**Basic Structure of Prokaryotic and Eukaryotic Cells**

**Introduction to Cells**

The world and everything in it, such as the water and soil, is comprised of cells. Cells can be defined as “the smallest unit of life and the building blocks to all living organisms” [1]. These cells can range from blood and nerve cells found in the human body, to parenchyma and collenchyma cells found in plants, and more. All existing cells have three structures in common: cell membrane, cytoplasm, and DNA. The cell membrane protects the inside of the cells from external factors, while the cytoplasm is a gooey-like substance that supports all internal organelles. The DNA found inside cells contains all the genetic material. Though all cells have some similarities, there are two broad types into which they are categorized: eukaryotic and prokaryotic.

**Basic Structure of Eukaryotic Cells**

All animal and plant cells are classified as **eukaryotic cells**, or cells that are composed of organelles surrounded by a cell membrane. The cells range anywhere from 10-100 micrometers in diameter. The **organelles** that are bound by a membrane perform different functions within the cell, much like how players on a sports team utilize their abilities to contribute to the team’s success. Organelles may include nuclei, endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria, and chloroplasts. Each of these organelles perform a unique task in order for the cell to survive. The basic structure and functions of the eukaryotic cell will be broken down to grasp a better understanding of how the cell operates.

**Nucleus**

The other factor that distinguishes eukaryotic cells from others is the presence of a **nucleus** which are in both plant and animal cells**.** The nucleus is comparable to the function of a brain found in humans and animals. The nucleus contains all of the DNA information of the cell, and regulates all of the cell’s activity. It is made up of a nuclear envelope, chromatin, chromosomes, and a nucleolus. The nuclear envelope is like an outer membrane surrounding and protecting everything inside. The chromatin is DNA that is tangled and dispersed found inside the nuclear envelope, and holds the data needed to produce proteins. The DNA will condense to form chromosomes. DNA recognizes four bases that are used to encode this information: cytosine, thymine, guanine, and adenine. These names are more commonly referred to the first letter of the name, so cytosine would be referred to as “C”, thymine as “T”, guanine as “G”, and adenine as “A”. These bases come together to form complimentary base pairs in which “A” connects with “T”, and “C” to “G”. The “A”-“T” bonds are weaker because they only have two hydrogen bonds, whereas the “C”-“G” bonds have three hydrogen bonds, making it slightly stronger. One thing to note is that the “C”, “T”, “G”, and “A” are compliments with DNA. But, when the RNA needs to place a compliment of the DNA “A”, it would connect uracil, or a “U”, instead of a “T”. Basically, the “U” is taking place of the “T” in RNA. Understanding these names are essential to fully grasp the processes that occur inside the nucleus. When these bases come together, it is called a **base** **sequence**. When the DNA is being encoded, these four bases are uniquely sequenced in groups of three, and this triplet is called an **amino acid.** Amino acids can be thought of as the “protein language”. Amino acids can take 20 different forms and connect together like chains to tell the protein the genetic information it will consist of. The process that that allows the cell to produce proteins exists in three forms: replication, transcription, and translation. **Replication** occurs when DNA produces exact copies of itself. A cell will replicate its own DNA and then when this is complete, the single cell will divide into two daughter cells. **Transcription** is when the DNA is copied to RNA by the enzyme RNA polymerase. Like DNA, RNA works in the same manner that is has a complimentary base that it always connects to. This is the first step in protein synthesis. The DNA is first unzipped by helicase so that the mRNA (messenger RNA) is able to be made according to the DNA’s order. Nucleotides of RNA will match with DNA, and this makes mRNA. Unlike replication and transcription, translation does not occur in the nucleus, so this will be discussed in a later section

**Endoplasmic Reticulum (ER)**

The **endoplasmic reticulum,** also known as the ER, has a network of membranes that assist in carrying molecules throughout the cell. The ER is located in both plant and animal cells. These membranes consist of phospholipid bilayers that have hydrophilic (water-loving) heads on opposite sides facing either side of the membrane, and hydrophobic (water-hating) tails that back into each other. The membranes are consecutively folded, giving it a large surface area [3]. There are two types of ER that are within the eukaryotic cell; the rough ER and the smooth ER. The **rough ER** has its name because it appears rough on the outside, and this is because the exterior is covered in ribosomes. The rough ER’s main function is to help package proteins. These proteins are actually made by the ribosomes that are attached to the exterior, and that also float freely around the cell. These ribosomes help assemble amino acids into polypeptide chains. This chain is then sent inside the ER. The **smooth ER** has no ribosomes attached to it, and appears smooth and flush. It acts like a warehouse for enzymes, ions and lipids, and also helps in detoxifying substances. Upon the completion of the polypeptide chain from the ER, it is then sent to the Golgi apparatus.

**Golgi apparatus**

The **Golgi apparatus** is mainly used for processing the proteins that it was given, and packaging them correctly. This can be found in both plant and animal cells. The apparatus is made up of **Golgi bodies** which are membranous layers that are able to break down large proteins into smaller and more condensed hormones. Once this step occurs, the Golgi bodies are able to combine the broken down proteins with carbohydrates to make molecules. Once the proteins are packaged, they are squeezed into vesicles. Like the Golgi, the vesicles are also made up of a phospholipid membrane. After the proteins are secured in the vesicles, the packages will be sent to other parts of the cell, or just into the cytoplasm.

**Lysosome**

The Golgi body also produces **lysosomes** which are only found in animal cells**.** These organelles can be thought of as a recycling system that the cell uses to take in unwanted substances, or the waste that exists in the cell. These are used by the cell to break down waste throughout the cell. They are able to do this because they are packed with enzymes that are strong enough to breakdown waste that the cell does not need. Some of the items that the lysosomes break down are carbohydrates, nucleic acids, lipids, proteins, and other cell debris. This cell debris that is collected by the lysosomes and broken down by the enzymes is then injected into the cytoplasm that can be used by the cell as building material [3].

**Mitochondria**

The **mitochondria** is known as the powerhouse of plant and animal cells. This organelle is a smooth, oblong rod that is most essential for the cell to continue to survive. This is where the energy is derived from cellular respiration, also known as aerobic respiration. Three main sub processes used in this respiration are glycolysis, TCA cycle, and electron transport. Glycolysis is the splitting of consumed sugar molecules. The TCA cycle is the same thing as the Krebs cycle, which is the oxidation of acetyl-CoA that come from carbohydrates to produce energy. The electron transport chain is the last step in the process of aerobic respiration, and it moves electrons across the membrane and stores them, and collectively produces energy. Through this process the mitochondria uses carbohydrates, fats, and other molecules to kick start the production of Adenosine tri-phosphate, more commonly referred to as ATP [3]. ATP can be thought of as “the currency for biological systems” [4]. This process requires glucose and oxygen, which will then produce carbon dioxide and water, along with the energy source needed for the cell to operate. Not all cells require the same amount of energy to perform their designated functions, so some cells have more mitochondrion than others. The mitochondrion can vary from 1 all the way to 10,000, though most cells contain roughly 200 mitochondrion [5]. These organelles were estimated to have originated back when scientists believe everything were single-celled organisms. Over time, small eukaryotic cells engulfed prokaryotes and they lived in harmony. It was predicted that the prokaryotes continued to live and operate within the eukaryotes, and the eukaryotes began to depend on this process. Over the series of many generations, the eukaryotes evolved to continue this system while the previously engulfed prokaryotes became unable to survive on their own. Over the course of millions of years, this process came to be known as the endosymbiotic hypothesis, and this is how mitochondrion and chloroplasts came to be [6].

**Chloroplasts**

The **chloroplast** is also an energy-producing organelle unique to plant cells and photosynthetic algae. They are located in the cytosol of the cell. These disc-shaped organelles are essential to the success of plant cells because these double-membraned organelles take light from the sun and convert it into sugar and oxygen in a process called **photosynthesis**. The sugars produced in this process are either taken back up by the cell to use it or are consumed by a human or an animal. The sugars conserved are then harvested through cellular respiration, which also occurs in mitochondrion in animal and plant cells [7]. Specifically talking about plants, almost all of them are green. The leaves of trees, the grass, and other plants are green. Why is this? All of the parts of a plant that are visible besides the stems and branches all contain **chlorophyll**. They mostly appear to be green because chlorophyll have a green pigment to them.

**Cell Wall**

The **cell wall** is only found in plants cells. It can be defined as a strong and protective layer located outside of the cell membrane that provides protection and support for the cell. It also gives the cell its rigidity as well as its shape. It is essential to plant cells because it is able to dictate what enters and exists the cell in order to keep itself protected. There are tiny holes throughout the surface area of the cell wall that are called **plasmodesmata**, and these holes direct what nutrients enter and rids waste from the cell as well. The cell walls do a great job at retaining the water that the cell receives, and it also does not allow too much water to come in. They are able to prevent overexpansion by monitoring water intake, as well as filtering the molecules that come in. Not all cell walls are the same, and do differ from one another. For example, a large strong tree that is many years old has to have cell walls with great strength in order for it to remain stable and not fall over. On the other hand, flowers have cells with cell walls that are a lot more flexible in order for it to have plasticity and allow it to have more movement. The cell wall is made up of **cellulose**, which is a carbohydrate that is used for both protection and structure [8]. The cell wall is composed of three different layers. The top layer is called the **middle lamella,** and this “connects the cells together to form a strong structure” [8]. This layer is rich in pectin, which is a substance that strengthens the plant and allows it to more easily resist compression from outside sources. It also contains an enzyme that lets the object expand by breaking down the cell wall. This is essential for plants when growth is occurs. The second layer is the **primary wall**, and this layer contains microfibrils which weave with glycan. This increases the strength of the cell wall overall. The final layer, which is the most internal of all layers, is known as the **secondary wall**. This layer provides the rigidity that the cell needs and also is another form of compression strength.

**Basic Structure of Prokaryotic Cells**

**Prokaryotic cells** are unicellular organisms that lack a membrane-bound nucleus and membrane-bound organelles, such as bacteria or archaea. The word “prokaryote” originates from a Greek background, with “pro” meaning “before,” and “karyote” meaning “nut or kernel” [9]. These cells range from about 0.2-2.0 micrometers in diameter. Prokaryotes have been seen to come in different shapes like cocci (round-shaped), bacilli (rod-shaped), as well as spirilla (helical-shaped) [9]. Some are seen to have a **flagella** attached to the end of the structure, which allows it to be mobile by rotating it in a whip-like motion. They are much less complex than eukaryotic cells, with just a few basic structures that do not vary too far for that of eukaryotes. This is because prokaryotes were thought to be the first forms of life of the earth. From prokaryotes and through the evolution of other cells engulfing one another and reproducing and becoming reliant on the new functions of the obtained cells, eukaryotic cells are predicted to originate from prokaryotic cells.

**Commonalities between Eukaryotic and Prokaryotic Cells**

**Cell/Plasma Membrane**

The cell membrane is essential to both eukaryotic and prokaryotic cells. Its purpose is to enclose cell contents like organelles, all while monitoring what enters and leaves the cell [2]. Like the endoplasmic reticulum, it is composed of a phospholipid bilayer. These membranes have selective permeability, which means that they are able to choose what enters the cell and what remains outside of it. Things that commonly pass through the membrane include water and oxygen, while unwanted substances remain outside of the cell. Things can pass through the membrane through active transport and active transport. **Passive transport** requires no energy and allows the water and oxygen to easily and freely pass in and out. On the other hand, **active transport** is moving molecules against the concentration gradient, and this process requires ATP [2].

**Cytoplasm**

The **cytoplasm** is a jelly-like fluid that mainly assists the cell in securing all organelles. It holds the cell together and gives it structure. The cytoplasm can thought of as all substance in the cell besides the nucleus and organelles. It has three major components that make up cytoplasm. The first is the **cytosol,** and this is mostly just the substance that is known as intra-cellular fluid. It is mostly comprised of water, but also contains some solutes for the cell like dissolved proteins and sugars. The structures that make up the second component are called **cytoplasmic organelles**. These organelles are structures that were explained before, that exist within the cytoplasm [3]. The last component of the cytoplasm are called **inclusions**. These are basically stored nutrients throughout the cell like fats, crystals, and glycogen. Inside of the cytoplasm is called the cytoskeleton, which are protein stands that reinforce the shape and volume of the cell. This form of “skeleton” is unlike the human skeleton in that it does not retain a definite shape. It is able to adjust itself so the filament systems can strengthen or shorten very quickly [10]. This helps the cell be able to expand and grow, as well as divide. As the cytoskeleton is essential to the success of the cytoplasm, so are centrosomes. These structures are an important part for the cytoplasm to be able to do its job. Centrosomes assemble microtubules out of proteins that holds the cytoplasm together [2].

**Deoxyribonucleic Acid (DNA)**

**DNA** is defined as the molecule of heredity, or the genetic information passes through generations. Humans, animals, plants, and all forms of life that exists are made up of DNA. Without this information, cells would not be able to reproduce and there would be no life on earth. DNA is necessary in order for protein synthesis to occur. DNA is a double-helix structure that is made up of countless and repeating molecular units, which form **nucleotides**. Nucleotides can be thought of as the basic structural unit for all nucleic acids, like DNA. Each nucleotide consists of a 5-carbon sugar molecule, a phosphate group, as well as one of four nitrogenous bases. This 5-carbon sugar molecule has the name “deoxyribose,” which is how the beginning of DNA got its name. DNA is made up of two anti-parallel sugar-phosphate bonds that are connected by the complimentary nitrogenous bases. These nitrogenous bases are weak hydrogen bonds which can be broken apart very easily (this comes in handy when the bonds need to be separated to make copies during replication). These nucleotides together form polynucleotides. The top of one will run 5’ to 3’, and the anti-parallel strand will run 3’ to 5’. Both prokaryotes and eukaryotes have DNA, but it is stored differently in both cells. Eukaryotes store DNA in the nucleus of the cell, whereas prokaryotes do not.

**Ribosomes**

Besides being seen on the rough endoplasmic reticulum in a eukaryotic cell, **ribosomes** exist in prokaryotic cells as well. The ribosomes is the site in which protein synthesis occurs. This process is essential in order for cells to reproduce. In this process, a copy of the DNA needs to be made in order for it to replicate when it reaches the ribosome. This is called **translation**, in which the mRNA is used to bring together the amino acids to produce of protein. This form of replication occurs in the ribosomes that are produced by the nucleolus. When this process occurs, the mRNA will need to make its way to a ribosome which can be found on the rough ER or floating freely in the cytoplasm. The mRNA will attach to a ribosome where a start codon will be read to begin the replication process. A tRNA (transfer RNA) will then bring an amino acid to the codon on the original strand. A **codon** is a set of three nucleotides that make up a genetic code for a molecule, whether DNA or RNA. The codon that the tRNA brings is called an anti-codon, and will match up with the original codon. This process will continue, and when the amino acids connect, this is called a peptide bond. This process will repeat until a stop codon is reached. Once this happens, the protein formation is complete, and translation is done [2].

**Conclusion**

As you can see, all structures within cells play an important role. Though eukaryotic and prokaryotic cells have their differences, they do have common structures that can be seen in both. Not only do cells make up your entire body, but also make up everything on Earth! Cell’s functions are essential to understand, because it helps draw conclusions to how things operate beyond what we can see with our naked eye. It explains how our bodies function, and how plants are able to exist and grow. Cells are the base of how life continues to exist, and the explanation of their functions help us have a better understanding of it.

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