# Lab 4: Cell Structure and Function

## Purpose

To examine the connection between cell structure and function.

## Learning Objectives

At the conclusion of this exercise, students will be able to:

* Identify cell structures.
* Make inferences regarding cell function based on structure.
* Compare bacterial, plant, animal, and fungal cells.
* Compare prokaryotic, single-celled eukaryotic, and multi-celled eukaryotic cells.

## Why It’s Relevant

Cells are the fundamental unit of life, and understanding their structure is key to uncovering functions vital for their survival. By studying cells, biologists can effectively explore properties that sustain life and apply them to improving health.

## Introduction

All living organisms are made up of one or more cells, making the cell fundamental to defining life. At its simplest, a cell is a container; more technically, it is a structure that contains **cytosol**, a **phospholipid membrane**, and **genetic material**. Just as a container holds substances, a cell encloses a water-based liquid called cytosol within a phospholipid membrane. The genetic material may either float freely in the cytosol or be compartmentalized, where it provides instructions to cellular machinery that carries out the processes of life. While genetic material is crucial as the “commander-in-chief,” the cytosol itself is far from ordinary. Its chemical composition facilitates all the activities we recognize as life. Cells enable life through the confinement and regulation of chemical reactions, collectively known as **metabolism**. Although cellular metabolism occurs within the cell, it depends on continuous interaction with the external environment. For instance, cells in your cornea and skin exchange gases with the surrounding air, and every cell in your body relies on nutrient and waste exchanges facilitated by the circulatory and digestive systems.

Since life first appeared on Earth about 3.5 billion years ago, cells have evolved by responding to environmental challenges. As a result, a wide variety of cell types exist. Most species on Earth are single-celled, meaning their entire body is composed of one cell. Others, such as plants, animals, and fungi, are multicellular. Biologists typically group cells into categories based on their level of organization for easier identification and classification. The two main categories are **prokaryotes** and **eukaryotes**. Prokaryotes are less organized and generally lack membrane-bound structures known as **organelles**, while eukaryotes are more complex and feature a higher level of cellular organization. The term prokaryote translates to “before nucleus,” while eukaryote translates to “true nucleus.” Many scientists believe that eukaryotes evolved from prokaryotic ancestors through an event called **endosymbiosis**, in which two or more prokaryotes became interdependent. To understand how this may have happened, imagine a bacterial cell (prokaryote) living inside another cell to create a eukaryote by having membranous structures within a larger membrane-bound cell.

While the exact number of cell types on Earth is unknown, estimates suggest there are tens of millions. There are over 200 distinct cell types in the human body alone! With so many different kinds, it may seem overwhelming to study them. Fortunately, the principle of complementarity helps simplify this task. This principle means that a cell’s structure directly relates to its function. By observing a cell’s physical characteristics, scientists can infer its function. For example, cells lining our respiratory tract have hair-like structures called cilia, which resemble the sweeping end of a broom. Careful observation reveals that the purpose of cilia is to help clear debris from our respiratory tubes. There are many other examples of complementarity in cells found across a wide range of life forms. In this lab, you will learn to identify features common to all cells and recognize structures that differentiate them. You’ll also investigate whether cells are truly the smallest unit of life by investigating their ability to respond to stimuli.

## Comparing Cells

The principle of complementarity states that a cell's structure is directly related to its function. In this section of the lab, you will compare different cell types and make inferences about how specific structural features relate to their function. The goal is to view as many of the specimens as possible under the microscope. However, your instructor may elect to modify this procedure using online images / videos.

### Materials

**Safety Warning:** This lab utilizes hazardous materials. Be sure to follow your instructor’s direction on wearing proper personal protective equipment and disposal procedures. The Biology Department Laboratory Safety Practices must be followed.

* Compound light microscope
* Dissecting microscope
* Dropper bottle of methylene blue stain
* Dropper bottle of iodine stain
* Dropper bottle of Janus Green stain
* Dropper bottle of distilled water
* Dropper bottle of 7% sucrose

### Prepared slides or online images (a variety of the following chosen by your instructor)

* Cyanobacteria
* *Oscillatoria, Anabaena,* or *Nostoc*
* *Gleocapsa*
* Volvocine line of evolution slides *Chlamydamonas*, *Gonium*, *Pandorina*, *Eudorina*, and *Volvox*
* *Rhodospirillum rubrum*
* Muscle composite slide with three types (skeletal, cardiac, smooth)
* Duodenum cross section (simple columnar epithelial cell)
* Trachea cross section (pseudostratified epithelial cell)
* Multipolar neuron
* Amoeba proteus cell
* Fungal hyphae

### Living specimens or online images / video

* *Lactobacillus* (cheese curd)
* Fresh onion
* Live *Elodea* or *Cabomba*

## Procedure

### Prokaryotic cells

Cyanobacteria are among the largest prokaryotes. They possess pigments used for **photosynthesis**. Many cyanobacteria have cells arranged in chains (filaments).

#### View prepared slides of cyanobacteria:

1. Examine a prepared slide of *Oscillatoria*, *Anabaena*, or *Nostoc,* a filament of cells, and one of *Gloeocapsa*, a loosely arranged colony.
2. Focus with the low-power objective at 100X total magnification.
3. Rotate the high-power objective into place to view filaments and masses of cells at 400X total magnification.
4. Observe the cellular structures, then create a sketch comparing the relative size and shape of one filament of cells (*Oscillatoria*, *Anabaena*, or *Nostoc*) to the loosely arranged colony of *Gloeocapsa.*
5. Estimate their relative sizes by dividing the diameter field of view by the number of times the specimen fits across the field of view. Review the microscope lab for an explanation of how to estimate the size of specimens under the microscope. Answer questions 1-2 on the lab response form.

#### View a prepared slide of a spiral-shaped bacterium:

1. Examine a slide of Rhodospirillum *rubrum* under low (100X total magnification) and high power (400X total magnification). This bacterium has spiral morphology, and when several cells attach end to end, a snake-like aggregate can be observed. This makes these cells easy to view.
2. Draw the individual organism in question 3 of your lab response form, then answer question 4.

#### Prepare a wet mount of a Lactobacillus bacterial cell:

1. Prepare a wet mount of a curd of cottage cheese by placing a 10-mm-diameter curd on a drop of water in the middle of a glass slide.
2. Add a coverslip and examine the cheese with a compound light microscope.
3. Focus with the low-power objective.
4. Rotate the high-power objective into place to see masses of rod-shaped cells.
5. Observe the simple, external structure of the bacteria and draw their cellular shapes in your laboratory report. Answer questions 5-6 on the lab response form.

### Eukaryotic cells: Animal cells

#### Prepare a wet mount of a human cheek cell:

* 1. Place a drop of methylene blue on a clean microscope slide.
	2. Scrape the inside of your cheek with the blunt end of a flat toothpick and stir the scrapings into the drop of dye.
	3. Apply a coverslip to the slide.
	4. Examine under low power and observe the **squamous epithelial cells**. Their appearance is flattened with a large mass in the middle, like a fried egg.
	5. Increase the magnification to high power and observe the following:
		1. Cell membrane
		2. **Granular cytoplasm**
		3. Nucleus

You may notice some dark-stained bacteria on the surface of the epithelial cell. Compare the size and appearance of these epithelial cells to the prokaryotic cells observed earlier. Sketch their appearance and relative size in question 7 of the lab response form.

### Eukaryotic cells: Plant cells and close relatives

#### Prepare a wet mount of an epidermal onion cell:

1. Remove a 4x4 mm section of the thin, transparent **epidermis** from the underside surface of an onion bulb leaf.
2. Place this one-cell-thick tissue layer on a microscope slide so that it is completely flattened.
3. Apply two drops of iodine solution, then add a coverslip before viewing under a compound light microscope.
4. Examine under low and high power and prepare a sketch of these cells in question 8 of the lab response form. Note the following structures:
	1. Thick cell walls (not found in animal cells)
	2. Granular cytoplasm (can be observed with adjusted contrast)
	3. Nucleus
	4. **Nucleoli** (typically two) within the nucleolus
	5. Central vacuole (a fluid-filled space)
5. Prepare another slide as you did in steps 1-4 above, but this time stain with Janus Green B mixed with one drop of 7% sucrose.
6. Observe the **mitochondria**.

#### Prepare a wet mount of the leaflet of an aquatic plant:

1. Leaflets of the aquatic plant *Cabomba* are thin enough to examine living cells. Place a drop of distilled water on a clean slide and place a single leaflet in it. Mount the leaf with a coverslip and examine the preparation under low and high power.
2. The circular green bodies along the edges of the cell are **chloroplasts**. Chloroplasts are the site of photosynthesis in green plants.
3. Careful observation will reveal that the chloroplasts are moving within the cell. This is the result of cytoplasmic streaming, which is caused by forces exerted by the **cytoskeleton** to increase transport around the cell. Prepare a sketch of your observations in question 9 of the lab response form.

The list below represents a summary of the cellular structures you should have been able to visualize during your microscopic observations of various eukaryotic cells:

* Cell Membrane
* Cell Wall
* Chloroplasts
* Nucleus
* Cytoplasm
* Nucleolus/Nucleoli
* Vacuole

Briefly describe the function of each structure in question 10 of the lab response form.

#### View prepared slides of members of the Volvocine line of algal evolution:

The Volvocine line of evolution represents a progression toward multicellularity. True multicellular organisms exhibit division of labor. Prior to this, organisms primarily lived in **colonies** with minimal coordination among cells. View the following slides.

* *Chlamydomonas*
* *Gonium*
* *Pandorina*
* *Eudorina*
* *Volvox*

Respond to questions 11-20 in the lab response form.

#### Summary tables of cell characteristics

Complete **Tables 4.1-4.3** on the lab response form to help you identify key characteristics of each of the cell types examined in this exercise. For **Tables 4.1 and 4.2**, write Y or N for the presence or absence of structures. For **Table 4.3**, place a check in the box indicating whether the organism is single- or multi-celled.

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| Table 4.1: Indicate whether each structure is found in prokaryotes, eukaryotes, or both. |
|   | Prokaryotic Cell | Eukaryotic Cell |
| Nucleus |   |   |
| Organelles |   |   |
| DNA |   |   |

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| Table 4.2: Indicate whether each structure is found in plant cells, animal cells, or both. |
|   | Plant cell | Animal cell |
| Eukaryotic or prokaryotic |   |   |
| Cell wall |   |   |
| Cell membrane |   |   |
| Vacuole |   |   |
| Chloroplasts |   |   |
| Cytoplasm |   |   |

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| Table 4.3: Single-cell organism vs. multicell organism. |
| Organism Name | Single Cell | Multicell |
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#### Observing structural diversity of different cell types (optional)

View prepared slides that show the structural diversity of different types of cells and record your inferences regarding their function by filling in **Table 4.4** in the lab response form. Describe how the overall shape, special features, and other observable evidence support your hypothesis about the cell's function.

* Skeletal muscle cell
* Smooth muscle cell
* Cardiac muscle cell
* Duodenal intestine epithelial cell
* Trachea epithelial cell
* Multipolar nerve cell
* Amoeba proteus cell
* Fungal hyphal cell

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| Table 4.4: Cell shape diversity. |
| Type | Shape | Special features | Hypothesized function | Evidence to support your hypothesis |
| Muscle cell |   |   |   |   |
| Cheek cell |   |   |   |   |
| Duodenal intestine cell |   |   |   |   |
| Nerve cell |   |   |   |   |
| Amoeba proteus cell |   |   |   |   |
| Fungal cell |   |   |   |   |
| Bacterial cell |   |   |   |   |

## Alternate Procedure for Online Courses

### Create-a-cell workshop: Crafting a cell analogy

In this activity, you will create models of prokaryotic and eukaryotic cells. Your eukaryotic cell model can be of plant, animal, fungal, or protist origin. Your model should include at least the following structures:

#### Structures common to all eukaryotic cells (plant, animal, fungal)

* Nucleus: Stores DNA, controls cell activities
* Cell membrane: Regulates what enters and exits the cell
* Cytoplasm: Jelly-like fluid where organelles are suspended
* Mitochondria: Powerhouse of the cell, makes energy (ATP)
* Ribosomes: Make proteins
* Endoplasmic Reticulum (ER): Transports and processes proteins/lipids
* Golgi apparatus: Packages and ships cell products
* Vacuoles: Storage; function differs by cell type
* Cytoskeleton: Provides shape and helps with movement

#### Plant-specific structures

* Cell wall: Made of cellulose; provides support and shape
* Chloroplasts: Site of photosynthesis (contains chlorophyll)
* Large central vacuole: Maintains pressure and stores water/nutrients

#### Animal-specific structures

* Lysosomes: Break down waste and old cell parts
* Centrioles: Involved in cell division

Using your textbook or an online resource, study the structure of both prokaryotic and eukaryotic cells. Choose one cell from each category that interests you and then create models of them using household items to represent analogous structures. In biology, "analogy" refers to structures that look similar but have different origins.

Once your models are complete, post a photo of them to the discussion board. Along with the photo, explain why you selected each item to represent the corresponding cell structure. Make sure that your analogies have similar features to the actual cell structures, and be prepared to explain your reasoning for choosing each item.

Review at least two of your peers’ posts and provide constructive feedback. Do you agree with their analogies? Are there any organelles/structures that might need better representation? How might their models be improved, or do you have a different analogy in mind?