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# HUMAN ANATOMY AND PHYSIOLOGY – II

## UNIT 3

TOPIC :

- **Respiratory system**

  Anatomy of respiratory system with special reference to anatomy of lungs, mechanism of respiration, regulation of respiration Lung Volumes and capacities transport of respiratory gases, artificial respiration, and resuscitation methods.

# Respiratory System

→ Respiratory tract forms the path through which air passes from the nose to the lungs.

→ Exchange of gases during internal and external respiration is the major function of the respiratory system, along with this it also filters, warms, and humidifies the inhaled air.

→ Respiratory system includes the vocal cords for producing sound, lungs for controlling body pH levels, and the olfactory bulbs for smelling.

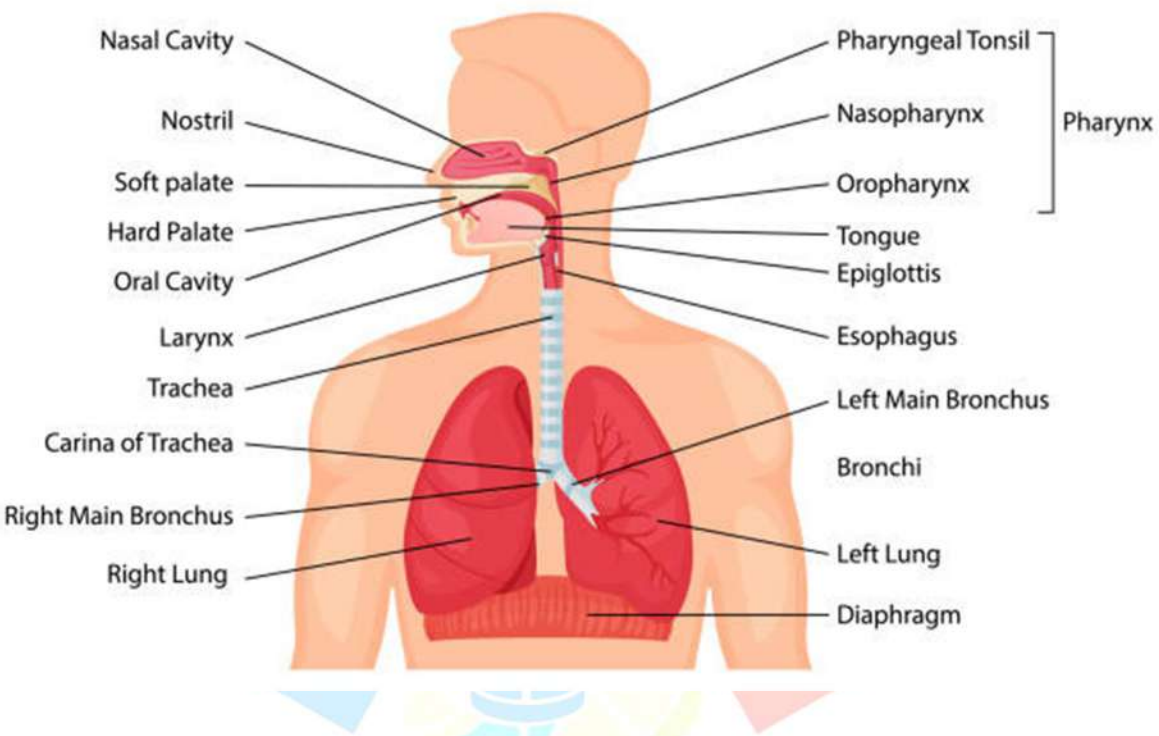
→ The cells demand a continuous supply of oxygen and in turn continuously eliminate carbon dioxide a metabolic waste product

**Events during Respiration**

1) Ventilation of lungs for inward and outward movement of air,
2) Exchange of gases between the blood and alveolar air
3) Excretion of water vapour, and
4) Supplying air to the larynx for voice production

**Parts of Respiratory System**

1. Nose
2. Pharyax (throat)
3. Larynx (Voice box)
4. Trachea (Wind pipe)
5. Bronchi and Bronchioles
6. Lungs, and
7. Alveoli




**Based on its Function the respiratory system is divided into**

- **Conducting Zone (Nose to Bronchioles ) :** This zone consists of respiratory organs forming a path for the conduction of inhaled air into the terminal bronchioles. It transports atmospheric air to the alveoli, discards foreign particles from the inhaled air, also humidifying and maintaining its temperature.
- **Respiratory Zone (Alveolar Duct to Alveoli) :** This zone consists of the alveoli and their ducts. It forms the site where 02 and $CO_2$ gases are exchanged between the blood capillaries and alveoli.

**Based on its anatomical structure, the respiratory system is divided into:**

- **Upper Respiratory Tract :** This zone consists of the organs outside the chest cavity (thorax), i.e., nose, pharynx, and larynx.
- **Lower Respiratory Tract :** This zone consists of the organs within the chest cavity, i.e., trachea, bronchi, bronchiole, alveolar duct, and alveoli.

# Nose

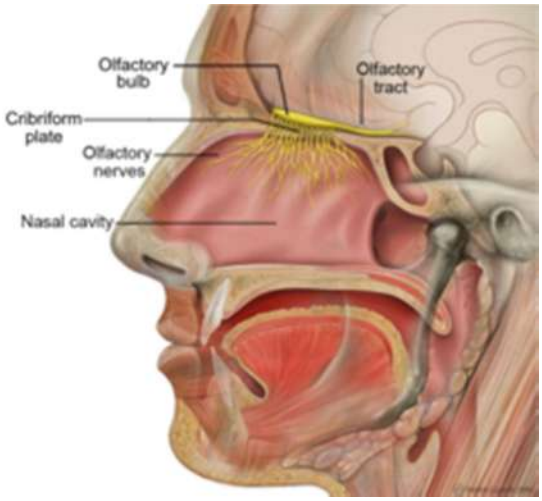
→ Nose is present between the forehead and the upper lip.

→ It is the first organ of the respiratory tract which receives the inhaled air and forms a passage for the air to reach the nasal cavity or nasal chamber.

→ Nose performs the process of warming, moistening, and filtering of the inhaled air.

**Anatomy**

- The structure of nose is divided into an external (the nose) and an internal (nasal cavities) part.
- Nasal cavity is a large irregularly-shaped cavity, divided into two equal halves by a septum.
- A perpendicular plate of ethmoid and vomer bones forms the posterior bony Part of the septum
- while its anterior part is formed by the hyaline cartilage.
- Nose is a bony and a cartilaginous structure.
- Its bony part is made up of the frontal, nasal, and maxillae bones .
- Its external cartilaginous part is made up of the septal cartilage, which forms the anterior portion. of the nasal septum; lateral cartilages form the inferior portion of the nasal bones; and alar cartilages form a portion of the nostrils.




**Functions**

- ✓ Respiration
- ✓ Air Conditioning
- ✓ Defence
- ✓ Vocal Resonance and Speech

# Pharynx

→ Pharynx (throat) is a funnel-shaped tube extending from the internal nares to the posterior part of oesophagus and anterior part of larynx.

→ It is made up of skeletal muscles, is lined with mucous membrane and is divided into nasopharynx, oropharynx, and laryngopharynx.

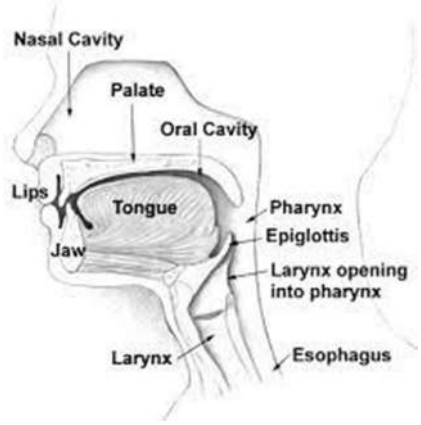
→ The nasopharynx contributes to respiration, while oropharynx and laryngopharynx have respiratory as well as digestive functions

→ The pharynx walls have three tissue layers:

- Lining Membrane (Mucosa)
- Middle Layer
- outer layer

**Anatomy**

- **Nasopharynx :** This part of the pharynx lies immediately posterior to the nasal cavity.
- **Oropharynx :** This part of the pharynx lies immediately posterior to the oral cavity
- **Hypopharynx or Laryngopharynx :** This part of the pharynx lies just inferior to the oropharynx and superior to the oesophagus.
- Epiglottis is a flap of connective tissue found at the entrance of the larynx.
- Pharynx forms the pathway for the passage of both food and air.
- The respiratory and digestive pathways diverge at the larynx.
- The larynx forms the pathway for the entry of air which is then carried to the lungs, while the oesophagus forms the pathway for the entry of food and fluids into the stomach




**Function**

- ✓ Passageway for Air and Food
- ✓ Taste
- ✓ Warming and Humidifying
- ✓ Hearing
- ✓ protection
- ✓ speech

## Larynx

→ Larynx is present as a triangular chamber in the front upper part of the neck.

→ A prominent elevation, called the Adam's apple is present just in front of the larynx.

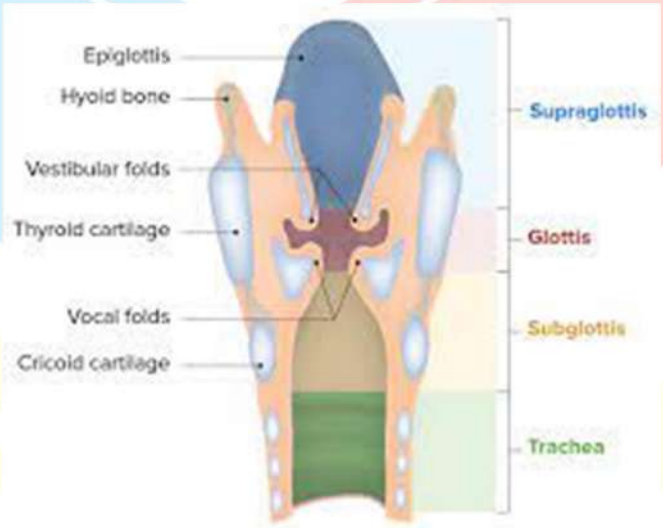
→ Its wall is made up of nine fibrocartilages connected by the ligaments and moved by the muscle

**Anatomy**

- ➢ **Thyroid Cartilage :** It is the largest cartilage (larger in men) which forms a covering around the anterior and lateral sides of larynx. This cartilage has the Adam's apple in its front part.
- ➢ **Cricoid Cartilage :** It is a signet ring-like cartilage present below the thyroid gland. It broader part lies towards the back.
- ➢ **Epiglottis :** It is a leaf-like cartilage which covers the larynx. It is anteriorly inserted in the thyroid cartilage; however its posterior part lies free. It acts as a flap which covers the tracheal opening during

swallowing so that the food does not enter the wind pipe but the food pipe.

- **Paired Caftilages**
  - **Arytenoids :** These are pyramid-shaped cartilages present on either side of cricoid cartilage.
  - **Corniculates :** These are very small and conical nodule-like cartilages present superiorly to the arytenoids.
  - **Cuneiforms :** These are narrow, elongated cartilages present on the sides above corniculates.




**Function**

- ✓ sound production
- ✓ speech
- ✓ Lower Respiratory Tract Protection
- ✓ Air Passageway
- ✓ Humidifying, Filtering, and Warming

## Trachea

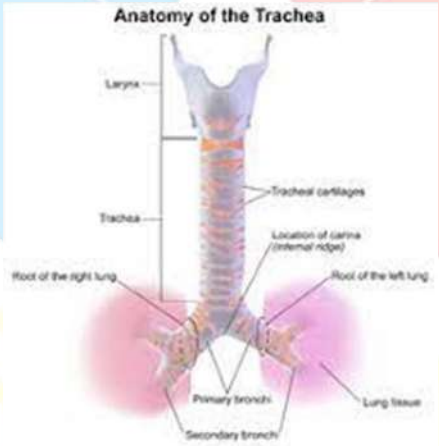
→ Trachea (or wind pipe) is a 10-11 cm long continuous pathway from the larynx, which extends downwards up to the 5$^{th}$ thoracic vertebra

→ Here it splits at the carine into right and left bronchi, entering the respective lungs.

→ It lies in the medium plane in front of the oesophagus.

**Anatomy**

- The trachea cartilages are covered by the following three tissue layers:
- **Outer Layer :** This layer is made up of fibrous and elastic tissues enclosing the cartilages.
- **Middle Layer :** This layer is made up of cartilages and bands of smooth muscles winding around the trachea helically. This layer also contain aerolar tissue blood, lynph vessels, and autonomic nerves
- **Inner Layer :** This layer is made up of ciliated columnar epithelium, containing mucus-secreting goblet cells.




**Function**

- ✓ The cartilages and elastic tissues of trachea are arranged such that they prevent kinking and obstruction of the airway during head and neck movements.
- ✓ It acts as a mucociliary escalator due to synchronised and regular beating of the cilia of mucous membrane.
- ✓ It warms, humidifies, and filters the inhaled air.
- ✓ It generates cough reflex as the laryngeal, tracheal, and bronchial nerve endings (sensitive to irritation) give rise to nerve impulses conducted to the respiratory centres of brain stem via vagus nerves

## Bronchi and Bronchioles

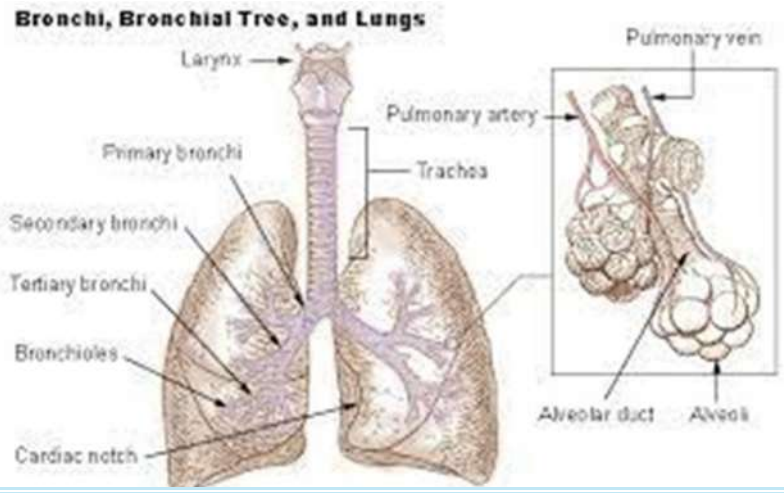
→ Bronchi (singular bronchus) are airway passages in the respiratory tract.

→ They carry the inhaled air into the lungs. They do not form the sites for gaseous exchange.

→ The two right and left bronchi are the primary ones and they enter the corresponding lungs Bronchioles are fine branches entering the lobules ( basic units of lungs )

**Anatomy**

- Bronchi are made up of complete cartilage ring the right and left bronchus are different from each other as the former is shorter and wider.
- Each primary bronchus splits into three right secondary or lobar bronchi (entering the superior, middle, and inferior lobes of the right lung ) and two left bronchi (entering the superior and inferior lobes of the left lung).
- The secondary bronchi further divide into tertiary or segmental bronchi which are distributed into bronchopulmonary segment.
- The tertiary or segmental bronchi then divide into smaller branches.
- Each bronchiole within the lobule divides into a number of terminal bronchioles which further sub-divide into two or more respiratory bronchioles.
- The final terminations of respiratory bronchioles are the alveolar ducts which in turn forms alveoli surrounded by capillaries



**Functions**

- ✓ They provide a passageway for the air.
- ✓ They regulate the volume of air entering the lungs by changing the diameter of respiratory passages due to contraction or relaxation of the muscles in their walls.
- ✓ They warm and humidify the inhaled air.
- ✓ They filter the air by removing Particulate matter.
- ✓ They generate cough reflex.

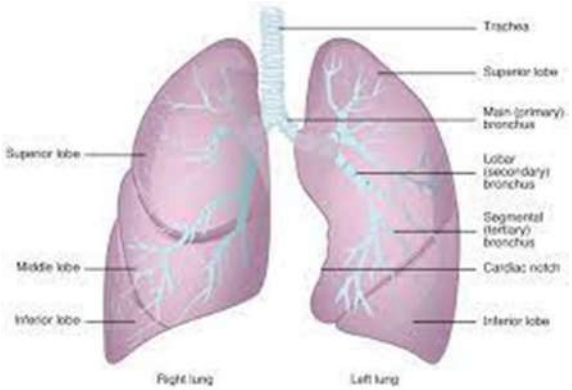
## Lungs

→ Lungs are present in the thoracic cavity as two coneshaped lobes separated by the heart and other structures of mediastinum. These structures also divide the thoracic cavity into two structurally different chambers

**Anatomy**

- ➢ Lungs are present within the cavities located on either side of the heart.
- ➢ Each lung has lobes, which are further divided into lobules containing alveoli.
- ➢ The medial surface of the left lung has a cardiac notch, while the right lung does not have a notch.
- ➢ Lungs have following parts
    - Apex
    - Base
    - Costal Surface
    - Medial Surface

- Mediastinum is an area present between the lungs and is occupied by the heart great vessels, trachea, right and left bronchi, lymph nodes and nerves.
- Pleura and Pleural Cavity
- Each lung is enclosed within a pleural membrane , made up of double layered serous membrane.
- Parietal pleura (the outer layer) line the thoracic cavity wall, while visceral pleura (the deep layer) line the lungs.
- Pleural cavity is the space between the two layers and contains pleural fluid.
- Lobes, Fissures, and Lobules
- Each lung is divided into separate lobes, the left lungs is divided into two lobes and the right one into three
- These lobes are further divided into numerous lobules containing alveoli.
- These lobes are separated by fissures.
- The superior and inferior lobes of the left lungs are separately by the oblique fissure extending inferiorly and anteriorly.
- On the other hand in the right lung, the superior part of oblique fissure seperates the superior and the inferior lobe, while its inferior part seperates the inferior and the middle lobe.
- This middle lobe is superiorly lined by the horizontal fissure




**Function**

- ✓ They alter the blood pH by altering the partial pressure of carbon dioxide.
- ✓ They filter out small blood clots formed in the veins.
- ✓ They filter out gas micro-bubbles formed in the venous blood stream.
- ✓ They alter the blood concentration of some biological substances and drugs.
- ✓ They convert angiotensin I to angiotens II by the action of angiotensin-converting enzyme.
- ✓ They form a soft, shock-absorbent protective layer for the heart.

## Alveoli

→ Alveoli (singular alveolus) are a hollow cavity found in the mammalian lungs.

→ Other vertebrates have different structure for gas exchange.

→ Pulmonary alveoli are the spherical projection of the respiratory bronchioles.

→ The alveolar membranes are the major sites where exchange of gases occurs with the blood.

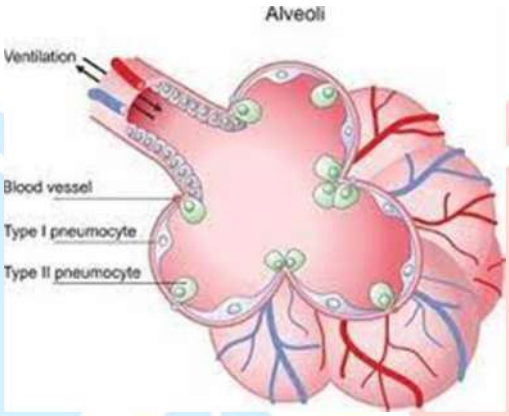
→ Alveoli are lined with epithelium and are made up of some collagen and elastin fibres.

→ These fibres allow the alveoli to stretch when they fill with air during breathing and to spring back so that carbon dioxide-rich air is expelled

**Anatomy**

- ➢ A human lung has around 300 million alveoli, each of them covered with a fine mesh of capillaries occupying 70% of its area .
- ➢ An alveolus in an adult human has an average diameter of 200-300μ, which expands when air is inhaled.
- ➢ Alveoli are made up of an epithelial layer and extracellular matnx surrounded by capillaries.

- Some alveolar walls have Pores between the alveoli these pores are called pores of Kohn




**Functions**

- ✓ External Respiration: They aid in external respiration in which gaseous exchange occurs between the alveoli and blood by diffusion
- ✓ Protection Against Microbes

# Mechanism of Respiration

- Respiration refers to the process of gas exchange in the body — the movement of oxygen into the body and carbon dioxide out of the body. The mechanism of respiration specifically describes how air enters and exits the lungs.
- It involves two main phases:
    - Inhalation (Inspiration) – Air enters the lungs
    - Exhalation (Expiration) – Air exits the lungs

## Inhalation (Inspiration)

→ Inhalation (or Inspiration) is the active phase of respiration in which air enters the lungs. It occurs due to the expansion of the thoracic cavity, which reduces pressure inside the lungs and causes air to rush in.

### Step-by-Step Mechanism of Inhalation

1. **Diaphragm contracts** → flattens downward
2. **External intercostal muscles contract** → lift ribs upward and outward
3. **Thoracic cavity volume increases** in all dimensions
4. **Intrapulmonary (alveolar) pressure decreases** (below atmospheric pressure)
5. **Air flows into the lungs** from higher to lower pressure (atmosphere → lungs)

## Exhalation (Expiration)

→ Exhalation (Expiration) is the process of expelling air out of the lungs into the atmosphere. It is the second phase of breathing and usually occurs passively under normal conditions.

## Step-by-Step Mechanism of Exhalation

### Passive Expiration

1. **Diaphragm relaxes** → moves upward
2. **External intercostals relax** → rib cage falls
3. **Thoracic cavity volume decreases**
4. **Intrapulmonary pressure increases** (above atmospheric pressure)
5. **Air is pushed out** of the lungs

### Forced Expiration

1. **Internal intercostals contract** → compress chest
2. **Abdominal muscles contract** → push diaphragm further up
3. **Intrapulmonary pressure rises significantly**
4. **Air is forcibly expelled**

# Regulation of Respiration

- Regulation of respiration refers to the control of the rate, depth, and rhythm of breathing in order to meet the body's oxygen demands and remove carbon dioxide efficiently. This regulation is primarily automatic, but it can also be voluntarily influenced.

## Types of Respiratory Regulation

| Type | Description |
|---|---|
| **Neural regulation** | Controlled by respiratory centers in the brainstem |
| **Chemical regulation** | Involves chemoreceptors detecting $CO_2$, $O_2$, and pH changes |

# Neural Regulation (Brain Control Centers)

→ Respiration is primarily regulated by centers in the medulla oblongata and pons of the brainstem.

### *A. Medullary Respiratory Center **(in Medulla Oblongata)***

| Sub-center | Function |
|---|---|
| **Dorsal Respiratory Group (DRG)** | Controls inspiration (normal breathing) by sending impulses to the diaphragm and external intercostals |
| **Ventral Respiratory Group (VRG)** | Active during forced breathing (both inspiration and expiration) |

### B. **Pontine Respiratory Centers** (in Pons)

| Center | Function |
|---|---|
| **Pneumotaxic Center** | Inhibits inspiration, controls rate and rhythm |
| **Apneustic Center** | Stimulates prolonged inspiration (limited by pneumotaxic center) |

## Chemical Regulation (via Chemoreceptors)

→ Breathing is also regulated by detecting chemical changes in the blood.

*Central Chemoreceptors*

- Location: Medulla oblongata
- Sensitive to: ↑$CO_2$ and ↓pH (due to carbonic acid formation)
- Effect: Stimulate increased breathing rate to eliminate excess $CO_2$

*Peripheral Chemoreceptors*

- Location: Carotid bodies (near carotid artery) and aortic bodies
- Sensitive to: ↓$O_2$, ↑$CO_2$, and ↓pH
- Effect: Increase rate and depth of breathing

# Lung Volumes and Capacities

→ The dynamic or static lung volumes/capacities are measured at varying degrees of inspiration or expiration.

→ Dynamic lung volumes depend upon the air flow rate; while the static lung volumes (the maximum volume to which a lung can be expanded) sub-divide into four standard volumes (i.e., tidal, inspiratory reserve, expiratory reserve, and residual volumes), four standard capacities inspiratory, Functional residual and total lung capacities ) and four non-overlapping volumes

1. **Tidal Volume (TV) :** It is the volume of air inspired or expired during a normal respiration. An average value for tidal volume is approximately 500ml i.e. a healthy man can inspire or expire approximately 6000-8000ml of air per minute
2. **Inspiratory Reserve Volume (IRV):** It is the additional volume of air, a person can inspire by a forcible inspiration. The average value for IRV is 2500-3000ml.
3. **Expiratory Reserve Volume (ERV):** It is the volume of air that a person can expire by a forcible expiration. The average value for ERV is 1000-1100ml.
4. **Residual Volume (RV):** It is the volume of air remaining in the lungs even after a forcible expiration. This average value for RV is 1100 - 1200ml

## Lung capacities are combination of two or more pulmonary volumes:

1. **Inspiratory Capacity (IC) :** It is the total volume of air a person can inspire after a normal expiration It includes TV + IRV. Its average value is about 3500ml

2. **Expiratory Capacity (EC) :** It is the total volume of air a person can expire after a normal inspiration. It includes TV + ERV. Its average value is about 1600ml
3. **Functional Residual Capacity (FRC} :** It is the volume of air that will remain in the lungs, after a normal expiration. It includes ERV+RV. Its average value is about 2300ml.
4. **Vital Capacity (VC) :** It is the maximum volume of air a person can breathe out after a forced inspiration. It includes ERV, TV, and IRV. Its average value is about 4600ml.
5. **Total Lung Capacity (TLC) :** It is the total volume of air accommodated in the lungs at the end of a forced inspiration. It include RV, ERV, TV. and IRV or VC ·+ RV. Its average value is about 5800ml TLC = VC + RV

# TRANSPORT OF RESPIRATORY GASES

→ Respiratory gases — oxygen ($O_2$) and carbon dioxide ($CO_2$) — are transported between the lungs and tissues via the bloodstream. This ensures cells receive oxygen for metabolism and remove waste $CO_2$.

# TRANSPORT OF OXYGEN ($O_2$)

➢ Oxygen transport refers to the movement of $O_2$ from the lungs to body tissues via the bloodstream. Since oxygen is poorly soluble in plasma, most of it is carried by hemoglobin inside red blood cells (RBCs).

**Step-by-Step Mechanism**

**A. In the Lungs (Oxygen Loading)**

- High partial pressure of $O_2$ ($PO_2$) in alveoli
- $O_2$ diffuses into pulmonary capillaries
- $O_2$ binds to hemoglobin in RBCs → forms oxyhemoglobin ($HbO_2$)
    - Hb+O2↔HbO2Hb + O_2 \leftrightarrow HbO_2Hb+O2 ↔HbO2
- Oxygenated blood is carried via pulmonary veins to the left heart and pumped to the body

**B. In the Tissues (Oxygen Unloading)**

- In tissues, $PO_2$ is low due to oxygen consumption
- Oxyhemoglobin dissociates → releases $O_2$
- $O_2$ diffuses into the interstitial fluid and then into body cells

# TRANSPORT OF CARBON DIOXIDE ($CO_2$)

- Carbon dioxide ($CO_2$) is a waste product of cellular respiration. It is transported from the tissues to the lungs via the bloodstream, where it is exhaled.
- $CO_2$ is more soluble in blood than oxygen, and it is transported in three main forms.

## Step-by-Step Mechanism

→ $CO_2$ is more soluble in blood than $O_2$ and is transported in three main forms:

***a.*** *As Bicarbonate Ion ($HCO_3^-$) (~70%)*

- Inside RBCs:
  $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$
  (catalyzed by **carbonic anhydrase**)
- $HCO_3^-$ diffuses into plasma, $Cl^-$ enters RBC to maintain charge balance (**chloride shift**).

***b.*** *As Carbaminohemoglobin ($HbCO_2$) (~20–23%)*

- $CO_2$ binds to the **globin** part (not the iron) of hemoglobin.
- Binding is enhanced in **deoxygenated Hb** (called **Haldane effect**).

***c.*** *Dissolved in Plasma (~7–10%)*

- Some $CO_2$ remains dissolved, contributing to **$PCO_2$** for diffusion into alveoli.

# ARTIFICIAL RESPIRATION

- Artificial respiration is a life-saving technique used to maintain breathing artificially when a person's normal breathing has stopped or is insufficient. It helps in the exchange of gases ($O_2$ in, $CO_2$ out) until normal respiration resumes or advanced medical help is available.

## Purpose

- To supply oxygen ($O_2$) to the lungs
- To remove carbon dioxide ($CO_2$) from the body
- To maintain life and brain function during respiratory failure or arrest

## Types of Artificial Respiration

| Type | Description |
|---|---|
| **Manual Methods** | Done by a rescuer without medical devices |
| **Mechanical Methods** | Done using machines (ventilators, resuscitators) in hospitals |

# Manual Methods

1. **Mouth-to-Mouth Respiration**

→ Most common and effective in emergencies
→ The rescuer blows air into the patient's mouth while pinching the nose shut
→ Air is exhaled by passive recoil

**Steps**

- Check airway, breathing, and circulation (ABC)
- Clear obstructions from the mouth/throat
- Tilt the head backward
- Give 2 rescue breaths, each lasting about 1 second
- Continue with CPR (if needed)

2. **Mouth-to-Nose Respiration**

→ Used when mouth is injured or inaccessible

3. **Holger Nielsen Method**

→ Victim is placed face down, arms moved rhythmically to compress chest and help breathing

4. **Schafer's Method**

→ Victim lies on the stomach, the rescuer applies rhythmic pressure on the back/lower ribs

# Mechanical Methods

- **Bag-Valve-Mask (BVM) Ventilation**
  - Uses a self-inflating bag, face mask, and sometimes oxygen
  - Common in ambulances and ERs
- **Ventilator (Mechanical Respirator)**
  - Machine delivers controlled airflow to lungs
  - Used in ICUs for patients who cannot breathe on their own

## Precautions During Artificial Respiration

- Ensure airway is clear (no food, vomit, or blockage)
- Avoid hyperventilation (too rapid breaths)
- Prevent gastric inflation (air entering the stomach)
- Use barrier devices (if available) to reduce disease transmission

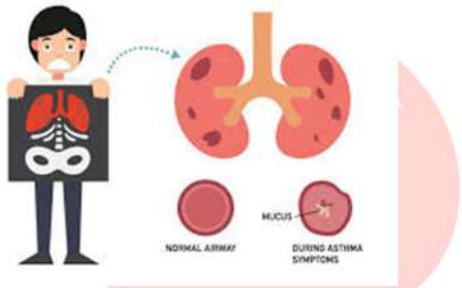
# Disorders of the Respiratory System

## 1. Asthma

- A chronic inflammatory disease of the airways that causes reversible airway narrowing.

**Cause**: Allergens (dust, pollen), pollution, exercise, cold air.

**Symptoms**:




- Wheezing
- Breathlessness
- Chest tightness
- Coughing (especially at night or early morning)

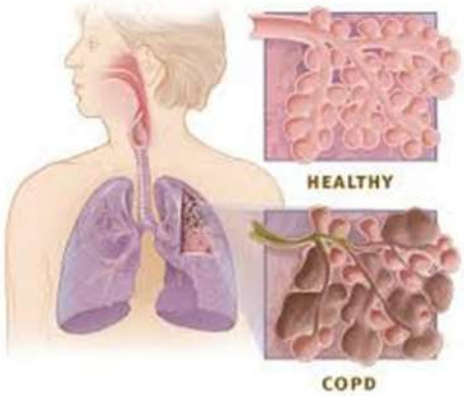
**Effect**: Airflow obstruction and reduced oxygen supply.

## 2. Chronic Obstructive Pulmonary Disease (COPD)

- A group of progressive lung diseases including chronic bronchitis and emphysema.

**Cause**: Smoking (primary cause), pollution, prolonged exposure to irritants.

**Symptoms**:




- Chronic cough
- Sputum production
- Shortness of breath
- Fatigue

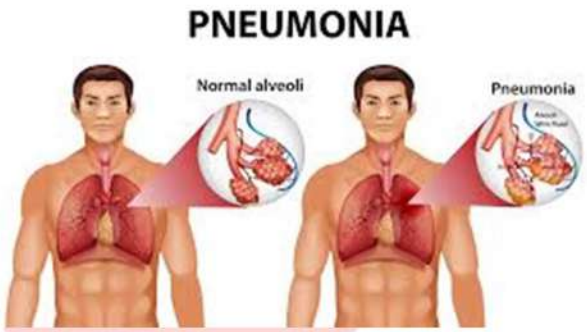
**Effect**: Irreversible airflow limitation, poor oxygen exchange.

## 3. Pneumonia

- Infection that causes inflammation and fluid accumulation in the alveoli.

**Cause**: Bacteria (e.g., *Streptococcus pneumoniae*), viruses, fungi.

**Symptoms**:




- High fever and chills
- Chest pain
- Productive cough (mucus or pus)
- Difficulty in breathing

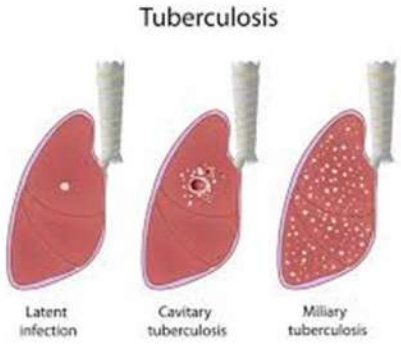
**Effect**: Impaired gas exchange, reduced oxygenation.

## 4. Tuberculosis (TB)

- A contagious bacterial infection caused by Mycobacterium tuberculosis.

**Transmission**: Through air droplets from infected individuals.

**Symptoms**:




- Persistent cough (>3 weeks)
- Blood in sputum
- Night sweats
- Weight loss and fatigue

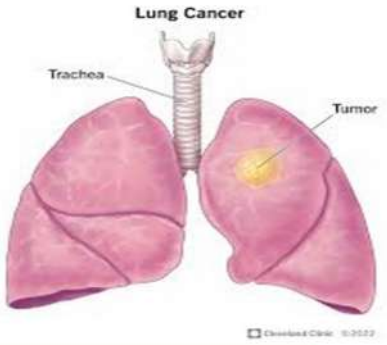
**Effect**: Destruction of lung tissue, can spread to other organs.

## **5.** Lung Cancer

- Malignant tumor of the lung tissue.

**Cause**: Smoking (main cause), air pollution, genetic factors.

**Symptoms**:




- Chronic cough
- Chest pain
- Hemoptysis (coughing up blood)
- Weight loss

**Effect**: Loss of lung function, metastasis to other organs.