**WHAT THE COLLEGE BOARD WANTS YOU TO KNOW ABOUT CELLULAR RESPIRATION AND PHOTOSYNTHESIS**

**Essential knowledge 2.A.2: Organisms capture and store free energy for use in biological processes.**

a. Autotrophs capture free energy from physical sources in the environment.

*Evidence of student learning is a demonstrated understanding of each of the following:*

1. Photosynthetic organisms capture free energy present in sunlight.

2. Chemosynthetic organisms capture free energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen.

b. Heterotrophs capture free energy present in carbon compounds produced by other organisms.

*Evidence of student learning is a demonstrated understanding of each of the following:*

1. Heterotrophs may metabolize carbohydrates, lipids and proteins by hydrolysis as sources of free energy.

2. Fermentation produces organic molecules, including alcohol and lactic acid, and it occurs in the absence of oxygen.

c. Different energy-capturing processes use different types of electron acceptors.

*To demonstrate student understanding of this concept, make sure you can explain*

* NADP+ in photosynthesis
* Oxygen in cellular respiration

d. The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture free energy present in light to yield ATP and NADPH, which power the production of organic molecules.

*Evidence of student learning is a demonstrated understanding of each of the following:*

1. During photosynthesis, chlorophylls absorb free energy from light, boosting electrons to a higher energy level in Photosystems I and II.

2. Photosystems I and II are embedded in the internal membranes of chloroplasts (thylakoids) and are connected by the transfer of higher free energy electrons through an electron transport chain (ETC).

3. When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of hydrogen ions (protons) across the thykaloid membrane is established.

4. The formation of the proton gradient is a separate process, but it is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase.

5. The energy captured in the light reactions as ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast.

e. Photosynthesis first evolved in prokaryotic organisms; scientific evidence supports that prokaryotic (bacterial) photosynthesis was responsible for the production of an oxygenated atmosphere; prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.

f. Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that harvest free energy from simple carbohydrates.

*Evidence of student learning is a demonstrated understanding of each of the following:*

1.  Glycolysis rearranges the bonds in glucose molecules, releasing free energy to form ATP from ADP and inorganic phosphate, and resulting in the production of pyruvate.

2.  Pyruvate is transported from the cytoplasm to the mitochondrion, where further oxidation occurs.

3. In the Krebs cycle, carbon dioxide is released from organic intermediates ATP is synthesized from ADP and inorganic phosphate via substrate level phosphorylation and electrons are captured by coenzymes.

4. Electrons that are extracted in the series of Krebs cycle reactions are carried by NADH and FADH2 to the electron transport chain.

g. The electron transport chain captures free energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes.

*Evidence of student learning is a demonstrated understanding of each of the following:*

1. Electron transport chain reactions occur in chloroplasts (photosynthesis), mitochondria (cellular respiration) and prokaryotic plasma membranes.

2. In cellular respiration, electrons delivered by NADH and FADH2 are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP+.

3. The passage of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the thylakoid membrane of chloroplasts, with the membrane(s) separating a region of high proton concentration from a region of low proton concentration. In prokaryotes, the passage of electrons is accompanied by the outward movement of protons across the plasma membrane.

4. The flow of protons back through membrane-bound ATP synthase by chemiosmosis generates ATP from ADP and inorganic phosphate.

5. In cellular respiration, decoupling oxidative phosphorylation from electron transport is involved in thermoregulation.

h. Free energy becomes available for metabolism by the conversion of ATP→ADP, which is coupled to many steps in metabolic pathways.

**Student Objectives:**

* **Compare the major features of chemoheterotrophic and photoautotrophic nutritional processes.**
* **Explain the necessity of electron shuttles in metabolic pathways.**
* **Explain the inputs, major processes, and outputs of glycolysis, fermentation, and aerobic cellular respiration.**
* **Trace the movement of energy and matter through all respiratory processes.**
* **Localize all respiratory processes to their locations in a typical eukaryotic cell.**
* **Explain the inputs, major processes, and outputs of the light reactions and the Calvin Cycle.**
* **Trace the movement of energy and matter through all photosynthetic processes.**
* **Localize all photosynthetic processes to their location in a typical eukaryotic, autotrophic cell.**
* **Describe the process of chemiosmosis and compare its function in photosynthetic and respiratory pathways.**
* **Explain the relationship between photosynthesis and respiration at the subcellular, organismal, and ecosystem levels of organization.**
* **Compare the relative efficiencies of anaerobic cellular respiration and aerobic cellular respiration.**
* **Explain how energetic requirements contribute to the adaptations of organisms.  Provide examples to support your statements.**
* **Propose experimental designs by which the rate of photosynthesis and respiration can be measured and studied.**

Learning Objectives:

* The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store and use free energy.
* The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy.