CELL PHYSIOLOGY

KCSE Biology Notes Form 1, Topic 4

TOPICS

1. Meaning of cell physiology
2. Structure and properties of cell membrane (Theories of membrane structure not required)
3. Physiological processes - diffusion, osmosis and active transport
4. Factors affecting diffusion, osmosis and active transport
5. Role of diffusion, osmosis and active transport in living organisms
6. Water relations in plant and animal cells: turgor, plasmolysis, wilting and haemolysis
7. Practical Activities
8. Diffusion as demonstrated with Potassium permanganate or potassium iodide/flower dyes/coloured plant extracts/smoke
9. Experiments with visking tubing and living tissues: fresh arrow roots/cassava/sweet potatoes/leaf petioles/Irish potatoes/carrots
10. Plasmolysis can be demonstrated by using any of the following: spirogyra, epidermal cells of onion or raw egg that has been put in dilute hydrochloric acid overnight

Lesson Objectives

By the end of the topic, the learner should be able to:

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a) Define cell physiology

b) Correlate the membrane structure with cell physiology in relation to permeability

c) Differentiate between diffusion, osmosis and active transport

d) State and describe factors affecting diffusion, osmosis and active transport

e) Carry out experiments on diffusion and osmosis

f) Explain the roles of diffusion, osmosis and active transport in living organisms

g) Explain turgor and plasmolysis in terms of osmotic pressure.

Meaning of cell physiology

The term physiology refers to the functions that occur in living organisms.

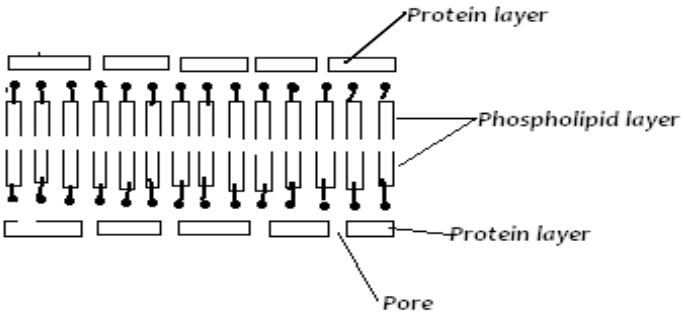
Cell physiology refers to the process through which substances move across the cell membrane.

Several physiological processes take place inside the cell e.g. respiration.

Oxygen and glucose required enter the cell while carbon (IV) oxide and water produced leave the cell through the cell membrane.

Structure and properties of cell membrane

- ✓ The cell membrane is the protective barrier that shelter cellular contents.
- ✓ Movement of all substances into and out of the cells takes place across the cell membrane.
- ✓ It is made up of protein and lipid molecules.
- ✓ Lipid molecules have phosphate group attached to it on one end.
- ✓ They are then referred to phospholipids.
- ✓ The phospholipids are arranged to form a double layer.
- ✓ The ends with phosphate group face outwards.
- ✓ The proteins are scattered throughout the lipid double layer.
- ✓ Some of these proteins act as carrier molecules that channel some material in and outside the cells.
- ✓ The cell membrane allows certain molecules to pass through freely while others move through with difficulty and still others do not pass through at all.
- ✓ This is selective permeability and the cell membrane is described as semi-permeable.



Cell membrane Structure

Properties of cell membrane

Permeability

- ✓ The cell membrane is semi-permeable.
- ✓ It allows small molecules that are soluble in lipid to pass through with more ease than water soluble molecules.
- ✓ This is due to the presence of the phospholipids double layer.

Polarity

- ✓ The cell membrane has electrical charges across its surface.it has positive charged ions on the outside and negatively charged ions on the inside. This property contributes to electrical impulses sent along nerve cells.
- ✓ Sensitivity to changes in temperature and pH
- ✓ Very high temperatures destroy the semi-permeability nature of the cell membrane because the proteins are denatured by extreme pH values have the same effect on the membrane permeability.
- ✓ Physiological processes
- ✓ Some of the physiological processes include diffusion, osmosis and active transport.

Diffusion

- ✓ Diffusion is the movement of molecules or ions from a region of high concentration to a region of low concentration aided by a concentration gradient.

- ✓ Diffusion continues to occur as long as there is a difference in concentration between two regions (concentration gradient).
- ✓ Stops when an equilibrium is reached i.e., when the concentration of molecules is the same in both regions.
- ✓ Diffusion is a process that occurs inside living organisms as well as the external environment..
- ✓ Does not require energy.

Factors Affecting Diffusion

Concentration Gradient

An increase in the concentration of molecules at one region results in a steeper concentration gradient which in turn increases the rate of diffusion.

Temperature

High temperature increases kinetic energy of molecules. They move faster hence resulting in an increase in rate of diffusion, and vice versa.

Size of Molecules or Ions

The smaller the size of molecules or ions, the faster their movement hence higher rate of diffusion.

Density

The denser the molecules or ions diffusing, the slower the rate of diffusion, and vice versa.

Medium

The medium through which diffusion occurs also affects diffusion of molecules or ions. For example, diffusion of molecules through gas and liquid media is faster than through a solid medium.

Distance

This refers to the thickness or thinness of surface across which diffusion occurs. Rate of diffusion is faster when the distance is small i.e., thin surface.

Surface Area to Volume Ratio

The larger the surface area to volume ratio, the faster the rate of diffusion.

For example, in small organisms such as Amoeba the surface area to volume ratio, is greater hence faster diffusion than in larger organisms.

Role of Diffusion in Living Organisms

Some processes that depend on diffusion include the following:

- ✓ **Gaseous exchange:** Movement of gases through respiratory surfaces is by diffusion.
- ✓ **Absorption of materials into cells**: cells obtain raw materials and nutrients from the surrounding tissue fluid and blood through diffusion, e.g., glucose needed for respiration diffuses from blood and tissue fluid into cells.
- ✓ **Excretion:** Removal of metabolic waste products like carbon (IV) oxide, and ammonia out of cells is by diffusion.
- ✓ **Absorption** of the end-products of digestion from the intestines is by diffusion.

Osmosis

- ✓ Osmosis is the movement of water molecules from a region of high water concentration to a region of low water concentration through a semi-permeable membrane.
- ✓ Osmosis is a special type of diffusion that involves the movement of water molecules only and not solute molecules.
- ✓ Osmosis takes place in cells across the cell membrane as well as across non-living membranes e.g. cellophane or visking tubing which are also semi-permeable,
- ✓ It is purely a physical process.

Factors Affecting Osmosis

Size of solute molecules-

Osmosis' occurs only when solute molecules are too large to pass through a semi-permeable membrane.

Concentration Gradient.

Osmosis occurs when two solutions of unequal solute concentration are separated by a semi-permeable membrane.

Temperature.

High temperatures increase movement of water molecules hence influence osmosis. However, too high temperatures denature proteins in cell membrane and osmosis stops.

Pressure

Increase in pressure affects movement of water molecules.

As pressure increases inside a plant cell, osmosis decreases.

Roles of Osmosis in Living Organisms

The following processes depend on osmosis in living organisms:

- ✓ Movement of water into cells from the surrounding tissue fluid and also from cell to cell.
- ✓ Absorption of water from the soil and into the roots of plants.
- ✓ Support in plants especially herbaceous ones, is provided by turgor pressure, which results from intake of water by osmosis.
- ✓ Absorption of water from the alimentary canal in mammals.
- ✓ Re-absorption of water in the kidney tubules.
- ✓ Opening and closing stomata.

Water Relations in Plant and Animal Cells

- ✓ The medium (solution) surrounding cells or organisms is described by the terms ***hypotonic, hypertonic and isotonic.***
- ✓ A solution whose solute concentration is more than that of the cell sap is said to be ***hypertonic***. A cell placed in such a solution loses water to the surroundings by osmosis.

- ✓ A solution whose solute concentration is less than that of the cell sap is said to be ***hypotonic***. A cell placed in such a solution gains water from the surroundings by osmosis.
- ✓ A solution which has the same solute concentration as the cell sap is said to be ***isotonic***. When a cell is placed in such a solution there will be no net movement of water either into or out of the cell.

Osmotic Pressure

- ✓ The term osmotic pressure describes the tendency of the solution with a high solute concentration to draw water into itself when it is separated from distilled water or dilute solution by a semi-permeable membrane.
- ✓ Osmotic pressure is measured by an osmometer.
- ✓ When plant cells are placed in distilled water or in a hypotonic solution, the osmotic pressure in the cells is higher than the osmotic pressure of the medium.
- ✓ This causes the water to enter the cells by osmosis.
- ✓ The water collects in the vacuole which increases in size.
- ✓ As a result the cytoplasm is pushed outwards and it in turn presses the cell membrane next to the cell wall.
- ✓ This builds up water pressure (hydrostatic pressure) inside the cell.
- ✓ When the cell is stretched to the maximum, the cell wall prevents further entry of water into the cell.
- ✓ Then the cell is said to be fully turgid.
- ✓ The hydrostatic pressure developed is known as turgor pressure.

Plasmolysis

- ✓ When a plant cell is placed in a hypertonic medium, it loses water by osmosis.
- ✓ The osmotic pressure of the cell is lower than that of the medium.

- ✓ The vacuole decreases in size and the cytoplasm shrinks as a result of which the cell membrane loses contact with the cell wall.
- ✓ The cell becomes flaccid. The whole process is described as plasmolysis.
- ✓ Incipient plasmolysis is when a cell membrane just begins to lose contact with the cell wall.
- ✓ Plasmolysis can be reversed by placing the cell in distilled water or hypotonic solution.
- ✓ However, full plasmolysis may not be reversed if cell stays in that state for long.

Wilting

- ✓ The term wilting describes the drooping of leaves and stems of herbaceous plants after considerable amounts of water have been lost through transpiration.
- ✓ It is observed in hot dry afternoons or in dry weather.
- ✓ This is when the amount of water lost through transpiration exceeds the amount absorbed through the roots.
- ✓ Individual cells lose turgor and become plasmolysed and the leaves and stems droop.
- ✓ The condition is corrected at night when absorption of water by the roots continue while transpiration is absent.
- ✓ Eventually, wilting plants may die if the soil water is not increased through rainfall or watering.

Water Relations in Plants and Animals

Haemolysis

- ✓ Haemolysis is the bursting of cell membrane of red blood cells releasing their haemoglobin.
- ✓ It occurs when red blood cells are placed in distilled water or hypotonic solution.
- ✓ This is because the cell membrane does not resist further entry of water by osmosis after maximum water intake.

Crenation

- ✓ Takes place when red blood cells are placed in hypertonic solution.
- ✓ They lose water by osmosis, shrink and their shape gets distorted.

- ✓ Animal cells have mechanisms that regulate their salt water balance (osmoregulation) to prevent above processes that lead to death of cells.
- ✓ An Amoeba placed in distilled water, i.e. hypotonic solution, removes excess water using a contractile vacuole.
- ✓ The rate of formation of contractile vacuoles increases.

Active Transport

- ✓ Active transport is the movement of solutes such as .glucose, amino acids and mineral ions;
- ✓ From an area of their low concentration to an area of high concentration.
- ✓ It is movement against a concentration gradient and therefore energy is required.
- ✓ As such it only takes place in living organisms.
- ✓ The energy needed comes from respiration.
- ✓ Certain proteins in the cell surface membrane responsible for this movement are referred to as carrier proteins or channel proteins.
- ✓ The shape of each type of carrier protein is specific to the type of substances conveyed through it.
- ✓ It has been shown that the substance fits into a particular slot on the protein molecule,
- ✓ As the protein changes from one form of shape to another the substance is moved across and energy is expended.

Factors Affecting Active Transport

Availability of oxygen

- ✓ Energy needed for active transport is provided through respiration.
- ✓ An increase in the amount of oxygen results in a higher rate of respiration.
- ✓ If a cell is deprived of oxygen active transport stops.

Temperature

- ✓ Optimum temperature is required for respiration, hence for active transport.
- ✓ Very high temperatures denature respiratory enzymes.

- ✓ Very low temperatures inactivate enzymes too and active transport stops.

Availability of carbohydrates

- ✓ Carbohydrates are the main substrates for respiration.
- ✓ Increase in amount of carbohydrate results in more energy production during respiration and hence more active transport.
- ✓ Lack of carbohydrates causes active transport to stop.

Metabolic poisons

- ✓ Metabolic poisons e.g. cyanide inhibit respiration and stops active transport due to lack of energy.

Role of Active Transport in Living Organisms

Processes requiring active transport:

- ✓ Absorption of mineral salts from the soil into plant roots.
- ✓ Absorption of end products of digestion e.g. glucose and amino acids from the digestive tract into blood stream.
- ✓ Excretion of metabolic products e.g. Urea from the cells.
- ✓ Re-absorption of useful substances and mineral salts back into blood capillaries from the kidney tubules.
- ✓ Sodium-pump mechanism in nerve cells.
- ✓ Re-absorption of useful materials from tissue fluid into the blood stream.

Practical Activities

1. *Experiment to Demonstrate Diffusion*

- ✓ Various coloured substances such as: dyes, plant extracts and chemicals like potassium permanganate are used.
- ✓ Potassium manganate (VII) crystals are introduced to the bottom of a beaker filled with water using a glass tubing or drinking straw which is then removed.
- ✓ Observations are made and the disappearance of the crystals and subsequent uniform colouring of water noted.

2. *Experiment to Demonstrate Osmosis Using a Visking Tubing*

- ✓ A strip of visking tubing 8-10 cm is cut and tied at one end using strong thread.
- ✓ About 2 ml of 25% sucrose solution is put inside and the other end tied with thread.
- ✓ The tubing is washed under running water and then blotted to dry.
- ✓ It is immersed in a beaker containing distilled water and left for at least one hour or overnight.
- ✓ It will then be observed that the visking tubing has greatly increased in size and has become firm.
- ✓ A control experiment can be set up using distilled water inside the visking tubing in place of sucrose solution.

3. *Experiment to Show Osmosis using Living Tissue*

- ✓ Irish potato tubers are peeled and scooped out to make hollow space at the centre.
- ✓ Sucrose solution is placed inside the hollow, and the potato tuber placed in a beaker or petri-dish with distilled water. A control is set using a boiled potato.
- ✓ Another one using distilled water inside hollow in place of sugar solution.
- ✓ The experiment is left for 3 hours to 24 hours.

4. Experiment to Demonstrate Turgor and Plasmolysis in Onion Epidermal Cells

- ✓ Two strips of onion epidermis are obtained.
- ✓ One is placed on a slide with distilled water while the other is placed on a slide with 25% sucrose solution and a coverslip placed on top of each.
- ✓ The mounted epidermis is observed under low power microscope and then left for 30 minutes.
- ✓ After 30 minutes, observations are made again.
- ✓ The cells in distilled water have greatly enlarged. Cells in 25% sucrose have shrunk.