**BIOCHEMISTRY & CELL BIOLOGY END-OF-CHAPTER SYNTHESIS & EVALUATION QUESTIONS**

**Chapter 2 – The Chemical Context of Life**

**10. Scientific Inquiry/Science Practices 3 & 4**

The complex shapes of biological molecules determine the great specificity with which they interact with one another and form weak or strong bonds.

Hypothesis: Receptor cells on the filaments of the male silkworm moth’s antennae contain cell-surface molecules that are complementary in shape to sex attractant molecules (pheromones) produced by the female silkworm moth.

This hypothesis leads to several testable predictions. (1) Silkworm moth pheromones will bind to specific sites on the cells of the filaments of the male’s antennae. (2) If it is possible to synthesize molecules that are very similar in shape to silkworm moth pheromones, these molecules will also attract male silkworm moths. (3) Chemical or temperature treatments that modify the molecular shape of silkworm moth pheromones will reduce the attractiveness of these molecules to male silkworm moths.

An experiment could be designed to test the third prediction. A number of male silkworm moths could be exposed to two separate treatments. In the first treatment, unaltered pheromones would be released near male silkworm moths, and the response of the moths would be noted. The second treatment would be identical in every way except that the pheromone would be heated to permanently modify its molecular shape before it was released.

**11. Focus on Big Idea 1**

It would be surprising if the percentages of naturally occurring elements in most organisms were *not* roughly the same, because all organisms evolved on Earth (with its unique elemental composition) and all are genetically related to one another. (Species living under unusual conditions might differ more than others, though.) Further, we might predict that the more similar the percentages of naturally occurring elements are in two species, the more closely related those two species are.

**12. Focus on Big Idea 4**

**Sample key points:**

* Water’s versatility as a solvent arises from the polar covalent bonds of water molecules.
* Water molecules form hydrogen bonds with atoms that are part of polar covalent bonds in other molecules.
* The partially charged regions of water molecules are attracted to oppositely charged ions.

**Sample top-scoring answer:**

Water is the solvent of life, a function emerging from the polar covalent bonds of water molecules. A water molecule consists of an oxygen atom bonded to two hydrogen atoms. Due to oxygen’s high electronegativity, the shared electrons are attracted closer to the oxygen at the apex of this V-shaped molecule. The resulting partial negative charge associated with oxygen and partial positive charge associated with each hydrogen result in hydrogen bonding between adjacent water molecules.

Water molecules also form hydrogen bonds with atoms in polar covalent bonds in other molecules, dissolving those molecules. The partial positive and negative regions of water molecules are also attracted to negatively and positively charged ions, respectively, forming hydration shells around ions that separate them from each other and dissolve them. Most of the chemical reactions of life involve solutes that are dissolved in water, so the properties of water that allow it to form hydrogen bonds are crucial to life on Earth.

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**Chapter 3 – Carbon and the Molecular Diversity of Life**

**9. Scientific Inquiry/Science Practice 6**

DNA has many phosphate groups along the backbone of each strand, so the molecule has many negative charges. Therefore, you might expect a DNA-binding protein to have many amino acids with positively charged side chains. These are the basic amino acids in Figure 3.17: lysine, arginine, and histidine. (In fact, DNA-binding proteins do have regions that are rich in these three amino acids.)

**10. Focus on Big Idea 1**

All proteins would *not* be expected to show the same degree of divergence. Some cellular functions are more essential than others to the survival of the organism. Proteins perform most cellular functions, so some proteins could be considered more essential than others. You should therefore expect the amino acid sequences of more essential proteins to be more highly conserved (retained with little or no change) than those of less essential proteins. Moreover, different species often live in different habitats and experience different selection pressures. Consequently, you should expect different degrees of divergence among the proteins shared by species that live in different habitats.

**11. Focus on Big Idea 4**

**Sample key points:**

* Amino acids share common chemical groups but have unique side chains that allow for variation.
* Common components allow the formation of polypeptides, whose repeating units interact to establish secondary structure.
* Interactions of the varying side chains determine tertiary structure.
* The combination allows for an almost infinite number of possible different structures, each with a different function.

**Sample top-scoring answer:**

The structure of an amino acid, including both common and varying groups, is key to its function. The common groups (amino and carboxyl groups attached to an α carbon) allow amino acids to link together into a polypeptide of any length via peptide bonds. The repeating subunits of the polymer can interact with each other, forming α helices and β pleated sheets that establish secondary structure. The varying groups are the amino acid side chains. Each polypeptide therefore has a unique sequence of side chains attached to the common backbone. Interactions between the side chains determine the tertiary structure of the polypeptide. A combination of secondary and tertiary structure establishes the overall 3-D structure of a protein (or one of its subunits), which determines its function. Amino acid structure thus allows for an almost infinite number of possible protein structures, accounting for the diversity of proteins functioning in a cell.

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**Chapter 4 – A Tour of the Cell**

**9. Scientific Inquiry/Science Practice 4**

You could start by examining the organism and especially its mystery organelle by TEM at high magnification, looking closely for structural similarities with known organelles. Then, starting with a suspension of the organism in an aqueous solution, you could carry out cell fractionation: successive centrifugations at higher and higher speeds, saving the pellet at each stage. Using electron microscopy on material from the pellets, you could identify the pellet containing the organelles of interest. You could then re-suspend these organelles in solution, and test them for the activities of various enzymes, which might reveal the organelle's function in the cell. You could also attempt to isolate DNA from the organelles and compare any you find with DNA from normal mitochondria and chloroplasts. If, for example, the organelles contain enzymes known to participate in cellular respiration and also contain DNA similar to known mitochondrial DNA, you could conclude that the mystery organelle is most likely a mitochondrion. An organelle unrelated or more distantly related to known organelles might take much additional study to figure out.

**10. Focus on Big Idea 1**

Unity is best revealed by cell structures that are shared. Almost all biological membranes are phospholipid bilayers. This feature arose early in the evolution of life on Earth and has been consistently retained by all subsequent life-forms. Ribosomes also originated early and are found in all cells. Mitochondria arose early in the origin of eukaryotic cells, all of which seem to contain mitochondria or related organelles. The less commonly shared a structure is, the more likely it is a specialized adaptation. Cilia and flagella of the “9 + 2” variety are seen only in motile eukaryotes and in eukaryotic cells that move fluid substances past them.

**11. Focus on Big Idea 4**

**Sample key points:**

* Life emerges from the integration of the functions performed by individual cell components.
* Organelles and cellular structures are not alive on their own; their activities must be integrated with those of other components.
* Some of the characteristics of life include the ability to transform energy, to respond to the environment, and to reproduce and pass along characteristics to offspring.
* Although the nucleus contains instructions for all cell components, other cell components are required to carry them out.
* “Life” as a phenomenon is an emergent property of the parts of a cell.

**Sample top-scoring answer:**

The phenomenon we call “life” emerges from the integration of all the functions performed by the individual structures and organelles of a cell. Not one of the cellular components could exist indefinitely on its own. Integrating the activity of all cellular components allows a cell to display the fundamental characteristics of life: the ability to transform energy, to respond to the environment and interact with other organisms, and ultimately to reproduce and pass along characteristics to offspring. The nucleus houses the genetic instructions for the proteins needed for a cell’s functions, but it could not carry out those instructions without the cooperation of ribosomes on which to build proteins, the endoplasmic reticulum and Golgi apparatus to modify them, and mitochondria to convert fuel energy to ATP to drive the process. Furthermore, the arrangement of all these organelles in relation to each other is crucial. Life is an emergent property that results from the intricate organization and orchestrated functioning of these and other cellular components.

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**Chapter 5 – Membrane Transport and Cell Signaling**

**7. Scientific Inquiry/Science Practice 3**

Hypothesis: Sucrose and H+ move together into the plant cell through a cotransport protein, with sucrose moving up a concentration gradient and H+ moving down an electrochemical gradient. The H+ gradient is maintained by a proton pump, which requires ATP. This hypothesis is consistent with the data: The proton pump builds up an H+ gradient across the membrane by pumping protons out of the cell, which accounts for the decrease in pH seen in the solution. Once the gradient is sufficient, H+ can move down its electrochemical gradient into the cell, and sucrose moves with it. The proton pump, using ATP, pumps protons out of the cell, maintaining a gradient with a steady, higher concentration of H+ outside (lower pH than the starting pH).

If an inhibitor of ATP regeneration is added, the cell's ATP will be used up, and the proton pump will no longer be able to work. The surplus of H+ outside the cell will continue to drive cotransport only until the outside H+ concentration is the same as that inside the cell, at which point the gradient has been eliminated. Thus, you would see the pH in the solution rise until the gradient is no longer sufficient to drive cotransport, at which point sucrose transport would cease and the pH would remain steady.

**8. Science, Technology, and Society**

If a plant cell is placed in a hypertonic solution such as that found in wet saline soils, water will be lost by osmosis from the cytoplasm and central vacuole of the cell. The cell may plasmolyze as the plasma membrane pulls away from the cell wall, causing the cell to shrivel and die. Even if soil salinity is not at lethal levels, water becomes less available to plants as soil salinity increases because of the tendency of water to leave the plants’ cells.

Plants vary considerably in their salinity tolerance. Plant breeders are attempting to breed varieties of crop plants that are relatively tolerant of soil salinity. In the short term, irrigation minimizes the deleterious effects of saline soils on crops by diluting the solution outside the roots. Because the water eventually evaporates, however, irrigation increases the accumulation of salts in soil over the long term and thus increases demand for scarce water in arid areas.

**9. Focus on Big Idea 1**

One might expect protists that live in hypertonic environments to have the opposite sort of adaptations from those seen in *Paramecium.* An example would be membranes that impede water loss to the environment. An organism that regularly experiences fluctuations in environmental salt concentrations (such as organisms in shallow tide pools) might be expected to have both types of adaptations, plus the ability to activate and inhibit them as its needs change.

**10. Focus on Big Idea 2**

**Sample key points:**

* The plasma membrane is selectively permeable and regulates the passage of materials.
* Nonpolar molecules diffuse through the lipid bilayer.
* Polar molecules require transport proteins.
* Cholesterol enters by receptor-mediated endocytosis.
* Hormones bind to receptors and trigger the secretion of enzymes by exocytosis.
* Ions move through specific ion channels, which may be gated.
* The sodium-potassium pump actively transports Na+ and K+.
* All of these mechanisms enable a cell to exchange materials with its environment.

**Sample top-scoring answer:**

The selectively permeable plasma membrane mediates the passage of substances into and out of the cell via several mechanisms. Small nonpolar molecules, such as O2 and CO2, can easily diffuse through the hydrophobic interior of the lipid bilayer, which interferes with entry of polar substances, even very small ones. Larger polar molecules, such as glucose and amino acids, require specific carrier proteins that bind and move them across the membrane. Cholesterol (carried by LDLs) is brought into the cell by receptor-mediated endocytosis. Hormones bind to cell surface receptors that trigger the secretion of digestive enzymes: the enzymes are packaged in vesicles and released by exocytosis. Ions move through specific ion channels, which may be gated. The energy-requiring sodium-potassium pump actively transports Na+ and K+. Together, the hydrophobic interior of the lipid bilayer, the activities of transport proteins and receptor proteins on the cell surface, and the expenditure of ATP to drive active transport allow the plasma membrane to regulate the cell’s exchange of materials with its environment.