Cell Structure and Function – Major Concepts and Learning Activities[1]

These Teacher Notes present key concepts and suggest learning activities that engage students in active learning and counteract some common student misconceptions. Students often think of a cell as a static structure consisting of multiple independent parts. They often do not understand how the parts of the cell work together to accomplish the multiple functions of a dynamic living cell.

Section I presents key concepts and learning activities concerning cell structure and function, including differences between prokaryotic and eukaryotic cells and different types of eukaryotic cells. Section II presents key concepts and learning activities concerning the structure and function of cell membranes. The cell membrane is a particularly clear example of how the structure and function of a cell part can be understood in terms of the types and organization of its component molecules. The structure and function of mitochondria and chloroplasts are discussed further in the overview of cellular respiration and photosynthesis (https://serendipstudio.org/exchange/bioactivities#energy). Nucleus and ribosome functioning is discussed further in the overview of molecular biology (https://serendipstudio.org/exchange/bioactivities#molecbio).

Each recommended learning activity has a Student Handout and Teacher Notes with biology background and suggestions for implementation. Each of the recommended learning activities helps students to meet the Next Generation Science Standards (specifics are given in the Teacher Notes for each activity).

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I. Cell Structure and Function

Key Concepts

- All organisms are made up of one or more cells.
- Cells are the smallest biological unit that is alive.
- All cells have DNA, ribosomes, a cell membrane, and cytoplasm, which includes cytosol and a cytoskeleton.
- The rate of diffusion into and out of a cell is proportional to the surface area of the cell membrane. In contrast, the rate that a cell uses substances such as O_2 is proportional to cell volume. As cell size increases, the surface-area-to-volume ratio decreases. This explains why cells are tiny.
- A eukaryotic cell has a true nucleus with a membrane around its DNA, whereas a prokaryotic cell does not have a membrane around its DNA.
- Membrane-enclosed organelles in eukaryotes include the nucleus, rough endoplasmic reticulum and Golgi apparatus, which work together with ribosomes to produce and process the proteins that are secreted from the cell. Mitochondria make the ATP which provides the energy for protein synthesis and many other cellular processes. This illustrates how different organelles work together to accomplish the activities of life.
- Prokaryotes have a wide diversity of chemical capabilities.
- Cells are dynamic and active.
- Different types of eukaryotic cells have different shapes and different amounts of specific molecules and organelles, corresponding to their different functions in different parts of an organism or in different eukaryotic organisms (e.g. animals vs. plants).

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[1] By Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania, © 2023. These Teacher Notes and multiple activities for teaching biology are available at http://serendipstudio.org/exchange/bioactivities.
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Learning Activities

Introduction to Cells

https://serendipstudio.org/exchange/bioactivities/CellIntro

In this minds-on analysis and discussion activity, students learn about the characteristics shared by all cells and the differences between prokaryotic and eukaryotic cells, bacteria and archaea, and animal and plant cells. Students analyze the reasons why cells are so small. They also learn about the diverse chemical capabilities of prokaryotes, the functions of the organelles in eukaryotic cells, and how organelles work together to accomplish the activities of life.

Structure and Function of Cells, Organs and Organ Systems[2]

http://serendipstudio.org/exchange/bioactivities/SFCellOrgan

In this activity, students analyze multiple examples of the relationship between structure and function in diverse human cells and in the digestive system. Students learn that cells are dynamic, with constant molecular activity. Students analyze examples that illustrate how organelles work together to accomplish cellular functions and organs and organ systems work together to accomplish functions needed by the organism. Finally, students evaluate the claim that structure is related to function in cells, organs and organ systems.

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II. Cell Membrane Structure and Function

Key Concepts:

- Each cell is surrounded by a selectively permeable cell membrane which regulates what gets into and out of the cell. A selectively permeable membrane allows some types of molecules and ions to pass through, but not others.
- Osmosis results in net movement of water across a selectively permeable membrane from a solution with a lower concentration of solute particles to a solution with a higher concentration of solute particles. If a cell is surrounded by a hypertonic solution (with a greater concentration of solute particles than the cytosol inside the cell), there will be net movement of water out of the cell. Conversely, if a cell is surrounded by a hypotonic solution, there will be net movement of water into the cell. The effects of osmosis are responsible for phenomena such as water intoxication when a person drinks too much water too fast.
- Nonpolar molecules can diffuse across the phospholipid bilayer of the cell membrane.
- Membrane proteins allow ions and small polar molecules to cross the cell membrane. In passive transport, facilitated diffusion results in the net movement of substances from a region of higher concentration to a region of lower concentration. In active transport, membrane proteins use energy to pump ions or molecules from a region of lower concentration to a region of higher concentration.
- Large molecules such as proteins do not cross the cell membrane, but proteins can be secreted from the cell by exocytosis.

[2] A teacher who wants to use the cell-related content of this activity, without the content related to organs and organ systems, can use the three pages of the Student Handout provided at the end of the Teacher Notes for Introduction to Cells.
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Learning Activities

Introduction to Osmosis
http://serendipstudio.org/sci_edu/waldron/#osmosis
In this hands-on, minds-on activity, students investigate the effects of hypotonic and hypertonic solutions on eggs that have had their shells removed. As students interpret their results, they develop a basic understanding of the process of osmosis. As they answer additional analysis and discussion questions, students learn about the effects of osmosis on animal and plant cells and apply their understanding of osmosis to the interpretation of several "real-world" phenomena.

Cell Membrane Structure and Function
http://serendipstudio.org/exchange/waldron/diffusion
This activity includes two hands-on experiments and numerous analysis and discussion questions to help students understand how the characteristics and organization of the molecules in the cell membrane result in the selective permeability of the cell membrane. In the hands-on experiments, students first evaluate the selective permeability of a synthetic membrane and then observe how a layer of oil can be a barrier to diffusion of an aqueous solution. Students answer analysis and discussion questions to learn how the phospholipid bilayer and membrane proteins play key roles in the cell membrane function of regulating what gets into and out of the cell. Topics covered include ions, polar and nonpolar molecules; simple diffusion through the phospholipid bilayer; facilitated diffusion through membrane proteins; and active transport by membrane proteins. An optional additional page introduces exocytosis and endocytosis.

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III. Additional Resources for Teaching about Cells

BioMan: Cells (https://biomanbio.com/HTML5GamesandLabs/Cellgames/Cells.html) offers an online game that helps students learn about the parts of an animal cell (https://biomanbio.com/HTML5GamesandLabs/Cellgames/cellexplorerpagehtml5.html) and another online game that helps students learn about the structure and function of the cell membrane (https://biomanbio.com/HTML5GamesandLabs/Cellgames/celldefensehtml5page.html).

Cell Vocabulary Review Game (http://serendipstudio.org/exchange/bioactivities/cellvocab)

Why do some plants grow in odd shapes?
(https://serendipstudio.org/exchange/bioactivities/plant)
In this analysis and discussion activity, students investigate several examples of plants that have grown in odd shapes. As students analyze these phenomena, they learn (1) how the zones of cell division and elongation contribute to the growth of stems and roots; (2) how the effects of a plant hormone on cell elongation contribute to plant responses to light and gravity; and (3) how differentiated cells (xylem cells, phloem cells and photosynthetic cells) cooperate to supply all parts of the plant with needed molecules and ions. In this activity, students interpret data from scientific studies, develop and refine scientific models, and answer additional analysis and discussion questions.

Inside the Cell – Chapters 1 and 2 provide an informative overview of the cell.
(https://www.nigms.nih.gov/education/Booklets/Inside-the-Cell/Pages/Home.aspx)
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