**Cell Energetics Curriculum Summary**

1. **All living systems require constant input of free energy.**
   1. Life requires a highly ordered system.
      1. Order is maintained by constant free energy input into the system.
      2. Loss of order or free energy flow results in death.
      3. Increased disorder and entropy are offset by biological processes that maintain or increase order.
   2. Living systems do not violate the second law of thermodynamics, which states that entropy increases over time.
      1. Order is maintained by coupling cellular processes that increase entropy (and so have negative changes in free energy) with those that decrease entropy (and so have positive changes in free energy).
      2. Energy input must exceed free energy lost to entropy to maintain order and power cellular processes.
      3. Energetically favorable exergonic reactions, such as ATP🡪ADP, that have a negative change in free energy can be used to maintain or increase order in a system by being coupled with reactions that have a positive free energy change.
   3. Energy-related pathways in biological systems are sequential and may be entered at multiple points in the pathway.
      1. *For example:*

• Krebs cycle

• Glycolysis

• Fermentation

1. **Organisms capture and store free energy for use in biological processes.**
   1. Heterotrophs capture free energy present in carbon compounds produced by other organisms.
      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.

***X Specific steps, names of enzymes and intermediates of the glycolysis and fermentation pathways are beyond the scope of the course and the AP Exam.***

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

• Oxygen in cellular respiration

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

***X Memorization of the steps in glycolysis and the Krebs cycle, or of the structures of the molecules and the names of the enzymes involved, are beyond the scope of the course and the AP Exam.***

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

***X The names of the specific electron carriers in the ETC are beyond the scope of the course and the AP Exam.***

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

1. **The structure and function of subcellular components, and their interactions, provide essential cellular processes.**
   1. Mitochondria specialize in energy capture and transformation.
      1. Mitochondria have a double membrane that allows compartmentalization within the mitochondria and is important to its function.
      2. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds called cristae.
      3. Cristae contain enzymes important to ATP production; cristae also increase the surface area for ATP production.
2. **Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.**
   1. Different regions of the vertebrate brain have different functions.
      1. *For example:*

• Vision

• Hearing

• Muscle movement

• Abstract thought and emotions

• Neurohormone production

• Forebrain (cerebrum), midbrain (brainstem) and hindbrain (cerebellum)

• Right and left cerebral hemispheres in humans

***X The types of nervous systems, development of the human nervous system, details of the various structures and features of the brain parts, and details of specific neurologic processes are beyond the scope of the course and the AP Exam.***