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| **AP Biology** | **Curriculum Map** **Cellular Energetics** http://www.jeffersontownship.org/Portals/0/Images/Logos/hornet.jpg |
| Textbook Resources:**Chapters 8, 9, 10** | Month(s):**January-February** | Time Frame:**15 days (11/4 block)** | Assessment:**Reading Quizzes****Unit Test** |
| **Learning Targets** | **Support Text** | **Bozeman Podcasts** |
| **EK 2.A.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.
 | **Energy Transformations**Chapter 8.1 (p.142-145) | [Life Requires Free Energy](http://www.bozemanscience.com/012-life-requires-free-energy) |
| 1. 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.
 | **Free Energy & Metabolism**Chapter 8.2 (p.147-149)**ATP & Coupled Reactions**Chapter 8.3 (p.149-151) | [Gibbs Free Energy](http://www.bozemanscience.com/gibbs-free-energy)[ATP: Adenosine Triphosphate](http://www.bozemanscience.com/atp-adenosine-triphosphate) |
| 1. Energy-related pathways in biological systems are sequential and may be entered at multiple points in the pathway.
	* + Krebs cycle
		+ Glycolysis
		+ Calvin cycle
		+ Fermentation
 | **Catabolism of Macromolecules**Fig 9.19 (p.180) | [Enzymes](https://paul-andersen.squarespace.com/048-enyzmes)[Photosynthesis & Respiration](http://www.bozemanscience.com/013-photosynthesis-and-respiration) |
| **EK 4.B.1: Interactions between molecules affect their structure and function.** |
| 1. The shape of enzymes, active sites and interaction with specific molecules are essential for basic functioning of the enzyme.
2. For an enzyme-mediated chemical reaction to occur, the substrate must be complementary to the surface properties (shape and charge) of the active site. In other words, the substrate must fit into the enzyme’s active site.
3. Cofactors and coenzymes affect enzyme function; this interaction relates to a structural change that alters the activity rate of the enzyme. The enzyme may only become active when all the appropriate cofactors or coenzymes are present and bind to the appropriate sites on the enzyme.
 | **Enzymes Structure & Function**Chapter 8.4 (p.152-155) | [Enzymes](https://paul-andersen.squarespace.com/048-enyzmes)[Enzyme Catalysis LAB](http://www.bozemanscience.com/ap-bio-lab-3-enzyme-catalysis) |
| 1. Other molecules and the environment in which the enzyme acts can enhance or inhibit enzyme activity. Molecules can bind reversibly or irreversibly to the active or allosteric sites, changing the activity of the enzyme.
 | **Environmental & Molecular Impact on Enzymes**Chapter 8.4 (p.155-157)**Regulation of Enzymatic Activity**Chapter 8.5 (p.158-160) |
| 1. The change in function of an enzyme can be interpreted from data regarding the concentrations of product or substrate as a function of time. These representations demonstrate the relationship between an enzyme’s activity, the disappearance of substrate, and/ or presence of a competitive inhibitor.
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| 1. Change in the structure of a molecular system may result in a change of the function of the system.
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| **EK 2.A.2: Organisms capture and store free energy for use in biological processes.** |
| 1. Free energy becomes available for metabolism by the conversion of ATP→ADP, which is coupled to many steps in metabolic pathways.
 | **ATP & Coupled Reactions**Chapter 8.3 (p.149-151) | [Gibbs Free Energy](http://www.bozemanscience.com/gibbs-free-energy)[Coupled Reactions](http://www.bozemanscience.com/coupled-reactions-2) |
| 1. Different energy-capturing processes use different types of electron acceptors
	* + NADP+ in photosynthesis
		+ NAD+ /FAD and oxygen in cellular respiration
 | **Oxidation/Reduction Reactions & NADH**Chapter 9.1 (p.164-167) | [Photosynthesis & Respiration](http://www.bozemanscience.com/013-photosynthesis-and-respiration)[Anaerobic Respiration](http://www.bozemanscience.com/anaerobic-respiration) |
| 1. Heterotrophs capture free energy present in carbon compounds produced by other organisms.
2. Heterotrophs may metabolize carbohydrates, lipids and proteins by hydrolysis as sources of free energy.
3. Fermentation produces organic molecules, including alcohol and lactic acid, and it occurs in the absence of oxygen.
 | **Energy Flow in An Ecosystem**Fig 9.2 (p.163)**Overview of Cellular Respiration**Chapter 9.1 (p.167-168)**Fermentation**Chapter 9.5 (p.177-179) |
| 1. Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that harvest free energy from simple carbohydrates.
2. 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.
3. Pyruvate is transported from the cytoplasm to the mitochondrion, where further oxidation occurs.
4. 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.
5. Electrons that are extracted in the series of Krebs cycle reactions are carried by NADH and FADH2 to the electron transport chain.
 | **Glycolysis**Chapter 9.2 (p.168-169)**Citric Acid (Krebs) Cycle**Chapter 9.3 (p.170-172) |
| 1. The electron transport chain captures free energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes.
2. Electron transport chain reactions occur in chloroplasts (photosynthesis), mitochondria (cellular respiration) and prokaryotic plasma membranes.
3. 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+.
4. 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.
5. The flow of protons back through membrane-bound ATP synthase by chemiosmosis generates ATP from ADP and inorganic phosphate.
6. In cellular respiration, decoupling oxidative phosphorylation from electron transport is involved in thermoregulation.
 | **Electron Transport Chain**Chapter 9.4 (p.172-177) | [Photosynthesis & Respiration](http://www.bozemanscience.com/013-photosynthesis-and-respiration)[The Importance of Oxygen](http://www.bozemanscience.com/the-importance-of-oxygen)[Photosynthesis LAB](http://www.bozemanscience.com/ap-bio-lab-4-plant-pigments-photosynthesis) |
| 1. Autotrophs capture free energy from physical sources in the environment.
2. Photosynthetic organisms capture free energy present in sunlight.
3. Chemosynthetic organisms capture free energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen.
 | **Energy Flow in An Ecosystem**Fig 9.2 (p.163)**Photosynthesis Overview**Chapter 10.1 (p.184-189)Figure 10.22 (p.203) |
| 1. 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.
2. During photosynthesis, chlorophylls absorb free energy from light, boosting electrons to a higher energy level in Photosystems I and II.
3. 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).
4. 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.
5. 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.
6. 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.
 | **Light-Dependent Reactions**Chapter 10.2 (p.189-197)**Calvin Cycle**Chapter 10.3 (p.198-199) |
| 1. 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.
 | **Importance of Photosynthesis**Chapter 10 (p.203) | [The Origin of Life – Scientific Evidence](http://www.bozemanscience.com/011-the-origin-of-life-scientific-evidence) |
| **EK 2.C.1: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.** |
| 1. Negative feedback mechanisms maintain dynamic homeostasis for a particular condition (variable) by regulating physiological processes, returning the changing condition back to its target set point.
	* + - Inhibition of cellular respiration by ATP and citrate
 | **Regulation of Enzymatic Activity**Chapter 8.5 (p.158-160)**Regulation of Cellular Respiration**Chapter 9.6 (p.181) | n/a |
| **EK 3.D.1: Cell communication processes share common features that reflect a shared evolutionary history.** |
| 1. In multicellular organisms, signal transduction pathways coordinate the activities within individual cells that support the function of the organism as a whole.
* Epinephrine stimulation of glycogen breakdown in mammals
 | **Cyclic AMP**Chapter 11.3 (p.216-217)Figure 45.7 & 45.8 | [Fight or Flight Response](http://www.bozemanscience.com/fight-or-flight-response/?rq=fight%20or%20flight)[Signal Transmission](http://www.bozemanscience.com/032-signal-transmission-and-gene-expression) |
| **EK 4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.** |
| 1. Many adaptations of organisms are related to obtaining and using energy and matter in a particular environment.
 | **Photorespiration**Chapter 10.4 (p.199-202) | [Photosynthesis](https://www.youtube.com/watch?v=g78utcLQrJ4&feature=youtu.be) |
| 1. Interactions among cells of a population of unicellular organisms can be similar to those of multicellular organisms, and these interactions lead to increased efficiency and utilization of energy and matter.
* Bacterial community around geothermal vents
* Bacterial community in the rumen of animals
 | **Prokaryotic Metabolic Pathways**Chapter 27.3 (p.564-565)**Mutualistic Adaptations**Chapter 41.4 (p.889-891) | n/a |
| **EK 1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.** |
| 1. Structural and functional evidence supports the relatedness of all domains.
	1. Metabolic pathways are conserved across all currently recognized domains.
 | **Comparison of Chemiosmosis**Chapter 10.2 (p.196) | [Endosymbiosis](http://www.bozemanscience.com/endosymbiosis/?rq=endosymbiosis) |
| 1. Structural evidence supports the relatedness of all eukaryotes.
* Membrane-bound organelles (mitochondria and chloroplasts)
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| **EK 4.C.1: Variation in molecular units provides cells with a wider range of functions.** |
| 1. Variations within molecular classes provide cells and organisms with a wider range of functions.
* Chlorophylls
 | **Photosynthetic Pigments**Chapter 10.2 (p.190-192) | [Photosynthesis](https://www.youtube.com/watch?v=g78utcLQrJ4&feature=youtu.be)[Cellular Variation](http://www.bozemanscience.com/052-cellular-variation) |
| **EK 4.A.2: The structure and function of subcellular components, and their interactions, provide essential cellular processes.** |
| 1. Mitochondria specialize in energy capture and transformation.
2. Mitochondria have a double membrane that allows compartmentalization within the mitochondria and is important to its function.
3. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds called cristae.
4. Cristae contain enzymes important to ATP production; cristae also increase the surface area for ATP production.
 | **Mitochondria & Chloroplasts**Chapter 6.5 (p.109-110) |  |
| 1. Chloroplasts are specialized organelles found in algae and higher plants that capture energy through photosynthesis.
	1. The structure and function relationship in the chloroplast allows cells to capture the energy available in sunlight and convert it to chemical bond energy via photosynthesis.
	2. Chloroplasts contain chlorophylls, which are responsible for the green color of a plant and are the key light-trapping molecules in photosynthesis. There are several types of chlorophyll, but the predominant form in plants is chlorophyll.
	3. Chloroplasts have a double outer membrane that creates a compartmentalized structure, which supports its function. Within the chloroplasts are membrane-bound structures called thylakoids. Energy-capturing reactions housed in the thylakoids are organized in stacks, called “grana,” to produce ATP and NADPH2, which fuel carbon-fixing reactions in the Calvin-Benson cycle. Carbon fixation occurs in the stroma, where molecules of CO2 are converted to carbohydrates.
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| **Vocabulary** |
| bioenergetics | allosteric inhibitor | phosphofructokinase | substrate level phosphorylation | thylakoid | antenna pigments |
| enzymes | allosteric activator | matrix | chemiosmosis | spongy parenchyma | photosystem I |
| exergonic reaction | feedback inhibition | inner mitochondrial membrane | electron transport chain | vascular bundles | photosystem II |
| endergonic reaction | noncompetitive inhibition | outer mitochondrial membrane | fermentation | xylem | P680 |
| activation energy | competitive inhibition | intermembrane space | lactic acid (lactate) | phloem | P700 |
| enzyme specificity | first law of thermodynamics | acetyl coenzyme A | ethanol (ethyl alcohol) | lower epidermis | NADPH |
| substrates | second law of thermodynamics | Krebs cycle | NADH | stomata | carbon fixation |
| active site | entropy | citric acid cycle | FADH2 | guard cells | ribulose bisphosphate (RuBP) |
| enzyme-substrate complex | photosynthesis | oxaloacetate | cuticle | light-dependent reactions | rubisco |
| induced fit | cellular respiration | citric acid | upper epidermis | Calvin cycle | photorespiration |
| coenzymes | aerobic respiration | cytochromes | palisade parenchyma | photons | PEP carboxylase |
| cofactors | anaerobic respiration | proton gradient | mesophyll cells | chlorophyll a/b | bundle sheath cells |
| allosteric sites | glycolysis | ATP synthase | stroma | carotenoids | C3, C4, CAM pathways |
| allosteric regulators | pyruvic acid (pyruvate) | oxidative phosphorylation | grana | reaction center | endosymbiotic theory |
| glucagon/insulin | epinephrine | brown fat | obligate anaerobe | facultative anaerobe |  |