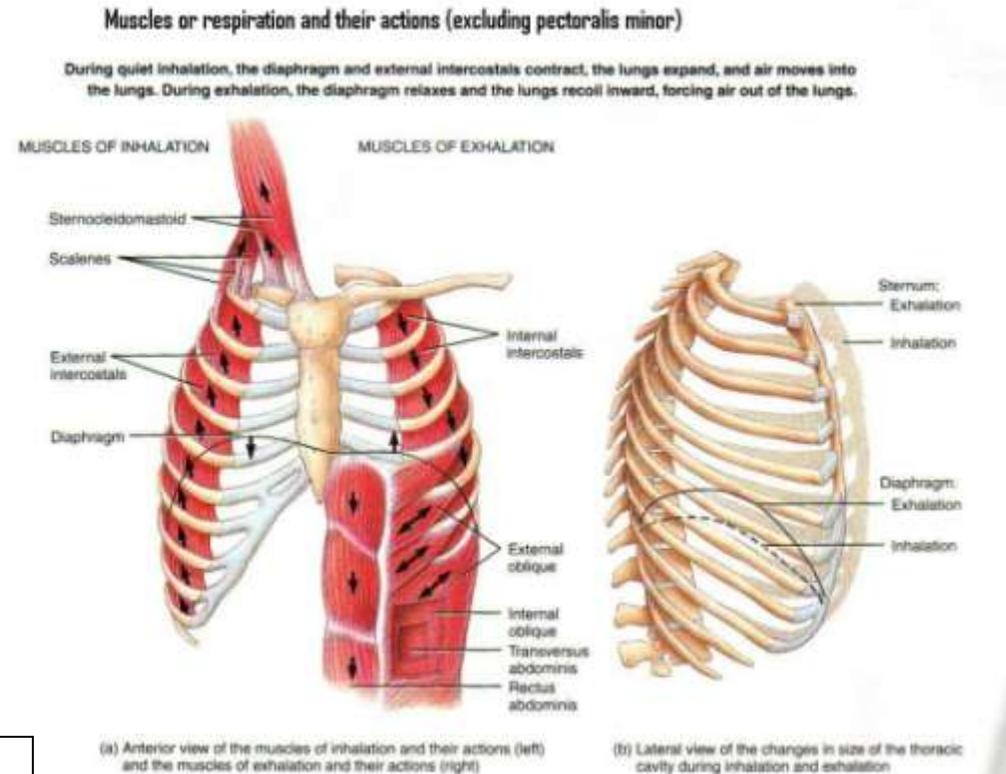
The primary muscles of respiration are:

- **The Diaphragm:** this is a dome shaped muscle, which separates the thoracic and abdominal cavities.
- **The Intercostal Muscles:** (external and internal) There are 11 pairs of intercostal muscles and they are located in the spaces between the 12 pairs of ribs.
- **Accessory muscles of respiration.** Any muscle that attaches onto a rib is potentially a muscle of respiration, and includes: the scalenes, quadratus lumborum, Serratus posterior (superior and inferior) sternocleidomastoid, and pectoralis minor.

## Inspiration

The diaphragm flattens down and the external intercostal muscle contract, pulling the ribs up and out, increasing the thoracic space; this causes air to flow in to the lungs with their consequent expansion, causing inspiration.

**Figure 3 - Muscles of Respiration**



## Expiration

Relaxation of the respiratory muscles and the natural elasticity of the lung tissue reverse the above process. The elastic alveoli, which were stretched, now recoil. The pressure of the air in the lungs is now greater than the atmospheric air, and this causes air to move out of the lungs, producing expiration.

## Definitions

**Respiration:** This is the process of supplying oxygen to and removing carbon dioxide from the tissues. These gases are carried in the blood, oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. The gas exchanges in the lungs are called external respiration and those in the tissues are called internal respiration.

**Alveoli:** These are the functional units of the lungs. Exchange of oxygen and carbon dioxide takes place through the walls of the alveoli and the walls of the pulmonary capillaries.

**Tidal Volume:** This is the amount of air that moves in and out with each normal breath.

**Eupnoea:** Normal, quiet respiration

**Hyperpnoea:** Increased respiration with stress or exercise

**Dyspnoea:** Difficulty in breathing e.g. with asthma

**Inspiratory Reserve Volume:** This is the maximal additional volume of air that can be inspired at the end of a normal inspiration.

**Expiratory Reserve Volume:** This is the maximal additional quantity of air that can be expired at the end of a normal expiration.

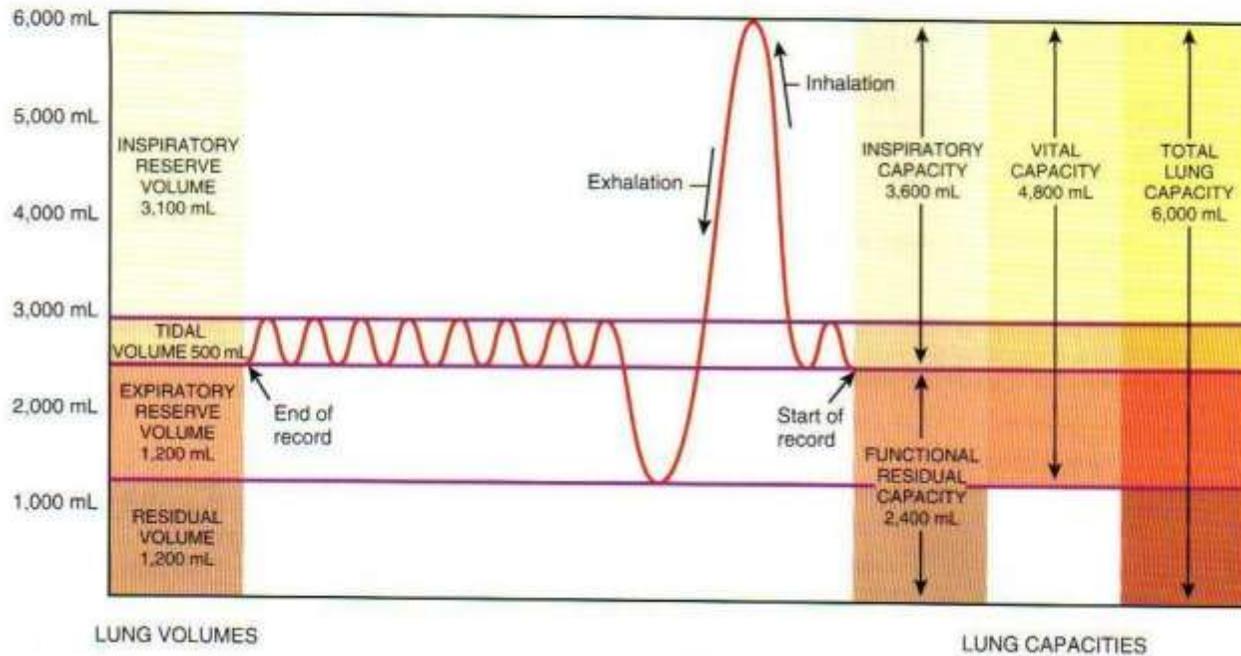
**Vital Capacity:** This is the volume of air that can be moved in a single breath.

**Residual Volume:** This is the amount of air that remains in the lungs after maximal expiration; also called dead space air.

**Total Lung Capacity:** This is the lung volume at its maximum (i.e., after a maximal inspiration).

**Figure 4 - Spirogram of Respiration**

**Spirogram showing lung volumes in millilitres (read graph from right to left)**

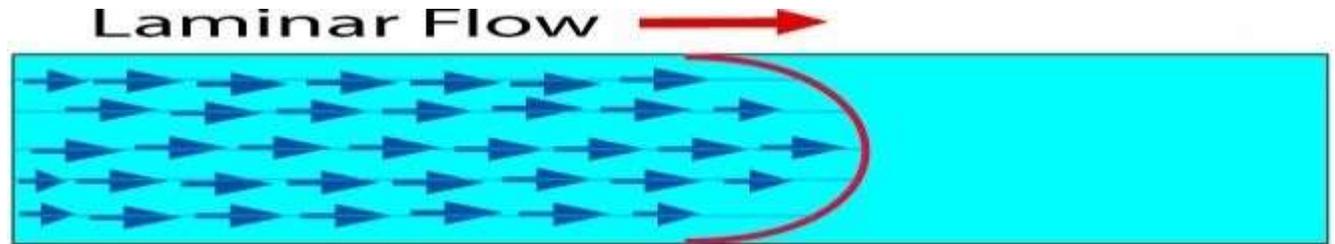


**Average Composition of Air**

Inspired	Expired
Nitrogen 78%	Nitrogen 78%
Inert gases 1%	Inert gases 1%
Oxygen 21%	Oxygen 17%
Carbon dioxide-negligible	Carbon dioxide 4%
Water vapour-variable	Water vapour-to saturation at body temp.

## Laminar flow

Laminar flow is descriptive of how a gas or fluid flows along a pipe. It flows fastest in the centre of the tube, becoming gradually slower towards the outside of the tube, where the gas is in contact with the inner layer of the tube itself; hence there are 'layers' (laminae) of flow.



There is an equation which describes this flow

$$F \propto r^4$$

This equation explains that the flow along the tube is proportional to the fourth power of the radius. This is meaningless until you consider it in a dynamic situation; if there is a very small change in the radius, it will create a very big change in the rate of flow; this can be a cause of some disorders.

## Exercise and the respiratory system

The function of the respiratory tree is to provide oxygen for the tissues and to remove carbon dioxide; during exercise pulmonary respiration increases linearly for about 60-90% of the individual's capacity. When there is increased oxygen consumption at a cellular level, there is a consequent increase in blood carbon dioxide. This is detected in the respiratory centre in the brain stem, which initiates an increase in the rate of respiration.

## Disorders of the Respiratory System

### Viral infections

E.g. colds and influenza

### Allergic rhinitis

This is an inflammation of the nasal mucosa due to an allergy, e.g. house dust mite, pollen cats and feathers.

### Sinusitis

This is an inflammation of the frontal and/or maxillary sinuses; it can be caused by allergy infection or stress.

### Asthma

Asthma is a general term for difficulty in breathing. Bronchial asthma is the result of the constriction of smooth muscles in the bronchial and bronchiolar walls, accompanied by inflammation and excess mucus secretion. The condition has various causes including exercise, stress, idiopathic and caused by an allergic reaction. Medication allows the smooth muscle to relax (Ventolin/Salomol) and suppression of inflammation (Becotide). This is not to be confused with cardiac asthma (see later).

## **Pneumonia**

Pneumonia is the term generally used to indicate infection and inflammation of lung tissue. It can be caused by a number of factors – chemicals, bacteria, viruses, protozoa or fungi –but the usual infective agent is a Streptococcus bacterium. Pneumonia most readily attacks people who are already weakened by illness or whose lungs are damaged.

## **Bronchitis**

This is general term denoting inflammation of the bronchi and can be caused by a bacterial infection. It is usually preceded by a common cold or influenza or may complicate measles or whooping cough in children.

## **Emphysema**

This is a dilatation of the terminal bronchiole. This with a breakdown of the walls separating the alveolar sacs, resulting in a bulla, has various effects of the respiration of the person. It causes persistent dyspnoea. The normal arrangement of alveolar sacs creates very small spaces which can be held open by the nature of the lung and by the surface tension of the fluids; however with the formation of bullae, these will have a tendency towards collapsing. Because of this the person will artificially maintain an increasing chest capacity, using all the accessory muscles of respiration. There is reduced tidal volume, an increased chest diameter and a constant need for medication. There is a genetic disposition to this condition.

## **Chronic Obstructive Pulmonary Disease**

Previously known as chronic obstructive airways disease, this is a term that includes the chronic disease processes listed above.