AP Biology
Cell Structure and Function – Topics 2.1 through 2.6

Topic 2.1 Cell Structure: Subcellular Components

<table>
<tr><td colspan="2">Enduring Understanding SYI-1

Living systems are organized in a hierarchy of structural levels that interact.</td></tr>
<tr><td>Learning Objective</td><td>Essential Knowledge</td></tr>
<tr><td>SYI-1.D
Describe the structure and/or function of subcellular components and organelles.</td><td>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 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.
b. Mitochondria have a double membrane. The outer membrane is smooth, but the inner membrane is highly convoluted, forming folds.
c. Lysosomes are membrane-enclosed sacs that contain hydrolytic enzymes.
d. A vacuole is a membrane-bound sac that plays many 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.</td></tr>
</table>

Topic 2.2 Cell Structure and Function

<table>
<tr><td colspan="2">Enduring Understanding SYI-1

Living systems are organized in a hierarchy of structural levels that interact.</td></tr>
<tr><td>Learning Objective</td><td>Essential Knowledge</td></tr>
<tr><td>SYI-1.E
Explain how subcellular components and organelles contribute to the function of the cell.</td><td>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 support.
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.</td></tr>
<tr><td>SYI-1.F
Describe the structural features of a cell that allow organisms to capture, store and use energy.</td><td>ENE-1.F.1
The folding of the inner membrane increases the surface area, which allows for more ATP to be synthesized.

ENE-1.F.2
Within the chloroplast are thylakoids and the stroma.

ENE-1.F.3
The thylakoids are organized into stacks, called grana.

ENE-1.F.4
Membranes contain chlorophyll pigments and electron transport proteins that comprise photosystems.

ENE-1.F.5
The light-dependent reactions of photosynthesis occur in the grana.

ENE-1.F.6
The stroma is the fluid within the inner chloroplast membrane and outside of the thylakoid.

ENE-1.F.7
The carbon fixation (Calvin-Benson cycle) reactions of photosynthesis occur in the stroma.

ENE-1.F.8
The Krebs cycle (citric acid cycle) reactions occur in the matrix of the mitochondria.</td></tr>
</table>

	ENE-1.F.9 Electron transport and ATP synthesis occur on the inner mitochondrial membrane.

Topic 2.3 Cell Size

Enduring Understanding ENE-1 The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.	
Learning Objective	**Essential Knowledge**
ENE-1.B Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment. **ERROR – The correct equation for the volume of a cube is:** $V = s^3$	**ENE-1.B.1** Surface area-to-volume ratios affect the ability of biological systems 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: $V = \frac{4}{3}\pi r^3$ Volume of a Cube: $V = s^2$ Volume of a Rectangular Solid: $V = lwh$ Volume of a Cylinder: $V = \pi r^2 h$ Surface Area of a Sphere: $SA = 4\pi r^2$ Surface Area of a Cube: $SA = 6s^2$ Surface Area of a Rectangular Solid: $SA = 2lh + 2lw + 2wh$ Surface Area of a Cylinder: $SA = 2\pi rh + 2\pi r^2$ 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 Explain how specialized structures and strategies are used for the efficient exchange of molecules to 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

Enduring Understanding ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.	
Learning Objective	**Essential Knowledge**
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.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 with 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 Describe the Fluid Mosaic Model of cell membranes.	**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

Enduring Understanding ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.	
Learning Objective	**Essential Knowledge**
ENE-2.C Explain how the structure of biological membranes influence selective 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, include 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 channel and transport proteins. **ENE-2.C.5** Polar uncharged molecules, including H_2O, pass through the membrane in small amounts.
ENE-2.D Describe the role of the cell wall in maintaining cell structure and function.	**ENE-2.D.1** Cell walls of plants, prokaryotes, and fungi are composed of complex carbohydrates.

Topic 2.6 Membrane Transport

Enduring Understanding ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.	
Learning Objective	**Essential Knowledge**
ENE-2.E Describe the mechanisms that organisms use to maintain solute and water balance.	**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 Describe the mechanisms that organisms use to transport large molecules across the plasma membrane.	**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 process 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.

AP Biology
Cell Structure and Function – Topics 2.7 through 2.9

Topic 2.7 Facilitated Diffusion

<table>
<tr><td colspan="2">Enduring Understanding ENE-2

Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.</td></tr>
<tr><td>Learning Objective</td><td>Essential Knowledge</td></tr>
<tr><td>ENE-2.G
Explain how the structure of a molecule affects its ability to pass through the plasma membrane</td><td>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 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.</td></tr>
</table>

Topic 2.8 Tonicity and Osmoregulation

<table>
<tr><td colspan="2">Enduring Understanding ENE-2

Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.</td></tr>
<tr><td>Learning Objective</td><td>Essential Knowledge</td></tr>
<tr><td>ENE-2.H
Explain how concentration gradients affect the movement of molecules across membranes.</td><td>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.</td></tr>
</table>

	RELEVANT EQUATION Water Potential: $\Psi = \Psi_p + \Psi_s$ $\Psi_p =$ pressure potential $\Psi_s =$ solute potential
ENE-2.I Explain how osmoregulatory mechanisms contribute to the health and survival of organisms.	**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** $\Psi_s = -iCRT$ where: $i =$ ionization constant $C =$ molar concentration $R =$ pressure constant $\left(R = 0.0831 \frac{L \bullet bars}{mol \bullet K}\right)$ $T =$ temperature in Kelvin (°C + 273)

Topic 2.9 Mechanisms of Transport

Enduring Understanding ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.	
Learning Objective	**Essential Knowledge**
ENE-2.J Describe the processes that allow ions and other molecules to move across membranes.	**ENE-2.J.1** A variety of processes allow for movement of ions and other molecules across membranes, including passive and active transport, endocytosis, and exocytosis.

AP Biology
Cell Structure and Function – Topics 2.10 and 2.11

Topic 2.10 Compartmentalization

Enduring Understanding ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.	
Learning Objective	**Essential Knowledge**
ENE-2.K Describe the membrane-bound structures of the eukaryotic cell.	**ENE-2.K.1** Membranes and membrane-bound organelles in eukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions.
ENE-2.L Explain how internal membranes and membrane-bound organelles contribute to compartmentalization of eukaryotic cell functions.	**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

Enduring Understanding 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.	
Learning Objective	**Essential Knowledge**
EVO-1.A Describe similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells.	**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 Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts.	**EVO-1.B.1** Membrane-bound organelles evolved from previously free-living prokaryotic cells via endosymbiosis.