

SLO 5: Gaseous Exchange

5.1 Introduction

5.1.1 Differentiate Between Breathing And Respiration

Basis	Breathing (Ventilation)	Respiration
Type of Process	A physical and mechanical process involving muscle movement.	A biochemical/metabolic process.
Location	Occurs in specific respiratory organs like the nose, windpipe, and lungs.	Occurs inside all living cells, specifically within the mitochondria.
Function	Inhales oxygen-rich air and exhales carbon dioxide-rich air.	Breaks down glucose to produce usable energy (ATP), water, and carbon dioxide.
Energy Production	Does not produce energy itself.	Releases energy in the form of ATP for the body's functions.
Control	Can be both voluntary and involuntary.	Is an involuntary and automatic process.
Enzymes	No enzymes are involved in the process.	Requires a series of enzymes to catalyze the different steps.
Stages	Involves two stages: inhalation (inspiration) and exhalation (expiration).	Involves multiple cycles like glycolysis, the Krebs cycle, and the electron transport chain (in aerobic respiration).

5.2 Gaseous Exchange in Plants

5.2.1 Compare Photosynthesis And Respiration In Plants

Photosynthesis	Respiration
Photosynthesis is the process where light energy converted in chemical energy.	Respiration is the process where chemical energy converted into energy of ATP.
It occurs only in chlorophyll containing organisms.	It occurs in all organisms.
It occurs only in the presence of light.	It occurs throughout the life.
It occurs in chloroplast.	It occurs in mitochondria.
The reactants are Carbon dioxide and water.	Reactants are carbohydrates and oxygen
Products are glucose	Products are carbon dioxide and water

5.2.2 Describe The Process Of Gaseous Exchange In Plants, Highlighting The Roles Of Stomata In The Leaves And Lenticels In The Stems

Plants have no organs or systems for the exchange of gases with the environment. Every cell of the plant body exchanges gases with the environment by its own. The leaves and young stems have stomata in their epidermis. The gaseous exchange occurs through these stomata. The inner cells of leaves (mesophyll) and stems also have air spaces among them, which help in the exchange of gases.

Leaf cells face two situations. During the daytime when the mesophyll cells of leaves are carrying out photosynthesis and respiration side by side, the oxygen produced in photosynthesis is utilized in cellular respiration. Similarly, the carbon dioxide produced during cellular respiration is utilized in photosynthesis. However, during night when there is no photosynthesis occurring, the leaf cells get oxygen from the environment and release carbon dioxide through stomata.

In woody stems and mature roots, the entire surface is covered by bark which is impervious to gases or water. However, there are certain pores in the layer of bark. These are called the lenticels. The lenticels allow air to

pass through them. Gases diffuse in and out of the general surface of the young roots. The gases are found in the soil surrounding the roots. The aquatic plants get the oxygen dissolved in water and release carbon dioxide in the water. The lenticels are slightly more raised than the general surface of the stem.

5.3 Gaseous Exchange in Human Beings

5.3.1 Relate The Structure Of Human Respiratory System With Its Function

Part	Structure	Function
Nasal Passage	Nasal hair (cilia), mucous	Filter and maintain air temperature
Pharynx	Muscular tube	Separate food and air to their path
Larynx	A cartilaginous structure (voice box) containing vocal cords	Produce sound, prevent food/liquid from entering airway
Glottis	The opening between the vocal cords within the larynx.	Regulates the flow of air into the trachea and contributes to phonation (speech).
Trachea	A tube supported by strong, incomplete C-shaped rings of cartilage.	Cartilage rings maintain an open airway and the tube structure directs air into the bronchi. Lined with cilia and mucus to continue filtering air.
Bronchi	Trachea branches into two bronchi, have cartilage	Conduction of air deep into the lungs. The branching structure ensures air reaches all areas of the lungs.
Bronchioles	Bronchi subdivide into progressively finer, tree-like network of smaller tubes made of smooth muscle.	Ensure air reaches all areas of the lungs. Smooth muscle in bronchioles allows regulation of airflow diameter.
Alveoli	Tiny, balloon-like air sacs with extremely thin, single-celled walls, surrounded by a dense network of capillaries.	Primary site of gas exchange (diffusion of oxygen into the blood and carbon dioxide out of the blood) due to the large surface area and short diffusion distance.
Lungs	Spongy, elastic organs containing millions of alveoli, bronchi, bronchioles, and blood vessels	The primary organs of respiration, designed to house the structures necessary for ventilation and efficient gas exchange.
Pleural membranes	Double-layered membrane (visceral and parietal) with a small amount of lubricating pleural fluid in between.	The fluid acts as a lubricant to reduce friction during breathing and creates negative pressure (suction) that keeps the lungs adhered to the chest wall, allowing them to expand and contract with the thoracic cavity
Thoracic cavity	An airtight, dome-shaped chamber that encloses the lungs and heart.	provide a controlled environment where volume can be increased or decreased to create the pressure gradients required for airflow.
Ribs	Twelve pairs of curved bones that form a protective cage around the lungs. Their flexible articulations	flexible articulations with the spine allow them to move upward and outward (like a bucket handle) during inhalation to increase thoracic volume.
Sternum	Located centrally at the front of the chest, it serves as the anterior attachment point for most ribs.	During inhalation, it moves forward and upward (pump-handle motion), further expanding the anterior-posterior diameter of the thoracic cavity

External Intercostal Muscles	Located between the ribs, with fibers running diagonally downward and forward.	They contract during inhalation to lift the rib cage up and out, expanding the chest cavity.
Internal Intercostal Muscles	Located deep to the external intercostals, with fibers running perpendicular to them.	They are primarily involved in forced exhalation (e.g., during exercise or coughing). They contract to pull the rib cage downward and inward, rapidly decreasing thoracic volume to expel air.
Diaphragm	A large, dome-shaped muscle forming the floor of the thoracic cavity. It is the primary muscle of inspiration.	When it contracts, it flattens and moves downward, increasing the vertical dimension of the thoracic cavity and drawing air into the lungs.

5.3.2 Describe The Role Of Goblet Cells, Mucus And Ciliated Epithelial Cells In Protecting The Breathing System From Pathogens And Particles

Goblet Cells

Specialized, goblet-shaped cells scattered from the nasal cavity to the larger bronchioles. Their primary function is to synthesize and secrete mucins, which are gel-forming glycoproteins. They act as unicellular glands that release mucus onto the airway surface in response to irritants like smoke or pathogens.

Mucus

A sticky, viscous substance composed primarily of water (approx. 97%), mucins, and antimicrobial proteins. It forms a protective blanket over the respiratory lining. Its stickiness allows it to trap pathogens (bacteria, viruses) and particles (dust, smoke, allergens). Beyond mechanical trapping, it contains antimicrobial agents that help kill invading microbes.

Ciliated Epithelial Cells

Cells featuring hundreds of tiny, hair-like projections called cilia on their apical surface. These cells account for more than half of the epithelial cells in the conducting airways. The cilia beat in a coordinated, synchronized wave-like motion (approximately 8–20 Hz). This motion pushes the trapped mucus upward away from the lungs toward the pharynx (throat). Once reached, the mucus is either swallowed—where stomach acid destroys the pathogens—or coughed out.

5.3.3 Assess The Overall Impact Of A Malfunctioned Respiratory Organ Or Structure On The Overall Function Of Respiratory System

A malfunction in any part of the respiratory system—whether a conducting airway, gas exchange surface, or mechanical pump—disrupts the delicate balance of oxygen delivery and carbon dioxide removal, leading to systemic consequences.

Disruption of Gas Exchange

- Malfunctions in the alveoli (e.g., fluid buildup from pneumonia or wall destruction in emphysema) directly impair the diffusion of gases.
- Hypoxemia: Insufficient oxygen enters the blood, depriving vital organs like the brain and heart of energy.
- Hypercapnia: Carbon dioxide builds up, leading to respiratory acidosis, confusion, and potential loss of consciousness.

Failure of Ventilation Mechanics

- Diaphragm Paralysis: Can reduce total lung capacity by up to 75–80% in bilateral cases, often requiring permanent mechanical ventilation.

- **Pleural/Rib Damage:** A collapsed lung (pneumothorax) or broken ribs prevent the lungs from expanding fully, causing rapid, shallow breathing and extreme fatigue as the body works harder to compensate.

Loss of Protective Barriers

- **Malfunctioning goblet cells or cilia** (e.g., from chronic smoking or genetic conditions like cystic fibrosis) disable the "mucociliary escalator".
- **Infection Risk:** Without the upward sweeping motion of cilia, trapped pathogens remain in the lungs, leading to recurrent pneumonia and chronic inflammation.

5.3.4 Explain The Adaptations Of Alveoli For Efficient Gaseous Exchange

Each lung is made up of millions of alveoli. Each alveolus is the respiratory surface. It's a pouch like microscopic structure made up of only one layer of cells. It is enclosed by a dense capillary network. In each alveolus, exchange of gases takes place between air and blood.

5.3.5 Explain Gaseous Exchange In Alveoli

The gaseous exchange takes place at the level of alveoli. Oxygen brought in by air is taken up by the hemoglobin of RBCs of blood and vice versa the carbon dioxide brought by the blood is given out to the air present in alveoli. This gaseous exchange involves diffusion which becomes possible at this level because both alveolus and blood capillaries, are only one cell layered in thickness.

5.3.6 Predict The Overall Impact On Alveolar Function If A Specific Alveolar Adaptation Is Compromised

Compromised Feature	Physical Result	Impact on Function
Surface Area	Fewer sacs	Less space for gas exchange.
Wall Thickness	Thicker barrier	Slower rate of diffusion.
Moisture/Surfactant	Dry/Collapsed sacs	Gases cannot dissolve; Alveoli fail to inflate.
Blood Supply	Stagnant blood	Loss of concentration gradient; diffusion ceases.

5.3.7 Describe Mechanism Of Breathing

Inspiration or Inhalation

During inspiration, the rib muscles contract and ribs are raised. At the same time the diaphragm contracts and is lowered. These movements increase the area of the thoracic cavity, which reduces the pressure on lungs. As a result, the lungs expand and the air pressure within them also decreases. The air from outside rushes into the lungs to equalize the pressure on both sides. The breathing movements are involuntary to a large extent. However, we can control the rate of breathing but not for a long time.

Expiration or Exhalation

After the gaseous exchange in the lungs, the impure air is expelled out in exhalation. The rib muscles relax bringing the ribs back to the original position. The diaphragm muscles also relax and it gets its raised dome shape. This reduces the space in the chest cavity and increases the pressure on lungs. The lungs contract and the air is expelled out of them.

5.3.8 Analyses The Effect Of Exercise On The Rate And Depth Of Breathing

Humans breathe 16 -20 times per minute in normal circumstances i.e. at rest. The rate of breathing is controlled by the respiratory center in the brain. The respiratory center is sensitive to the concentration of carbon dioxide in the blood. When we do exercise or some hard job our muscle cells carry out cellular respiration at a greater rate. It results in the production of more carbon dioxide which is released in the blood. This greater than normal concentration of carbon dioxide stimulates the respiratory center of brain.

The respiratory center sends messages to the rib muscles and diaphragm to increase the rate of breathing so that the excess carbon dioxide present in blood can be removed out of body. During exercise or other hard physical works, the breathing rate may increase up to 30-40 times per minute.

5.3.9 Differentiate Between The Composition Of Inspired And Expired Air

Components (%)	Inspired air (%)	Expired air (%)
Oxygen	About 21	About 16
Carbon dioxide	About 0.03	About 4
Nitrogen	About 79	About 79
Water Vapor	Variable	saturated

5.3.10 Predict The Physiological Implications Of Changes In The Composition Of Inspired And Expired Air Under Different Conditions

At Rest:

- Inspired Air: High O₂ (21%), Low CO₂ (0.04%), Variable Water Vapor.
- Expired Air: Lower O₂ (~16%), Higher CO₂ (~4%), Saturated Water Vapor.

During Exercise:

- O₂ Levels: Increase significantly (above 4%) because cells are producing it as a waste product at a faster rate.
- CO₂ Levels: Decrease further (below 16%) because the blood is "stripping" more oxygen from the alveoli to meet muscle demand.
- Temperature: Expired air becomes warmer due to the heat generated by metabolic reactions.

Exposure To Polluted Environments:

- Inspired air contains Carbon Monoxide, Sulfur Dioxide, or Particulate Matter (Smoke/Dust).
- Carbon Monoxide: It has a much higher affinity for hemoglobin than O₂. It forms Carboxyhemoglobin, permanently occupying the space meant for oxygen.
- Reduced oxygen-carrying capacity of the blood, leading to headaches, dizziness, or even death (suffocation at a cellular level).
- Particulate Matter: Triggers excess mucus production and inflammation of the bronchioles (Bronchitis), reducing the amount of air that actually reaches the alveoli.

5.4 Respiratory Disorders

5.4.1 Describe Causes, Symptoms, Treatment And Prevention Of Respiratory Diseases:

Bronchitis:

The inflammation of the air passage ways is termed as Bronchitis. It is caused either by smoking or by some bacteria. It is characterized by cough, increased mucous secretion, shortness of breath and low fever.

Emphysema:

It is related to the progressive destruction to the alveoli due to long term exposure usually to the industrial pollutants. It is characterized by laborious breathing. It causes cough with phlegm production.

Pneumonia:

It is an infectious disease usually caused by special bacteria, viruses or fungi. In pneumonia, the alveoli are infected so they may be filled with fluid or pus. The breathing becomes difficult. The patient suffers from fever, cough, chill and chest pain.

Asthma:

It is an inflammatory condition of air-ways of lungs. It is characterized by shortness of breath, chest pain, fever, wheezing sound during expiration and cough. Asthma is actually an allergic response to pollens, dust, smoke, fur, feathers and number of other substances. It may obstruct the air-ways making it difficult to breath for its patient.

Lung Cancer:

Lung cancer is usually associated with smoking. Due to smoke or air pollution, abnormal cells appear in lungs which may spread to other tissues. The major signs and symptoms are cough with blood, shortness of breath, repeated lung infections, weight loss, bone ache, hoarseness, weakness, fatigue, etc.

5.4.2 Analyze The Effects Of Smoking

Lungs:*Chronic Diseases:*

1. *Ciliary Paralysis & Bronchitis:* Tar paralyzes the cilia (tiny hairs) that sweep mucus out. The mucus accumulates, bacteria trap in it, and the bronchioles become inflamed. This leads to Chronic Bronchitis (the "Smoker's Cough").
2. *Emphysema (The "Alveoli Trap"):* Long-term smoking causes the walls of the alveoli to break down and lose elasticity. Smaller alveoli merge into larger, inefficient sacs.

Impact:

Drastic reduction in surface area for gas exchange. The patient is constantly short of breath because cannot diffuse fast enough.

Carcinogenesis:

Tar contains over 50 known carcinogens that cause mutations in lung cell DNA, leading to uncontrolled cell division (Lung Cancer).

Circulatory System:

1. *Atherosclerosis:* Chemicals in smoke damage the inner lining of the arteries. This allows fats and cholesterol to deposit more easily, forming Plaque.
2. *Arteriosclerosis:* Nicotine and other toxins cause the artery walls to harden and lose elasticity, leading to Hypertension (High Blood Pressure).
3. *Thrombosis (Blood Clots):* Nicotine makes blood platelets more likely to clump together. If a clot forms in a narrowed coronary artery, it causes a Heart Attack (Myocardial Infarction). If it happens in the brain, it causes a Stroke.
4. *Reduced Oxygen Tension:* Because Carbon Monoxide occupies haemoglobin, the heart has to pump faster and harder to supply enough oxygen to the tissues, leading to premature heart fatigue.