

QUIZ – QUESTIONS & ANSWERS – UNIT 2 – CELLULAR STRUCTURE & FUNCTION

1. Explain the roles of the smooth and rough endoplasmic reticulum (ER) in the cell. How do they differ in structure and function?
2. How do lysosomes and peroxisomes contribute to cellular homeostasis? Compare their functions and contents.
3. Describe the process of protein synthesis and transport through the endomembrane system.
4. Explain how the structure of mitochondria supports their function in cellular respiration.
5. Compare and contrast prokaryotic and eukaryotic cells in terms of their structure and organelles.
6. How do chloroplasts contribute to the energy needs of a plant cell? Discuss their structure and function.
7. What is the role of the cytoskeleton in maintaining cell shape and facilitating cell movement?
8. Describe the process of osmosis and how it affects cells in different types of solutions (hypertonic, hypotonic, isotonic).

FREE RESPONSE QUESTIONS (FRQ's)

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SHORT ANSWERS

1. Explain the roles of the smooth and rough endoplasmic reticulum (ER) in the cell. How do they differ in structure and function?

The rough endoplasmic reticulum (RER) is characterized by the presence of ribosomes on its surface, giving it a "rough" appearance under a microscope. These ribosomes are sites of protein synthesis, and proteins synthesized on the RER are often destined for secretion or for use in the cell membrane. The RER also plays a role in the folding and modification of these proteins, such as adding carbohydrate groups to form glycoproteins.

In contrast, the smooth endoplasmic reticulum (SER) lacks ribosomes and is involved in lipid synthesis, detoxification of drugs and poisons, and calcium storage, particularly in muscle cells. The structural difference between the RER and SER reflects their distinct functions; the RER is specialized for protein synthesis and processing, while the SER is involved in lipid metabolism and the detoxification of harmful substances.

2. How do lysosomes and peroxisomes contribute to cellular homeostasis? Compare their functions and contents.

Lysosomes are membrane-bound organelles containing hydrolytic enzymes that break down macromolecules such as proteins, lipids, and nucleic acids. They play a key role in cellular digestion, breaking down cellular waste and damaged organelles in a process called autophagy. This helps maintain cellular homeostasis by preventing the accumulation of waste and damaged components, which could otherwise interfere with cellular function.

Peroxisomes, on the other hand, are involved in the breakdown of fatty acids and the detoxification of harmful substances like hydrogen peroxide (H_2O_2), a byproduct of cellular metabolism. Unlike lysosomes, peroxisomes contain oxidative enzymes, such as catalase, which help neutralize toxic byproducts. Although both organelles contribute to cellular cleanup, lysosomes focus on macromolecule digestion, while peroxisomes specialize in oxidative detoxification.

3. Describe the process of protein synthesis and transport through the endomembrane system.

Protein synthesis begins in the ribosomes, which may be free-floating in the cytoplasm or attached to the rough endoplasmic reticulum (RER). Proteins destined for secretion or for use in membranes are synthesized in ribosomes on the RER. As the proteins are synthesized, they are inserted into the lumen of the RER, where they undergo folding and post-translational modifications.

Once processed, these proteins are packaged into vesicles and transported to the Golgi apparatus. In the Golgi, proteins undergo further modifications, such as glycosylation, and are sorted for their final destinations. After leaving the Golgi, the proteins are transported in vesicles to the plasma membrane, lysosomes, or secreted outside the cell through exocytosis, completing the process of protein transport in the endomembrane system.

4. Explain how the structure of mitochondria supports their function in cellular respiration.

Mitochondria are often referred to as the "powerhouses" of the cell due to their role in ATP production through cellular respiration. Their double-membrane structure is essential for this function. The outer membrane acts as a protective barrier, while the inner membrane is highly folded into structures called cristae. These cristae increase the surface area for the electron transport chain, a crucial component of ATP synthesis during oxidative phosphorylation.

The matrix, the space within the inner membrane, contains enzymes that are involved in the citric acid cycle (Krebs cycle). The proximity of the citric acid cycle enzymes to the electron transport chain enhances the efficiency of ATP production. Together, the cristae and matrix structures allow mitochondria to maximize ATP generation through the various stages of cellular respiration.

5. Compare and contrast prokaryotic and eukaryotic cells in terms of their structure and organelles.

Prokaryotic cells, such as bacteria, lack membrane-bound organelles, including a nucleus. Their genetic material is found in a region called the nucleoid, which is not enclosed by a membrane. Prokaryotic cells also have ribosomes, a plasma membrane, and often a cell wall, but they do not have complex organelles like mitochondria or chloroplasts.

Eukaryotic cells, in contrast, have a well-defined nucleus that houses their DNA. They also contain a variety of membrane-bound organelles, including the endoplasmic reticulum, Golgi apparatus, mitochondria, and in plant cells, chloroplasts. These specialized organelles enable compartmentalization of different cellular processes, allowing for greater efficiency and complexity in cellular functions.

6. How do chloroplasts contribute to the energy needs of a plant cell? Discuss their structure and function.

Chloroplasts are the site of photosynthesis in plant cells, where light energy is converted into chemical energy stored in the form of glucose. They contain a double membrane, with an internal system of membrane-bound sacs called thylakoids. These thylakoids are stacked into structures known as grana, and they contain chlorophyll, the pigment that captures light energy.

The light reactions of photosynthesis occur in the thylakoid membranes, where the energy from sunlight is used to produce ATP and NADPH. The Calvin cycle, which synthesizes glucose, takes place in the stroma, the fluid-filled space surrounding the thylakoids. Chloroplasts thus play a crucial role in meeting the energy needs of a plant by converting solar energy into a usable chemical form.

7. What is the role of the cytoskeleton in maintaining cell shape and facilitating cell movement?

The cytoskeleton is a network of protein filaments that provides structural support to the cell, helping maintain its shape and enabling movement. It is composed of three main types of filaments: microfilaments (actin filaments), intermediate filaments, and microtubules. Microfilaments are involved in cell movement and muscle contraction, as well as providing structural support for the cell membrane.

Microtubules, on the other hand, form a scaffold for the cell and play key roles in intracellular transport, cell division (mitosis), and the formation of cilia and flagella, which enable cell movement. Intermediate filaments provide mechanical strength, helping the cell resist tension. Together, these components of the cytoskeleton ensure that the cell maintains its shape, organizes its internal structure, and can move when necessary.

8. Describe the process of osmosis and how it affects cells in different types of solutions (hypertonic, hypotonic, isotonic).

Osmosis is the diffusion of water across a selectively permeable membrane from an area of lower solute concentration to an area of higher solute concentration. This process is vital for maintaining the balance of water in cells. When a cell is placed in a hypertonic solution (higher solute concentration outside the cell), water moves out of the cell, causing it to shrink or undergo plasmolysis in plant cells.

In a hypotonic solution (lower solute concentration outside the cell), water enters the cell, causing it to swell and potentially burst in animal cells (lysis). However, plant cells are protected from bursting by their rigid cell wall. In an isotonic solution, the solute concentration is equal inside and outside the cell, resulting in no net water movement, and the cell remains in equilibrium.

FRQ's

9) Membrane Structure and Function

The structure of the cell membrane is essential for its function. Explain how the phospholipid bilayer and membrane proteins contribute to the overall function of the membrane. Additionally, describe two specific types of membrane transport and provide examples of substances that utilize each type.

The phospholipid bilayer forms the basic framework of the cell membrane, with hydrophilic heads facing outward and hydrophobic tails facing inward. This arrangement creates a semi-permeable barrier, allowing the membrane to regulate the entry and exit of molecules. Membrane proteins, embedded within the bilayer, play crucial roles in cell communication, transport, and maintaining homeostasis. Integral proteins, for example, span the membrane and are involved in transport, while peripheral proteins may assist in cell signaling.

There are two primary types of membrane transport: passive and active. Passive transport, such as diffusion, allows molecules to move across the membrane without the use of energy, down their concentration gradient. For instance, oxygen and carbon dioxide diffuse easily across the membrane. Facilitated diffusion, a subtype of passive transport, involves transport proteins that help larger or polar molecules like glucose cross the membrane.

Active transport, on the other hand, requires energy in the form of ATP to move molecules against their concentration gradient. The sodium-potassium pump is an example of active transport, where sodium ions are pumped out of the cell while potassium ions are pumped in. This process is vital for maintaining cellular electrochemical gradients and is key to nerve function.

Both types of transport are essential for maintaining a stable internal environment, ensuring that essential nutrients enter the cell while waste products and harmful substances are expelled.

10) Compartmentalization and Eukaryotic Cells

Describe how compartmentalization enhances the function of eukaryotic cells. Focus on the role of organelles such as the nucleus, endoplasmic reticulum, and mitochondria, and how their structure is related to their specific functions.

Compartmentalization allows eukaryotic cells to isolate different biochemical processes in specific organelles, enhancing the efficiency and regulation of cellular activities. The nucleus, for example, is surrounded by a double membrane called the nuclear envelope. This structure keeps the DNA protected from metabolic activities occurring in the cytoplasm, while nuclear pores regulate the passage of molecules like mRNA. The separation of transcription and translation processes between the nucleus and the cytoplasm is crucial for gene regulation.

The endoplasmic reticulum (ER) exists in two forms: rough and smooth. The rough ER, studded with ribosomes, is responsible for protein synthesis and folding, particularly for proteins that will be secreted or integrated into membranes. In contrast, the smooth ER synthesizes lipids and detoxifies harmful substances. The structural differentiation between rough and smooth ER allows each to specialize in its respective functions, supporting the overall cellular metabolism.

Mitochondria, often referred to as the "powerhouses" of the cell, are the sites of aerobic respiration. Their double membrane structure, with a highly folded inner membrane (cristae), increases surface area for the electron transport chain, where ATP is generated. Compartmentalization within mitochondria allows for a controlled environment where the necessary enzymes and substrates can efficiently drive the production of energy.

Thus, compartmentalization in eukaryotic cells enables specialization, leading to increased efficiency in cellular processes and allowing complex organisms to maintain homeostasis and respond to environmental changes.

11) Cell Communication and Signal Transduction Pathways

Explain the general process of a signal transduction pathway in a cell. Use the example of the insulin receptor to illustrate how cell signaling regulates glucose uptake. Include how receptor activation leads to a cascade of events within the cell.

A signal transduction pathway involves the transmission of a signal from a receptor on the cell surface to a specific cellular response. This process typically occurs in three stages: reception, transduction, and response. During reception, a signaling molecule (ligand) binds to a receptor protein on the cell membrane, causing a conformational change in the receptor. This change activates the receptor, triggering the transduction phase, which often involves a cascade of molecular events that amplify the signal. Finally, the response phase results in a specific cellular change, such as gene expression or enzyme activity.

The insulin receptor is a classic example of signal transduction. Insulin, a hormone secreted by the pancreas, binds to its receptor on the surface of muscle or liver cells. This binding activates the receptor's tyrosine kinase activity, initiating a cascade of phosphorylation events within the cell. These events activate various signaling molecules, ultimately leading to the translocation of glucose transporter proteins (GLUT4) to the cell membrane.

Once GLUT4 is inserted into the membrane, glucose can enter the cell via facilitated diffusion. This process is critical for maintaining blood glucose levels, as insulin signaling enhances glucose uptake by cells, reducing blood sugar levels after meals. Dysfunction in this pathway can lead to conditions like type 2 diabetes, where cells become resistant to insulin, impairing glucose regulation.

Signal transduction pathways are crucial for cells to respond to external signals and maintain homeostasis, with the insulin receptor playing a vital role in energy balance and metabolism.

12) Prokaryotic vs. Eukaryotic Cells

Compare and contrast prokaryotic and eukaryotic cells in terms of their structure and function. Highlight the advantages of eukaryotic cellular complexity, and discuss how these differences influence the types of organisms that can be supported by each cell type.

Prokaryotic and eukaryotic cells differ significantly in both structure and complexity. Prokaryotic cells, found in organisms like bacteria and archaea, lack membrane-bound organelles and a defined nucleus. Their genetic material is located in a region called the nucleoid, and they have simpler structures, such as a single circular chromosome and a few ribosomes for protein synthesis. They often have a rigid cell wall and sometimes flagella for motility.

In contrast, eukaryotic cells, found in plants, animals, fungi, and protists, possess a nucleus that encloses their DNA and various membrane-bound organelles, such as mitochondria, the endoplasmic reticulum, and the Golgi apparatus. This compartmentalization allows for specialized functions to occur within specific regions of the cell, enhancing efficiency and regulation. For example, the mitochondria generate ATP, while the lysosomes break down cellular waste.

The complexity of eukaryotic cells allows them to support multicellular organisms with highly specialized tissues and organs. For example, in animals, different cell types like neurons, muscle cells, and blood cells perform distinct functions, supporting complex life processes such as movement, sensation, and internal regulation. Eukaryotic cells can also undergo processes like meiosis, enabling sexual reproduction and greater genetic diversity.

Prokaryotes, although simpler, have advantages such as faster replication and the ability to survive in extreme environments due to their simpler metabolic pathways. However, the complexity of eukaryotic cells enables the formation of more diverse and sophisticated organisms, which has allowed them to dominate many ecological niches.