

AP[®]
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AP[®] Teacher Manual
Sample Chapter

BIOLOGY

Mc
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Education

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Chapter 4: Cell Structure and Function

AP Unit(s): Unit 2 - Cell Structure and Function

Chapter Section	Activities and Labs	Topics Covered
4.1 Cellular Level of Organization	<ul style="list-style-type: none"> Nature of Science Special Feature: <i>Microscopy Today</i> (SE, pp. 60-61) Procedure 1 in Investigation 4 (AP Lab Manual) with worksheet Limits to Cell Size (TM, p. 13-14) 	2.1, 2.2, 2.3
4.2 Prokaryotic Cells		2.5, 2.11
4.3 Introduction to Eukaryotic Cells	<ul style="list-style-type: none"> Endosymbiosis Demonstration (TM, p. 5) Review of Cellular Organelles (TM, p. 6-8) Build-A-Cell (TM, p. 9-12) 	2.10, 2.11
4.4 The Nucleus and Ribosome		2.1, 2.10, 2.11
4.5 The Endomembrane System		2.1, 2.2, 2.3, 2.10
4.6 Microbodies and Vacuoles		2.2, 2.3, 2.10
4.7 The Energy-Related Organelles		2.1, 2.2, 2.3, 2.10, 2.11
4.8 The Cytoskeleton		
Review and Assessment	Assessing the Big Ideas (SE, pp. 80-81) Applying the Science Practices (SE, pp. 81) Focus Review Guide (pp. 19-29) Study Strategies (TM, p. 15) Additional Questions for AP Practice (TM, p. 16)	

Key Concepts

- The cell theory states that all organisms consist of one or more cells and that cells come from existing cells
- Cells are limited in size by their surface-to-volume ratio
- Prokaryotic cells evolved first and are smaller than eukaryotic cells
- Prokaryotic cell membranes do not fold to provide surface area for enzyme attachment
- The theory of endosymbiosis explains the origin of many organelles
- The nucleus of the eukaryotic cells evolved from enfolding of the cell membrane to surround the chromatin material
- Ribosomes are the site of protein synthesis and are composed of rRNA and proteins
- The endomembrane system moves and modifies proteins and in some cases synthesizes lipids
- Vacuoles and microbodies can store material for use or export and in some cases contain enzymatic reactions
- Chloroplasts are the site of carbohydrate production in photosynthetic eukaryotic cells
- Mitochondria are the site of conversion of molecules to ATP in eukaryotic cells
- Cytoskeleton consists of actin filament, intermediate filaments and microtubules and functions to support the nucleus and plasma membrane and to move organelles as needed

Key Terms

capsule	eukaryotic cells	plasma membrane
cell wall	glycocalyx	prokaryotic cells
chloroplast	mitochondrion	ribosome
cytoplasm	nucleoid region	surface-area-to-volume ratio
endomembrane system	nucleus	ratio
endosymbiotic theory	organelles	vacuoles

Teaching Strategies

This will probably not be the first time that your students have heard about organelles. The evolutionary connection between the first cells on Earth, the prokaryotes, and the theory of endosymbiosis will probably be new to them. I would start with organelles and the differences between prokaryotes and eukaryotes and then move to endosymbiosis.

This chapter also contains information about the restrictions on cell size. Chapter 5 concentrates on cell membranes and transport but Procedure 1 in Investigation 4 of the College Board Manual involves a cell size activity. I would have students conduct this investigation now.

Teaching Tips for the New Curriculum

It can be easy to get carried away with fun activities and models of cells, but the curriculum places only limited focus on knowing the names and functions of individual organelles. The learning objective to focus on is SYI-1.E. Most students in an AP class will have background on the basic functions covered in SYI-1.D so a simple but effective graphic organizer can do the trick. The larger focus in AP Biology is how the organelles work in unison and how their functions are interdependent. Having students practice scenarios based on overall cellular function rather than organelle function can allow for review of the organelles while getting to the next level of understanding at the same time. The organelles and their individual roles in the cell are similar to vocabulary, but understanding the interactions between them is something that can't really be studied with flashcards.

Suggested Approach

Class time: Allow three days consisting of 45 minute periods to cover the information on cells.

Day 1: 20 minute lecture on prokaryotes, eukaryotes and endosymbiosis.

Demonstration of endosymbiosis

Day 2: Have students work in groups to review cellular organelles with the attached worksheet.

Day 3: Have students conduct Procedure 1 in Investigation 4 of the College Board Manual. Attached is a worksheet to accompany this investigation.

Teaching Tip: One alternative approach to cells is to assign a cell project like the one detailed in the activities section. The project is intended for group work and involves cell communication which is described in Chapter 5.

Student Misconceptions and Pitfalls

One common misconception about cells that many students have is that ribosomes have a double membrane because they are organelles. Ribosomes do not have a membrane. Most students get the function of the nucleolus, production of rRNA, confused with the function of the nucleus, housing DNA and site of mRNA production.

Suggested Activities

Attached are directions/worksheets for the following activities:

1. **Endosymbiosis Demonstration:** Students will watch how it is thought one prokaryote became trapped inside another.
2. **Review of Cellular Organelles:** Students will fill out a worksheet to review the organelles.
3. **Build-A-Cell:** Students will build a model of a cell out of edible materials.
4. **Limits to Cell Size:** A worksheet to accompany Procedure 1, Investigation 4 in the AP Lab Manual

Endosymbiosis Demonstration

Allow five minutes for a short demonstration on endosymbiosis. Prior to class, place a small balloon inside of a larger balloon. Blow both balloons up together to represent one prokaryote becoming trapped inside of another cell. Explain that the trapped cell evolved into the mitochondria and ask students to provide evidence that this occurred. They should be able to tell you that the mitochondrion today has its own DNA, its own ribosomes, is about the same size as a prokaryotic cell and has an inner membrane structure similar to the enfolding of a prokaryotic cell membrane.

Review of Cellular Organelles

Work in groups to review the characteristics of different cellular organelles. **Sketch** the basic structure of the organelle, **describe** its function, and **identify** if it is found in prokaryotes and/or eukaryotes, or if it is specific to animals or plants.

CELL ORGANELLES						
Cell Part	Structure	Function	Prokaryotes	Eukaryote	Animal	Plant
Plasma membrane						
Cell wall						
Ribosomes						
Chromatin						
Nucleus and nuclear envelope						
Cytoplasm						
Cytoskeleton						
Nucleolus						

CELL ORGANELLES						
Cell Part	Structure	Function	Prokaryotes	Eukaryote	Animal	Plant
Endoplasmic reticulum						
Golgi apparatus						
Mitochondria						
Chloroplast						
Vacuole						
Lysosomes, peroxisomes, and secretory vesicles						
Cilia						
Flagella						

CELL ORGANELLES						
Cell Part	Structure	Function	Prokaryotes	Eukaryote	Animal	Plant
Centriole						
Plastid						

Build-A-Cell

This project helps students understand in detail how homeostasis is maintained by organisms. This includes the structure and interactions that occur between various cells, tissues, and organs. Students will produce a model of a specialized cell that will emphasize how structure fits function.

Projects will center around one of the specialized cells that are found in the immune, endocrine, or lymphatic system.

Suggested Groups:

- 1: Non-specific immune response in plants, vertebrates, and invertebrates
- 2: Specific Immunity (cell mediated response): Helper T-cells, cytotoxic T-cells, MHC
- 3: Humoral Response: B- cells, plasma cells, antibodies, helper T-cells
- 4: Active and Passive Immunity: memory cells and 2nd exposure
- 5: Structure of Neuron: glial cells, neuron, astrocytes: action potential & neurotransmitters
- 6: Hearing and Vision: sensory receptors, integration of sensory input
7. Endocrine: insulin: feedback mechanisms: pancreatic cell
8. HGH in conjunction with Insulin like growth factor: liver cell
9. Anterior Pituitary: neurosecretory cell
10. Testosterone/estrogen: oocyte or spermatocyte

1. Students will need to research the shape and components that are found in your specialized cell. They will construct a 3-D model of a specialized cell, labeling organelles and other important structures that are found in your cell.

- For this portion of the activity, provide students with a diagram of a cell. Then, ask students to design a 3D cell model based off of the diagram using edible components. You can either provide the components or make this a take-home activity. This activity can be performed individually, in pairs, or in small groups.
- To get students started on how to choose appropriate components, ask students questions such as: what would be a good representation for a ribosome? M&Ms? Cheerios? Olives? Encourage students to consider how the parts function as well as how they are structured and where they are located in the cell.

2. The student will research and provide detailed information about cell signaling that occurs in this system.

- What is the significance of signals that are received by this cell(s) and where do these signals originate?
- What types of signals are initiated by your one of cell(s) and what is their target?
- What is the specific signal transduction pathway and what is the desired response?

3. Make connections between normal cell functioning and a disease state.
 - The disease cannot be cancer.
 - Communicate with a support group or health care provider that works with this disease. Proof of this connection includes printed emails or printed material from the organization.
 - Describe a day in high school for a teenage with this disease.
4. Have students describe the cell's contribution to maintaining homeostasis for the human body.
5. Have students explain one example of an evolutionary trend for the system that their cell represents.
5. Student Handout is on following page.

Build-A-Cell

How is homeostasis is maintained by organisms?

In this activity, you will produce a model of a specialized cell that will emphasize how structure fits function.

1. Choose one of the specialized cells that are found in the immune, endocrine, or lymphatic system such as:
 - 1: Non-specific immune response in plants, vertebrates, and invertebrates
 - 2: Specific Immunity (cell mediated response): Helper T-cells, cytotoxic T-cells, MHC
 - 3: Humoral Response: B- cells, plasma cells, antibodies, helper T-cells
 - 4: Active and Passive Immunity: memory cells and 2nd exposure
 - 5: Structure of Neuron: glial cells, neuron, astrocytes: action potential & neurotransmitters
 - 6: Hearing and Vision: sensory receptors, integration of sensory input
 7. Endocrine: insulin: feedback mechanisms: pancreatic cell
 8. HGH in conjunction with Insulin like growth factor: liver cell
 9. Anterior Pituitary: neurosecretory cell
 10. Testosterone/estrogen: oocyte or spermatocyte
2. Research the shape and components that are found in your specialized cell.
3. Construct a 3-D model of a specialized cell, labeling organelles and other important structures that are found in your cell, out of edible materials.
4. Research and provide detailed information about cell signaling that occurs in this system.
 - What is the significance of signals that are received by this cell(s) and where do these signals originate?
 - What types of signals are initiated by your one of cell(s) and what is their target?
 - What is the specific signal transduction pathway and what is the desired response?

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 - The disease cannot be cancer.
 - Communicate with a support group or health care provider that works with this disease. Proof of this connection includes printed emails or printed material from the organization.
 - Describe a day in high school for a teenage with this disease.
6. Describe the cell's contribution to maintaining homeostasis for the human body.
7. Explain one example of an evolutionary trend for the system that their cell represents.

Grades will reflect organization, technical accuracy, and a clear, engaging, creative presentation.

Remember to:

8. use visual aids
9. be organized in your presentation
10. provide an outline summary with works cited page for your fellow classmates.
Outlines should not exceed front and back of a page, no smaller than 11 font
11. write important vocabulary on the board
12. practice your presentation out loud prior to the classroom presentation
13. take time to coordinate your presentation among group members
14. if you need to use notes during your presentation, make them in an outline form
15. at no time should you be reading to your classmates
16. cite all images you 'borrow' for you visual presentation
 - citation should be with/on the image itself
17. cite all sources you use to gain information

Limits to Cell Size

to accompany Procedure 1, Investigation 4

Surface Area to Volume Ratio Activity

Cube: The surface area and volume of a cube can be found with the following equations:

$$S = 6l^2 \text{ and } V = l^3$$

$$S = 6l^2 \text{ and } V = l^3$$

where S = surface area (in units squared), V = volume (in units cubed), and l = the length of one side of the cube.

1. From the baking dish, cut blocks of specific sizes:

1cm x 1cm x 1cm

2cm x 2cm x 2cm

3cm x 3cm x 3cm. Calculate volume, surface area, SA:V ratio for each block.

2. Immerse each block in white vinegar.

Time and record how long it takes for the blue to completely disappear.

Create a data table for your results- time and SA:V ratios for each cube.

Prepare a Data Table 1 and place this information into that data table.

3. Then take an ice cube block of the agar and design and make your own cell to maximize volume mass, but minimize diffusion time.

- No donut-like holes through the agar cell.
- No poking, prodding, touching beaker containing agar cell in vinegar.
- Teacher determines when 100% diffusion takes place.
- Students mass agar at conclusion of race...cell must not break when handled.
- Disqualification if cell breaks upon massing.
- Winner = highest ratio of mass divided by time.

Analysis Questions

1. Describe the results from the comparative diffusion trials in Table 1.
2. Explain the results from the comparative diffusion trials in Table 1.
3. In general, what is the relationship between cell volume and diffusion time?
4. In general, what is the relationship between surface area and diffusion time?
5. Explain why cells can't get very, very big.
6. Explain how cell shape can be modified so that diffusion can support life processes.
7. Which team's cell won the race? Offer a hypothesis as to why.

Study Strategies

These activities are designed for those students struggling with the language demands of the AP Biology course.

Using Visual and Contextual Support

Intermediate

Before reading, have students take a close look at the visual support. Have them use the image as they work in pairs to form questions about the selection. After reading, have partners compare their original predictions with questions they answered no. Have them discuss how their ideas changed or stayed the same. Move around the room to monitor progress.

Comprehension Skill

Advanced High

Ask questions about lesson content to elicit complete sentences:

What is the cell theory? *The cell theory states that all organisms consist of one or more cells and that cells come from existing cells.* What purpose do vacuoles and microbodies serve in a cell? *Vacuoles and microbodies can store material for use or export and in some cases contain enzymatic reactions.*

Additional Questions for AP Practice

1. Explain the theory of endosymbiosis and justify its role in evolution.
2. Describe the components of the endomembrane system and explain their importance.
3. Choose the best prediction of the fate of a protein that is produced on a ribosome that is embedded in the rough endoplasmic reticulum.
 - A) The protein will be added to new rRNA and become part of a new ribosome.
 - B) The protein will be released immediately via exocytosis and act as a signal protein.
 - C) The protein will definitely have a carbohydrate attached to it in the lumen of the ER.
 - D) The protein may be delivered to the golgi for further processing.
4. Determine the surface area to volume ratio of a cell with a roughly cube shape of $3.25 \mu\text{m}$.
5. Describe the features of a cell that organisms in all Domains share.

Answers to Additional Questions for AP Practice

- 1. The endosymbiotic theory states mitochondria and chloroplasts were independent prokaryotes that took up residence in a eukaryotic cell. The functions within the cell became specialized with the mitochondria becoming specialized to produce ATP. Endosymbiosis was a beginning step toward the origin of the eukaryotic*
- 2. The endomembrane system consists of the nuclear envelope, the membranes of the endoplasmic reticulum, the Golgi apparatus, and several types of vesicles. This system compartmentalizes the cell so that particular enzymatic reactions are restricted to specific regions and overall cell efficiency is increased. The vesicles transport molecules from one part of the system to another.*
- 3. D is the best answer. Most proteins are added to the rRNA in the nucleolus. Most proteins have some sort of refinement before they are released from the cell. While many proteins have carbohydrates added to them in the lumen of the ER, not all of them are processed in this way.*
- 4. SA: $3.25 \times 3.25 \times 6 = 63.375 \mu\text{m}$. Volume = $3.25 \times 3.25 \times 3.25 = 34.328$
SA: Volume = 63.375: 34.328 or reduced to 1.8: 1*
- 5. All cells have a cell membrane, DNA and RNA, ribosomes, and cytoplasm. All cells practice the central dogma of biology; DNA carries the code for protein production that is passed onto mRNA. mRNA is used as instructions for making a protein by attaching to a ribosome and providing the code for which amino acids should be delivered to the ribosome by the tRNA.*

Student Edition Chapter Review Answers

Key for Question Alignment Codes	Description of Key
X	This question is not relevant to the updated AP Biology curriculum. It contains specific knowledge, vocabulary, or references that students are no longer tested on. You can skip over these.
Y	This question addresses something that isn't directly in the updated AP Biology curriculum; however, the concept might be useful to teach while teaching the noted Learning Objective. You can use these to build deeper understanding or provide additional examples of concepts.
Z	This question addresses multiple Essential Knowledge pieces at one time. See the Learning Objectives that are being assessed as there might be more than 1.

Answers to Assessing the Big Ideas Questions

Question 1
<p>Cells tend to be small, with sizes ranging between 1 and 100 μm. These small sizes help to ensure that cells have a favorable surface-area-to-volume ratio. Choose the statement that explains why a favorable surface-area-to-volume ratio is advantageous.</p> <p>A) Higher surface-area-to-volume ratios improve the efficiency of transporting materials in and out of cells B) Lower surface-area-to-volume ratios improve the efficiency of transporting materials in and out of cells C) Higher surface-area-to-volume ratios speed up the flow of cytoplasm within cells D) Higher surface-area-to-volume ratios slow down the flow of cytoplasm within cells</p>
<p>Answer: A</p> <p>Having a high surface-area-to-volume ratio means that a cell has a lot of plasma membrane ("surface area") compared to its interior contents ("volume"). That is, there are enough entrances and exits to allow the exchange of sufficient materials with the world outside the cell.</p>
<p>Essential Knowledge: ENE-1.B.1 • Learning Objective: ENE-1.B • Science Practices: 7</p>

Question 2

As proposed by Lynn Margulis, the Serial Endosymbiotic Theory suggested that eukaryotic cells evolved when an ancient cell engulfed another, forming a permanent symbiotic relationship. The engulfed cells became organelles such as mitochondria and chloroplasts. **Choose** the evidence that best justifies this claim.

- A) Both mitochondria and chloroplasts perform energy functions
- B) Eukaryotic cells have many mitochondria
- C) Eukaryotic cells have traits in common with archaea
- D) Mitochondria and chloroplasts contain circular loops of unique DNA

Answer: D

Prokaryotic cells have DNA in the form of circular loops; the fact that their DNA is different from nuclear DNA suggests that mitochondria were once independent organisms.

Essential Knowledge: EVO-1.B.1 • Learning Objective: EVO-1.B • Science Practices: 6

Question 3

The evolutionary history of prokaryotic and eukaryotic cells has been intensely studied. Which statement would best **justify** the claim that ribosomes are one of the most ancient of all cellular organelles?

- A) Ribosomes are directly involved in vital energy processes
- B) Some ribosomes are attached to endoplasmic reticulum
- C) Ribosomes are found in all cell types in organisms from all 3 domains
- D) Ribosomes in eukaryotes are made of r-RNA, but in prokaryotes they are made of t-RNA

Answer: C

The observation that ribosomes are present in all 3 domains of life implies that they would have been present in the earliest cells, from which modern cells have evolved. Answers A and D are not true.

Essential Knowledge: SYI-1.D.2 • Learning Objective: SYI-1.D • Science Practices: 6

Question 4

Eukaryotic cells possess an extensive endomembrane system. The extensive use of internal membranes gives eukaryotic cells certain useful advantages not seen in prokaryotic cells.

Choose the example that correctly describes one of these advantages.

- A) Nucleic acids can freely mingle with cytoplasmic enzymes
- B) Lysosomes can maintain a much lower pH than the surrounding cytosol
- C) Endoplasmic reticulum is prevented from forming vesicles
- D) Surface area available for chemical reactions is greatly decreased

Answer: B

Lysosomes contain digestive enzymes that work best at lower pH. By being wrapped in a membrane, these enzymes can operate in an acidic environment. The protective membrane allows the lysosome to do its job of breaking down and recycling old organelles without damaging other cell structures.

Essential Knowledge: ENE-2.L.1 • Learning Objective: ENE-2.L • Science Practices: 1

Question 5

Mitochondria are organelles specialized to perform cellular respiration. Mitochondria have their own DNA. Before a cell divides, mitochondria divide in two, doubling the number of mitochondria in the parent cell. Mitochondria cannot be grown in cell-free cultures in the lab. From the answers below, **choose** the best conclusion based on the observations about mitochondria.

- A) Mitochondria are not essential to cells
- B) Cellular respiration is not essential to cells
- C) Mitochondria are self-sustaining, independent of a host cell
- D) Mitochondria are not self-sustaining, and require nuclear DNA

Answer: D

Though mitochondria contain DNA, which codes for some essential respiratory proteins, they also require other proteins coded for by nuclear DNA. Similarly, in order to divide, they require additional proteins, again coded for by nuclear DNA. Thus they cannot be grown separately, outside the cell.

Essential Knowledge: EVO-1.B.1 • Learning Objective: EVO-1.B • Science Practices: 6

Question 6

The liver is an organ with many functions. For example, it plays a major role in the breakdown of fats in the body. **Choose** the organelle that would most likely be abundant in liver cells that break down fats.

- A) Lysosome
- B) Endoplasmic reticulum
- C) Peroxisome
- D) Ribosomes

Answer: C

Peroxisomes

Essential Knowledge: SYI-1.D.6 • Learning Objective: SYI-1.D • Science Practices: 1

Question 7

Actin is a globular protein that forms filaments in many different cells. A disorder that disabled actin filaments would most likely reduce what type of cellular activity?

- A) Glucose synthesis
- B) Movement
- C) Protein synthesis
- D) Digestion of waste material

Answer: B

Actin is involved in many types of movement in eukaryotic cells, including cell crawling, muscle contraction, and cell division.

Essential Knowledge: X Learning Objective: X • Science Practices: X

Question 8

The endoplasmic reticulum (ER) and the Golgi apparatus are prominent components of the endomembrane system. While the two structures have similarities in appearance, they have slightly different functions. Select an example that describes a difference between ER and Golgi:

- A) The ER may add sugars to proteins to make glycoproteins, while the Golgi may modify that glycoprotein
- B) The ER contains ribosomes and is never smooth, while the Golgi is always smooth
- C) The ER consists of channels, while the Golgi consists of saccules
- D) The ER is found in animal cells, while the Golgi is found in plant cells

Answer: A

Rough ER produces proteins, but also contains enzymes that allow it to add sugar chains to those proteins. Once in the Golgi, the glycoproteins may have their sugar chains modified to a different sugar.

Essential Knowledge: Z • Learning Objective: SYI-1.D/E • Science Practices: 1

Question 9

Mitochondria are often referred to as the “powerhouse” of the cell. Identify which statement most accurately identifies the function of the mitochondrion.

- A) They make the energy needed for all cellular functions
- B) They transform electromagnetic energy into chemical energy
- C) They make ATP molecules as a part of cellular respiration
- D) They organize the electrical energy found in certain molecules

Answer: C

It is not possible to “make” energy, as stated in answer B. Mitochondria make ATP molecules, which store chemical energy released from carbohydrates.

Essential Knowledge: SYI-1.F.1 • Learning Objective: SYI-1.F • Science Practices: 1

Question 10

The process of building and controlling proteins on ribosomes is a vital part of a cell's activities. Some manufactured proteins will travel through the ER for processing. What determines whether or not a protein travels through the ER?

- A) The protein must be manufactured in the nucleus
- B) The protein must originate from a neighboring cell
- C) The presence of a signal peptide at the start of the protein
- D) The presence of a signal recognition particle bound to mRNA

Answer: C

The signal peptide at the head of a forming protein will bind with a signal recognition particle (SRP). This combination temporarily halts protein synthesis until the SRP binds to a receptor in the wall of the ER. At this point, the SRP binds off and a channel opens in the ER. Protein synthesis resumes and the protein is fed into the ER channel.

Essential Knowledge: X • Learning Objective: X • Science Practices: X

Answers to Free Response Questions

Question 11

Cells, the smallest units of living matter, make life possible.

- Draw** one generalized prokaryotic cell AND one generalized eukaryotic cell.
- Label** the cellular components.
- Answer** the question: What are two major differences a between prokaryotic and eukaryotic cells? Make sure that these differences are evident in your drawings.

Answer (4 points maximum)

Labeled diagrams and descriptions of differences may include:

Drawings and Labels (1 point each)

- Prokaryotic cell (should include at least 3 of the following for full credit):
- Cell envelope (plasma membrane, cell wall and glycocalyx)
- Cytoplasm
- Nucleoid region
- Ribosomes

Eukaryotic cell (should include at least 3 of the following for full credit):

- Plasma membrane
- Cell wall, chloroplasts and/or vacuole only if diagram is clearly representing a plant cell
- Nucleus
- Cytoplasm
- Organelles (Rough and Smooth ER, Golgi)
- Mitochondria
- Peroxisomes, Lysosomes, Vesicles, and/or Ribosomes

Descriptions of differences (1 point each)

- Nucleus: Prokaryotic cells lack a nucleus and nucleolus and instead have a nucleoid region where their DNA is located.
- Endomembrane system: Membranes and membrane-bound organelles in eukaryotic cells localize (compartmentalize) intracellular metabolic processes and specific enzymatic reactions, as seen with the ER and Golgi.
- Eukaryotic cells may also contain organelles not found in prokaryotic cells, such as: mitochondria, chloroplasts (plants), peroxisomes, and lysosomes (animals).
- Eukaryotic cells are composed of a cytoskeleton.
- Take note: While prokaryotic cells usually have a cell wall, plant cells (eukaryotic) do as well. Additionally, while animal cells often have centrioles, prokaryotic cells and plant cells do not. Animal cells often have flagella or cilia as well, though in different numbers from prokaryotic cells.

Essential Knowledge: Z • Learning Objective: EVO-1.A & SYI-1.D & SYI-1.E • Science Practices: 1 & 2

Question 12

The subcellular components of eukaryotic cells increase cell efficiency.

- a) **Describe** two scenarios where scientists have found subcellular structures interact.
- b) **Explain** how these interactions provide essential functions for the cell.

Answer (4 points maximum)

Description of the subcellular structures and the appropriately linked explanation their contributions to essential functions may include:

Descriptions of interactions (1 point each)

- Ribosomal RNA and protein interact to form ribosomes.
- Membrane-bound ribosomes and the endoplasmic reticulum work together as the rough ER.
- The endomembrane system includes the ER, the Golgi apparatus, the lysosomes, and transport vesicles.
- Mitochondria have a double membrane that allows compartmentalization within the mitochondria. The outer membrane is smooth, but the inner is highly convoluted, forming folds call cristae. Cristae contain enzymes important to ATP production; cristae also increase the surface area for ATP production. The matrix contains DNA and ribosomes. For cellular respiration, the cytoplasm of the cell is also involved.
- The cytoskeleton interacts with many organelles. Intermediate filaments support the nuclear and plasma membranes and interact with other cells. Microtubules radiate out from the centrosome and are the system along which vesicles and other organelles move.
- Ribosomes and the nucleus with its structures (and possibly cytoplasm and rough ER) function together in protein synthesis.

Explanation of functions (1 point each)

- Ribosomal RNA and protein interact to become the site of protein synthesis where the translation of genetic instructions yields specific polypeptides.
- Rough endoplasmic reticulum provides site-specific protein synthesis and plays a role in intracellular transport.
- Through their interactions, newly produced proteins and lipids are modified, packaged and transported throughout the cell. Lysosomes are produced by the Golgi and contain digestive enzymes.
- Cellular respiration: Mitochondria specialize in energy capture and transformation. Liver cells need a great concentration of mitochondria due to their high metabolic needs.
- These interactions provide cell structure, support, internal transport, interactions between cells (such as forming tissues), and mediate the occurrence of cell division.
- These interactions are involved in protein synthesis from DNA.

Essential Knowledge: SYI-1.E.1 • Learning Objective: SYI-1.E • Science Practices: 1

Question 13

Organisms share many conserved features that evolved and are widely distributed among organisms today. **Describe** THREE specific examples of evidence from cells and their structures that support the concept of common ancestry for all organisms.

Answer (3 points maximum)

Student descriptions include the following connections:

- Cell Theory: The work of Brown, Schleiden, and Schwann contributed to the idea that all organisms are composed of cells, the basic units of structure and function in organisms.
- Cell Theory: The work of Virchow showed that cells self-reproduce and that “every cell comes from a preexisting cell.”
- Fossil Record: Suggests the first cells were prokaryotes.
- Endomembrane System: Organelles (nucleus, Golgi, and ER) are believed to have evolved due to the invagination of the plasma membrane.
- Endosymbiotic Theory: Mitochondria and chloroplasts were independent prokaryotes that took up residence in a eukaryotic cell. Both organelles are similar to bacteria in size and structure and are surrounded by a double membrane. They also contain genetic material (DNA) that is a circular loop like in prokaryotes, and they produce some proteins. Their ribosomes resemble those of prokaryotes.

Essential Knowledge: EVO-1.B.1 • Learning Objective: EVO-1.B • Science Practices: 3

Answers to Applying the Science Practices Questions

Think Critically Questions

Question 1: Interpret the diagram by naming two complexes on the Golgi apparatus that might be involved in vesicle fusion.

Answer:

The two complexes are targeting complex and unknown targeting complex.

Question 2: Hypothesize an explanation for vesicle transport based on what you have read about cytoplasm and the cytoskeleton.

Answer:

Vesicle transport might be directed through the cytoplasm by microtubules.