CHAPTER

4

Respiratory System

Introduction

- **Respiration** is an oxidative process involving the oxidation of food substances such as carbohydrates, fats and proteins within the tissues to form CO_2, water and consequent release of energy. The released energy is temporarily stored as ATP. Respiration may be of two types *ie*, **Anaerobic respiration** (the respiration without oxygen) and **Aerobic respiration** (respiration that requires oxygen).

Anaerobic Respiration

- When food is oxidised without using molecular oxygen, the respiration is called anaerobic respiration, *eg*, anaerobic bacteria, yeast, parasitic worms like *Ascaris, Taenia, Fasciola* etc.
- In micro-organisms, the term **fermentation** is more commonly used in place of anaerobic respiration which is defined as the anaerobic breakdown of carbohydrates and other organic compounds into alcohols, organic acids, gases etc with the help of micro-organisms or their enzymes.

Aerobic Respiration

- When oxygen is used for respiration, it is called aerobic respiration, *eg*, most plants and animals.
- In higher animals whole process of respiration includes **external respiration, internal respiration** and **cellular respiration**.

(a) External respiration or breathing

- **External respiration** is the process by which gases are exchanged between the blood and the air.
- It involves two phases : Inspiration and Expiration.
- **Inspiration** is a process by which fresh air enters the lungs.
- In it diaphragm becomes flat and gets lowered by the contraction of its muscle fibres and increasing the volume of thoracic cavity.
- In it the external intercostal muscles contract and pull the ribs and sternum upward and outward direction thus increasing the volume of thoracic cavity.
- **Expiration** is a process by which CO_2 is expelled out from the lungs.

Table 4.1 Respiratory Organs of Some Animals

Respiratory organs	Animals
Lungs	Reptiles, mammals
Skin	Frog, earthworm, leeches
Gills	Fishes, tadpoles, prawns
Tracheae	Insects, centipedes, millipedes
Body surface	Protozoans, porifers, coelenterates
Book lungs	Spider, scorpion, ticks, mites
Book gills	King crab, prawn, cray fish, *Daphnia*
Mental	Mollusca (*Unio*)
Air bladder	Lung fish, bony fishes (*eg, Labeo*)
Airsacs/lungs	Birds

- In it muscle fibres of the diaphragm relax making it convex, decreasing the volume of the thoracic cavity.
- External intercostal muscles relax and pull the ribs downward and inward direction, thus decreasing the size of the thoracic cavity.

(b) Internal respiration

- Internal respiration is the process by which gases are exchanged between blood and tissue fluid and between tissue fluid and cells.

(c) Cellular respiration

- Cellular respiration is the process by which cells use oxygen (O_2) for metabolism and give off CO_2 as a waste.

Human Respiratory System

- The conducting part of human respiratory system is highly complicated structurally and functionally.
- The respiratory system is derived from embryonic **endoderm.**

Table 4.2 Principal Organs of the Respiratory System

Structure	Description, general and distinctive features	Function
Nose	Jutting external portion supported by bone and cartilage; internal nasal cavity divided by midline nasal septum and lined with mucosa	Produces mucus; filters, warms and moistens incoming air; resonance chamber for speech
	Roof of nasal cavity contains olfactory epithelium	Receptors for sense of smell
	Paranasal sinuses around nasal cavity	Same as for nasal cavity; also lighten skull
Pharynx	Passageway connecting nasal cavity to larynx and oral cavity to oesophagus; three subdivisions : nasopharynx, oropharynx and laryngopharynx	Passageway for air and food
	Houses tonsils (lymphoid tissue masses involved in body protection against pathogens)	Facilitates exposure of immune system to inhaled antigens
Larynx	Connects pharynx to trachea, framework of cartilage and dense connective tissue; opening (glottis) can be closed by epiglottis or vocal folds	Air passageway; prevents food from entering lower respiratory tract
	Houses true vocal cords	Voice production
Trachea	Flexible tube running from larynx and dividing inferiorly into two primary bronchi ; walls contain C-shaped cartilages that are incomplete posteriorly where connected by trachealis muscle	Air passageway; cleans, warms and moistens incoming air
Bronchial tree	Consists of right and left primary bronchi, which subdivide within the lungs to form secondary and tertiary bronchi and bronchioles, bronchiolar walls contain complete layer of smooth muscle ; constriction of this muscle impedes expiration	Air passageways connecting trachea with alveoli; cleans, warms and moistens incoming air
Alveoli	Microscopic chambers at termini of bronchial tree; walls of simple squamous epithelium underlain by thin basement membrane; external surfaces intimately associated with pulmonary capillaries	Main sites of gas exchange
	Special alveolar cells produce surfactant	Reduces surface tension; helps to prevent lung collapse
Lungs	Paired composite organs located within pleural cavities of thorax, composed primarily of alveoli and respiratory passageways; stroma is fibrous elastic connective tissue, allowing lungs to recoil passively during expiration	House respiratory passages smaller than the primary bronchi
Pleurae	Serous membranes, parietal pleura lines thoracic cavity, visceral pleura covers external lung surfaces	Produce lubricating fluid and compartmentalize lungs

Pulmonary Volumes and Capacities

- The quantities of air, the lung can receive, hold or expel under different conditions are called **pulmonary volumes** and combination of two or more pulmonary volumes are called **pulmonary capacities.**
- The apparatus commonly used to measure the pulmonary volumes is a **spirometer or respirometer.**
- The recording of breathing is known as **spirogram.**

Table 4.3 Pulmonary Volumes and Capacities for Males and Females

Measurement	Adult male average value	Adult female average value	Description
Respiratory volumes			
Tidal Volume (TV)	500 mL	500 mL	Amount of air inhaled or exhaled with each breath under resting conditions
Inspiratory Reserve Volume (IRV)	3100 mL	1900 mL	Amount of air that can be forcefully inhaled after a normal tidal volume inhalation
Expiratory Reserve Volume (ERV)	1200 mL	700 mL	Amount of air that can be forcefully exhaled after a normal tidal volume exhalation
Residual Volume (RV)	1200 mL	1100 mL	Amount of air remaining in the lungs after a forced exhalation
Respiratory capacities			
Total Lung Capacity (TLC)	6000 mL	4200 mL	Maximum amount of air contained in lungs after a maximum inspiratory effort ; TLC = TV + IRV + ERV + RV
Vital Capacity (VC)	4800 mL	3100 mL	Maximum amount of air that can be expired after a maximum inspiratory effort, VC = TV + IRV + ERV (should be 80% TLC)
Inspiratory Capacity (IC)	3600 mL	2400 mL	Maximum amount of air that can be inspired after a normal expiration; IC = TV + IRV
Functional Residual Capacity (FRC)	2400 mL	1800 mL	Volume of air remaining in the lungs after a normal tidal volume expiration; FRC = ERV + RV

Transport of Gases in Blood

Oxygen Transport

- 98.5% of oxygen (O_2) is transported by blood with the help of the respiratory pigment **haemoglobin** present in erythrocytes (RBCs).
- One molecule of haemoglobin can carry as much as four oxygen molecules.
- One gram of haemoglobin binds about 1.34 mL of oxygen (O_2). Thus, 100 mL of pure blood carries about 20 mL of oxygen.

Oxygen-haemoglobin dissociation curve

- When a graph is plotted between percent saturation of haemoglobin and oxygen tension, a curve is obtained which is termed as Hb-O_2 dissociation curve.
- At normal condition that is on P_{CO_2} of 40 mm Hg concentration, this curve is **sigmoid** and **normal.**
- Due to **increase in concentration of** CO_2, curve shifted towards **right side.**
- Due to **decrease in concentration of** CO_2, curve shifted towards **left side.**

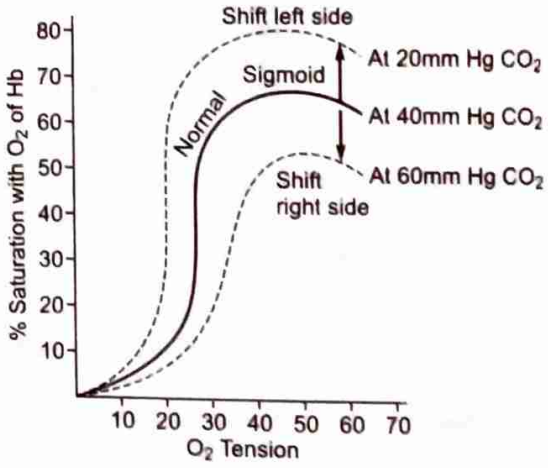

Fig. 4.1 Dissociation curve

Bohr's effect

- Hb-O_2 dissociation curve shifts to right when CO_2 tension in blood is high. **Bohr's effect** discovered by **Bohr** in 1904.
- Deoxygenation of oxyhaemoglobin is directly proportional to the blood P_{CO_2}.
- CO_2 of tissue fluid and alveoli does not exert Bohr's effect.

Carbon dioxide Transport

- Transport of carbon dioxide by blood is much easier than that of oxygen due to high solubility of CO_2 in water.
- About 7% of CO_2 is transported as dissolved in plasma, 23% as carbaminohaemoglobin and 70% as bicarbonates.
- Most of the CO_2 is transported by blood in the form of **sodium bicarbonate** in plasma.

Chloride shift or Hamburger's phenomenon

- To maintain electrostatic neutrality of plasma, many chloride ions diffuse from plasma into RBCs and bicarbonate ions pass out. The chloride content of RBCs increases when oxygenated blood becomes deoxygenated. This is termed as **chloride shift.**

- Entering of Cl^- ions into RBC is known as **positive chloride shift**.
- Shifting of Cl^- ion from RBC into plasma is known as **negative chloride shift.**

Haldane's effect

- Haldane effect is important in promoting CO_2 transport.
- Oxyhaemoglobin behaves as a strong acid. As more and more oxyhaemoglobin forms in the lungs, it releases more and more H^+ ions increasing the acidity of blood. This is known as **Haldane effect.**

Respiratory Pigments

Table 4.4 Respiratory Pigments in Some Animals

Name of pigment	Colour (oxidised)	Metal	Place	Example
Haemoglobin	Red	Fe	RBC	Chordata (Vertebrate)
Haemocyanin	Blue	Cu	Plasma	Mollusca and Arthropoda
Haemoerythrin	Red	Fe	Corpuscle	Annelida, *Sipunculoidea, Lingula*
Echinochrome	Red	Fe	Coelomic fluid	Echinodermata
Haemoglobin	Red	Fe	Plasma	Earthworm, *Nereis, Arenicola, Chironomas* insect, *Planorbis*
Pinnaglobin	Brown	Mn	Coelomic fluid	*Pinna* (Mollusc)

Medical Terminology

Table 4.5 Some Common Medical Terminology

Terminology	Explanation
Apnea	Absence of breathing
Eupnea	Normal breathing
Hypopnea	Decreased breathing rate
Hyperpnea	Increased breathing rate
Dyspnea	Painful breathing
Acapnoea	Absence of CO_2 in blood
Hypocapnea	Deficiency of CO_2 in blood
Hypercapnea	Excess of CO_2 in blood

Disorders of Respiratory System

Bronchitis It is caused by the permanent swelling in bronchi. As a result of bronchitis cough is caused and thick mucous with pus cells is spitted out.

Bronchial asthma It is an allergic attack of breathlessness associated with bronchial obstruction, characterized by coughing difficult breathing.

Emphysema A condition in which the walls separating the alveoli breaks resulting in reduction of surface area for exchange of respiratory gases. Heavy cigarette smoking leads to **emphysema.**

Pneumonia **Pneumonia** is an acute infection or inflammation of the alveoli. The most common cause of pneumonia is the pneumococcal bacterium *Streptococcus pneumoniae.*

Table 4.6 Some Common Respiratory Movements

Movement	Mechanism and result
Cough	Taking a deep breath, closing glottis and forcing air superiorly from lungs against glottis, glottis opens suddenly and a blast of air rushes upward, can dislodge foreign particles or mucus from lower respiratory tract and propel such substances superiorly
Sneeze	Similar to a cough, except that expelled air is directed through nasal cavities as well as through oral cavity; depressed uvula closes oral cavity off from pharynx and routes air upward through nasal cavities; sneezes clear upper respiratory passages
Crying	Inspiration followed by release of air in a number of short expirations; primarily an emotionally induced mechanism
Laughing	Essentially same as crying in terms of air movements produced; also an emotionally induced response
Hiccups	Sudden inspirations resulting from spasms of diaphragm, believed to be initiated by irritation of diaphragm or phrenic nerves, which serve diaphragm; sound occurs when inspired air hits vocal folds of closed glottis
Yawn	Very deep inspiration, taken with jaws wide open; formerly believed to be triggered by need to increase amount of oxygen in blood but this theory is now being questioned; ventilates all alveoli (not the case in normal quiet breathing)