TOPIC 3.2
Enzyme Catalysis

SUGGESTED SKILLS

Questions and Methods

3.C.b
Identify experimental procedures that are aligned to the question, including identifying appropriate controls.

3.C.c
Identify experimental procedures that are aligned to the question, including justifying appropriate controls.

Required Course Content

ENDURING UNDERSTANDING

ENE-1
The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.

LEARNING OBJECTIVE

ENE-1.E
Explain how enzymes affect the rate of biological reactions.

ESSENTIAL KNOWLEDGE

ENE-1.E.1
The structure and function of enzymes contribute to the regulation of biological processes—

a. Enzymes are biological catalysts that facilitate chemical reactions in cells by lowering the activation energy.

SUGGESTED SKILL

Argumentation

6.E.c

Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on data.

AVAILABLE RESOURCES

- AP Biology Lab Manual > **Enzyme Lab**
- Classroom Resources > **Visualizing Information**

TOPIC 3.3 Environmental Impacts on Enzyme Function

Required Course Content

ENDURING UNDERSTANDING

ENE-1

The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
ENE-1.F Explain how changes to the structure of an enzyme may affect its function.	**ENE-1.F.1** Change to the molecular structure of a component in an enzymatic system may result in a change of the function or efficiency of the system— a. Denaturation of an enzyme occurs when the protein structure is disrupted, eliminating the ability to catalyze reactions. b. Environmental temperatures and pH outside the optimal range for a given enzyme will cause changes to its structure, altering the efficiency with which it catalyzes reactions. **ENE-1.F.2** In some cases, enzyme denaturation is reversible, allowing the enzyme to regain activity.
ENE-1.G Explain how the cellular environment affects enzyme activity.	**ENE-1.G.1** Environmental pH can alter the efficiency of enzyme activity, including through disruption of hydrogen bonds that provide enzyme structure.

continued on next page

LEARNING OBJECTIVE

ENE-1.G

Explain how the cellular environment affects enzyme activity.

ESSENTIAL KNOWLEDGE

RELEVANT EQUATION

$$pH = -\log[H^+]$$

EXCLUSION STATEMENT—*Students must understand the underlying concepts and applications of this equation, but performing calculations using this equation are beyond the scope of the course and the AP Exam.*

ENE-1.G.2

The relative concentrations of substrates and products determine how efficiently an enzymatic reaction proceeds.

ENE-1.G.3

Higher environmental temperatures increase the speed of movement of molecules in a solution, increasing the frequency of collisions between enzymes and substrates and therefore increasing the rate of reaction.

ENE-1G.4

Competitive inhibitor molecules can bind reversibly or irreversibly to the active site of the enzyme. Noncompetitive inhibitors can bind allosteric sites, changing the activity of the enzyme.

SUGGESTED SKILL

Argumentation

6.C

Provide reasoning to justify a claim by connecting evidence to biological theories.

TOPIC 3.4
Cellular Energy

Required Course Content

ENDURING UNDERSTANDING

ENE-1

The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.

LEARNING OBJECTIVE

ENE-1.H

Describe the role of energy in living organisms.

ESSENTIAL KNOWLEDGE

ENE-1.H.1

All living systems require constant input of energy.

ENE-1.H.2

Life requires a highly ordered system and does not violate the second law of thermodynamics—

a. Energy input must exceed energy loss to maintain order and to power cellular processes.

b. Cellular processes that release energy may be coupled with cellular processes that require energy.

c. Loss of order or energy flow results in death.

EXCLUSION STATEMENT—*Students will need to understand the concept of energy, but the equation for Gibbs free energy is beyond the scope of the course and the AP Exam.*

ENE-1.H.3

Energy-related pathways in biological systems are sequential to allow for a more controlled and efficient transfer of energy. A product of a reaction in a metabolic pathway is generally the reactant for the subsequent step in the pathway.

TOPIC 3.5
Photosynthesis

SUGGESTED SKILL

Argumentation

6.B

Support a claim with evidence from biological principles, concepts, processes, and/or data.

AVAILABLE RESOURCES

- AP Biology Lab Manual > **Photosynthesis Lab**
- Classroom Resources > **Visualizing Information**

Required Course Content

ENDURING UNDERSTANDING

ENE-1

The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy.	ENE-1.I.1 Organisms capture and store energy for use in biological processes— a. Photosynthesis captures energy from the sun and produces sugars. i. Photosynthesis first evolved in prokaryotic organisms. ii. Scientific evidence supports the claim that prokaryotic (cyanobacterial) photosynthesis was responsible for the production of an oxygenated atmosphere. iii. Prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis. ENE-1.I.2 The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture energy present in light to yield ATP and NADPH, which power the production of organic molecules.
ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	ENE-1.J.1 During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II.

continued on next page

LEARNING OBJECTIVE

ENE-1.J

Explain how cells capture energy from light and transfer it to biological molecules for storage and use.

ESSENTIAL KNOWLEDGE

ENE-1.J.2

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

ENE-1.J.3

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

ENE-1.J.4

The formation of the proton gradient is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase.

ENE-1.J.5

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

EXCLUSION STATEMENT—*Memorization of the steps in the Calvin cycle, the structure of the molecules, and the names of enzymes (with the exception of ATP synthase) are beyond the scope of the course and the AP Exam.*

TOPIC 3.6
Cellular Respiration

Required Course Content

ENDURING UNDERSTANDING

ENE-1

The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.

LEARNING OBJECTIVE

ENE-1.K

Describe the processes that allow organisms to use energy stored in biological macromolecules.

ESSENTIAL KNOWLEDGE

ENE-1.K.1

Fermentation and cellular respiration use energy from biological macromolecules to produce ATP. Respiration and fermentation are characteristic of all forms of life.

ENE-1.K.2

Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that capture energy from biological macromolecules.

ENE-1.K.3

The electron transport chain transfers energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes—

a. Electron transport chain reactions occur in chloroplasts, mitochondria, and prokaryotic plasma membranes.

b. In cellular respiration, electrons delivered by NADH and $FADH_2$ are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is $NADP^+$. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules.

continued on next page

SUGGESTED SKILL

Representing and Describing Data

4.A

Construct a graph, plot, or chart.

AVAILABLE RESOURCES

- AP Biology Lab Manual > **Cellular Respiration Lab**
- Classroom Resources > **Visualizing Information**

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
ENE-1.K Describe the processes that allow organisms to use energy stored in biological macromolecules.	c. The transfer of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the internal 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 movement of protons across the plasma membrane. d. The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate. This is known as oxidative phosphorylation in cellular respiration, and photophosphorylation in photosynthesis. e. In cellular respiration, decoupling oxidative phosphorylation from electron transport generates heat. This heat can be used by endothermic organisms to regulate body temperature. **EXCLUSION STATEMENT**—*The names of the specific electron carriers in the electron transport chain are beyond the scope of the course and the AP Exam.*
ENE-1.L Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	**ENE-1.L.1** Glycolysis is a biochemical pathway that releases energy in glucose to form ATP from ADP and inorganic phosphate, NADH from NAD+, and pyruvate. **ENE-1.L.2** Pyruvate is transported from the cytosol to the mitochondrion, where further oxidation occurs. **ENE-1.L.3** In the Krebs cycle, carbon dioxide is released from organic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred to the coenzymes NADH and $FADH_2$. **ENE-1.L.4** Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and $FADH_2$ to the electron transport chain in the inner mitochondrial membrane.

continued on next page

LEARNING OBJECTIVE

ENE-1.L

Explain how cells obtain energy from biological macromolecules in order to power cellular functions.

ESSENTIAL KNOWLEDGE

ENE-1.L.5

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

ENE-1.L.6

Fermentation allows glycolysis to proceed in the absence of oxygen and produces organic molecules, including alcohol and lactic acid, as waste products.

ENE-1.L.7

The conversion of ATP to ADP releases energy, which is used to power many metabolic processes.

EXCLUSION STATEMENT—*Specific steps, names of enzymes, and intermediates of the pathways for these processes are beyond the scope of the course and the AP Exam.*

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

SUGGESTED SKILL

Argumentation

6.C

Provide reasoning to justify a claim by connecting evidence to biological theories.

AVAILABLE RESOURCES

- Classroom Resource > **Evolution and Change**
- AP Biology Lab Manual > **BLAST Lab**

ILLUSTRATIVE EXAMPLES

- Different types of phospholipids in cell membranes allow the organism flexibility to adapt to different environmental temperatures.
- Different types of hemoglobin maximize oxygen absorption in organisms at different developmental stages.
- Different chlorophylls give the plant greater flexibility to exploit/absorb incoming wavelengths of light for photosynthesis.

TOPIC 3.7 Fitness

Required Course Content

ENDURING UNDERSTANDING

SYI-3

Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

LEARNING OBJECTIVE

SYI-3.A

Explain the connection between variation in the number and types of molecules within cells to the ability of the organism to survive and/or reproduce in different environments.

ESSENTIAL KNOWLEDGE

SYI-3.A.1

Variation at the molecular level provides organisms with the ability to respond to a variety of environmental stimuli.

SYI-3.A.2

Variation in the number and types of molecules within cells provides organisms a greater ability to survive and/or reproduce in different environments.