Unit 02: Cell Structure and Function

Content Area:	**Science**
Course(s):	**AP Biology**
Time Period:	**October**
Length:	**3 weeks**
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Transfer Skills

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.

On the exam, students frequently can correctly identify an organelle but fail to accurately describe its function. Students should be able to explain the relationships between structure and function on both the subcellular and cellular level. Avoid using catchy analogies (e.g., cell city) and food-based models because on the exam students tend to write about the analogy without demonstrating an understanding of its underlying concept using appropriate terminology. The graphing skills learned in this unit are important. Students should be able to label the independent and dependent variables with units, correctly plot data points with appropriate scaling, and correctly represent the data in question. For instance, a line graph should be used for continuous data and a bar graph for categorical data. Students often fail to earn points because they draw error bars incorrectly and fail to use them to draw conclusions about the significance of the data.

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.

Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.

Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

Essential Questions

How did eukaryotic cells evolve?

How do the mechanisms for transport across membranes support energy conservation?

What are the advantages and disadvantages of cellular compartmentalization?

How are living systems affected by the presence or absence of subcellular components?

Content

Prokaryotic vs. eukaryotic cells

Compartmentalization and the structure and function of cellular organelles

Endosymbiosis

Cell specialization

Cell size vs. surface area to volume ratio in relationship to efficiency

Cell membrane structure and function

Transport across cell membranes

Water potential

Osmoregulation

Nervous system and neuron structure and function

Learning Objectives

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

ENE-2.G Explain how the structure of a molecule affects its ability to pass through the plasma membrane.
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.
ENE-2.J Describe the processes that allow ions and other molecules to move across membranes.
ENE-2.K Describe the membranebound structures of the eukaryotic cell.
ENE-2.L Explain how internal membranes and membranebound organelles contribute to compartmentalization of eukaryotic cell functions.
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.

Standards

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.
***X** Specific functions of smooth ER in specialized cells is beyond the scope of the course and the AP exam.*
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.
***X** The role of the Golgi in the synthesis of specific phospholipids and the packaging of specific enzymes for lysosomes, peroxisomes and secretory vesicles is beyond the scope of the course and the AP exam.*
b. Mitochondria have a double membrane.
c. Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes.
d. A vacuole is a membrane-bound sac that plays many and differing roles. In plants, a specialized large vacuole serves multiple functions.
e. Chloroplasts are specialized organelles that are found in photosynthetic algae and plants. Chloroplasts have a double outer membrane.
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.
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.
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 he 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.
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.
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 N2, O2, and CO2 , freely pass across the membrane. Hydrophilic substances, such as large polar molecules and ions, move across the membrane through embedded channel and transport proteins.
ENE-2.C.5 Polar uncharged molecules, including H2O, 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.
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.

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 movement of ions across the membrane.

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.

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.

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.

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.

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.

EVO-1.A.1 Membrane-bound organelles evolved from once free-living prokaryotic cells via endosymbiosis.

EVO-1.A.2 Prokaryotes generally lack internal membranebound 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.