Unit 01: Chemistry of Life

Content Area:	**Science**
Course(s):	**AP Biology**
Time Period:	**September**
Length:	**3 weeks**
Status:	**Published**

Transfer

This first unit sets the foundation for students to understand the chemical basis of life, which is needed for mastery of future areas of focus and provides students with a survey of the elements necessary for carbon-based systems to function. Students learn that water and the properties of water play a vital role in the survival of individuals and biological systems. They also learn that living systems exist in a highly complex organization that requires input of energy and the exchange of macromolecules. This unit also addresses in detail how and in what conformations molecules called monomers bond together to form polymers. The structure of monomers and polymers determines their function. In the units that follow, students will need to understand and explain the interaction and bonding of atoms to form molecules. Students work through enzyme structure and function, learning the ways in which the environment plays a role in how enzymes perform their function(s).

The AP Biology Exam requires students to make predictions and justify their reasoning in real-world scenarios. Students are expected to interpret and evaluate experimental results, analyze biological concepts and scientific investigations, and perform data analysis and statistical testing. A foundational concept for students to understand is that biological systems depend on relationships that, when compromised, can have far-reaching consequences within the system. These consequences can sometimes be deleterious for cells, organisms, and even ecosystems. This understanding will help students make and justify predictions about how the changes in a biological system affect its function. On the exam, students tend to struggle with the use of language and similar terms, for example, protein versus proton. This confusion often results in a failure to earn points on freeresponse questions. Teachers should hold students accountable for the proper use of appropriate terms throughout the course.

Enduring Understandings

Living systems are organized in a hierarchy of structural levels that interact.

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

Heritable information provides for continuity of life.

Essential Questions

What is the role of energy in the making and breaking of polymers?

How do living systems transmit information in order to ensure their survival?

How would living systems function without the polarity of the water molecule?

Content

Structure of Water and Hydrogen Bonding

Structure and Function of Biological Macromolecules (carbs, lipids, and nucleic acids)

Strucuture and Function of Proteins (focus on enzymes)

Theories on the origin organic molecules and cells

Vocabulary

polarity, hydrogen bonding, cohesion, adhesion, hydrophilic, hydrophobic, organic vs inorganic molecules, monomer, polymer, condensation, hydrolysis, 4 levels of protein structure, enzyme, active site, substrate, allosteric (non-competitive) regulation, competitive regulation, panspermia, abiogenesis, RNA hypothesis

Learning Objectives

SYI-1.A Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.
ENE-1.A Describe the composition of macromolecules required by living organisms.
SYI-1.B Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.
SYI-1.C Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule.
IST-1.A Describe the structural similarities and differences between DNA and RNA.
ENE-1.D Describe the properties of enzymes.
ENE-1.E Explain how enzymes affect the rate of biological reactions.
ENE-1.F Explain how changes to the structure of an enzyme may affect its function.
ENE-1.G Explain how the cellular environment affects enzyme activity.
SYI-3.E Describe the scientific evidence that provides support for models of the origin of life on Earth.

Standards (Essential Knowledge)

SYI-1.A.1 The subcomponents of biological molecules and their sequence determine the properties of that molecule.

SYI-1.A.2 Living systems depend on properties of water that result from its polarity and hydrogen bonding.

SYI-1.A.3 The hydrogen bonds between water molecules result in cohesion, adhesion, and surface tension.

ENE-1.A.1 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.

ENE-1.A.2 Atoms and molecules from the environment are necessary to build new molecules—

a. Carbon is used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Carbon is used in storage compounds and cell formation in all organisms.

b. Nitrogen is used to build proteins and nucleic acids. Phosphorus is used to build nucleic acids and certain lipids.

SYI-1.B.1 Hydrolysis and dehydration synthesis are used to cleave and form covalent bonds between monomers.

X The molecular structure of specific nucleotides and amino acids is beyond the scope of the course and the AP exam.

X The molecular structure of specific carbohydrate polymers is beyond the scope of the course and the AP exam.

SYI-1.B.2 Structure and function of polymers are derived from the way their monomers are assembled—

a. In nucleic acids, biological information is encoded in sequences of nucleotide monomers. Each nucleotide has structural components: a five-carbon sugar (deoxyribose or ribose), a phosphate, and a nitrogen base (adenine, thymine, guanine, cytosine, or uracil). DNA and RNA differ in structure and function.

b. In proteins, the specific order of amino acids in a polypeptide (primary structure) determines the overall shape of the protein. Amino acids have directionality, with an amino (NH2) terminus and a carboxyl (COOH) terminus. The R group of an amino acid can be categorized by chemical properties (hydrophobic, hydrophilic, or ionic), and the interactions of these R groups determine structure and function of that region of the protein.

c. Complex carbohydrates comprise sugar monomers whose structures determine the properties and functions of the molecules.

d. Lipids are nonpolar macromolecules—

i. Differences in saturation determine the structure and function of lipids.

ii. Phospholipids contain polar regions that interact with other polar molecules, such as water, and with nonpolar regions that are often hydrophobic.

X The molecular structure of specific lipids is beyond the scope of the course and the AP exam.

SYI-1.C.1 Directionality of the subcomponents influences structure and function of the polymer—

a. Nucleic acids have a linear sequence of nucleotides that have ends, defined by the 3' hydroxyl and 5' phosphates of the sugar in the nucleotide. During DNA and RNA synthesis, nucleotides are added to the 3' end of the growing strand, resulting in the formation of a covalent bond between nucleotides.

b. DNA is structured as an antiparallel double helix, with each strand running in opposite 5' to 3' orientation. Adenine nucleotides pair with thymine nucleotides via two hydrogen bonds. Cytosine nucleotides pair with guanine nucleotides by three hydrogen bonds.

c. Proteins comprise linear chains of amino acids, connected by the formation of covalent bonds at the carboxyl terminus of the growing peptide chain.

d. Proteins have primary structure determined by the sequence order of their constituent amino acids, secondary structure that arises through local folding of the amino acid chain into elements such as alpha-helices and beta-sheets, tertiary structure that is the overall three-dimensional shape of the protein and often minimizes free energy, and quaternary structure that arises from interactions between multiple polypeptide units. The four elements of protein structure determine the function of a protein.

e. Carbohydrates comprise linear chains of sugar monomers connected by covalent bonds. Carbohydrate polymers may be linear or branched.

ST-1.A.1 DNA and RNA molecules have structural similarities and differences related to their function—

a. Both DNA and RNA have three components—sugar, a phosphate group, and a nitrogenous base—that form nucleotide units that are connected by covalent bonds to form a linear molecule with 5' and 3' ends, with the nitrogenous bases perpendicular to the sugar-phosphate backbone.

b. The basic structural differences between DNA and RNA include the following:
i. DNA contains deoxyribose and RNA contains ribose.
ii. RNA contains uracil and DNA contains thymine.
iii. DNA is usually double stranded; RNA is usually single stranded.
iv. The two DNA strands in double-stranded DNA are antiparallel in directionality.

ENE-1.D.1 The structure of enzymes includes the active site that specifically interacts with substrate molecules.

ENE-1.D.2 For an enzyme-mediated chemical reaction to occur, the shape and charge of the substrate must be compatible with the active site of the enzyme.

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.

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.1 Environmental pH can alter the efficiency of enzyme activity, including through disruption of hydrogen bonds that provide enzyme structure.
X *Students must understand the underlying concepts and applications of the pH equation, but performing calculations with this equation is 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-1.G.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.

SYI-3.E.1 Several hypotheses about the origin of life on Earth are supported with scientific evidence—
a. Geological evidence provides support for models of the origin of life on Earth.
i. Earth formed approximately 4.6 billion years ago (bya). The environment was too hostile for life until 3.9 bya, and the earliest fossil evidence for life dates to 3.5 bya. Taken together, this evidence provides a plausible range of dates when the origin of life could have occurred.
b. There are several models about the origin of life on Earth—
i. Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized because of the presence of available free energy and the absence of a significant quantity of atmospheric oxygen (O2).
ii. Organic molecules could have been transported to Earth by a meteorite or other celestial event.
c. Chemical experiments have shown that it is possible to form complex organic molecules from inorganic molecules in the absence of life—
i. Organic molecules/monomers served as building blocks for the formation of more complex molecules, including amino acids and nucleotides.
ii. The joining of these monomers produced polymers with the ability to replicate, store, and transfer information.

SYI-3.E.2 The RNA World Hypothesis proposes that RNA could have been the earliest genetic material.