# Cell Structure and Function Lecture Guide

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*Number in outline corresponds to the slide number in the PowerPoint presentation.

1. As you learned in Module 1, cells are the smallest unit of life that can exist as a single entity. The constituents of a cell (i.e. atoms and molecules) are not living things, but when put together in the intricate matrix that is a cell, it becomes clear that they are the building blocks for life. This Module explores in detail the next level of organization of life by examining the components of a cell with focus on three different types of organisms: bacteria, plants, and animals. There are technically two additional organisms that are unique in their own ways (protists and fungi), but the first three are the most relevant to this course, and, therefore, we will keep our attention on them. As you move through this Lecture, as well as read the assigned text, make note of the images that are used to depict these three organisms as they will be an important visual guide as you move forward.

2. One of the most important inventions that help develop and advance the understanding of living things was the microscope. The very first documented look at a cell through a microscope occurred in 1665, and over the next 200 years many biologists, physicians, and inventors gave us the modern cell theory, and for over 160 years the cell theory has been considered a fundamental tenet of biology. The **cell theory** outlines the three unifying principles that connect all types of cells, regardless of type. The statement 'Cells are the smallest unit of life that can exist as a single entity' sums up in basic terms the first two principles: all living organisms are made up of one or more cells, and the smallest organisms are made up of a single cell. The third principle, all cells arise from preexisting cells, will be covered at length later on in the course.

3. Before we really dive into the specific differences of the 3 types of cells we are focusing on, we must first understand the features that are present in all cells, regardless of type.

    a. In terms of structures, all cells contain 3 structures: the plasma membrane, which controls everything that moves in and out of the cell, an aqueous (water-based) internal environment called the **cytoplasm**, and protein-making structures called **ribosomes**. Although there are some differences of these structures depending on the classification of organism, they are nonetheless present in every cell.

    b. As you already know from Module 1, all cells contain DNA and RNA. These molecules contain all the information that a cell needs to build and maintain itself. Along with DNA and RNA, cells all have the characteristics of life, such as the ability to carry out metabolism, maintain a constant internal environment, and grow and reproduce. You may want to go back and review these characteristics as needed.

    c. Although plant and animal cells are larger than bacteria cells, all cells are by necessity very, very small. All parts of the cell need to communicate with other parts of itself and the external environment and must rely on random and slow processes, such as diffusion across the plasma membrane, to do so. This means the size is limited so that no one part of the cell is too far away from the plasma membrane.

    d. Finally, all cells are going to use many of the same essential elements (carbon, oxygen, and hydrogen, for example) and minerals (calcium, sodium, amino acids, etc.). Again, the specifics will vary with the cell, but, as an example, all DNA molecules require phosphorus. Therefore, all cells need phosphorus available in their environment.

4. In the first Module, we defined **prokaryotes** as bacteria cells and **eukaryotes** as all other types of cells. Let's review some of the differences between eukaryotes and prokaryotes before continuing on. Bacteria are single celled organisms, arose first in evolutionary history, and are relatively simple cells. They do not contain specialized compartments, called **organelles**, which carry out specific functions for the cell. All processes, including energy production, metabolism, and molecule construction happen in the cytoplasm of the cell. It is this reason that makes bacteria cells so much smaller than plant or animal cells. The organelles that are found in eukaryotic cells have very specific functions for the cells. They focus entirely on one aspect of cellular processes and, therefore, are capable of higher output of products. Some of these organelles function as transportation inside the cell, meaning that the products that come from specific organelles can be efficiently transported long distances, whereas bacteria cells have to rely entirely on random movement of materials through the cytoplasm. Bacteria also all have cell walls that cover the cell, in addition to the cell membrane. Some eukaryotic cells, on the other hand, do not have cell walls. Of the eukaryotic cells, plants, fungi, and some protists have cells walls. As a matter of fact, animal cells are the only group of organisms that are guaranteed to not have cells walls as part of their structure.

5. Now that we have a basic understanding of cells in general and some the similarities and difference of eukaryotic and prokaryotic cells, let's explore the inner workings of the cell in detail. In the slides that follow, you will notice that, in the top right hand side of the slide, one or more of these cell images will appear. This is a quick reference guide to which type of cell contains the component covered on that particular slide. (Recall that we are focusing only on plant, animal, and bacteria.) You might also notice that many of the components to be covered are compared to aspects of a city or town. Often times, cells are compared to the inner workings of a city. Think about the infrastructure of the city you live in. There are several departments that are responsible for keeping your city running smooth, clean and tidy, and the citizens able to move through. You have streets and highways to direct and control traffic through your town, garbage services to dispose of trash in a safe and sanitary fashion, post offices to deliver and pick up mail, and storage facilities to manage surplus materials. Without each and every one of these services, your town would likely fall into disrepair and chaos, right? So it is with the eukaryotic cell. Each organelle we will cover in the following slides serves a very specific and necessary purpose, and without it, the cell could not survive.

    a. Your text does a great job of covering the functions of each of the components we will explore, so be sure to keep it handy as you move through the Lecture. Use the text to explore the details on basics presented on the slides, and some supplemental and/or interesting aspects will be covered in the Lecture guide.

6. Awesome video alert! This amazing and beautiful video, titled "The Inner Life of a Cell", was created by scientists at Harvard, and it follows the processes that occur in an immune cell that is circulating through your bloodstream. Although you will be unlikely to really grasp a lot of what you are looking at right now, click on the video and pay particular attention to structures that you see within the cell. At the very least, it might whet your appetite to learn more! At the end of this Lecture you will be prompted to view this video again and see if you can recognize any of the structures you saw but didn't recognize the first time around. In fact, we will revisit this video a few time throughout the course as we continue to explore structures, functions, and processes that occur in cells. If you have trouble playing the video within the presentation viewer, want to view it in full screen mode, or want to read up on the technology used to create this beauty, you can visit http://www.studiodaily.com/2006/07/cellular-visions-the-inner-life-of-a-cell/ to access the video.

7. Let's start with the components that are found in all cells, regardless of type. The **plasma membrane** is like the gatekeeper of the cell. Nothing goes in or out without express permission from the

membrane, it facilitates communication with other cells when necessary, and it is easily the most important component of the cell. So important, in fact, that we will go into a significant amount of detail in the next Module for the course.

a. We looked at the major molecular component of the membrane in Module 2: the phospholipid. Recall that phospholipids within the membrane have two parts, the hydrophilic head and the hydrophobic tail. There are two very important aspects that must be understood about the plasma membrane, both of which are related to the structure of the phospholipid. #1, the phospholipids contained within are not bonded together in any way. They are spontaneously formed due to their hydrophilic and hydrophobic regions.

b. And #2, the membrane is actually a **bilayer**, meaning there are two layers of the membrane, with the hydrophobic tails of each layer pointed towards each other and the hydrophilic heads pointed towards the aqueous surroundings, both inside and outside the cell. The heads are automatically drawn to the aqueous surroundings and the tails are repelled. Think about it like those goofy clown punching bags. No matter how hard you hit it, that bag will pop right back up because of the weight at the base. So it is with phospholipids. They will always form a bilayer when surrounded by water to protect those tails.

8. In addition to the phospholipids, there are a variety of other molecules, most of them proteins, incorporated into the membrane. Some of them span the entire width of the membrane and some of them are found on either the inner or outer surfaces of the membrane, depending on the function of that molecule. These molecules can act as channels that allow other materials to move in and out of the cell, some of them act as attachment molecules to the cell's surroundings, and some of them act as recognition molecules for other cells. We won't go into the details of all the functions and types of membrane molecules. Let's consider a couple of examples, just to help visualize some of the purposes these molecules serve.

   a. An example of why **recognition molecules** are needed is the immune system. In the bodies of most vertebrates there are immune cells that circulate throughout the body looking for anything that doesn't belong. If that immune cell comes across something that it doesn't recognize it will immediately attack it, as well as call in reinforcements to the site of the foreign invader. Recognition proteins tell these immune cells that they belong and are supposed to be there. It is for this reason that many organ transplant recipients must repress their immune system, so that it doesn't attack and destroy the transplanted organ.

   b. **Receptor proteins** most often trigger some sort of event inside the cell in response to conditions in its environment. An example here is the control of glucose levels in the bloodstream. The pancreas is responsible for monitoring sugar levels in your blood, and it does so with receptor proteins on the surface of its cells. When there is enough sugar in your blood to trigger these receptors, it sets off a cascade of events in the cell to create and excrete insulin. The insulin, in turn, triggers receptor proteins in your liver to start taking up glucose and converting it to glycogen for short term storage.

   c. Just as the level of saturation in the fatty acid tails (covered in Module 2) helps regulate the fluidity of the membrane, **cholesterol** also plays a role in that function. Cells that have high level of cholesterol are more rigid than those with lower levels- one of the reasons that your doctor concerns him or herself with your cholesterol levels. Cells that require a lot of structure, such as skin cells and those cells in your blood vessels, may have a higher cholesterol content than, say, cells that line your intestinal walls that are responsible for absorbing nutrients for the food you consume. Some cholesterol is necessary in your diet because it serves a variety of functions besides membrane fluidity, including hormone production.

9. The **cytoplasm** is also a “structure” that is found in all cells. We learned in Module 2 that water plays a huge role in a variety of metabolic and homeostatic processes, and the cytoplasm is where this magic happens. Without an aqueous environment, water soluble molecules would be unavailable to the cell, the formation of ions such as sodium and chloride couldn’t happen, and, depending on the cell, water facilitates some extremely important chemical processes such as photosynthesis, protein synthesis, and DNA replication.

10. From this point on, we are into components that are only found in eukaryotic cells, and one of the most important components of these cells is the cytoskeleton. The **cytoskeleton** is like the highway system of the cell. Not only does the cytoskeleton help control the overall shape and movement of a cell, but it is also responsible for movement of materials inside the cell. The cytoskeleton is one of the many components that allow eukaryotes to be so much larger than prokaryotic cells. As an example of how the cytoskeleton facilitates cell movement, consider a slime mold (a large single celled protist that oozes across the forest floor eating dead plant material). The slime mold oozes by continuously assembling cytoskeleton structures in the front of the cell while simultaneously deconstructing cytoskeleton at the back end, thus creating forward movement in its oozing nature. Use your text to learn about the structure and function of each of the types of proteins that can be found in the cytoskeleton. Be sure to review the function of cilia and flagella and the role of microtubules in their structure.

11. The **nucleus** is usually the largest part of the cell and is often visible with a standard microscope, whereas most other organelles are too small to see without a high powered microscope. The nuclear envelope is actually a double membrane with pore complexes that tightly control what goes in and out of the nucleus- even more so than the plasma membrane. The main purpose of the nucleus is to house and protect the genetic material of the cell, as well as facilitate DNA replication and RNA production.

12. There are three main components of the internal **membrane system**: the **endoplasmic reticulum** (ER), the **Golgi apparatus** (sometimes referred to as the Golgi body), and a variety of **vesicles**. The main thing to take away from this graphic is the placement of each part within the cell. Depending on the function of the cell in question, these components may be bigger or smaller, but the placement is always the same. The ER lays closest to the nucleus and towards the center of the cell. The **Rough ER**, which we will define in the next slides, lays closest to the nucleus, and the **Smooth ER** lays between the Rough ER and the Golgi apparatus. Golgi apparatus is the outermost part of the membrane system, and vesicles bud off of the smooth ER and Golgi to move to different parts of the cell, or in some cases, to the plasma membrane to release its contents out of the cell.

13. The **Endoplasmic reticulum** is much like a production factory. Based upon the needs of the cell, it is responsible for producing most of the molecules the cell needs to use or ship out of the cell. The rough ER is called so because it has ribosomes, structures that are responsible for protein construction, embedded on its surface, thus giving it a rough appearance. The smooth ER doesn’t have ribosomes embedded on the surface because the smooth ER doesn’t make proteins. Instead, it is responsible for constructing fats and hormones, often destined to be excreted by the cell. Refer to your text to explore some of the details of each of these structures and to learn why certain cells are more abundant in these structures than others.

    a. Ribosomes also float freely in the cytoplasm of the cell, and where the ribosome is found gives you a hint as to what types of proteins it creates. Typically speaking, free floating ribosomes are responsible for making proteins that remain inside and are used by the cell, whereas ribosomes that are embedded in the rough ER are responsible for making proteins that are destined to leave the cell. Milk proteins, for example, that are produced in the mammary cells of mammals are produced in the rough ER and shipped to the surface of the cell to be excreted into the mammary ducts during lactation.

14. The **Golgi apparatus** acts much like the post office of the cell. It receives packages, or vesicles, from the ER to be processed and sent off to their ultimate destination. The contents of those packages will often define what type of vesicle it is. Those containing digestive enzymes become **lysosomes**. **Peroxisomes** contain molecules that help break down toxic substances that are created through normal cellular processes, or sometimes they will fuse with other vesicles that bring toxic chemicals into the cell.

15. **Vesicles** can be thought of as the taxi cabs of the cell, responsible (with the help of the cytoskeleton) for delivering contents to other parts of the cell, bringing contents to the surface of the cell to be released, or in some cases, to bring molecules into the cell. These vesicles are called **food vacuoles**, capturing materials from the extracellular matrix. These food vacuoles will often fuse with **lysosomes** to begin the digestion process, chopping the contents into useable materials for the cell.

16. The **mitochondria** is the power station of the cell, responsible for producing energy in the form of ATP. In animal cells, ATP is constructed from glucose molecules that the cell takes in from food consumed by the animal. In plant cells, the glucose comes from glucose produced through the process of photosynthesis. Both of these processes will be explored in detail later on in the course.

17. **Chloroplasts** are found solely in plants cells and are the site of photosynthesis. Photosynthesis captures energy in sunlight and converts it into glucose molecules, the main source of energy for the cell. Use your text to learn the details of the internal structure of the chloroplast, making note of the physical appearance. Just as with mitochondria, we will see this organelle again in more detail later in the course. Most importantly, the green color of the chloroplast comes from **chlorophyll**, the pigment that is responsible for capturing sunlight.

18. Plants have other unique structures not found in animal cells, the **central vacuole** and a **cell wall** composed of cellulose and pectin. Remember, bacteria have cell walls as well, but bacterial cells walls have a completely different composition and function that we will not be exploring in this course.

    **a.** The central vacuole is the main storage facility for a plant cell and takes up the majority of the cell volume. Keep in mind that plants cannot move or seek out food and water like animals can, so this is an extremely important organelle for the plant. In addition to storage of food and water, the vacuole can also contain pigments. Petals on flowers, for example, get their color from pigments stored in the central vacuole. If a plant produces toxic chemicals to deter predation from herbivores, these chemicals are often stored in here as well.

    **b.** The cell wall of plants are mainly constructed in the Golgi apparatus, and one of its main functions is to give the plant cell shape and govern communication between adjacent cells. Plant cells have a much more geometrical appearance to them, much more so than most animal cells which often have no specific shape at all.

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