**Study Plan: Episode 2—The Unity of Living Systems**

1. **Read the UNIT OVERVIEW presented in this Study Guide.**
2. **View the video "The Unity of Living Systems."**
3. **Read UNIT OBJECTIVES and KEY CONCEPTS sections of this study guide.**
4. **View the video a second time, this time taking notes. Pay particular attention to topics identified by the UNIT OBJECTIVES or KEY CONCEPTS as significant.**
5. **Read Chapter 2 in Microbes and Society.**
6. **Read Chapter 3 in Microbes and Society.**
7. **Test your mastery of the material by answering the Review Questions at the end of this Study Guide.**
8. **Check your answers against the answer key; review material relating to any questions you missed.**
9. **You should now be able to recognize a typical prokaryotic cell and label the major parts and do the same with a eukaryotic cell.**
10. **Explore further! See articles listed in Suggested Further Reading that sound interesting.**

**Unit Overview**

The fundamental processes and building blocks of life are the same in all living systems. While prokaryotic and eukaryotic cells differ in internal architecture, many of their structures and processes are similar or identical. Both types of cell are defined by a cell membrane. Each contains DNA and uses RNA to translate its stored genetic information into proteins. Both use ATP for short-term energy storage. Both types need to reproduce. Even viruses, not considered cells because they lack the ability to reproduce on their own, are equipped with DNA or RNA to direct their replication and guide the assembly of proteins in host cells!

In prokaryotic cells, DNA and its synthesis occur in the cytoplasm; sub-cellular structures are limited and none are membrane-bound. In eukaryotic cells, DNA and its synthesis are confined within a membrane-bound nucleus and the cell is characterized by organelles, membrane-bound structures that compartmentalize many important cellular functions. It is thought certain eukaryotic organelles, such as chloroplasts and mitochondria, originated as intracellular parasites and could today be characterized as intracellular “symbionts”!

The diversity of life is derived from the assembly of common building blocks into unique organisms, each ideally suited to competitively exploit its environment and harvest the energy and nutrients necessary for growth and reproduction.

**Unit Objectives**

· List the common traits shared by both eukaryotic and prokaryotic cells.

· Compare and contrast the structure of a prokaryotic and a eukaryotic cell.

· Explain how a virus differs from a cell

**Key Terms**

* 1o (Primary structure)
* 2o (Secondary structure)
* 3o (Tertiary structure)
* 4o (Quaternary structure)
* Amino acid
* Archaea
* Carbohydrates
* Cellulose
* Denaturation
* DNA
* Enzyme
* Eubacteria
* Eukaryote
* Genus
* Hydrophilic
* Hydrophobic
* Lipid
* Monera
* Nomenclature
* Nucleic acid
* Nucleotide
* Peptidoglycan
* Phospholipid
* Polysaccharide
* Prokaryote
* Protein
* Protista
* RNA
* Species
* Taxonomy

**Key Concepts**

**COMPONENTS COMMON TO PROKARYOTIC AND EUKARYOTIC CELLS**

All cells have similar raw materials/share common traits which include a membrane made of lipid (fats), proteins and nucleic acids (DNA and RNA). The DNA provides the blue print for the cell's construction. Tthe common traits provide the machinery for the cells to grow and reproduce.

**Carbohydrates**

* Carbohydrates are molecules that contain carbon, hydrogen, and oxygen, usually in the ratio of CH2O.
* These molecules often serve as the main energy source for organisms, especially glucose.
* Interestingly, these molecules can be joined together into long chains with or without branching.
* When found in long chains they are called polysaccharides (poly = many). The building blocks of polysaccharides are called monosaccharides (mono = 1) and we often see glucose, galactose, and fructose as the building blocks for bigger carbohydrates.
* Maltose is a monosaccharide that yeast break down to produce ethanol (alcohol) found in wine and beer.
* Disaccharides include:
  + lactose 🡪 glucose and galactose
  + sucrose 🡪 glucose and fructose
* Cellulose is a structural polysaccharide that we find in the cell walls of plants. Protozoan found in the intestinal tract of termites is responsible for the breakdown of the cellulose and they share some of the glucose from the cellulose with the termite.
* Peptidoglycan is a polysaccharide that has amino acids holding the subunits together to produce a strong structural component of the cell walls of bacteria. The two saccharides found in this compound are:
  + NAM = *n*-acetylmuramic acid
  + NAG = *n*-acetylglucosamine

**Lipids**

* Like carbohydrates, are composed of carbon, hydrogen, and oxygen. However, they usually have more hydrogen atoms attached, which really changes the characteristics of the molecule.
* Lipids serve as the building blocks for:
  + Fats
  + Phospholipids
  + Steroids
* We are most concerned with the phospholipids since they make up most of the cell membrane.
* Phospholipids have hydrophilic (water-loving) regions and hydrophobic (water-fearing) regions that are ultimately responsible for the amazing properties of the cell membrane.

**Proteins**

* Proteins function as enzymes, as components of cell structure, as transporters of materials across the cell membrane and in cell movement.
* The building blocks of proteins are amino acids. Proteins are made by the joining of the amino acids into chains (joining between two amino acids is called a peptide bond).
  + Amino acids have carbon, hydrogen, oxygen, and nitrogen. A couple of amino acids also have sulfur atoms.
  + Amino acids have an amino group, represented by –NH2 and an organic acid, represented by -COOH
* Protein structure:
  + Primary (1o) – the sequence of the amino acids in that particular protein
  + Secondary (2o) – the manner in which the amino acids start interacting with each other; they form an alpha () helix or a beta ()-pleated sheet.
  + Tertiary (3o) – the manner in which the protein folds up to form a 3-dimensional molecule.
  + Quaternary (4o) – molecules that are composed of more than one peptide, such as hemoglobin as four polypeptides working together.
* Proteins can be denatured, which means that they lose their shape and their function. This can be achieved with heat or chemicals.

**Nucleic Acids**

* The two kinds of nucleic acid molecules are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
* Nucleic acids are composed of units called nucleotides (more about this later)
  + Nucleotides are made up of three components: a sugar, a phosphate and a base. The sugar differs between DNA (deoxyribose) and RNA (ribose). The different bases in DNA are cytosine, adenine, guanine and thymine (you will often see C, A, G and T instead of their names).
  + The nucleotides are held together by a strong bond (covalent bond) between the sugar group and the phosphate group. Thus, you will occasionally hear about the sugar-phosphate backbone.
  + The DNA molecule is a composed of 2 strands that form a helix (hence it is called the double helix); RNA is usually single-stranded.
* The specialized functions of different types of cells are determined by the genetic information stored in DNA.
  + A different blueprint means a different organism or cell
* RNA translates the information stored in DNA to construct proteins.
* Adenosine triphosphate (ATP), a nucleotide, is the major carrier of energy in all cells.

**Cytoplasmic or cell membrane**

* The cytoplasmic membrane contains/surrounds the "cytoplasm' and regulates what enters and leaves the cell.
* It is about 50% lipid (fat molecules) and 50% protein. The lipids are called phospholipids because they have a water loving end (a phosphate group) and a water hating tail (fat region). They spontaneously arrange themselves into two rows, hydrophobic (water hating) tails facing inward, away from the water on either side of the membrane, hydrophilic heads (water loving) facing out to associate with the water. (covered in MCB 13)
* Only molecules that like lipid can move through the layer (just like pouring water on oil they do not mix). The molecules that like water move through proteins in the membrane.
* In prokaryotes, proteins involved in respiration and photosynthesis, if present are located in the cell membrane.

**DISTINGUISHING CHARACTERISTICS AND STRUCTURES**

Only eukaryotic cells have a nucleus. Karyon means nucleus. Prokaryote means "before" nucleus and eukaryote means "true" nucleus.

**Architecture**

* Prokaryotic cells have an undifferentiated, grainy interior with no membrane-bound organelles. They have a nucleoid (a mass of DNA) rather than a membrane-bound nucleus.
* Prokaryotic cells are usually much smaller than eukaryotic cells.
* In eukaryotic cells, membrane-bound organelles compartmentalize different chemical activities and provide systems of transportation within the cell. The nucleus is also a membrane-bound structure but it contains the DNA.

**Cell Walls**

The majority of prokaryotic cells have cells walls which are chemically different from cell walls in eukaryotic cells.

* Bacteria have a complex and chemically unique (composed of peptidoglycan molecules) cell wall outside of their cell membrane.
  + The cell wall comes in two basic types that account for staining differences with a stain called the Gram stain (gram-negative bacteria vs gram -positive bacteria).
  + The gram-positive bacteria have either a very thick layer or many layers of peptidoglycan. The gram-negative have a much thinner layer of peptidoglycan.
  + Some antibiotics only act on one type of cell – penicillin is used to kill the gram-positive bacteria because penicillin messes up the peptidoglycan.
* The cell wall functions to give bacteria their characteristic shape and contain the cell's internal or turgor pressure. Bacterial cells' turgor pressure is extremely high because their contents are concentrated.
* The cell walls of archaea are chemically different.
* Many bacteria have a capsule or slime layer exterior to the cell wall. This layer functions in cell adhesion and helps to protect the bacteria.
* Eukaryotic cell walls, if present, are chemically different. FYI
  + Algae have a cell wall composed of cellulose.
  + Fungi have a cell wall composed of chitin; some have a cellulose cell wall.
  + Plants have a cell wall composed of cellulose
  + Animals lack a cell wall.

**Membrane:**

* The cell membrane of prokaryotes and eukarotes are very similar. They are composed of the same phospholipids and serve the same function, which is to allow food in and let wastes out.

**Cytoplasm**:

**Prokaryotes**

* In prokaryotes, the cytoplasm is a matrix composed primarily of water and protein where the cell's vital chemical reactions (metabolism) take place.
* The nucleoid or nuclear region is a mass of DNA usually arranged in a single circular molecule, the bacterial chromosome.
  + Some bacteria have plasmids, small extra-chromosomal DNA molecules that encode special functions. (we will return to these in video 5)
* Prokaryotic cytoplasm is packed with ribosomes, small structures that manufacture proteins. Prokaryotic ribosomes are equivalent in function to eukaryotic ribosomes but structurally they are smaller.
* Some bacteria have storage granules or gas vacuoles.
* Some bacteria form endospores, hardy resting structures that allow the organism to survive unfavorable conditions; they germinate to produce new vegetative cells when conditions improve.

**Eukaryotes**

* A lattice-like network of proteins forms a cytoskeleton; it functions to support the cell and is used when cells move.
* A membrane-bound nucleus containing nucleoli and the DNA is present.
  + Nucleoli are dense masses of RNA and proteins that manufacture ribosomes.
* DNA is associated with proteins (called histones) and organized into packages called chromosomes.
* A membrane system consisting of the endoplasmic reticulum (ER) and Golgi apparatus sorts and packages molecules produced by the cell.
  + Smooth ER (SER) is the site of phospholipid synthesis; rough ER (RER) is the site of most protein synthesis; ribosomes associated with RER are responsible for its rough appearance.
* Free ribosomes are present in the cytoplasm and participate in the synthesis of some proteins.
* Lysosomes contain enzymes that break down materials brought into the cell (recycling center of the cell)
* Mitochondria and chloroplasts are double-membrane-bound organelles that house proteins involved in respiration and photosynthesis, respectively. These proteins participate in ATP synthesis.
* Membranes around organelles is also a lipid bilayer composed of phospholipids

**Appendages:**

**Prokaryotes**

* Pili (pilus is singular) are straight hair-like appendages that attach bacteria to other cells.
* A sex pilus attaches bacteria to other bacteria for sharing of DNA.
* Flagella are appendages that allow bacteria to move toward favorable chemicals such as nutrients and away from harmful ones (called chemotaxis).
  + They are structurally different than eukaryotic flagella

**Eukaryotes**

* Eukaryotic cells do not have pili.
* Certain protozoa have flagella or cilia that function for locomotion.
* The only human cell with a flagellum is the sperm cell.
* Some humans cells have cilia (i.e. respiratory tract to move materials).

**Viruses**

* Viruses are very tiny and are not cells.
* Viruses need a host cell to reproduce; they cannot reproduce on their own outside of a living cell
* Viruses consist of a core of genetic material (RNA or DNA); a protein coat called a capsid. some also have an outer membrane coat called an envelope
* Viruses invade all types of cells (there are plant viruses, animal viruses, bacterial viruses etc).
* Once they invade the cell they shed their protein coat and hijack the host cell’s biosynthetic machinery (enzymes, ribosomes, and all the material needed) in order to reproduce.
* After the genetic material is copied and new components for the protein coat are made the virus parts assemble themselves and leave the cell (sometimes killing it).
* It only takes a few hours for a virus to infect a cell and then produce up to 1 million new viruses.
* Viruses do not all look alike. They are classified by their shape – icosahedral or helix. The viruses that infect bacteria are more complex in appearance (they look something like a lunar lander).
* Viruses come in a range of sizes, as well. The smallpox virus is fairly large (as viruses go) while the polio virus is much smaller.

**More about bacteria:**

* Bacteria are usually found in some form of three basic shapes – bacillus (rod-shaped), coccus (spherical in shape), and spiral.
* Notorious members of the bacillus-shaped organisms cause anthrax, diphtheria, tetanus, botulism, diarrhea, and some forms of pneumonia.
* The bad members of the coccus-shaped bacteria cause some forms of pneumonia, gonorrhea, strep throat, and Scarlet Fever.
* The spiral-shaped bacteria have their bad members as well. They cause cholera and syphilis.

**Review Questions**

**Fill In**

1. The building blocks of proteins are \_\_\_\_\_\_.

2. \_\_\_\_\_\_ is the nucleic acid that encodes the genetic information in a cell.

3. DNA has the shape of a \_\_\_\_\_\_.

4. The \_\_\_\_\_\_of a bacterial cell withstands turgor pressure, preventing the bursting of the cell.  
  
5. The four bases in DNA are \_\_\_\_\_\_, \_\_\_\_\_\_, \_\_\_\_\_\_, and \_\_\_\_\_\_.   
  
6. The \_\_\_\_\_\_ is the boundary around all cells.   
  
7. \_\_\_\_\_\_ are appendages found in both eukaryotic and prokaryotic cells that allow cells to move.   
  
8. \_\_\_\_\_\_is the nucleotide that is the energy molecule for all cells.

**True/False**

1. \_\_\_\_ Mitochondria and chloroplasts are thought to have arisen from bacteria

2. \_\_\_\_The term prokaryotic means true nucleus.

3. \_\_\_\_The hydrophobic tail of a phospholipid molecule is composed of chains of fat molecules.

4. \_\_\_\_ Ribosomes are responsible for the roughness of the RER.

5. \_\_\_\_ All cell walls are chemically the same.

6. \_\_\_\_ All cells, even viruses, are able to reproduce on their own.   
  
7. \_\_\_\_ All cells have ribosomes.  
  
8. \_\_\_\_ Only human cells are invaded by viruses.

**Multiple Choice**

1. Select the correct statement about DNA.

A) It contains the sugar ribose.

B) It is usually single-stranded.

C) It is used to synthesize RNA

D) it is only found in eukaryotic cells.

2. Select the correct statement about prokaryotic cells.

A) Human cells are prokaryotic cells.

B) Most are smaller than eukaryotic cells.

C) Their nucleus has a defined membrane.

D) They contain many kinds of organelles.

3. By chemotaxis, bacteria swim toward a

A) favorable source of oxygen.

B) magnetic field.

C) source of nutrient.

D) source of light.

4. Which cell appendage is used for attachment by bacterial cells?

A) cilium

B) flagellum

C) pilus

D) pseudopodium

5. Which cell organelle is often associated with protein synthesis?

A) lysosomes

B) Golgi apparatus

C) mitochondrion

D) RER

6. Which cell organelle produces the energy for the cell?

A) lysosomes

B) Golgi apparatus

C) mitochondrion

D) RER (Rough endoplasmic reticulum)

7. A cell membrane

A) is a bilayer

B) limits the cytoplasm

C) has proteins in it

D) surround the cytoplasm

E) all are correct

**Answers**

**Fill In**

1. amino acids

2. DNA

3. double helix

4. Cell wall

5. Adenine, Thymine, Guanine, and Cytosine

6. cell membrane

7. flagella

8. ATP

**True/False**

1. T

2. F

3. T

4. T

5. F

6. F

7. T

8.F

**Multiple Choice**

1. C 2. B 3. C 4. C 5. D 6. C 7. E

**Suggested Readings**

Fawcett, D. 1981. *The Cell: An atlas of fine structure.* New York: W.H. Freeman.

Inouye, M., ed. 1986. *Bacterial outer membranes as model systems*. New York: John Wiley.

Krawiec, S., and Riley, M. 1990. Organization of the bacterial chromosome. *Microbiological Reviews* 54:502-39.

Rothman, J. 1985. The compartmental organization of the Golgi apparatus. *Scientific American* 244:57-67.