RESPIRATORY SYSTEM

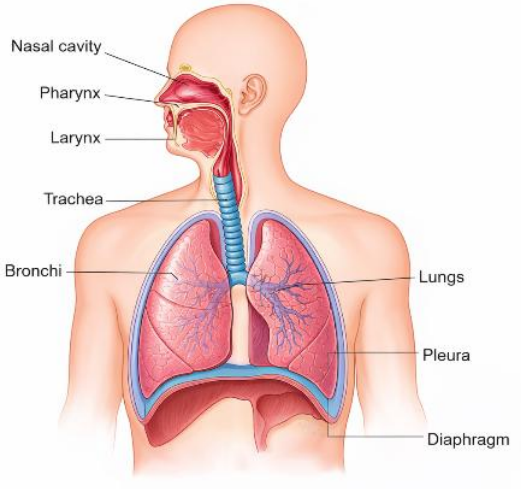
Respiratory system is the system through which oxygen present in the atmospheric air is supplied to the lungs and from the lungs to the body cells. It also helps in the removal of carbon dioxide from the body. The respiratory system consists of a series of organs that are involved in the supply of oxygen to the body cells and removal of carbon dioxide from them. The respiratory tract starts at the nose and ends at the lungs. The oxygen enters the body through nose and carbon dioxide comes out through the nose.

Functions of respiratory system:

1. The primary function of respiratory system is the functioning and outward movement of air upon inhalation and exhalation.
2. To supply oxygen to the body cells upon inhalation.
3. To remove carbon dioxide from the cells and expel it through exhalation.
4. It warms, humidifies and filters the atmospheric air before it reaches the lungs.
5. Responsible for sound production.
6. It helps in maintenance of normal acid-base balance.

Basic functions of respiratory system

1. **Ventilation**
   It is the process of movement of air into and out of the lungs.
2. **External respiration**
   It is the exchange of oxygen and carbon dioxide between the lungs and blood.
3. **Internal respiration**
   It is the exchange of oxygen and carbon dioxide between the blood and tissue cells.
4. **Transport of gases**
   Oxygen is carried from the blood to the lungs so that the recently acquired oxygen in the inhaled air in lungs can be transported to the tissues while CO_2 can be eliminated via exhaled air.



Respiratory System

Factors Affecting Respiration

1. **Temperature**
   Optimum temperature required for normal activity of respiratory enzymes is 20–30°C. Increase in the temperature of body decreases the rate of respiration with time. The rate of respiration in the peripheral tissues, i.e., does follow any particular order or very low temperature. At high temperature peripheral vascular volume increases which in turn increases the rate of heart beat and decreases thereby increasing the rate of respiration. This results in an increase in the blood flow to the lungs, thereby increasing the rate of respiration.
2. **Oxygen**
   The minimum concentration of oxygen required for aerobic respiration is 3–10%. Decrease in the amount of O_2 in the air increases the rate of respiration. As oxygen level decreases the amount of lactic acid increases.
3. **Carbon dioxide**
   Increase of carbon dioxide in the body increases the rate of respiration because excess CO_2 present in the lungs reacts with water forming carbonic acid which makes the brain sensitive to the amount of blood bicarbonate (blood acidity). Thus the rate of respiration increases due to the acidity of the blood.
4. **Exercise**
   Exercise increases metabolic activity of the body and thereby increases the accumulation of lactic acid and CO_2 in the blood. The rate of respiration increases as the body requires more oxygen and expels more CO_2. During exercise the inflammatory substances dilate the vessels in the muscles by reducing the hydrogen concentration and increases the breathing capacity.
   During exercise breathing becomes deeper and rapid. The rate of respiration becomes more.
5. **Disease**
   Some diseases of respiratory system are caused by virulent organisms by respiratory infections. Infections lead to obstruction in the air passage, cold, chest congestion and wheezing which causes chest discomfort. These diseases increases the rate of respiration.
6. **Age**
   The respiratory movements are highest in children and lowest in old age. It varies according to the type of body that are altering in the metabolic activity.
7. **Emotions**
   Emotions like fear, anger and sadness increase the rate of respiration.
8. **Gastro-esophageal reflux disease (GERD)**
   This is a disease of stomach in which the stomach contents goes back to oesophagus, the symptoms of this are heart burn. Depending on how long the asthma has being in the body this disease increases the pressure on respiratory system. The esophagus is located above the diaphragm unlike the stomach which lies below the diaphragm. The lower esophageal sphincter (LES) which helps in preventing acid from entering the esophagus may not work properly. If the LES fails, stomach acid moves up into the esophagus. This increases the heart burn and chest discomfort which in turn increases the rate of respiration.

Internal Factors

(a) **Adrenaline (epinephrine)** is the flight or fight hormone that usually increases the rate of respiration by increasing the rate of breathing by increasing the heart rate which leads to increased metabolic rate. Acetylcholine is another hormone that decreases the rate of respiration by decreasing the airways on to new occupation by decreasing the airways on to new occupation by closing up. This leads to constriction of bronchial tubes.

(b) **Physical Factors**
Physical disturbance, injury or infection, respiration either increase or decreases.

(c) **Chemical Factors**
Chemical compounds like atropine, histamine, nicotine and drugs, anaesthetics, cyanide, opiates, aldehydes inhibit respiration.

Functions of Respiration

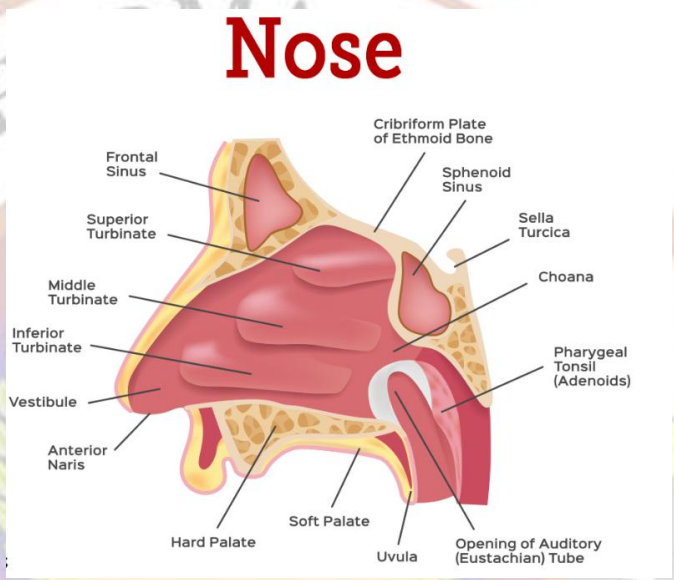
1. **Exchange of Gases**
   Respiration helps in carrying oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. Oxygen enters the lungs via inhalation and CO_2 leaves the lungs by exhalation. This means the process helps maintain the exchange of gases.
   One of the functions is to reduce carbon dioxide level in the blood. Carbon dioxide is a major factor for the regulation of respiration.
2. **Regulation of Blood Temperature**
   Respiration helps in the regulation of blood temperature.
3. **Regulation of Blood Pressure**
   It helps in the regulation of blood pressure by controlling the vasoconstriction and vasodilation in the body.
4. **Maintenance of Acid-Base Balance**
   Respiration helps to maintain the pH of blood and body fluids by removing CO_2.
5. **Voice Production**
   Respiration helps in voice production. The air passing through the vocal cords produces sound.
6. **Smell**
   It helps in smelling by passing air through the olfactory region.
7. **Excretion**
   During the process of expiration certain metabolic substances like water vapour, ammonia, ketones and few drugs etc. are excreted along with carbon dioxide.

2. ANATOMY OF RESPIRATORY ORGANS

The respiratory organs are divided into:

1. **Upper Respiratory System**
   – Nose
   – Pharynx (Throat)
   – Larynx, trachea, bronchi and associated structures
2. **Lower Respiratory System**
   – Lungs (i.e., primary bronchi, bronchial tree and respiratory portion)

1. Nose



Nose is a specialized organ that marks the beginning of respiratory system. It is divided into external and internal nose.

(a) **External Nose**
It is a projecting part visible on face. This is formed by nasal bones, frontal bones and maxillary bones. It is supported by flexible plates of hyaline cartilage. The shape of nose depends on the arrangement of bones and cartilage.
The nostrils or external nares are the openings on the underside of the nose.
The external portion of the nasal cavity opens out into the face by a pair of openings known as external nares. It is divided into right and left nasal cavity by the nasal septum.

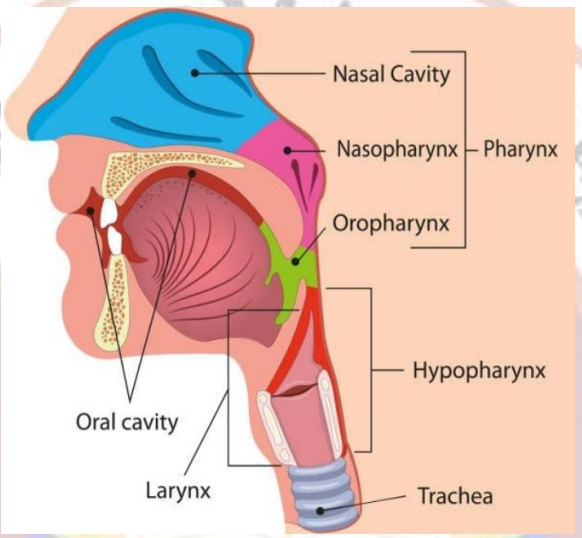
(b) **Internal Nose**
It includes the nasal cavity and extends from the posterior part of internal nose to the level of larynx. It is lined by mucous membrane.
The opening of the internal nose are the posterior nares. Nasal cavity opens into the nasopharynx. Additionally, there are hollow spaces inside the skull bones (maxilla, frontal bone, ethmoid bone and sphenoid bone) known as paranasal sinuses. These sinuses are lined with

mucous membrane which helps in warming and humidifying the inhaled air. These sinuses help in reducing the weight of skull.

Functions of Nose:

1. The basic function of nose is to warm, humidify and filter the inspired air.
2. The olfactory epithelium helps in the sensation of smell.
3. The paranasal sinuses function as resonance chambers for speech.

2. Pharynx



Pharynx is the passage for both air and food. It is a funnel-shaped structure about 12–14 cm long. It is situated behind the nasal cavity, oral cavity and larynx. It extends from the base of skull to the level of 6th cervical vertebra where it continues as the oesophagus. It is lined by mucous membrane.

Pharynx is divided into **three regions**:

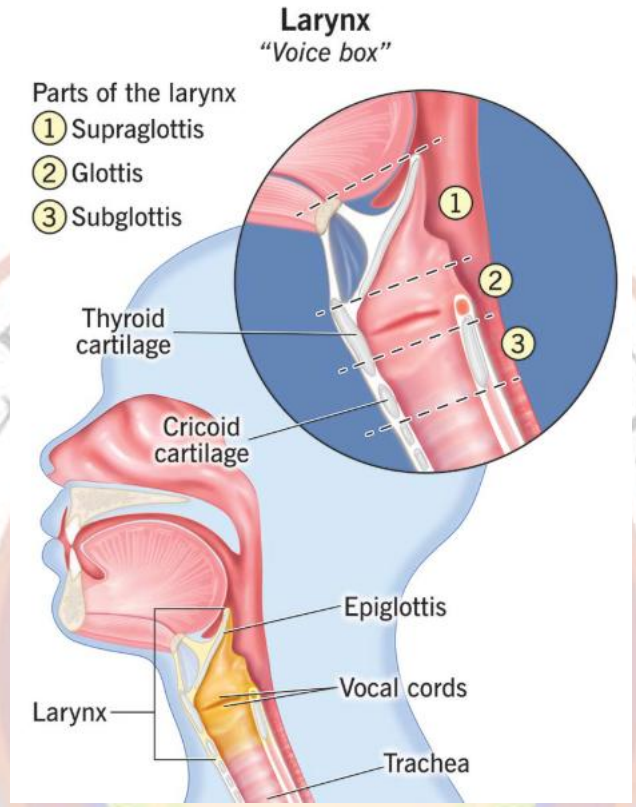
1. **Nasopharynx**
   It lies behind the nasal cavity and extends up to the soft palate. The eustachian tube opens into the nasopharynx.
2. **Oropharynx**
   It lies behind the oral cavity and extends from soft palate to the upper margin of the epiglottis. Both food and air pass through this region.
3. **Laryngopharynx**
   It extends from the upper margin of epiglottis to the lower margin of cricoid cartilage. It opens anteriorly into the larynx and posteriorly into the oesophagus.

Functions of Pharynx:

1. It serves as a common passage for food and air.

2. It helps in resonance of voice.
3. It provides immunity as it contains lymphoid tissue.

3. Larynx



Larynx is also known as **voice box**. It is a cartilaginous structure present in front of the laryngopharynx and upper part of trachea. It extends from the root of the tongue to the trachea. It is about 4–5 cm in length.

The larynx is made up of **nine cartilages**:

- **Three unpaired cartilages** — Thyroid, Cricoid, Epiglottis
- **Three paired cartilages** — Arytenoid, Corniculate, Cuneiform

1. **Thyroid cartilage**
   It is the largest cartilage of the larynx. It consists of two laminae which meet anteriorly to form the laryngeal prominence (Adam's apple).
2. **Cricoid cartilage**
   It is a ring-shaped cartilage situated below the thyroid cartilage.
3. **Epiglottis**
   It is a leaf-shaped cartilage situated behind the tongue. It prevents entry of food into the larynx during swallowing by closing the glottis.

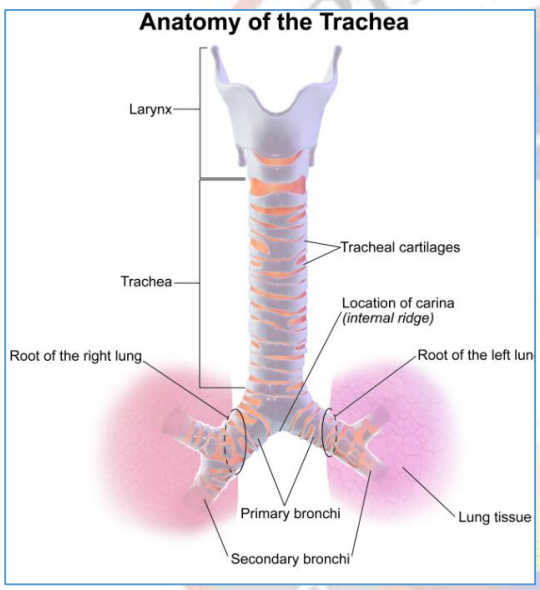
The paired cartilages help in movements of vocal cords.

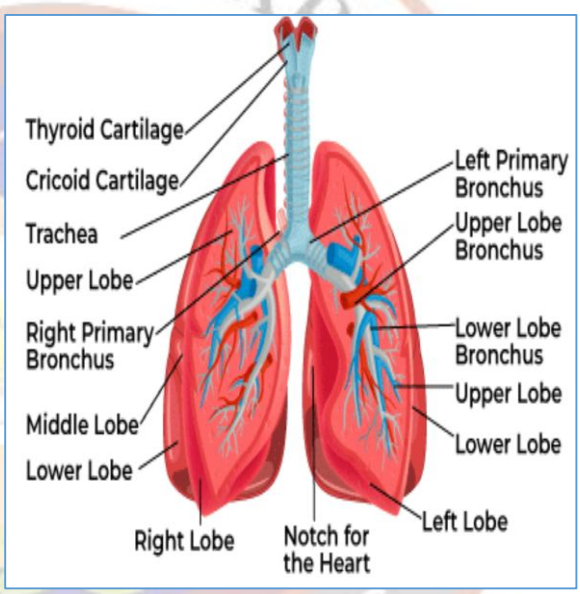
Inside the larynx are **vocal cords**.
The opening between the vocal cords is called the **glottis**.

Functions of Larynx:

1. It produces sound (phonation).
2. It provides passage for air.
3. Epiglottis prevents aspiration of food.
4. Helps in coughing.

4. Trachea





Trachea is also known as **windpipe**. It is a tubular structure about **10–12 cm** long and **2–2.5 cm** in diameter. It extends from the lower border of cricoid cartilage to the level of 5th thoracic vertebra where it divides into right and left primary bronchi.

Trachea is supported by **16–20 C-shaped hyaline cartilages** which prevent collapse of tracheal wall.
The posterior part is made up of **smooth muscle**.

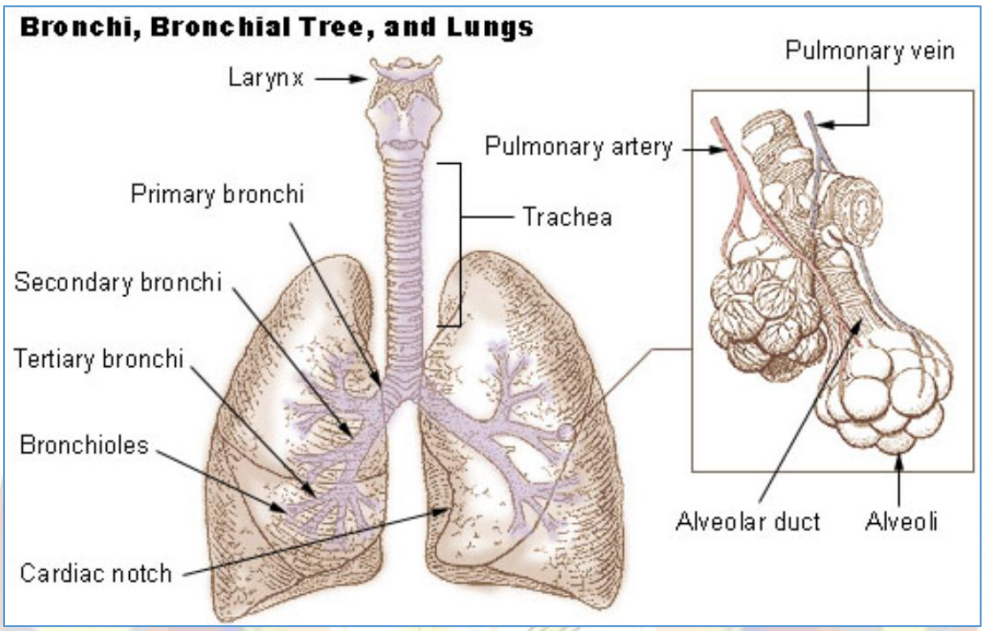
The inner lining of trachea is **ciliated columnar epithelium** with goblet cells which secrete mucus.

Functions of Trachea:

1. It provides a passage for air to the bronchi.
2. The mucus traps foreign particles.

3. Cilia move the mucus upward to be expelled or swallowed.

5. Bronchi



At the lower end of the trachea, it divides into **right and left primary bronchi**. The right primary bronchus is **wider, shorter and more vertical** than the left bronchus. Each primary bronchus enters the corresponding lung and divides into **secondary bronchi** (one for each lobe of the lung). The secondary bronchi further divide into **tertiary bronchi**, which branch repeatedly to form **bronchioles**, then **terminal bronchioles**, and finally **respiratory bronchioles**.

The respiratory bronchioles open into **alveolar ducts**, which end in clusters of **alveoli**.
This whole branching network is known as the **bronchial tree**.

Functions of Bronchi and Bronchioles:

1. They allow the passage of air into the lungs.
2. They warm, humidify and filter inspired air.
3. They distribute air to different regions of the lungs.
4. Bronchioles control the resistance and distribution of air flow.

Lungs

Lungs are **two cone-shaped** organs located in the thoracic cavity on either side of the mediastinum.
The lungs are **soft, spongy and elastic** in nature.

Each lung is enclosed in a double-layered membrane called **pleura**:

- The **outer layer** is the **parietal pleura**
- The **inner layer** is the **visceral pleura**

Between these two layers is the **pleural cavity**, which contains a thin layer of **pleural fluid** that reduces friction during breathing.

The **right lung** is larger than the left lung and is divided into **three lobes**:

- Superior lobe
- Middle lobe
- Inferior lobe

The **left lung** has **two lobes** — superior and inferior — because the heart occupies part of the left thoracic cavity (cardiac notch).

Each lung is further divided into **lobules**, which contain:

- A lymphatic vessel
- A terminal bronchiole
- An arteriole and venule
- A cluster of alveoli

Alveoli

Alveoli are tiny, thin-walled air sacs where **gaseous exchange** takes place.
Each lung contains about **300–350 million alveoli**, providing a large surface area for gas exchange.

The wall of each alveolus is lined by **simple squamous epithelium** and contains **surfactant-secreting cells** which prevent the alveoli from collapsing.

Surrounding each alveolus is a network of **pulmonary capillaries** that help in the exchange of oxygen and carbon dioxide.

Functions of Alveoli:

1. They are the main site of gaseous exchange.
2. They provide a large surface area for diffusion.
3. Surfactant reduces surface tension to keep alveoli open.

3. LUNGS

Lungs are the essential organs of respiratory system, situated in the thoracic cavity on either side of mediastinum. They are cone-shaped structures and are soft, spongy and elastic.

Each lung is covered by **double-layered membrane known as pleura**.

➤ **Outer layer** – Parietal pleura

➤ **Inner layer** – Visceral pleura

Between these two layers lies the **pleural cavity** which contains pleural fluid. This fluid reduces friction during breathing movements.

The **right lung** is larger and has **three lobes** – Superior, Middle and Inferior lobes.
The **left lung** is smaller and has **two lobes** – Superior and Inferior lobes – due to the presence of cardiac notch.

Each lung is further divided into **lobules**. Each lobule contains:

1. A lymphatic vessel
2. A terminal bronchiole
3. A pulmonary arteriole
4. A pulmonary venule
5. A cluster of alveoli

4. Alveoli

Alveoli are the tiny sac-like structures present at the ends of alveolar ducts. They are the primary site for the exchange of gases. Each lung contains approximately **300–350 million** alveoli.

The wall of alveoli is composed of **simple squamous epithelium** and contains **surfactant-secreting cells** (type II pneumocytes). Surfactant prevents the collapse of alveoli by reducing surface tension.

Each alveolus is surrounded by a network of **pulmonary capillaries** which help in the gaseous exchange.

Functions of Alveoli:

1. They act as the site of exchange of gases.
2. Surfactant helps in reducing surface tension and prevents alveolar collapse.
3. They provide large surface area for diffusion.

5. Pleura

Pleura is a double-layered serous membrane which encloses and protects each lung.

The layers are:

1. **Parietal pleura** – lines the thoracic wall.
2. **Visceral pleura** – covers the lungs.

The pleural cavity between these layers contains **pleural fluid** which reduces friction during breathing.

Functions of Pleura:

1. It protects the lungs.
2. Helps in smooth movement during breathing.

6. Mechanism of Respiration

Respiration includes two phases:

1. **Inspiration (Inhalation)**
2. **Expiration (Exhalation)**

Breathing is a **mechanical process** that involves the movement of air into and out of the lungs. This process depends upon the **pressure changes** within the thoracic cavity.

Inspiration (Inhalation)

Inspiration is the **active process** of breathing in air.

During inspiration:

1. **Diaphragm contracts** and flattens.
2. **External intercostal muscles contract**, raising the ribs upward and outward.
3. This increases the **anteroposterior and transverse diameter** of the thoracic cavity.
4. As a result, **intrapulmonary (alveolar) pressure decreases**.
5. Air flows from the atmosphere (higher pressure) into the lungs (lower pressure).

Thus, inspiration occurs when **thoracic volume increases** and **pressure decreases**.

Expiration (Exhalation)

Expiration is the **passive process** of breathing out air.

During expiration:

1. **Diaphragm relaxes** and becomes dome-shaped.
2. **External intercostal muscles relax**, bringing ribs downward.
3. Thoracic volume decreases.
4. **Intrapulmonary pressure increases**, and air is forced out of the lungs.

Expiration occurs when **thoracic volume decreases** and **pressure increases**.

Forced Expiration

In forced expiration (e.g., coughing, vigorous exercise):

- **Internal intercostal muscles** contract.
- **Abdominal muscles** contract, pushing the diaphragm upward.
- This results in a rapid expulsion of air.

Differences Between Inspiration and Expiration

Inspiration	Expiration
Active process	Passive process
Diaphragm contracts	Diaphragm relaxes
Thoracic volume increases	Thoracic volume decreases
Air enters lungs	Air leaves lungs

7. Lung Volumes and Capacities

The **amount of air** inspired or expired during breathing is known as **lung volume**.
A **combination of two or more lung volumes** is known as **lung capacity**.

Lung volumes and capacities can be measured by **spirometry**.

Lung Volumes

1. **Tidal Volume (TV)**
   It is the amount of air inspired or expired during **normal breathing**.
   Normal value: **500 mL**
2. **Inspiratory Reserve Volume (IRV)**
   It is the maximum amount of air that can be inspired **after normal inspiration**.
   Normal value: **3000 mL**
3. **Expiratory Reserve Volume (ERV)**
   It is the maximum amount of air that can be expired **after normal expiration**.
   Normal value: **1000–1100 mL**
4. **Residual Volume (RV)**
   It is the amount of air that **remains in the lungs** after maximum expiration.
   Normal value: **1200 mL**

Lung Capacities

1. **Inspiratory Capacity (IC)**
   IC = TV + IRV
   It is the maximum amount of air inspired after normal expiration.
2. **Functional Residual Capacity (FRC)**
   FRC = ERV + RV
   It is the amount of air remaining in the lungs after normal expiration.

3. **Vital Capacity (VC)**
   VC = TV + IRV + ERV
   It is the maximum amount of air exhaled after maximum inspiration.
4. **Total Lung Capacity (TLC)**
   TLC = TV + IRV + ERV + RV
   It is the total volume of air present in the lungs after maximum inspiration.

8. Exchange of Gases

The exchange of gases occurs in two places:

1. **External Respiration**
2. **Internal Respiration**

External Respiration

External respiration is the exchange of gases between **alveoli of the lungs** and **pulmonary capillaries**.

- **Oxygen** diffuses from alveoli → blood
- **Carbon dioxide** diffuses from blood → alveoli

This exchange occurs due to **differences in partial pressure** of gases (diffusion principle).

External Respiration (continued)

External respiration takes place in the lungs between the alveoli and the pulmonary capillaries. This exchange of gases occurs by the process called **diffusion**.

The direction of diffusion depends on the **partial pressures** of gases:

- **Partial pressure of oxygen (PO_2)** is higher in the alveoli and lower in blood → oxygen diffuses into blood.
- **Partial pressure of carbon dioxide (PCO_2)** is higher in blood and lower in alveoli → carbon dioxide diffuses into alveoli.

Thus, the exchange continues until the partial pressures become equal on both sides.

Internal Respiration

Internal respiration is the exchange of gases between **systemic tissues** and **blood** (systemic capillaries).

- The **partial pressure of oxygen (PO_2)** is higher in systemic capillaries and lower in tissues → oxygen diffuses from blood into tissues.

- The **partial pressure of carbon dioxide (PCO_2)** is higher in tissues and lower in systemic capillaries → carbon dioxide diffuses from tissues into blood.

Internal respiration continues until the equilibrium is reached.

Transport of Oxygen

Oxygen is transported in the blood in two ways:

1. **Dissolved form**
   About **1.5%** of oxygen is transported dissolved in plasma.
2. **Combined with haemoglobin**
   About **98.5%** of oxygen is transported combined with haemoglobin (Hb) in the red blood cells forming **oxyhaemoglobin (HbO_2)**.

The amount of oxygen that binds with haemoglobin depends on:

- Partial pressure of oxygen
- pH of blood
- Temperature
- Amount of carbon dioxide

Transport of Carbon Dioxide

Carbon dioxide is transported in three forms:

1. **Dissolved in plasma**
   Around **7%** of CO_2 is transported dissolved directly in plasma.
2. **As carbamino compounds**
   About **23%** of CO_2 combines with haemoglobin forming **carbaminohaemoglobin**.
3. **As bicarbonate ions (HCO_3^-)**
   About **70%** of CO_2 is transported as **bicarbonate ions** in plasma.

Formation of Bicarbonate Ions

Inside the red blood cells, carbon dioxide combines with water to form **carbonic acid (H_2CO_3)**. This reaction is catalyzed by the enzyme **carbonic anhydrase**.

Carbonic acid then **dissociates** into:

- **Hydrogen ions (H^+)**
- **Bicarbonate ions (HCO_3^-)**

The **bicarbonate ions** diffuse out of the RBCs into the plasma, while **chloride ions (Cl^-)** move into the RBCs to maintain electrical neutrality.
This is called the **chloride shift** or **Hamburger phenomenon**.

9. Regulation of Respiration

Respiration is regulated by the **respiratory center** located in the **medulla oblongata** and **pons** of the brainstem.

The respiratory center consists of:

1. **Medullary rhythmicity area**
2. **Pneumotaxic area (pons)**
3. **Apneustic area (pons)**

1. Medullary Rhythmicity Area

This area controls the **basic rhythm** of breathing.

It has two groups of neurons:

- **Inspiratory neurons** – active during inspiration
- **Expiratory neurons** – active during forceful expiration

Normal expiration is **passive**, so expiratory neurons are mostly inactive during quiet breathing.

2. Pneumotaxic Area

The pneumotaxic center is located in the **upper pons**.

Functions:

- Regulates **rate** of breathing
- Sends inhibitory impulses to the inspiratory center
- Prevents **overfilling** of lungs
- When pneumotaxic center is active → **breathing becomes rapid**

3. Apneustic Area

Located in the **lower pons**.

Functions:

- Stimulates inspiratory neurons

- Prolongs inspiration
- When apneustic center is active → **breathing becomes deep and prolonged**

The pneumotaxic area inhibits the apneustic area.

10. Nerve Supply of Lungs

Lungs receive nerve supply from **both sympathetic and parasympathetic nerves**.

a. Parasympathetic (Vagus nerve)

- Causes **bronchoconstriction**
- Increases bronchial secretions

b. Sympathetic nerves

- Cause **bronchodilation**
- Decrease bronchial secretions

Thus, parasympathetic and sympathetic nerves have **opposite effects** on the bronchi.

11. Respiratory Disorders

1. **Asthma**
   Asthma is a chronic inflammatory disease of the airways.
   The smooth muscles of bronchioles undergo **spasm**, causing **narrowing** of bronchioles leading to difficulty in breathing.
   Symptoms include:
   - Wheezing
   - Cough
   - Shortness of breath
   - Chest tightness
2. **Bronchitis**
   It is the **inflammation of bronchi**.
   It may be **acute or chronic**.
   Causes include infection, smoking, pollution, etc.
   Symptoms:
   - Cough
   - Sputum production
   - Difficulty in breathing
3. **Emphysema**
   In this condition, the **alveolar walls are destroyed**, leading to reduced surface area for gas exchange.
   Lungs lose their elasticity and remain expanded.
   It is common in **smokers**.

4. **Pneumonia**
   Pneumonia is the **infection of lungs**, usually caused by bacteria or viruses.
   Alveoli get filled with fluid.
   Symptoms:
   - Fever
   - Cough
   - Chest pain
   - Difficulty in breathing

5. **Tuberculosis (TB)**
   Tuberculosis is an infectious disease caused by *Mycobacterium tuberculosis*.
   It mainly affects the lungs but can also affect other organs.
   Symptoms include:
   - Persistent cough
   - Weight loss
   - Fever
   - Night sweats
6. **Lung Cancer**
   It is a malignant growth in the tissues of the lung.
   The most common cause is **smoking**.
   It may spread to other organs.
7. **Chronic Obstructive Pulmonary Disease (COPD)**
   COPD includes **emphysema** and **chronic bronchitis**.
   It is characterized by **obstruction of airflow**.
   Symptoms include:
   - Cough
   - Sputum
   - Breathlessness
8. **Common Cold**
   It is a viral infection of the upper respiratory tract.
   Symptoms:
   - Sneezing
   - Runny nose
   - Sore throat
   - Mild fever

Physiology of Respiration

Respiration includes:

1. **Pulmonary Ventilation (breathing)**
2. **External Respiration**
3. **Internal Respiration**
4. **Transport of gases**

Pulmonary Ventilation

Pulmonary ventilation is the movement of air **into and out of the lungs**.

It consists of two phases:

1. **Inspiration (inhalation)**
2. **Expiration (exhalation)**

External Respiration

External respiration is the exchange of gases between:

- **Alveoli**
- **Pulmonary capillaries**

Oxygen moves from alveoli into blood,
Carbon dioxide moves from blood into alveoli.

Internal Respiration

Internal respiration is the exchange of gases between:

- **Tissue cells**
- **Systemic capillaries**

Oxygen moves from the blood into the tissues.
Carbon dioxide moves from the tissues into the blood.

Transport of Gases

Gases are transported in the blood by the following methods:

Transport of Oxygen

Oxygen is transported in two ways:

1. **Dissolved in plasma** – 1.5%
2. **Combined with haemoglobin** – 98.5%

Transport of Carbon Dioxide

Carbon dioxide is transported in three ways:

1. **Dissolved in plasma** – 7%
2. **Carbamino compounds** – 23%
3. **As bicarbonate ions** – 70%

Respiratory Centre

The respiratory centre is located in the **medulla oblongata** and **pons**.

It includes:

1. **Medullary rhythmicity area**
2. **Pneumotaxic area**
3. **Apneustic area**

These centres regulate the rate and depth of respiration.

Factors Affecting Respiration

Respiration is affected by:

- **Chemical factors** (CO_2, O_2, H^+ ions)
- **Temperature**
- **Exercise**
- **Emotions**
- **Age**
- **Diseases**

Chemical factors are the most important regulators.

Chemo Receptors

Chemoreceptors are **specialized receptors** that detect changes in chemical composition of blood.

There are two types of chemoreceptors:

1. **Central chemoreceptors**
    - Located in the **medulla oblongata**
    - Sensitive to changes in **CO_2** and **H^+ ion concentration** in cerebrospinal fluid
    - Increase in CO_2 stimulates the respiratory centre to increase breathing
2. **Peripheral chemoreceptors**
    - Located in the **carotid bodies** and **aortic bodies**
    - Sensitive to **low oxygen level (hypoxia)**

- Also respond to increased CO_2 and H^+ ions
- When oxygen level falls, these receptors stimulate the respiratory centre to increase ventilation

Role of Chemoreceptors

Chemoreceptors play an important part in the **regulation of respiration**.
They act by sending impulses to the respiratory centre.

- **Increased CO_2** → increased rate and depth of breathing
- **Decreased O_2** → stimulates peripheral chemoreceptors
- **Increased H^+ ions** → increases respiration
- **Decreased CO_2** → reduces respiration

Thus, carbon dioxide is the most **powerful respiratory stimulant**.

Stretch Receptors

Stretch receptors are located in the **walls of bronchi and bronchioles**.

Function:

- When lungs inflate excessively, stretch receptors send impulses to the respiratory centre to **stop inspiration**
- This protects lungs from over-inflation
- Known as the **Hering–Breuer Reflex**

Higher Brain Centres

The **cerebral cortex** can voluntarily control breathing (e.g., holding breath, speaking, singing). However, voluntary control is limited—automatic control takes over when CO_2 levels rise.

The **hypothalamus** and **limbic system** also influence respiration during emotions like fear, anxiety, crying, laughing.

Non-Respiratory Functions of Respiratory System

Apart from ventilation and exchange of gases, respiratory system performs many other functions such as:

1. **Speech Production**
   The air passing through the vocal cords in the larynx helps in the production of voice.
2. **Olfaction (Smell)**
   The upper part of the nasal cavity contains olfactory receptors which help in the sense of smell.
3. **Filtration of Blood**
   Small blood clots present in the veins may get trapped in the lungs thereby preventing these clots from reaching the heart or brain.
4. **Defence Mechanism**
   The respiratory tract contains cilia and mucus which help in trapping and removing dust particles, microorganisms and other foreign particles.
5. **Regulation of Acid-Base Balance**
   Respiratory system helps maintain normal pH of blood by regulating carbon dioxide levels.
6. **Heat Loss**
   During expiration, heat is lost from the body in the form of water vapour.