MENTOR HIGH SCHOOL KITENDE

PROPOSED GUIDE FOR BIOLOGY PAPER 1

BEGINNING OF TERM 11 2025

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Item 1.

A pharmaceutical company has developed a new drug designed to target a specific protein embedded in the plasma membrane of cancer cells. However, during clinical trials, the drug appears to have reduced efficacy, which scientists suspect is due to changes in the membrane structure caused by elevated cholesterol levels in these cells.

Using your understanding of the fluid mosaic model:

a) Explain how elevated cholesterol levels might alter the structure and function of the plasma membrane.
b) Discuss how these changes could affect the interaction between the drug and its target protein.
c) Propose one modification to the drug design or delivery strategy to overcome the observed issue, and justify your answer.

a) Elevated cholesterol inserts between phospholipids, reducing membrane fluidity and possibly altering protein positioning and movement.
b) Reduced fluidity may hinder protein mobility or accessibility, affecting drug binding and lowering efficacy.
c) Modify the drug to increase lipid solubility or use nanoparticle delivery systems to enhance membrane penetration.

Item 2.

A team of bioengineers is developing synthetic vesicles to mimic human cell membranes for targeted drug delivery. During testing, they notice that the vesicles are too rigid and do not allow for proper fusion with target cells, limiting their effectiveness.

Using your knowledge of the fluid mosaic model of the plasma membrane:

a) Explain the core principles of the fluid mosaic model and evaluate how this model helps us understand membrane behavior in living cells.
b) Identify two specific components of a natural plasma membrane that the engineers should consider including or modifying in their synthetic vesicles.
c) For each component identified in (b), analyze how it would improve the vesicle's ability to mimic the structure and function of a natural membrane.

a) The fluid mosaic model describes a flexible bilayer of phospholipids with embedded, movable proteins. It explains dynamic behavior essential for membrane functions like fusion and signaling.
b) Phospholipids and cholesterol.
c) Unsaturated phospholipids increase fluidity; cholesterol regulates membrane stiffness and stability.

Item 3.

A group of researchers is studying a newly discovered microorganism found in deep-sea hydrothermal vents. Under the microscope, the organism appears to lack a defined nucleus, but it carries out all essential life processes such as respiration, growth, and reproduction. Some team members argue that it may not qualify as a true living organism because of its simple structure.

Using your understanding of cells and the cell theory:

a) Explain how the principles of the cell theory apply to both simple and complex organisms, and assess their relevance in classifying the microorganism.
b) Analyze how the characteristics of this microorganism either support or challenge the cell theory.

c) Evaluate why structural simplicity does not necessarily exclude an organism from being classified as living. Use examples to support your answer.

a) The cell theory applies to all living things—unicellular or multicellular. It supports classifying this microbe as living despite structural simplicity.
b) The organism is a single cell and performs life functions, supporting the cell theory. Its lack of nucleus aligns with prokaryotic cell structure.
c) Many prokaryotes are structurally simple yet fully living, e.g., bacteria. Simplicity does not negate function or life status.

Item 4

In a school laboratory, students conduct an experiment to investigate how temperature affects the activity of the enzyme catalase on hydrogen peroxide. They observe that the reaction is fastest at around 37°C but slows down significantly at both lower and higher temperatures. One group concludes that the enzyme simply "stops working" outside the optimal temperature range.

Using your understanding of enzymes and the lock-and-key hypothesis:

a) Using the lock-and-key hypothesis, evaluate how temperature changes might influence the interaction between catalase and hydrogen peroxide.
b) Explain why enzyme activity decreases at both low and high temperatures, referring to the structure of the enzyme.
c) Suggest how this experiment could be improved to give more reliable results on how temperature affects enzyme activity. Justify your suggestion.

a) At low temperatures, fewer collisions occur, slowing binding. At high temperatures, the enzyme may denature, deforming the active site.
b) Low temperature reduces kinetic energy and collisions. High temperature disrupts tertiary structure, denaturing the enzyme.
c) Use a buffer to control pH, repeat trials for reliability, and maintain exact temperatures with a water bath.