Life Sciences, Grade 11, Gaseous Exchange

Definitions

Breathing/ventilation: Mechanical process of taking oxygen into the lungs and releasing carbon dioxide from the lungs

Cellular Respiration: The chemical process which takes place in the mitochondria. Oxygen is used to break down glucose to release energy. Carbon dioxide and water vapour are released as waste products

Gas exchange: A physical process, which takes place by means of diffusion. It involves the exchange of gases between the air and the blood in the lungs as well as the blood and tissues of the body

Inhalation: The process of breathing in air.

Exhalation: The process of breathing out air.

Diaphragm: A large, dome-shaped muscle at the base of the lungs involved in breathing.

Intercostal muscles: Muscles between the ribs that aid in breathing (external and internal).

Thoracic cavity: The chest cavity containing the lungs and heart.

Pressure gradient: The difference in pressure between two areas, causing air (or gas) to flow from high pressure to low pressure.

Alveoli: Tiny air sacs in the lungs where gaseous exchange occurs.

Capillaries: Tiny blood vessels surrounding the alveoli and tissues, facilitating gas exchange.

Squamous epithelium: A single layer of flat cells lining the alveoli.

Endothelium: A single layer of cells lining the capillaries.

Haemoglobin: An iron-containing protein in red blood cells that transports oxygen.

Concepts

The need for gaseous exchange:

- Photosynthesis + CR requires GE
- Humans respire aerobically in order to obtain the energy required for living activities
    - We obtain O2 and remove CO2 through GE
    - If CO2 accumulates in cells, it is toxic
    - Both O2 and CO2 are soluble in plasma (liquid components of blood)

Requirements for an efficient gaseous exchange surface	**How the human gaseous exchange surface fulfils this requirement**
It must have a **large surface area to volume ratio -** this maximises the amount of O2 and CO2 that is able to diffuse across it	It is made up of a number of air sacs (alveoli) which offer a large surface area
must be **thin and permeable** - so that diffusion can occur more rapidly and efficiently	The alveoli are lined with a single layer of thin walled squamous epithelial cells (flattened)
It must be **moist** - O2 and CO2 diffuse when dissolved in H2O	Lining of alveoli is kept moist by a thin film of moisture created by tissue fluid
It must be **well protected** - need to be protected from mechanical injury and drying out	Thoracic cage protects lungs from mechanical damage and the double pleural membrane protects it from drying out
It must be well **ventilated** - this ensures that O2 rich air is continually brought into contact with the gaseous exchange surface	Diaphragm and intercostal muscles, together with the rib cage, make up an efficient breathing system
Vascular - it must have an efficient method of transporting gases to and from the gaseous exchange surface	Alveoli have a rich capillary supply (therefore an efficient transport system)

Structures

- **Nostrils:**
    - lead into the nasal cavity and are separated by a vertical septum
    - Air enters through the nostrils
    - They are also lined with tiny hairs which remove dust from incoming air

- **Nasal cavity:**
    - There are three spongy turbinate bones which divide the nasal cavity into three passages (increasing surface area)
    - nasal passages are lined with ciliates columnar epithelial tissue - goblet cells that secrete mucus •
    - The turbinate bones slow down the air that is inhaled into the nasal cavity
        - warmed by the blood
        - moistened and filtered of dust and pathogens by the mucus
        - dust and pathogens are trapped in the mucus and swept out by the cilia

- **Pharynx:**
    - Connects the nasal cavity to larynx
    - Leads into trachea via the valve like glottis between the vocal cords

- **Larynx:**
    - Held open by complex cartilage that forms the Adam's apple
    - Larynx contains vocal cords
    - Air phases over the cords causing them to vibrate and sound is produced

- **Trachea:**
    - Strengthened and held open by C-shaped cartilage rings that don't meet at the back
    - The epiglottis is a flap of cartilage that seals off the trachea when you swallow food
    - lined with ciliated columnar epithelium, which continues to filter the air as it passes down the trachea to the bronchi

- **Bronchi and Bronchioles:**
    - Trachea divides into two bronchi which enter each of the lungs. Held open by cartilage rings

    - Each bronchus branches into a number of smaller air passages called bronchioles
    - lined with ciliated columnar epithelium and facilitate passage of air into the bronchioles
    - Facilitate the passage of air into the alveoli

- **Alveoli:**
    - Air sacs that are lined with simple, flattened squamous epithelial tissue
    - Each alveolus is surrounded by a network of capillaries (lined with a single layer of endothelium)
    - sites for gaseous exchange
    - Pulmonary artery returns CO2 to the lungs from heart
    - Pulmonary vein carries O2 away from lungs towards the heart

- **Lungs:**
    - Cone shaped, elastic and spongy with its base touching the diaphragm
    - Right lung has three lobes while the left lung only has two (to make room for the heart)
    - Lined by a double pleural membrane (separated by pleural fluid)
    - Pleural membrane acts as a lubricant and helps prevent friction during inhalation and exhalation

- **Ribs:**
    - 12 pairs of ribs
    - protect lungs from mechanical injury
- **Intercostal muscles:**
    - found between the ribs
    - Contract and relax during inhalation and exhalation, therefore altering the volume of air in the chest

- **Diaphragm:**
    - a sheet of muscle below the lungs

- contracts (flattens) and relaxes during inhalation and exhalation, therefore altering the volume of air in the chest

Mechanism of Breathing

- **Inhalation (Breathing In)**:
    1. Diaphragm muscle contracts, flattens, and moves downwards.
    2. External intercostal muscles between the ribs contract; internal intercostal muscles relax.
    3. The ribcage lifts upwards and pushes outwards.
    4. This increases the volume of the thoracic cavity and decreases air pressure inside the lungs.
    5. Atmospheric pressure becomes greater than the pressure in the lungs.
    6. Air flows into the lungs down the pressure gradient.
- **Exhalation (Breathing Out)**:
    1. Diaphragm muscle relaxes and moves upwards.
    2. External intercostal muscles relax; internal intercostal muscles contract.
    3. The ribcage moves downwards and pushes inwards.
    4. This decreases the volume of the thoracic cavity and increases air pressure in the lungs.
    5. Atmospheric pressure becomes lower than the pressure in the lungs.
    6. Air flows out of the lungs down the pressure gradient.
- **How is O2 transported?**
    - Mainly by the red blood cells in the form of oxyhaemoglobin
    - Small proportion dissolved in the blood plasma
- **How is CO2 transported?**
    - Mainly as bicarbonate ions

    - By the red blood cells in the form of carbaminohaemoglobin
    - Dissolved in the blood plasma
- **Composition of inhaled air**
    - In order for oxygen and carbon dioxide to move into or out of an organism, a diffusion gradient must exist
        - Exhaled air always contains more CO_2 and less O_2 than the atmosphere
        - The atmosphere = 21% O_2 and 0,04% CO_2
        - Exhaled air = 16% O_2 and 4% CO_2

Gaseous Exchange at the Lungs (Alveoli)

- During inhalation, the **alveoli** have a high concentration of O_2 and a low concentration of CO_2.
- The blood **capillaries** surrounding the alveoli have a low concentration of O_2 and a high concentration of CO_2.
- O_2 dissolves in the moisture on the wall of the alveolus and diffuses into the capillary.
- O_2 passes through the **squamous epithelium** lining the alveolus and a single layer of **endothelium** lining the capillary.
- O_2 is picked up by **haemoglobin** and transported by red blood cells (RBC).
- CO_2 from the blood capillary diffuses into the alveolus to be exhaled.

Gaseous Exchange at the Tissues

- The blood from the lungs that has a high concentration of O_2 travels through the arteries to the tissues where it will be used for Cellular Respiration
- The cells have a low concentration of O_2 and a high concentration of CO_2 (product of CR)
- The oxyhaemoglobin splits into O_2 and haemoglobin

- The O2 diffuses through the capillary walls into the tissue fluid and then into the cells
- CO2 diffuses from the cells into the tissue fluid and into the blood capillaries

Homeostatic Control of Breathing

- **Homeostasis:** Process of maintaining a constant, internal environment within narrow limits despite changes that take place internally and externally
- respiratory system of the brain = medulla oblongata + pons varoli
    1. controls heart rate and breathing rate
- Rate of breathing is controlled by the amount of CO2 in the blood
    1. Carbonic acid can form, so it lowers the pH
- Enzymes are sensitive to pH so breathing rate increases to get rid of CO2
- If CO2 concentration increases, breathing rate will increase so you increase the intake of O2 and expel more CO2
- **What happens when Carbon dioxide levels in the blood increase above normal levels?**
    1. Receptor cells in the carotid artery are stimulated by the drop in pH
    2. Cells send impulses to the medulla oblongata in the brain
    3. Medulla oblongata stimulates the breathing muscles and heart
    4. Rate and depth of breathing increases and the heart rate increases
    5. More CO2 is taken to and exhaled from the lungs
    6. The CO2 levels in the blood and pH return to normal

Effects of Altitude on Gas Exchange

- At high altitudes, air pressure is lower and hence there is a lower partial pressure of oxygen (less O2 because less air overall) This makes it more difficult for haemoglobin to take up and transport oxygen
- Respiring tissue will receive less oxygen – leading to symptoms such as fatigue, headaches and rapid pulse
- Over time, the body may begin to acclimatise to the lower oxygen levels at high altitudes:
    - Red blood cell production will increase in order to maximise oxygen uptake and transport
    - Red blood cells will have a higher haemoglobin count with a higher affinity for oxygen

- Improve rate of gas exchange
- Muscles will produce more myoglobin and have increased blood supply to improve overall oxygen supply
- Kidneys will **begin** to secrete alkaline urine (removal of excess bicarbonates improves buffering of blood pH)
- People living permanently at high altitudes will have a greater lung surface area and larger chest sizes
- Professional athletes will often incorporate high altitude training in order to adopt these benefits prior to competition
- Athletes may commonly either train at high altitudes (live low train high) or recover at high altitudes (live high – train low

Diseases:

	Causes	**Symptoms**	**Treatments**
Asthma:	● environmental/ genetic ● Exposure to air pollutants ● Airborne allergens ● Respiratory infections ● Physical activity ● Cold air ● Air pollutants/ irritant ● Certain medications ● Strong emotion/ stress ● Sulfites/ preservatives in food ● Gastreosophageao reflux disease	● wheezing ● shortness of breath ● chest tightness and coughing ● trouble sleeping ● coughing attacks	● aimed to prevent inflammation which causes mucus and bronchi spasm ● Medication that reduces inflammation and dilated airways ● follow asthma action plan ● Get vaxxed against influenza + pneumonia ● Identify + avoid triggers
Hay Fever:	Allergies to different allergens: spores of moulds + pollens in the air ● tree pollen ● Grass pollen	● Itchy nose and eyes ● Runny nose/nasal congestion	● Antihistamines (tablet form or nasal spray) ● nasal spray ● Cough syrup

	• Ragweed pollen • dust mites + cockroach droppings • dander from pets • Spores	• watery, itchy red eyes • Sneezing • Coughing • Fatigue • mucus in throat • Allergic shiners	• Eye drops
Bronchitis:	Acute: viral infection (/chemicals) Chronic: associated with smoking	• Wheezing • persistent Coughing • Shortness of breath • Sputum produced when coughing • Sore throat • Blocked nose + sinus	• Use inhalers to open airways, • drink fluid to prevent sticky secretions + bed rest • Antibiotics might be needed when chronic bronchitis develops a bacterial infection • Smokers stop smoking
Emphysema:	• caused by smoking, particularly in people who have a genetic predisposition to the disease • Air pollutants • Respiratory infections	• Constant shortness of breath • Chest tightness • Coughing + wheezing • Increased mucus production • Ongoing fatigue • Find it difficult to lie flat • Reduces lung capacity - fewer alveoli	• Bronchodilator medication • Anti-inflammatory medication • Oxygen therapy • Lung volume reduction surgery • Not smoking
Lung Cancer:	• Cigarette smoking (carcinogens)	• Hoarseness	• surgery early • Chemotherapy

	• develops when abnormal + uncontrollable growth from cell division develops into mass/ tumour • Adenocarcinoma (only one non-smokers can get)	• chest pain, especially during deep breaths • wheezing or shortness of breath • coughing up bloody sputum • a cough that won't go away • tiredness and fatigue	• Radiotherapy