West Windsor-Plainsboro Regional School District
AP Biology Curriculum

The Mission of the West Windsor-Plainsboro Science Department

Our mission is to cultivate science learners who have the foundational knowledge to make ethical, scientifically literate decisions and the ability to apply scientific practices in order to contribute to the needs of society and a changing world.

- **Vision**

  We envision a K-12 science experience that supports and challenges every student in their science learning journey. We will:
  - *Capitalize on diversity by reaching and exciting students at all levels and interests by differentiating learning within classrooms and by offering a robust program of studies.*
  - *Emphasize authentic science and engineering practices and leverage the interdisciplinary nature of science with arts, technology, math, reading, and writing.*
  - *Integrate scientific knowledge and 21st century competencies to prepare students to make informed decisions and take action to address real world problems.*

Unit Title: Unit 1 Chemistry of Life
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
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.
Recommended Pacing
5-7 Class Periods
NGSS Standards
HS-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and differentiation in producing and maintaining complex organisms and map their relationships using tools.

Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Graph functions expressed symbolically show the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

21st Century Life and Careers/Technology Standards:

8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.
8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming:
All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.
9.2.12.C.4 Analyze how economic conditions and societal changes influence employment trends and future education.

9.2.12.C.3 Identify transferable career skills and design alternate career plans.

Social Studies

Standard 6.1 U.S. History: America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies: All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus

Unit Enduring Understandings

- SYI-1 Living systems are organized in a hierarchy of structural levels that interact.
- ENE-1 the highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
- IST-1 Heritable information provides for continuity of life.

Unit Learning Objectives

Topic 1.1: Structure of Water and Hydrogen Bonding

- SYI-1.A Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.

Topic 1.2: Elements of Life

- ENE-1.A Describe the composition of macromolecules required by living organisms.

Topic 1.3: Introduction to Biological Molecules

- SYI-1.B Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.

Topic 1.4: Properties of Biological Macromolecules

- SYI-1.B Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.

Topic 1.5: Structure and Function of 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.

Topic 1.6 Nucleic Acids

- IST-1.A Describe the structural similarities and differences between DNA and RNA.

Unit Essential Knowledge

Topic 1.1: Structure of Water and Hydrogen Bonding

- 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

Topic 1.2: Elements of Life

- 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.

Topic 1.3: Introduction to Biological Molecules

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

Topic 1.4: Properties of Biological Macromolecules

- 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.

Topic 1.5: Structure and Function of Biological Macromolecules

- 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 the 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.

Topic 1.6 Nucleic Acids

- IST-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

Evidence of Learning

Common Assessment: **Properties of Water Lab**

In this assessment activity, students will be assessed on their knowledge of the properties of water as well as the use of appropriate statistical tools to analyze their data.

Resources

Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8

Suggested Resources:

Biochemistry POGIL

PBD Insulin Protein Folding

Properties of Water Campaign

Case Study: A Can of Bull?

Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology

Unit Title: Unit 2 Cell Structure and Function
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
The cell is the basic unit of life. Cells contribute to the organization of life and provide the environment in which organelles function. Organelles in turn provide compartmentalization and organize cellular products for dispersal and waste for disposal. Cells have membranes that allow them to establish and maintain an internal environment. These membranes also control the exchange of material with the cell's external environment—an important, foundational concept. The maintenance of the internal and external conditions of a cell is called homeostasis. Student understanding of these concepts will be necessary in later units when the focus of instruction shifts to cellular products and by-products and when students learn why cellular exchange of energy and materials matters.
Recommended Pacing
11-13 Class Periods
NGSS Standards
HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Connecting with English Language Arts/Literacy and Mathematics

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Instructional Focus

Unit Enduring Understandings

- SYI-1 Living systems are organized in a hierarchy of structural levels that interact.
- ENE-1 The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
- ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.
- EVO-1 Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

Unit Learning Objectives

Topic 2.1: Cell Structure: Subcellular Components

- SYI-1.D Describe the structure and/ or function of subcellular components and organelles.

Topic 2.2: Cell Structure and Function

- SYI-1.E Explain how subcellular components and organelles contribute to the function of the cell
- SYI-1.F Describe the structural features of a cell that allow organisms to capture, store, and use energy

Topic 2.3: Cell Size

- ENE-1.B Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.

- ENE-1.C Explain how specialized structures and strategies are
- used for the efficient exchange of molecules to the environment.

Topic 2.4: Plasma Membranes

- ENE-2.A Describe the roles of each of the components of the cell membrane in maintaining the internal environment of the cell.
- ENE-2.B Describe the Fluid Mosaic Model of cell membranes.

Topic 2.5: Membrane Permeability

- ENE-2.C Explain how the structure of biological membranes influences selective permeability
- ENE-2.D Describe the role of the cell wall in maintaining cell structure and function.

Topic 2.6: Membrane Transport

- ENE-2.E Describe the mechanisms that organisms use to maintain solute and water balance.
- ENE-2.F Describe the mechanisms that organisms use to transport large molecules across the plasma membrane.

Topic 2.7: Facilitated Diffusion

- ENE-2.G Explain how the structure of a molecule affects its ability to pass through the plasma membrane.

Topic 2.8: Tonicity and Osmoregulation

- ENE-2.H Explain how concentration gradients affect the movement of molecules across membranes.
- ENE-2.I Explain how osmoregulatory mechanisms contribute to the health and survival of organisms.

Topic 2.9: Mechanisms of Transport

- ENE-2.J Describe the processes that allow ions and other molecules to move across membranes.

Topic 2.10: Cell Compartmentalization

- ENE-2.K Describe the membrane bound structures of the eukaryotic cell.
- ENE-2.L Explain how internal membranes and membrane bound organelles contribute to compartmentalization of eukaryotic cell functions.

Topic 2.11: Origins of Cell Compartmentalization

- EVO-1.A Describe similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells.
- EVO-1.B Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts.

Unit Essential Knowledge

Topic 2.1: Cell Structure: Subcellular Components

- SYI-1.D.1 Ribosomes comprise ribosomal RNA (rRNA) and protein. Ribosomes synthesize protein according to mRNA sequence.
- SYI-1.D.2 Ribosomes are found in all forms of life, reflecting the common ancestry of all known life.
- SYI-1.D.3 Endoplasmic reticulum (ER) occurs in two forms—smooth and rough. Rough ER is associated with membrane-bound ribosomes—
    - a. Rough ER compartmentalizes the cell.
    - b. Smooth ER functions include detoxification and lipid synthesis.
- SYI-1.D.4 The Golgi complex is a membrane-bound structure that consists of a series of flattened membrane sacs—

- a. Functions of the Golgi include the correct folding and chemical modification of newly synthesized proteins and packaging for protein trafficking.
- SYI-1.D.5 Mitochondria have a double membrane. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds.
- SYI-1.D.6 Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes.
- SYI-1.D.7 A vacuole is a membrane-bound sac that plays many and differing roles. In plants, a specialized large vacuole serves multiple functions.
- SYI-1.D.8 Chloroplasts are specialized organelles that are found in photosynthetic algae and plants. Chloroplasts have a double outer membrane.

Topic 2.2: Cell Structure and Function

- SYI-1.E.1 Organelles and subcellular structures, and the interactions among them, support cellular function—
  - a. Endoplasmic reticulum provides mechanical support, carries out protein synthesis on membrane-bound ribosomes, and plays a role in intracellular transport.
  - b. Mitochondrial double membrane provides compartments for different metabolic reactions.
  - c. Lysosomes contain hydrolytic enzymes, which are important in intracellular digestion, the recycling of a cell's organic materials, and programmed cell death (apoptosis).
  - d. Vacuoles have many roles, including storage and release of macromolecules and cellular waste products. In plants, it aids in retention of water for turgor pressure.
- SYI-1.F.1 The folding of the inner membrane increases the surface area, which allows for more ATP to be synthesized.
- SYI-1.F.2 Within the chloroplast are thylakoids and the stroma
- SYI-1.F.3 The thylakoids are organized in stacks, called grana.
- SYI-1.F.4 Membranes contain chlorophyll pigments and electron transport proteins that comprise the photosystems. SYI-1.F.5 The light-dependent reactions of photosynthesis occur in the grana.
- SYI-1.F.6 The stroma is the fluid within the inner chloroplast membrane and outside of the thylakoid.
- SYI-1.F.7 The carbon fixation (Calvin-Benson cycle) reactions of photosynthesis occur in the stroma.
- SYI-1.F.8 The Krebs cycle (citric acid cycle) reactions occur in the matrix of the mitochondria.
- SYI-1.F.9 Electron transport and ATP synthesis occur on the inner mitochondrial membrane.

Topic 2.3: Cell Size

- ENE-1.B.1 Surface area-to-volume ratios affect the ability of a biological system to obtain necessary resources, eliminate waste products, acquire or dissipate thermal energy, and otherwise exchange chemicals and energy with the environment.
  - RELEVANT EQUATIONS
    - Volume of a Sphere: r 4 V = π 3 3
    - Volume of a Cube: V = s2 Volume of a Rectangular Solid: V = lwh
    - Volume of a Cylinder: V = πr h2
    - Surface Area of a Sphere: SA = 4pr 2
    - Surface Area of a Cube: SA s = 6 2
    - Surface Area of a Rectangular Solid: SA = 2lh + 2lw + 2wh
    - Surface Area of a Cylinder: SA = 2πrh + 2πr2
    - r = radius l = length h = height w = width s = length of one side of a cube
- ENE-1.B.2 The surface area of the plasma membrane must be large enough to adequately exchange materials—
  - a. These limitations can restrict cell size and shape. Smaller cells typically have a higher surface area-to-volume ratio and more efficient exchange of materials with the environment.
  - b. As cells increase in volume, the relative surface area decreases and the demand for internal resources increases.

    - c. More complex cellular structures (e.g., membrane folds) are necessary to adequately exchange materials with the environment.
    - d. As organisms increase in size, their surface area-to-volume ratio decreases, affecting properties like rate of heat exchange with the environment.
- ENE-1.C.1 Organisms have evolved highly efficient strategies to obtain nutrients and eliminate wastes. Cells and organisms use specialized exchange surfaces to obtain and release molecules from or into the surrounding environment.

Topic 2.4: Plasma Membranes

- ENE-2.A.1 Phospholipids have both hydrophilic and hydrophobic regions. The hydrophilic phosphate regions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid regions face each other within the interior of the membrane.
- ENE-2.A.2 Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups.
- ENE-2.B.1 Cell membranes consist of a structural framework of phospholipid molecules that is embedded with proteins, steroids (such as cholesterol in eukaryotes), glycoproteins, and glycolipids that can flow around the surface of the cell within the membrane

Topic 2.5: Membrane Permeability

- ENE-2.C.1 The structure of cell membranes results in selective permeability.
- ENE-2.C.2 Cell membranes separate the internal environment of the cell from the external environment.
- ENE-2.C.3 Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model.
- ENE-2.C.4 Small nonpolar molecules, including N_2, O_2, and CO_2 , freely pass across the membrane. Hydrophilic substances, such as large polar molecules and ions, move across the membrane through embedded channels and transport proteins.
- ENE-2.C.5 Polar uncharged molecules, including H_2O, pass through the membrane in small amounts.
- ENE-2.D.1 Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments.
- ENE-2.D.2 Cell walls of plants, prokaryotes, and fungi are composed of complex carbohydrates.

Topic 2.6: Membrane Transport

- ENE-2.E.1 Passive transport is the net movement of molecules from high concentration to low concentration without the direct input of metabolic energy.
- ENE-2.E.2 Passive transport plays a primary role in the import of materials and the export of wastes.
- ENE-2.E.3 Active transport requires the direct input of energy to move molecules from regions of low concentration to regions of high concentration
- ENE-2.F.1 The selective permeability of membranes allows for the formation of concentration gradients of solutes across the membrane.
- ENE-2.F.2 The processes of endocytosis and exocytosis require energy to move large molecules into and out of cells—
    - a. In exocytosis, internal vesicles fuse with the plasma membrane and secrete large macromolecules out of the cell.
    - b. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane.

Topic 2.7: Facilitated Diffusion

- ENE-2.G.1 Membrane proteins are required for facilitated diffusion of charged and large polar molecules through a membrane—
    - a. Large quantities of water pass through aquaporins.

- b. Charged ions, including Na+ and K+, require channel proteins to move through the membrane.
- c. Membranes may become polarized by

- ENE-2.G.2 Membrane proteins are necessary for active transport.
- ENE-2.G.3 Metabolic energy (such as from ATP) is required for active transport of molecules and/ or ions across the membrane and to establish and maintain concentration gradients.
- ENE-2.G.4 The Na+/K+ ATPase contributes to the maintenance of the membrane potential

Topic 2.8: Tonicity and Osmoregulation

- ENE-2.H.1 External environments can be hypotonic, hypertonic or isotonic to internal environments of cells—
  - a. Water moves by osmosis from areas of high water potential/low osmolarity/ low solute concentration to areas of low water potential/high osmolarity/high solute concentration. RELEVANT EQUATION Water Potential: Ψ = Ψp s + Ψ Ψp = pressure potential Ψs = solute potential
- ENE-2.I.1 Growth and homeostasis are maintained by the constant movement of molecules across membranes
- ENE-2.I.2 Osmoregulation maintains water balance and allows organisms to control their internal solute composition/water potential. SOLUTE POTENTIAL OF A SOLUTION Ψs = −iCRT where: i = ionization constant C = molar concentration R = pressure constant T= Temperature in Kelvin (°C + 273)

Topic 2.9: Mechanisms of Transport

- ENE-2.J.1 A variety of processes allow for the movement of ions and other molecules across membranes, including passive and active transport, endocytosis and exocytosis.

Topic 2.10: Cell Compartmentalization

- ENE-2.K.1 Membranes and membrane-bound organelles in eukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions.
- ENE-2.L.1 Internal membranes facilitate cellular processes by minimizing competing interactions and by increasing surface areas where reactions can occur.

Topic 2.11: Origins of Cell Compartmentalization

- EVO-1.A.1 Membrane-bound organelles evolved from once free-living prokaryotic cells via endosymbiosis. EVO-1.A.2 Prokaryotes generally lack internal membrane bound organelles but have internal regions with specialized structures and functions.
- EVO-1.A.3 Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.
- EVO-1.B.1 Membrane-bound organelles evolved from previously free-living prokaryotic cells via endosymbiosis.

Evidence of Learning
Common Assessment
Osmosis & Diffusion Labs Diffusion and Osmosis Lab Documents Extension Poster Rubric
Resources
Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8
Suggested Resources:
Case Study: Little Girl Lost: Defective Cellular Organelles Osmosis Case Study Aquaporin Reading & Questions Aquaporin: PDB Molecule of the Month

Water Potential Problems

Transport Proteins: PDB Molecule of the Month

Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology

Unit Title: Unit 3 Cellular Energetics
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
In Unit 3, students build on knowledge gained in Unit 2 about the structure and function of cells, focusing on cellular energetics. Living systems are complex in their organization and require constant energy input. This unit will provide students with the knowledge necessary to master the concepts of energy capture and use. Students work through enzyme structure and function, learning the ways in which the environment plays a role in how enzymes perform their function(s). Students gain a deeper understanding of the processes of photosynthesis and cellular respiration, knowledge they will use in Unit 6 while studying how cells use energy to fuel life processes
Recommended Pacing
14-17 Class Periods
NGSS Standards
HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support an explanation for the cycling of matter and flow of energy in aerobic and anaerobic conditions, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Develop and write an explanation, based on evidence, for the cycling of matter and flow of energy in aerobic and anaerobic conditions by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples.
- Develop and strengthen an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

Mathematics

- Represent the cycling of matter and flow of energy among organisms in an ecosystem symbolically and manipulate the representing symbols. Make sense of quantities of and relationships between matter and energy as they cycle and flow through an ecosystem.
- Use a mathematical model to describe the cycling of matter and flow of energy among organisms in an ecosystem. Identify important quantities in the cycling of matter and flow of energy among organisms in an ecosystem and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.
- Use units as a way to understand the cycling of matter and flow of energy among organisms in an ecosystem. Choose and interpret units consistently in formulas to determine the cycling of matter and flow of energy

among organisms in an ecosystem. Choose and interpret the scale and the origin in graphs and data displays representing the cycling of matter and flow of energy among organisms in an ecosystem.

- Define appropriate quantities to represent matter and energy for the purpose of descriptive modeling of their cycling and flow among organisms in ecosystems.
- Choose a level of accuracy appropriate to limitations on measurement when reporting quantities representing matter cycles and energy flows among organisms in ecosystems.

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Social Studies

Standard 6.1 U.S. History: America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies: All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus

Unit Enduring Understandings

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

Unit Learning Objectives

Topic 3.1: Enzyme Structure

- ENE-1.D Describe the properties of enzymes.

Topic 3.2: Enzyme Catalysis

- ENE-1.E Explain how enzymes affect the rate of biological reactions.
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Topic 3.3: Environmental Impacts on Enzyme Function

- 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

Topic 3.4: Cellular Energy

- ENE-1.H Describe the role of energy in living organisms.

Topic 3.5: Photosynthesis

- ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

- ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use.

Topic 3.6 Cellular Respiration

- ENE-1.K Describe the processes that allow organisms to use energy stored in biological macromolecules.
- ENE-1.L Explain how cells obtain energy from biological macromolecules in order to power cellular functions.

Unit Essential Knowledge

Topic 3.1: Enzyme Structure

- 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.

Topic 3.2: Enzyme Catalysis

- 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

Topic 3.3: Environmental Impacts on Enzyme 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.1 Environmental pH can alter the efficiency of enzyme activity, including through disruption of hydrogen bonds that provide enzyme structure.
- 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.

Topic 3.4: Cellular Energy

- 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
- 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

- 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
- Organisms capture and store energy for use in biological processes— a. Photosynthesis captures energy from the sun and produces sugars.
- During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II.
- 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.

Topic 3.6 Cellular Respiration

- 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 are passed to a series of electron acceptor2 s 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.
    - 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.
- 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 FADH2.

- ENE-1.L.4 Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and FADH2 to the electron transport chain in the inner mitochondrial membrane.
- 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.

Evidence of Learning

Common Assessments

Enzyme Activity Pre-Lab & Enzyme Lab Presentations

Photosynthesis Lab Simulation

Resources

Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8

Suggested Resources:

Enzymes:

Ch. 6 Introduction to Metabolism Presentation

Photosynthesis:

HHMI Photosynthesis Animation and Student Worksheets

Photosynthesis Case Study: "Sweet Beats: Making Sugars Out of Thin Air

Photosynthesis Case Study" "Killing Chloroplasts

Cell Respiration:

Case Study: "Mystery of the Seven Deaths"

Cellular Respiration Lab

Glycolysis Activity-Paper Activity Constructing the Biochemical Pathway

Krebs Paper

Mitchell (Chemiosmosis) Paper

Alternative Fuels

Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology

Unit Title: Unit 4 Cell Communication & Cell Cycle
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
In Unit 4, students continue to learn about the role of cells, focusing on how cells use energy and information transmission to communicate and replicate. Through systems of complex transduction pathways, cells can communicate with one another. Cells can also generate and receive signals, coordinate mechanisms for growth, and respond to environmental cues. To maintain homeostasis, cells respond to their environment. They can also replicate and regulate replication as part of the cell cycle that provides for the continuity of life. In Unit 5, students will move on to learn about heredity
Recommended Pacing
9-11 Class Periods
NGSS Standards
HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis
HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Write an explanation that supports how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Draw evidence from informational texts to support how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- Make strategic use of digital media in presentations to enhance understanding of the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- Conduct short as well as more sustained research to determine how feedback mechanisms maintain homeostasis. Synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- Gather applicable information from multiple reliable sources to support claims that feedback mechanisms maintain homeostasis. Use advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- Make strategic use of digital media in presentations to enhance understanding of the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Mathematics

- Use a mathematical model to illustrate the role of cellular division and differentiation in producing and maintaining complex organisms. Identify important quantities in the role of cellular division and

differentiation in producing and maintaining complex organisms and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Graph functions expressed symbolically show the role of cellular division and differentiation in producing and maintaining complex organisms and show key features of the graph, by hand in simple cases and using technology for more complicated cases.
- Write a function that describes a relationship between the role of cellular division and differentiation and the production and maintenance of complex organisms.

21st Century Life and Careers/Technology Standards:

8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.
8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming:
All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.
9.2.12.C.4 Analyze how economic conditions and societal changes influence employment trends and future education.

9.2.12.C.3 Identify transferable career skills and design alternate career plans.

Social Studies

Standard 6.1 U.S. History: America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
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Instructional Focus

Unit Enduring Understandings

- IST-3 Cells communicate by generating, transmitting, receiving, and responding to chemical signals
- ENE-3 Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.
- IST-1 Heritable information provides for continuity of life

Unit Essential Knowledge

4.1: Cell Communication

- IST-3.A.1 Cells communicate with one another through direct contact with other cells or from a distance via chemical signaling—
    - a. Cells communicate by cell-to-cell contact.
- IST-3.B.1 Cells communicate over short distances by using local regulators that target cells in the vicinity of the signal-emitting cell —
    - a. Signals released by one cell type can travel long distances to target cells of another cell type.

4.2: Introduction to Signal Transduction

- IST-3.C.1 Signal transduction pathways link signal reception with cellular responses.
- IST-3.C.2 Many signal transduction pathways include protein modification and phosphorylation cascades.

- IST-3.D.1 Signaling begins with the recognition of a chemical messenger—a ligand—by a receptor protein in a target cell—
    - a. The ligand-binding domain of a receptor recognizes a specific chemical messenger, which can be a peptide, a small chemical, or protein, in a specific one-to-one relationship.
    - b. G protein-coupled receptors are an example of a receptor protein in eukaryotes.
- IST-3.D.2 Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell, which could include cell growth, secretion of molecules, or gene expression—
    - a. After the ligand binds, the intracellular domain of a receptor protein changes shape initiating transduction of the signal.
    - b. Second messengers (such as cyclic AMP) are molecules that relay and amplify the intracellular signal.
    - c. Binding of ligand-to-ligand-gated channels can cause the channel to open or close.

4.3: Signal Transduction

- IST-3.E.1 Signal transduction pathways influence how the cell responds to its environment.
- IST-3.F.1 Signal transduction may result in changes in gene expression and cell function, which may alter phenotype or result in programmed cell death (apoptosis).

4.4: Changes in Signal Transduction Pathways

- Changes in signal transduction pathways can alter cellular response—
    - a. Mutations in any domain of the receptor protein or in any component of the signaling pathway may affect the downstream components by altering the subsequent transduction of the signal.
- IST-3.G.2 Chemicals that interfere with any component of the signaling pathway may activate or inhibit the pathway.

4.5: Feedback

- ENE-3.A.1 Organisms use feedback mechanisms to maintain their internal environments and respond to internal and external environmental changes.
- ENE-3.B.1 Negative feedback mechanisms maintain homeostasis for a particular condition by regulating physiological processes. If a system is perturbed, negative feedback mechanisms return the system back to its target set point. These processes operate at the molecular and cellular levels.
- ENE-3.C.1 Positive feedback mechanisms amplify responses and processes in biological organisms. The variable initiating the response is moved farther away from the initial set point. Amplification occurs when the stimulus is further activated, which, in turn, initiates an additional response that produces system change.

4.6: Cell Cycle

- IST-1.B.1 In eukaryotes, cells divide and transmit genetic information via two highly regulated processes.
- IST-1.B.2 The cell cycle is a highly regulated series of events for the growth and reproduction of cells—
    - a. The cell cycle consists of sequential stages of interphase (G1, S, G2), mitosis, and cytokinesis.
    - b. A cell can enter a stage (G0) where it no longer divides, but it can reenter the cell cycle in response to appropriate cues. Nondividing cells may exit the cell cycle or be held at a particular stage in the cell cycle.
- IST-1.C.1 Mitosis is a process that ensures the transfer of a complete genome from a parent cell to two genetically identical daughter cells—
    - a. Mitosis plays a role in growth, tissue repair, and asexual reproduction.
    - b. Mitosis alternates with interphase in the cell cycle.
    - c. Mitosis occurs in a sequential series of steps (prophase, metaphase, anaphase, telophase).

4.7: Regulation of Cell Cycle

- IST-1.D.1 A number of internal controls or checkpoints regulate progression through the cycle.
- IST-1.D.2 Interactions between cyclins and cyclin dependent kinases control the cell cycle
- IST-1.E.1 Disruptions to the cell cycle may result in cancer and/or programmed cell death (apoptosis).

Learning Objectives

4.1: Cell Communication

- IST-3.A Describe the ways that cells can communicate with one another.
- IST-3.B Explain how cells communicate with one another over short and long distances.

4.2: Introduction to Signal Transduction

- IST-3.C Describe the components of a signal transduction pathway.
- IST-3.D Describe the role of components of a signal transduction pathway in producing a cellular response.

4.3: Signal Transduction

- IST-3.E Describe the role of the environment in eliciting a cellular response.
- IST-3.F Describe the different types of cellular responses elicited by a signal transduction pathway

4.4: Changes in Signal Transduction Pathways

- IST-3.G Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.

4.5: Feedback

- ENE-3.A Describe positive and/ or negative feedback mechanisms.
- ENE-3.B Explain how negative feedback helps to maintain homeostasis.
- ENE-3.C Explain how positive feedback affects homeostasis.

4.6: Cell Cycle

- IST-1.B Describe the events that occur in the cell cycle.
- IST-1.C Explain how mitosis results in the transmission of chromosomes from one generation to the next.

4.7: Regulation of Cell Cycle

- IST-1.D Describe the role of checkpoints in regulating the cell cycle.
- IST-1.E Describe the effects of disruptions to the cell cycle on the cell or organism

Evidence of Learning

Common Assessments

Cell Signaling Video Project

Diabetes and Insulin Signaling Case Study

Modeling: When Cells Don't Communicate

Resources

Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8

Suggested Resources:

HHMI Click & Learn
Stations
Pocket Mice HHMI Signaling
Who Killed Yew?
Overview Video & Questions
Videos & Questions
Cell Transduction Pathways POGIL

Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology

Unit Title: Unit 5 Heredity
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
Unit 5 focuses on heredity and the biological concepts and processes involved in ensuring the continuity of life. Students learn that the storage and transmission of genetic information via chromosomes from one generation to the next occur through meiosis. Meiotic division ensures genetic diversity, which is crucial to the survival of a species. In this unit, students gain a deeper understanding of Mendelian genetics and learn how non-Mendelian genetics describes those patterns of inheritance that seem to violate Mendel's laws. This unit also teaches the role played by chromosomal inheritance, environmental factors, and nondisjunction on an individual's phenotype. In Unit 6, students move on to learn about gene expression and regulation.
Recommended Pacing
9-11 Class Periods
NGSS Standards
HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, based on evidence, that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.

Mathematics

- Represent symbolically evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the variation and distribution of expressed traits in a population.

21st Century Life and Careers/Technology Standards:

8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.
8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming:
All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.
9.2.12.C.4 Analyze how economic conditions and societal changes influence employment trends and future education.

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Instructional Focus

Unit Enduring Understandings

- IST-1: Heritable information provides for continuity of life
- EVO-2: Organisms are linked by lines of descent from common ancestry
- SYI-3: Naturally occurring diversity among and between components within biological systems affects interactions with the environment

Unit Essential Knowledge

5.1: Meiosis

- IST-1.F.1: Meiosis is a process that ensures the formation of haploid gamete cells in sexually reproducing diploid organisms—
    - a. Meiosis results in daughter cells with half the number of chromosomes of the parent cell.
    - b. Meiosis involves two rounds of a sequential series of steps (meiosis I and meiosis II).
- IST-1.G.1: Mitosis and meiosis are similar in the way chromosomes segregate but differ in the number of cells produced and the genetic content of the daughter cells.

5.2: Meiosis & Genetic Diversity

- IST-1.H.1: Separation of the homologous chromosomes in meiosis I ensures that each gamete receives a haploid (1n) set of chromosomes that comprises both maternal and paternal chromosomes.
- IST-1.H.2: During meiosis I, homologous chromatids exchange genetic material via a process called “crossing over” (recombination), which increases genetic diversity among the resultant gametes
- IST-1.H.3: Sexual reproduction in eukaryotes involving gamete formation—including crossing over, the random assortment of chromosomes during meiosis, and subsequent fertilization of gametes—serves to increase variation.

5.3: Mendelian Genetics

- EVO-2.A.1: DNA and RNA are carriers of genetic information.
- EVO-2.A.2: Ribosomes are found in all forms of life
- EVO-2.A.3: Major features of the genetic code are shared by all modern living systems.
- EVO-2.A.4: Core metabolic pathways are conserved across all currently recognized domains.

- IST-1.I.1: Mendel's laws of segregation and independent assortment can be applied to genes that are on different chromosomes.
- IST-1.I.2: Fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in the zygote—
    - a. Rules of probability can be applied to analyze passage of single-gene traits from parent to offspring.
    - b. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genetically linked genes) can often be predicted from data, including pedigree, that give the parent genotype/phenotype and the offspring genotypes/phenotypes.

5.4: Non-Mendelian Genetics

- IST-1.J.1: Patterns of inheritance of many traits do not follow ratios predicted by Mendel's laws and can be identified by quantitative analysis, where observed phenotypic ratios statistically differ from the predicted ratios—
    - a. Genes that are adjacent and close to one another on the same chromosome may appear to be genetically linked; the probability that genetically linked genes will segregate as a unit can be used to calculate the map distance between them.
- IST-1.J.2: Some traits are determined by genes on sex chromosomes and are known as sexlinked traits. The pattern of inheritance of sex-linked traits can often be predicted from data, including pedigree, indicating the parent genotype/phenotype and the offspring genotypes/phenotypes.
- IST-1.J.3: Many traits are the product of multiple genes and/or physiological processes acting in combination; these traits therefore do not segregate in Mendelian patterns.
- IST-1.J.4: Some traits result from non-nuclear inheritance—
    - a. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow simple Mendelian rules.
    - b. In animals, mitochondria are transmitted by the egg and not by sperm; as such, traits determined by the mitochondrial DNA are maternally inherited.
    - c. In plants, mitochondria and chloroplasts are transmitted in the ovule and not in the pollen; as such, mitochondria-determined and chloroplast-determined traits are maternally inherited.

5.5: Environmental Effects on Phenotype

- SYI-3.B.1: Environmental factors influence gene expression and can lead to phenotypic plasticity. Phenotypic plasticity occurs when individuals with the same genotype exhibit different phenotypes in different environments.

5.6: Chromosomal Inheritance

- SYI-3.C.1: Segregation, independent assortment of chromosomes, and fertilization result in genetic variation in populations.
- SYI-3.C.2: The chromosomal basis of inheritance provides an understanding of the pattern of transmission of genes from parent to offspring.
- SYI-3.C.3: Certain human genetic disorders can be attributed to the inheritance of a single affected or mutated allele or specific chromosomal changes, such as nondisjunction.

Learning Objectives

5.1: Meiosis

- IST-1.F: Explain how meiosis results in the transmission of chromosomes from one generation to the next.
- IST-1.G: Describe similarities and/or differences between the phases and outcomes of mitosis and meiosis.

5.2: Meiosis & Genetic Diversity

- IST-1.H: Explain how the process of meiosis generates genetic diversity

5.3: Mendelian Genetics
- EVO-2.A: Explain how shared, conserved, fundamental processes and features support the concept of common ancestry for all organisms.
- IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws

5.4: Non-Mendelian Genetics
- IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.

5.5: Environmental Effects on Phenotype
- SYI-3.B: Explain how the same genotype can result in multiple phenotypes under different environmental conditions.

5.6: Chromosomal Inheritance
- SYI-3.C: Explain how chromosomal inheritance generates genetic variation in sexual reproduction.

Evidence of Learning

Common Assessment

FruitFly Lab with Lab Write Up

Resources

Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8

Suggested Resources & Activities:

Stickleback Genetics and Chi Squared
Mendel's Paper
Hemophilia Case Study
Meiosis and Genetics
Genetics Problems Doc
Mendelian Inheritance Presentation
Mendel's Law of Segregation
HHMI Sickle Cell Genetics
Effects of Environment
Genetic Disorders Project

Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology

Unit Title: Unit 6 Gene Expression & Regulation
Content Area: Science
Course & Grade Level: AP Biology, 11-12
Summary and Rationale
Progressing from the continuity of life to gene expression, in Unit 6 students gain in-depth knowledge about nucleic acids and their role in gene expression. Students receive a finer focus on the comparison between the structures of DNA and RNA. This unit highlights how an individual's genotype is physically expressed through that individual's phenotype. Understanding protein synthesis (transcription and translation) is vital to answering essential questions about gene expression. Regulation of gene expression and cell specialization are instrumental in ensuring survival within an individual and across populations. Unit 7 moves on to cover natural selection.
Recommended Pacing
18-21 Class Periods
NGSS Standards
HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
HS-LS1-1. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, based on evidence, that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.

Mathematics

- Represent symbolically evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the variation and distribution of expressed traits in a population.

21st Century Life and Careers/Technology Standards:

8.1 Educational Technology: All students will use digital tools to access, manage, evaluate, and synthesize information in order to solve problems individually and collaborate and to create and communicate knowledge.

8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming:
All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.
9.2.12.C.4 Analyze how economic conditions and societal changes influence employment trends and future education.

9.2.12.C.3 Identify transferable career skills and design alternate career plans.

Social Studies

Standard 6.1 U.S. History: America in the World. All students will acquire the knowledge and skills to think analytically about how past and present interactions of people, cultures, and the environment shape the American heritage. Such knowledge and skills enable students to make informed decisions that reflect fundamental rights and core democratic values as productive citizens in local, national, and global communities.
Standard 6.2 World History: Global Studies: All students will acquire the knowledge and skills to think analytically and systematically about how past interactions of people, cultures, and the environment affect issues across time and cultures. Such knowledge and skills enable students to make informed decisions as socially and ethically responsible world citizens in the 21st century.

Instructional Focus

Unit Enduring Understandings

- IST-1 Heritable information provides for continuity of life
- IST-2 Differences in the expression of genes account for some of the phenotypic differences between organisms.

Unit Essential Knowledge

6.1: DNA & RNA Structure

- IST-1.K.1 DNA, and in some cases RNA, is the primary source of heritable information.
- IST-1.K.2 Genetic information is transmitted from one generation to the next through DNA or RNA—
    - a. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNA molecules.
    - b. Prokaryotic organisms typically have circular chromosomes, while eukaryotic organisms typically have multiple linear chromosomes.
- IST-1.K.3 Prokaryotes and eukaryotes can contain plasmids, which are small extrachromosomal, double-stranded, circular DNA molecules.
- IST-1.L.1 DNA, and sometimes RNA, exhibits specific nucleotide base pairing that is conserved through evolution: adenine pairs with thymine or uracil (A-T or A-U) and cytosine pairs with guanine (C-G)— a. Purines (G and A) have a double ring structure. b. Pyrimidines (C, T, and U) have a single ring structure.

6.2: Replication

- IST-1.M.1 DNA replication ensures continuity of hereditary information—
    - a. DNA is synthesized in the 5’ to 3’ direction.
    - b. Replication is a semiconservative process—that is, one strand of DNA serves as the template for a new strand of complementary DNA.
    - c. Helicase unwinds the DNA strands.
    - d. Topoisomerase relaxes supercoiling in front of the replication fork.
    - e. DNA polymerase requires RNA primers to initiate DNA synthesis.
    - f. DNA polymerase synthesizes new strands of DNA continuously on the leading strand and discontinuously on the lagging strand.
    - g. Ligase joins the fragments on the lagging strand.

6.3: Transcription & RNA Processing

- IST-1.N.1 The sequence of the RNA bases, together with the structure of the RNA molecule, determines RNA function—
    - a. mRNA molecules carry information from DNA to the ribosome.
    - b. Distinct tRNA molecules bind specific amino acids and have anticodon sequences that base pair with the mRNA. tRNA is recruited to the ribosome during translation to generate the primary peptide sequence based on the mRNA sequence.
    - c. rRNA molecules are functional building blocks of ribosomes.
- IST-1.N.2 Genetic information flows from a sequence of nucleotides in DNA to a sequence of bases in an mRNA molecule to a sequence of amino acids in a protein.
- IST-1.N.3 RNA polymerases use a single template strand of DNA to direct the inclusion of bases in the newly formed RNA molecule. This process is known as transcription.
- IST-1.N.4 The DNA strand acting as the template strand is also referred to as the noncoding strand, minus strand, or antisense strand. Selection of which DNA strand serves as the template strand depends on the gene being transcribed.
- IST-1.N.5 The enzyme RNA polymerase synthesizes mRNA molecules in the 5’ to 3’ direction by reading the template DNA strand in the 3’ to 5’ direction.
- IST-1.N.6 In eukaryotic cells the mRNA transcript undergoes a series of enzyme-regulated modifications—
    - a. Addition of a poly-A tail.
    - b. Addition of a GTP cap.
    - c. Excision of introns and splicing and retention of exons.
    - d. Excision of introns and splicing and retention of exons can generate different versions of the resulting mRNA molecule; this is known as alternative splicing

6.4: Translation

- IST-1.O.1 Translation of the mRNA to generate a polypeptide occurs on ribosomes that are present in the cytoplasm of both prokaryotic and eukaryotic cells and on the rough endoplasmic reticulum of eukaryotic cells.
- IST-1.O.2 In prokaryotic organisms, translation of the mRNA molecule occurs while it is being transcribed.
- IST-1.O.3 Translation involves energy and many sequential steps, including initiation, elongation, and termination.
- IST-1.O.4 The salient features of translation include—
    - a. Translation is initiated when the rRNA in the ribosome interacts with the mRNA at the start codon.
    - b. The sequence of nucleotides on the mRNA is read in triplets called codons.
    - c. Each codon encodes a specific amino acid, which can be deduced by using a genetic code chart. Many amino acids are encoded by more than one codon.
    - d. Nearly all living organisms use the same genetic code, which is evidence for the common ancestry of all living organisms.
    - e. tRNA brings the correct amino acid to the correct place specified by the codon on the mRNA.
    - f. The amino acid is transferred to the growing polypeptide chain.
    - g. The process continues along the mRNA until a stop codon is reached.
    - h. The process terminates by release of the newly synthesized polypeptide/protein.
- IST-1.O.5 Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome into DNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny

6.5: Regulation of Gene Expression

- IST-2.A.1 Regulatory sequences are stretches of DNA that interact with regulatory proteins to control transcription.
- IST-2.A.2 Epigenetic changes can affect gene expression through reversible modifications of DNA or histones.
- IST-2.A.3 The phenotype of a cell or organism is determined by the combination of genes that are expressed and the levels at which they are expressed—
    - a. Observable cell differentiation results from the expression of genes for tissue specific proteins.
    - b. Induction of transcription factors during development results in sequential gene expression
- IST-2.B.1 Both prokaryotes and eukaryotes have groups of genes that are coordinately regulated—
    - a. In prokaryotes, groups of genes called operons are transcribed in a single mRNA molecule. The *lac* operon is an example of an inducible system.
    - b. In eukaryotes, groups of genes may be influenced by the same transcription factors to coordinately regulate expression.

6.6: Gene Expression & Cell Specialization

- IST-2.C.1 Promoters are DNA sequences upstream of the transcription start site where RNA polymerase and transcription factors bind to initiate transcription.
- IST-2.C.2 Negative regulatory molecules inhibit gene expression by binding to DNA and blocking transcription.
- IST-2.D.1 Gene regulation results in differential gene expression and influences cell products and function.
- IST-2.D.2 Certain small RNA molecules have roles in regulating gene expression.

6.7: Mutations

- IST-2.E.1 Changes in genotype can result in changes in phenotype—
    - a. The function and amount of gene products determine the phenotype of organisms.
        - i. The normal function of the genes and gene products collectively comprises the normal function of organisms.
        - ii. Disruptions in genes and gene products cause new phenotypes.
- IST-2.E.2 Alterations in a DNA sequence can lead to changes in the type or amount of the protein produced and the consequent phenotype. DNA mutations can be positive, negative, or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein.
- IST-4.A.1 Errors in DNA replication or DNA repair mechanisms, and external factors, including radiation and reactive chemicals, can cause random mutations in the DNA—
    - a. Whether a mutation is detrimental, beneficial, or neutral depends on the environmental context.
    - b. Mutations are the primary source of genetic variation.
- IST-4.A.2 Errors in mitosis or meiosis can result in changes in phenotype—
    - a. Changes in chromosome number often result in new phenotypes, including sterility caused by triploidy, and increased vigor of other polyploids.
    - b. Changes in chromosome number often result in human disorders with developmental limitations, including Down syndrome/ Trisomy 21 and Turner syndrome.
- IST-4.B.1 Changes in genotype may affect phenotypes that are subject to natural selection. Genetic changes that enhance survival and reproduction can be selected for by environmental conditions—
    - a. The horizontal acquisitions of genetic information primarily in prokaryotes via transformation (uptake of naked DNA), transduction (viral transmission of genetic information), conjugation (cell-to-cell transfer of DNA), and transposition (movement of DNA segments within and between DNA molecules) increase variation
    - b. Related viruses can combine/recombine genetic information if they infect the same host cell.
    - c. Reproduction processes that increase genetic variation are evolutionarily conserved and are shared by various organisms.

6.8: Biotechnology

- IST-1.P.1 Genetic engineering techniques can be used to analyze and manipulate DNA and RNA—
  - a. Electrophoresis separates molecules according to size and charge.
  - b. During polymerase chain reaction (PCR),
  - c. Bacterial transformation introduces DNA into bacterial cells.
  - d. DNA sequencing determines the order of nucleotides in a DNA molecule

Learning Objectives

6.1: DNA & RNA Structure

- IST-1.K Describe the structures involved in passing hereditary information from one generation to the next
- IST-1.L Describe the characteristics of DNA that allow it to be used as the hereditary material.

6.2: Replication

- IST-1.M Describe the mechanisms by which genetic information is copied for transmission between generations.

6.3: Transcription & RNA Processing

- IST-1.N Describe the mechanisms by which genetic information flows from DNA to RNA to protein.

6.4: Translation

- IST-1.O Explain how the phenotype of an organism is determined by its genotype.

6.5: Regulation of Gene Expression

- IST-2.A Describe the types of interactions that regulate gene expression.
- IST-2.A Describe the types of interactions that regulate gene expression.

6.6: Gene Expression & Cell Specialization

- IST-2.C Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism
- IST-2.D Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms.

6.7: Mutations

- IST-2.E Describe the various types of mutation.
- IST-4.A Explain how changes in genotype may result in changes in phenotype.
- IST-4.B Explain how alterations in DNA sequences contribute to variation that can be subject to natural selection.

6.8: Biotechnology

- IST-1.P Explain the use of genetic engineering techniques in analyzing or manipulating DNA.

Evidence of Learning

Common Assessments

Stickleback Evolution/Gene Regulation
Biotechnology Lab Setup & Analysis

Resources

Core Text: Biology in Focus *AP Edition, Campbell, ISBN-13: 978-0-13-310217-8

Suggested Resources:

HHMI Rock Pocket Mice Mutations
Case Study: Classic Experiments in Molecular Biology. The Transforming Factor
Lactose Intolerance Regulation Click and Learn

RNAi Click and Learn
DNA Molecule of the Month Assignment
Gene Expression POGIL
https://www.dnalc.org/resources/3d/04-mechanism-of-replication-advanced.html
Lactose Intolerance Questions
RNAi Questions
Adapted from AP Biology Course and Exam Description:
https://apcentral.collegeboard.org/pdf/ap-biology-course-and-exam-description-0.pdf?course=ap-biology