4 Cells: The Working Units of Life

Chapter Outline

You already know that living organisms are made up of cells. Think of cells as small, water-filled balloons holding the mixture of proteins, ions, and other molecules that is necessary for life. In this chapter you learn about intracellular organelles that compartmentalize biochemical activities necessary for cellular life. Not all cells have these organelles. In fact, the most numerous cells on the planet, those of the *Archaea* and *Bacteria*, lack organelles, and this absence of organelles is a defining characteristic of simple, ancient cells called prokaryotic cells. Eukaryotic cells, such as those in our bodies, are larger in size and have numerous membranous internal structures. These are the organelles. By relegating certain types of processes to certain types of organelles, eukaryotic cells are extremely efficient.

Chapter 4 spans all four of the **Big Ideas** in the AP Biology Curriculum Framework. Try to develop your understanding across these ideas.

Big Idea 1 recognizes that evolution ties together all parts of biology. In Chapter 4 we look at a theory for the development of cell complexity with:

- **1.D.2:** Scientific evidence from many different disciplines supports models of the origin of life.

Big Idea 2 recognizes that the utilization of free energy and use of molecular building blocks are characteristic fundamentals of life processes. Specifically, Chapter 4 includes:

- **2.A.3:** Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
- **2.B.3:** Eukaryotic cells maintain internal membranes that partition the cell into specialized regions, including the rough endoplasmic reticulum, mitochondria, chloroplasts, Golgi apparatus, nucleus, and smooth endoplasmic reticulum.

Big Idea 3 recognizes that living systems store, retrieve, and transmit information essential to life processes. Specifically, Chapter 4 lays this groundwork by including:

- **3.D.2:** Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling. Examples include immune cells and plasmodesmata between plant cells.

Big Idea 4 recognizes that biological systems interact in complex ways. Chapter 4 includes:

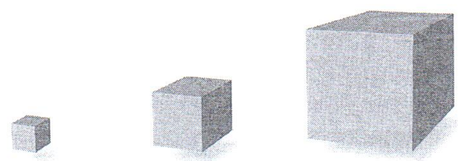
- **4.A.2:** The structure and function of subcellular components, and their interactions, provide essential cellular processes.

Chapter Review

Concept 4.1 *introduces the idea that multicellular life forms contain billions of cells. These cells come from pre-existing cells, and they are the basic units of most life forms. The principles that apply to single cells apply to whole organisms. Just like whole organisms, cells can stay alive and persist only when nutrients are available and waste materials do not reach dangerous or toxic levels. The size of cells is limited by how quickly materials can cross the membranes on the surface.*

1. Most cells are quite small. Limits on cell size are related to limits on the rate of movement of "good stuff in" and "bad stuff out" across cell membranes. Movement rates are greatly influenced by the surface area-to-volume ratio of the cells.

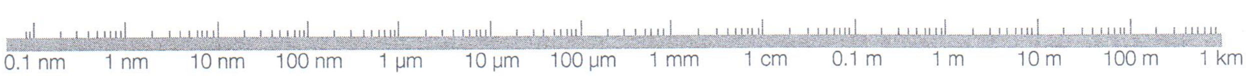
Imagine three cube-shaped cells. Given the dimensions shown for each cube-shaped cell here, calculate that cell's surface area, its volume, and its surface area-to-volume ratio.



	10 µm	20 µm	100 µm
Surface area (SA)			
Volume (V)			
SA:V ratio			

2. As the amount of a membrane-crossing toxin increases around the outside of the three cube-shaped cells in the above diagram, which cell would be the first to have an enriched concentration of the toxin in its center (core) region? Explain your answer using the surface area-to-volume ratio.

3. Use this logarithmic scale to determine how many 100 µm cells you would have to stack on top of each other to make the stack as tall as an athlete of 2 m height. (*Hint*: 2 m = ______ µm)



How many 10 µm prokaryotic cells would be needed to reach the same height? ______

Concept 4.2 *shows how the nucleoid region in prokaryotic cells serves the same hereditary functions served by the membrane-bound nucleus in eukaryotic cells.*

4. Explain how prokaryotes, despite lacking cellular organelles, are able to carry out many of the same enzymatically catalyzed biochemical conversions that eukaryotes carry out.

5. Describe, in general terms, the structural components of ribosomes, including a brief explanation of their function. Explain whether ribosomes are present only in eukaryotes, only in prokaryotes, or in both eukaryotes and prokaryotes. A drawing might be helpful, but make sure you explain the drawing.

6. Humans, perhaps unjustly, claim credit for inventing the wheel. Discuss the argument that prokaryotes using their flagella long preceded the human "invention" of the wheel.

7. Some models wrongly portray the prokaryotic cell as a plastic bag of alphabet soup with a golf ball included to represent the nucleus. Discuss how this model is not a good representation of a prokaryotic cell, and be sure to discuss the cytoskeleton in your answer.

Concept 4.3 *explains that the nucleus in a eukaryotic cell serves the same hereditary functions served by the nucleoid region in a prokaryotic cell. Eukaryotic cells also have many other cellular organelles.*

8. Many hormones, such as insulin, are proteins secreted by cells. Describe the structure and function of four cellular organelles needed for the synthesis and secretion of protein signals.

9. Identify the two primary groups of molecules that interact to become ribosomes, and include a description of where ribosomes are synthesized in eukaryotic cells.

10. One of your fellow classmates tells you, "The mitochondrion is the site where ingested glucose molecules are made into ATP molecules." Kindly point out the error of your classmate's statement by offering a statement that is more correct. (*Hint*: Is glucose biochemically converted to ATP?)

Concept 4.4 *explains how the cytoskeleton of eukaryotic cells provides strength and coordinates movement.*

11. Describe how the cilia-based movement of a paramecium is similar to, yet different from, movement by an amoeba.

12. Compare eukaryotic flagella and cilia in terms of structural size and in number present, using *Euglena* with flagella *versus* ciliated *Paramecium* as examples.

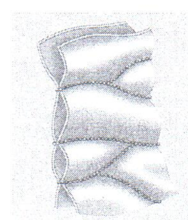
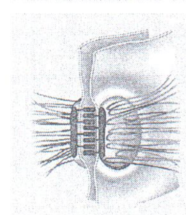
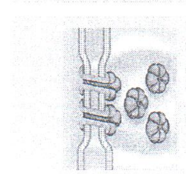
13. The longest cells of eukaryotes, as you might guess, are found as neurons in giraffes. Such cells can be two or more meters in length. The length of such cells includes an impressive mechanism for moving proteins from one end of the cell to the other. Describe the intracellular transport system, including vesicles, microtubules, and motor-proteins, for such long and thin cells.

Concept 4.5 *discusses how cells can interact with other cells and send and receive chemical signals at specialized regions on the surface of the cell.*

14. Correct and expand on this statement: "Adjacent plant cells are joined together by walls made up of only phospholipid molecules and proteins."

15. Correct and expand on this statement: "Sugar molecules hold adjacent animal cells together."

16. Specialized connections between adjacent cells in your heart hold them together closely so that blood does not leak out between the cells as the heart dynamically pumps your blood. The pressure of pumping would blow apart adjacent cells, were they not held tightly together by a second specialized connection. Furthermore, coordinated pumping activity of these cells relies on a third specialization between them. Describe how these three types of intercellular connections (shown at the right) work together in the functioning heart.

17. What do the characteristics of prokaryotic cells tell us about how the first eukaryotic cells originated? Using your knowledge of cellular organelles, create a model (flow chart) showing the steps involved in the evolution of eukaryotic cells from a chemical-rich environment.

Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter, we focus on **Science Practice 2:** The student can use mathematics appropriately. More specifically, we will use **Science Practice 2.2:** The student can apply mathematical routines to quantities that describe natural phenomena.

Question 18 addresses **Science Practice 2** by using your knowledge of math to enhance your understanding of biology. The ability to relate math to biology is important. You will calculate a surface area-to-volume ratio, then use this information to explain how cells of different sizes might eliminate wastes or procure nutrients faster by diffusion (**Learning Objective 2.6**). Why are cells the size they are?

18. Calculate the ratio (SA : V) of surface area (SA) to volume (V) for a cube with dimensions typical of eukaryotic cells (i.e., cells that are 0.1 mm in length on each side). Explain why bacteria need to divide well before they grow to the size of eukaryotic cells.