Respiratory System in humans

Why Do We Breathe?

•**The Core Purpose:** Respiration is the process of exchanging gases between the body and the outside environment.
•**Necessity:** All living cells need a continuous supply of **Oxygen (**O_2**)** to release energy from food (cellular respiration).
•**Waste Removal:** The process of cellular respiration produces **Carbon Dioxide (**CO_2**)** as a waste product, which must be efficiently removed.

Defining Respiration vs. Breathing

- **Breathing (Ventilation):** The physical, mechanical process of moving air in and out of the lungs.
- *Focus:* Involves muscles, bones, and pressure changes.
- **Respiration:** The overall chemical and gas exchange process. This includes:
- **External Respiration:** Gas exchange in the lungs.
- **Internal Respiration:** Gas exchange in the tissues.
- **Cellular Respiration:** Energy release inside the cells.

The Two Major Divisions of the System

- **Conducting Zone:** A series of interconnected tubes and passage ways that filter, warm, and moisten air, and conduct it to the lungs.
- *Includes:* Nose, Pharynx, Larynx, Trachea, Bronchi.
- **Respiratory Zone:** The site where actual gas exchange occurs.
- *Includes:* Respiratory bronchioles, alveolar ducts, and alveoli (air sacs).

The Nose and Nasal Cavity

- **Pathway:** Air normally enters the body through the nostrils (nares).
- **The Nasal Septum:** Divides the nasal cavity into two halves.
- **Conditioning Air:** The nasal cavity is lined with specialized cells that perform three key functions:
- **Warming:** Blood vessels warm the air.
- **Moistening:** Mucus adds humidity.
- **Filtering:** Hair and mucus trap dust and particles.

The Role of Mucus and Cilia

- **Mucus:** A sticky substance secreted by goblet cells. It traps inhaled dust, bacteria, and foreign particles.
- **Cilia:** Tiny, hair-like projections that continuously beat in a coordinated, wave-like motion.
- **The Mucociliary Escalator:** The cilia sweep the trapped mucus (and debris) towards the pharynx to be swallowed or expelled.

The Pharynx (Throat)

- **Shared Pathway:** The pharynx is a tube that serves as a common passageway for both air (from the nose) and food (from the mouth).
- **Three Regions:**
- **Nasopharynx:** Upper part, for air only.
- **Oropharynx:** Middle part, for both air and food.
- **Laryngopharynx:** Lower part, connects to the larynx and esophagus.

The Larynx (Voice Box)

- **Location:** Connects the pharynx to the trachea.
- **Primary Function:** Acts as the main organ of **voice production**.
- **Vocal Cords:** Folds of tissue inside the larynx that vibrate when air passes over them, producing sound.
- **The Epiglottis:** A flap of cartilage that covers the opening to the trachea during swallowing, preventing food from entering the airways.

The Trachea (Windpipe)

- **Structure:** A tube approximately 10-12 cm long that extends from the larynx down to the chest cavity.
- **Protection:** Reinforced by 16 to 20 C-shaped rings of **cartilage**.
- **Function of Cartilage Rings:** These rings keep the trachea permanently open, preventing it from collapsing during inhalation.
- **Lining:** Also lined with ciliated cells and mucus to continue filtering the air.

The Bronchi and Bronchial Tree

- **Bifurcation:** The trachea divides into two main tubes called the **Primary Bronchi** (one entering each lung).
- **Branching:** The primary bronchi divide further into smaller and smaller tubes, like the branches of a tree. This entire structure is called the **Bronchial Tree**.
- **Secondary and Tertiary Bronchi:** Subsequent divisions of the main bronchi.

Bronchioles: End of the Conducting Zone

- **Structure:** The smallest branches of the bronchial tree.
- **Difference from Bronchi:** Bronchioles lack cartilage rings.
- **Smooth Muscle Control:** They have smooth muscle tissue in their walls that can contract or relax to control the airflow into the deepest parts of the lungs (bronchodilation and bronchoconstriction).

The Lungs: Structure

- **Location:** Occupy most of the chest (thoracic) cavity.
- **Lobes:** The right lung has three lobes, and the left lung has two lobes (to make room for the heart).
- **Composition:** The lungs are primarily composed of millions of tiny air sacs (alveoli) and the network of blood vessels surrounding them.

The Pleura: Protective Layers

- **Definition:** The lungs are enclosed by a double-layered membrane called the **pleura**.
- **Layers:**
- **Visceral Pleura:** The inner layer, covering the surface of the lungs.
- **Parietal Pleura:** The outer layer, lining the chest cavity.
- **Pleural Fluid:** A thin film of fluid between the two layers that lubricates the surfaces, allowing them to slide smoothly during breathing.

The Respiratory Zone: Alveoli

- **Alveoli:** Tiny, grape-like clusters of air sacs at the end of the respiratory bronchioles.
- **Primary Function:** This is the **main site of gas exchange**.
- **Structure:** They have extremely thin walls, only one cell layer thick, and are heavily surrounded by capillaries.
- **Surface Area:** The total surface area of all alveoli is massive (about 70 square meters), maximizing exchange efficiency.

The Mechanism of Breathing (Ventilation)

- **Physical Basis:** Breathing is governed by changes in pressure, following the rule that air always flows from a region of **higher pressure** to a region of **lower pressure**.
- **Chest Cavity:** The volume of the chest cavity changes due to the movement of the diaphragm and rib cage.
- **Pressure Relationship:** Changing the volume of the chest cavity changes the pressure inside the lungs.

Key Muscles of Breathing: Diaphragm

- **Location:** A large, dome-shaped sheet of muscle located beneath the lungs, separating the thoracic cavity from the abdominal cavity.
- **Inspiration Role:** When the diaphragm contracts, it flattens and moves downward. This increases the vertical volume of the chest cavity.
- **Expiration Role:** When the diaphragm relaxes, it moves upward, decreasing chest volume.

Key Muscles of Breathing: Intercostals

- **Location:** Muscles found between the ribs.
- **External Intercostals:** Contraction pulls the ribs upward and outward, increasing the chest volume (Inspiration).
- **Internal Intercostals:** Contraction pulls the ribs downward and inward, decreasing chest volume (Forced Expiration).

Phase 1: Inspiration (Inhalation)

- **Contraction:** The diaphragm and external intercostal muscles contract.
- **Volume Change:** The volume of the thoracic cavity increases.
- **Pressure Change:** Because the volume increases, the pressure inside the lungs (intrapulmonary pressure) drops **below** the atmospheric pressure.
- **Air Flow:** Air rushes *in* from the outside to equalize the pressure difference.

Phase 2: Expiration (Exhalation)

- **Relaxation:** The diaphragm and external intercostal muscles relax (in quiet breathing).
- **Volume Change:** The volume of the thoracic cavity decreases.
- **Pressure Change:** The lung tissue recoils, and pressure inside the lungs rises **above** the atmospheric pressure.
- **Air Flow:** Air is pushed *out* of the lungs to equalize the pressure difference

External Respiration (The Lungs)

- **Definition:** The exchange of O_2 and CO_2 between the air in the alveoli and the blood in the alveolar capillaries.
- **Principle:** This process occurs purely by **diffusion**.
- O_2 **Movement:** Moves from the high O_2 concentration in the alveolar air into the low O_2 blood.
- CO_2 **Movement:** Moves from the high CO_2 blood into the low CO_2 alveolar air.

Internal Respiration (The Tissues)

- **Definition:** The exchange of O_2 and CO_2 between the blood in the systemic capillaries and the surrounding body tissues (cells).
- O_2 **Movement:** Moves from the high O_2 blood into the low O_2 tissue cells.
- CO_2 **Movement:** Moves from the high CO_2 waste product in the tissue cells into the low CO_2 blood.

Oxygen Transport in the Blood

- Two Ways:

- **Dissolved in Plasma:** A small amount (1.5%) is simply dissolved in the watery blood plasma.
- **Bound to Hemoglobin:** The vast majority (98.5%) is transported attached to the iron-containing protein **hemoglobin** inside red blood cells.

Hemoglobin: The O2 carrier

- **Structure:** Each hemoglobin molecule has four iron atoms, and each iron atom can bind one O2 molecule.
- **Oxyhemoglobin:** Hemoglobin with O2 bound (HbO2).
- **Deoxyhemoglobin:** Hemoglobin that has released its O2 (HHb).
- **Key Role:** Hemoglobin dramatically increases the O2 carrying capacity of the blood.

Carbon Dioxide Transport (Three Methods)

- CO_2 is transported in the blood in three main forms:

1. Dissolved in Plasma: About 7% is dissolved.
2. Bound to Hemoglobin: About 23% binds directly to the amino groups of hemoglobin, forming Carbaminohemoglobin ($HbCO_2$).
3. As Bicarbonate Ions (HCO_3^-): About 70% is converted to bicarbonate ions.

Regulation of Respiration: The Control Center

- **Respiratory Center:** The primary control center for breathing is located in the **Medulla Oblongata** and the **Pons** in the brainstem.
- **Medulla's Role:** Contains groups of neurons (dorsal and ventral) that rhythmically generate the basic breathing pattern (about 12-15 breaths per minute).
- **Pons' Role:** Modifies the rhythm set by the medulla, smoothing the transition between inspiration and expiration.

Chemical Control: Chemoreceptors

- **Definition:** Specialized sensory cells that monitor the chemical composition of the blood.
- **Central Chemoreceptors:** Located in the medulla, highly sensitive to changes in H+ concentration (which reflects CO_2 levels) in the cerebrospinal fluid.
- **Peripheral Chemoreceptors:** Located in the carotid arteries and aorta, sensitive to changes in PO_2, PCO_2, and pH in the blood.

The Dominant Chemical Stimulus (CO_2)

- **Primary Driver:** The level of CO_2 (via H^+ concentration) in the blood is the most potent and important regulator of breathing rate.
- **High** CO_2**:** If CO_2 levels rise, the blood becomes more acidic (H^+ increases). Chemoreceptors sense this and signal the medulla to **increase** the rate and depth of breathing.
- **Goal:** This quick increase in ventilation blows off the excess CO_2 and returns the blood pH to normal.

The Role of Oxygen in control

- **Secondary Driver:** O2 levels play a much smaller role in regulating breathing in healthy individuals.
- **Critical Drop:** The peripheral chemoreceptors are only strongly stimulated when the arterial PO2 drops dangerously low (less than 60 mmHg).
- **Mechanism:** Low O2 signals the medulla to increase ventilation, ensuring enough oxygen is taken in.

Nervous and Physical Control

- **Cerebral Cortex:** Allows us to consciously control our breathing (e.g., holding your breath, speaking).
- **Stretch Receptors (Hering-Breuer Reflex):** Receptors in the bronchi and bronchioles are stimulated when the lungs are over-inflated.
- **Function:** This reflex sends inhibitory signals to the medulla, preventing excessive inflation and protecting the lung tissue.

Respiratory Volumes: Introduction

- **Definition:** Specific volumes of air that are moved in and out of the lungs during different phases of breathing.
- **Importance:** Measuring these volumes helps assess the functional health of the lungs.

Key Respiratory Volumes

- **Tidal Volume (TV):** The volume of air inhaled or exhaled during normal, quiet breathing (about 500 mL).
- **Inspiratory Reserve Volume (IRV):** The extra volume of air that can be forcibly inhaled after a normal tidal inspiration.
- **Expiratory Reserve Volume (ERV):** The extra volume of air that can be forcibly exhaled after a normal tidal expiration.

Respiratory Capacities

- **Vital Capacity (VC):** The maximum volume of air that can be moved out of the lungs after a maximum inhalation.
- VC=TV+IRV+ERV
- **Residual Volume (RV):** The volume of air that always remains in the lungs even after a forceful expiration. This keeps the alveoli inflated.
- **Total Lung Capacity (TLC):** The total volume of air the lungs can hold after maximum inspiration.

Common Respiratory Disorders

- **Asthma:** Chronic inflammation of the airways, leading to bronchoconstriction, which makes breathing difficult.
- **Emphysema (COPD):** Destruction of the alveolar walls, reducing the surface area available for gas exchange.
- **Pneumonia:** Infection that causes inflammation and fluid buildup in the alveoli, hindering gas exchange.

Summary

- **The Respiratory Pathway:** Nose → Pharynx → Larynx → Trachea → Bronchi → Bronchioles → Alveoli.
- **Breathing:** A mechanical process driven by muscle contraction and pressure gradients.
- **Exchange:** Gas exchange occurs via simple diffusion, driven by partial pressure differences.
- **Control:** The CO_2 level in the blood is the primary chemical regulator, monitored by the chemoreceptors and controlled by the medulla.

Thank you

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