

# The Cell Interior and Function

## 5



### 5.0 CHAPTER PREVIEW

- Investigate and understand the organization and function of the cell interior.
- Define the differences between eukaryotic and prokaryotic cell structure.
- Discuss the structure and function of the following eukaryotic organelles and structures:
  - Protoplasm
  - Cytoplasm
  - Nucleoplasm
  - Cytoskeleton
  - Nucleus
  - Ribosome
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes and peroxisomes
  - Mitochondria
  - Plastids
  - Vacuoles
  - Middle lamella
  - Extracellular matrix

## 5.1 OVERVIEW

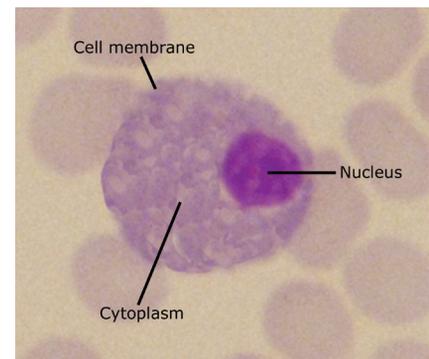
Once again, the focus of this chapter will be the cell, but now we will learn about the interior structures - organelles - and their functions in eukaryotic cells. We will cover the prokaryotic cells later in the course. Eukaryotes are more complex cell structures than the already complex prokaryotes. Eukaryotic cells contain a membrane-bound nucleus. They also have complicated, membrane-bound organelles. Prokaryotic cells do not have membrane-bound organelles.

The cell's structural plan calls for the interior to be surrounded by the cell membrane. Within the boundaries of the membrane, the cell is filled with a jelly-like substance, called the cytoplasm. Organelles are found in the cytoplasm. The cytoplasm is jelly-like so molecules and organelles can move through it effectively. There are many things transported through the cytoplasm every minute.

**Figure 5.1.1**

### Basic cell structure

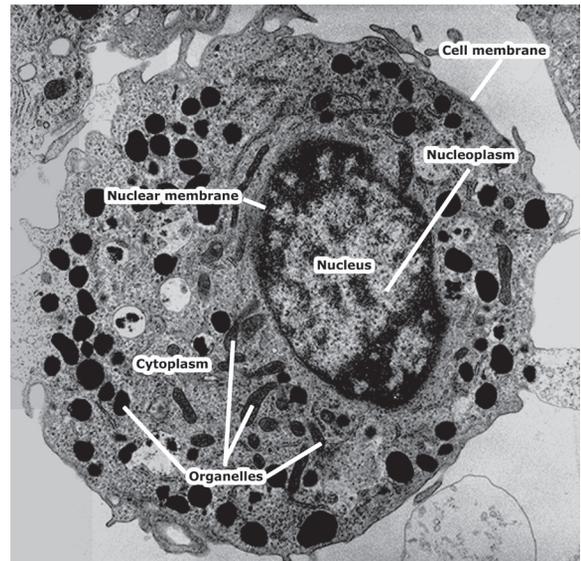
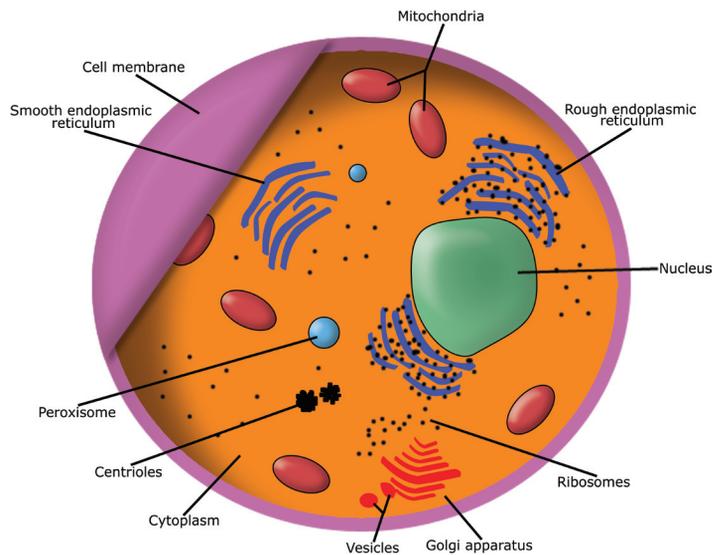
This is a light micrograph of an animal cell. The basic structures of the cell are labeled. All eukaryotic cells have this general structure of a cell nucleus surrounded by cytoplasm. The structure we learned about last chapter—the cell membrane—holds everything inside the cell and protects the cell from the environment.



## 5.2 ORGANELLES – GENERAL

**Organelles** are the individual functional units of all cells. Because any given cell has complicated functions that must be performed, the different functions of the cell are divided and spread out among the various structures inside the cell. For example, the protein-making organelle is called a ribosome. Vesicles function as storage and transport organelles. The nucleus is the organelle that houses and protects DNA in eukaryotic cells.

The organelles that are found in all eukaryotic cells are: protoplasm, cytoplasm, nucleoplasm, cytoskeleton, nucleus, nucleolus, ribosome, endoplasmic reticulum, Golgi apparatus, mitochondrion (plural mitochondria), lysosome/peroxisome and vacuoles. Structures that are found only in animal cells are centrioles. Structures that are found only in plant cells are plastids. Prokaryotic cells only contain one true organelle – ribosomes.



**Figure 5.2.1**

### General structure and organelles of eukaryotic cells

Above is an updated version of the animal cell graphic we saw last chapter. All of the organelles are labeled. The right electron micrograph is a human blood cell. The resolution is not good enough to make out many of the organelles, though. The nucleus is easily visible. It is filled with a jelly-like inside called nucleoplasm. Everything outside of the nucleus is called cytoplasm. Cytoplasm is a mixture of water, organelles, molecules and ions. The larger “sausage-shaped” organelles are mitochondria. Mitochondria manufacture almost all of the energy molecules for the cell. The large circular organelles with the light interior are vesicles. The very small black dots in the cytoplasm are ribosomes. They are all over the cytoplasm of most cells. As we proceed through this chapter, we will learn the function of all of the organelles shown.

## 5.3 PROTOPLASM

Technically, the **protoplasm** refers to all substances and objects contained inside the cell membrane. The protoplasm, therefore, includes the organelles, nucleus, and fluid inside the cell. The protoplasm is basically all the “stuff” within the boundaries of the cell membrane. The easiest way to remember what the protoplasm includes is that it consists of the cytoplasm and nucleus.

Technically, the breakdown of the protoplasm is as follows:

- The **cytoplasm** refers to all the structures outside the nucleus but inside the cell membrane.
- The cytoplasm contains the **cytosol**, which is the aqueous component of the cytoplasm.
- The cytosol contains about 70% water. The remaining 30% consists of ions and various soluble molecules such as proteins, enzymes, carbohydrates, and lipids.
- The cytoplasm includes all of the organelles except the nucleus. The nucleus is not considered to be part of the cytoplasm; it is part of the protoplasm.
- The cytoplasm also contains the skeletal structure of the cell called the cytoskeleton.

This mixture of the cytosol, the organelles, and the cytoskeleton give the cytoplasm the overall consistency of jelly.

## 5.4 NUCLEOPLASM

The nucleus is a large, membrane-bound organelle. Like the cell, the nucleus also has a fluid interior. This “plasm” of the nucleus is not called cytoplasm, though. It is called **nucleoplasm**. Like the cytoplasm, the nucleoplasm is mainly composed of water, ions and soluble molecules. In addition, eukaryotic DNA (deoxyribonucleic acid) is stored within the nucleoplasm. Recall that prokaryotic DNA is free within the cytoplasm.

The function of the cytoplasm and nucleoplasm is significant. The aqueous nature allows for molecules, ions, and organelles to be transported within the cell. The various molecules that are dissolved in the cytosol allow the organelles to use them for macromolecule synthesis. Also, the cytoplasm and nucleoplasm contribute to the maintenance of the cell's shape.

## 5.5 CYTOSKELETON

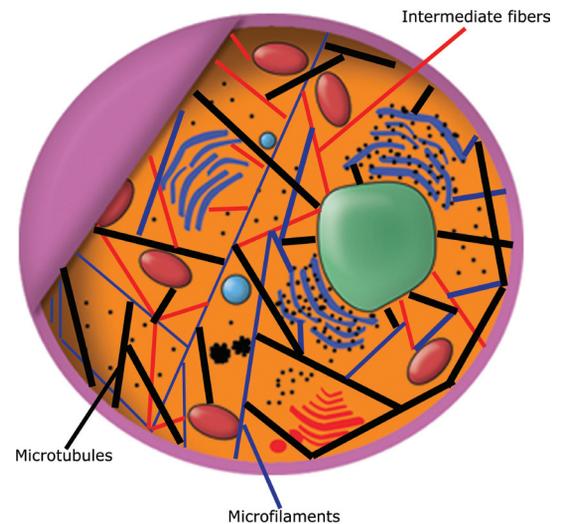
The cytoplasm and nucleoplasm exert a force directed outward from the inside to the outside. The cell membrane and nuclear membrane are not strong enough to counteract that force, however. If the structural integrity of the cell were left only to the cytoplasm and the nucleoplasm, both the cell and its nucleus would burst from the pressure. Fortunately, a complex network of proteins - called the **cytoskeleton** - is present to strengthen the cell and keep this from happening. The cytoskeletal proteins form an extensive meshwork, anchoring onto the interior of the cell membrane and the exterior of the nuclear membrane. There are also fibers that run between each other. Not only does the cytoskeleton serve to hold the cell together, it also:

- serves as an anchoring site for cell organelles and enzymes
- functions as the roadway for the movement of organelles and molecules within the cytoplasm

**Figure 5.5.1**

### Cytoskeleton

I have modified the animal cell graphic to represent what the cytoskeleton looks like. It looks kind of messy now, but that is what the cytoskeleton looks like—a very intricate interlacing of microtubules, intermediate fibers and microfilaments. This serves to hold the cell together, anchor organelles and enzymes in place and as a transport pathway within the cell.



## 5.6 CYTOSKELETAL PROTEINS, CILIA, AND FLAGELLA

The cytoskeleton is made up of three types of proteins: microtubules, intermediate fibers, and microfilaments. **Microtubules** are the largest of the cytoskeletal proteins and are composed of the protein **tubulin**. They are long, thin, and hollow tubes that are found just inside the cell membrane. Microtubules serve to provide structural support for the cell. Microfilaments are the smallest of the cytoskeletal proteins and are made of solid rods of the protein **actin**. Two chains of actin twisted together form a microfilament. Actin filaments are important in skeletal muscle contraction and intracellular transport. **Intermediate fibers** are cleverly named because they are not quite as big as microtubules, nor quite as small as micro-filaments. All three classes of cytoskeletal proteins interlace with one another to hold the cell together and provide a highway system. These are especially important structural cell supports.

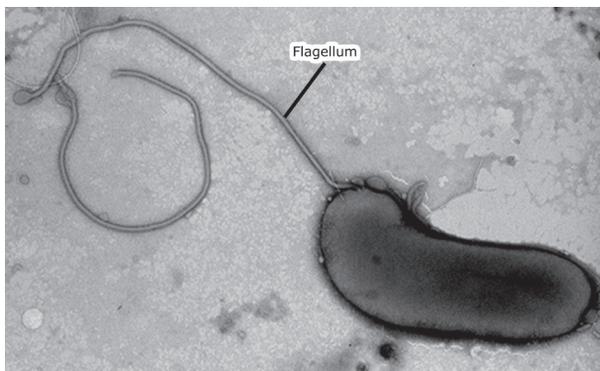
**Figure 5.6.1**

### Cytoskeletal Proteins and Their Function

Protein	Function
actin – microfilaments	cell structure; support; intracellular transport
intermediate fibers	cell structure; support
tubulin - microtubules	cell structure; support; intracellular transport; separate cells during cell division, make up eukaryotic flagella, cilia and centrioles

Microtubules also make up the structure of eukaryotic **flagella** and **cilia**. A flagellum is a long, thin projection from the cell surface that propels some eukaryotic cells by whipping back and forth. Cilia are shorter and more numerous cell projections that also move rhythmically back and forth. Some ciliated organisms use the cilia to move their bodies. This is true of many unicellular, ciliated organisms. Multicellular organisms use cilia to move substances past the cells. One example of this is the use of cilia in the respiratory tract (breathing tract) of animals. The cells that line the respiratory tract are covered with cilia. These beat back and forth in order to keep the areas clean from foreign substances such as dust particles and bacteria.

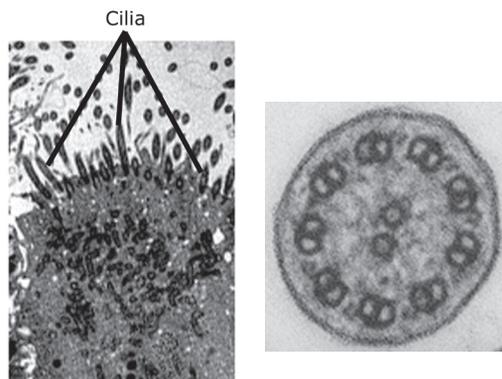
**Figure 5.6.2**



### Flagella

An electron micrograph of an organism with a flagellum is shown here. One cannot usually tell the difference between a eukaryotic and prokaryotic flagellum just by looking at it, though. This picture happens to be of a prokaryotic flagellum from a bacterium. No matter what the species, though, flagella function by whipping back and forth, propelling the organism. The difference between eukaryotic and prokaryotic flagella is great. All eukaryotic flagella are made up of multiple molecules of the protein tubulin. Prokaryotic flagella are made of a single molecule of the protein flagellin. In addition, eukaryotic flagella are actually extensions of the cytoplasm and are covered by the cell membrane. Prokaryotic flagella simply are molecules that extend out from the surface of the cell membrane.

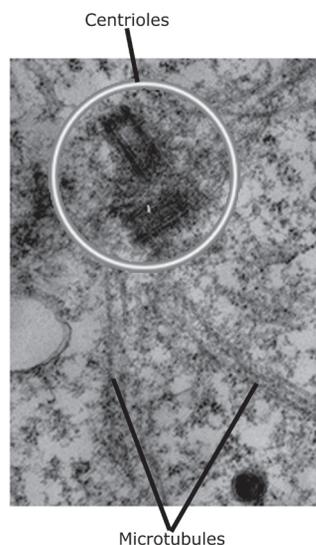
Microtubules are also important in moving genetic material during cell division. Microtubules make up the main structure of **centrioles**. Centrioles are found only in animal cells, and some fungi and algae. There are no centrioles in plants. Centrioles are important in cell division, where they help to pull the chromosomes (DNA) apart. We will discuss this later in the course. Centrioles are formed from nine sets of three microtubules arranged in a circle.



**Figure 5.6.3**

### Cilia

Both of these pictures are from an electron microscope. The picture on the left is of a cell with cilia extending from the surface. Cilia and eukaryotic flagella are both composed of microtubules, as well as other proteins. When cilia and flagella are viewed in cross section with an electron microscope, they have what is called the "**9 + 2 structure.**" This means there are nine pairs of microtubules surrounding a central core of two tubules, as can be seen in the cross section of a cilium on the right. Here, the dark line is the boundary of the cilia. Since cilia and flagella are extensions of the cytoplasm, this corresponds to the cell membrane. On the inside of the dark line, which is within the cytoplasm, are nine outer rings of paired microtubules. In the center are two more microtubules. This is the 9 + 2 structure. Cilia are not found in prokaryotic cells and are shorter than flagella. Also, normally organisms with cilia have more than 10 - sometimes even hundreds - of cilia. Usually eukaryotes with flagella have one or two flagella per cell.



**Figure 5.6.4**

### Centrioles

Here is an electron micrograph of part of the cytoplasm of an animal cell. Centrioles usually are seen paired together. Both centrioles are seen on their sides. Centrioles are made up of microtubules. They are made up of nine triplets of microtubules, rather than the 9 + 2 structure of cilia and flagella.