

Study Guide to Cell Structure

- I. **Prokaryotic Cells** [pro = before; karyose = kernel or nucleus]
- A. **Plasma Membrane:** Each cell is enclosed within a typical Singer fluid mosaic membrane which is composed of a phospholipid bilayer embedded with proteins and altered proteins. The primary function of the plasma membrane is to serve as a diffusion barrier between the interior of the cell and the environment. The surface of the cell may have prokaryotic **flagella** and/or **pili**. In more advanced prokaryotic cells, the plasma membrane may be invaginated to form respiratory structures called **mesosomes**, or photosynthetic structures called **thylakoids**.
 - B. **Nucleoid** [oid = resembling]: The nucleoid is a region in the center of the cell containing a large DNA molecule. The DNA is naked (not complexed with histone proteins) and circular, and is not properly called a chromosome. The nucleoid may also contain a variety of smaller circlets of DNA called **plasmids**. The specific selection of plasmids varies from cell to cell. The nucleoid is not surrounded by a nuclear envelope or any other membrane.
 - C. **Cytoplasm** (cyte = cell; plasm = fluid ground substance): Cytoplasm is a rich organic soup composed primarily of water, and containing a variety of ions, inorganic and organic molecules. The major organelles in the cytoplasm of a prokaryotic cell are **ribosomes**. Ribosomes are responsible for the process of translation (protein synthesis).
 - D. Prokaryotic cells contain no membrane bound organelles (other than mesosomes and thylakoids, which are actually invaginations of the plasma membrane).
 - E. **Cell Wall:** The prokaryotic cell is enclosed within a cell wall formed from a substance called **peptidoglycan**. Peptidoglycan is constructed from a long polysaccharide (glycol = sugar) cross-linked by short oligopeptide chains. Prokaryotic cells are generally divided into two major categories based upon the complexity of the cell wall. Gram positive cells have a relatively simple cell wall, while gram negative cells have a more complex, layered cell wall. (Gram positive and gram negative are derived from the response of the cell to a staining protocol called the gram stain; the more complex walls of gram negative cells prevent the dye from penetrating and staining the cells.)
 - F. **Capsule**, or Slime Layer: Some prokaryotic cells are embedded in a mucous-like substance called a capsule. The capsule material is **hygroscopic** (meaning that it holds water) and thus the capsule serves to keep the cell hydrated.
- II. **Eukaryotic Cells** [eu = true or authentic]
- A. **Nucleus** [pl. Nuclei]

1. **Nuclear Envelope:** The nuclear envelope is a **double** layer of membrane surrounding the nucleus. It serves as a barrier sequestering the nuclear contents from the rest of the cell, thus compartmentalizing DNA functions in a relatively small space. The nuclear envelope is pierced by numerous **nuclear pores**. These provide passage for large objects (such as newly-formed ribosomes) to move from the nucleus into the cytoplasm and vice versa. The nuclear envelope probably evolved via endogenous elaboration of the plasma membrane.
 2. **Nucleoplasm:** The nucleoplasm is a rich organic soup composed primarily of water. It contains a variety of ions, inorganic and organic compounds. The nucleoplasm particularly contains a large population of deoxyribonucleotides and ribonucleotides, and the enzymes particular to the process of DNA replication and transcription (RNA synthesis).
 3. **Chromatin/Chromosomes** [chromo = colored; tin = thread; soma = body]: The chromosomes are the bodies in the nucleus which carry the genetic information of the cell. Chromosomes are composed of a complex of DNA and protein called chromatin. Chromatin is approximately 50% (by weight) DNA and 50% protein. The proteins in chromatin are a special class of protein called histones. The number, sizes and shapes of the chromosomes in a cell are characteristic of the species from which the cell was isolated.
 4. **Nucleolus** [pl. Nucleoli]: A nucleus typically contains from one to four darkly staining bodies called nucleoli. Nucleoli are the sites of ribosome assembly. A ribosome is composed of proteins (made in the cytoplasm by other ribosomes) and special RNA's (ribosomal RNA's made in the nucleus by transcription from special regions of the DNA. These components are assembled in a nucleolus. A nucleolus really has no specific structure, and is not surrounded by a membrane. It is simply a collection of partially assembled ribosomes. When the ribosomes are completed, they leave the nucleolus and travel through a nuclear pore out into the cytoplasm. No ribosome functions in the nucleus. During mitosis or meiosis, when ribosome construction temporarily ceases, the nucleoli gradually disintegrate as the partially completely ribosomes are completed and leave, but no new ones are initiated.
- B. The **Membrane Systems:** Eukaryotic cells are characterized by containing a large number of structures composed all or partially of membranes. Several of these form an interconnecting functional network.
1. **Plasma Membrane:** Like the prokaryotic cell, the eukaryotic cell is separated from its environment by a Singer fluid mosaic membrane called the plasma membrane. The primary function of the plasma

membrane is to serve as a diffusion barrier between the cell and the environment.

a. Ways things get through membranes

i. **Passive processes:** These are processes which don't cost the cell energy. All of these processes are driven by diffusion, and thus are limited to movement with (or "down") the concentration gradient. In other words, they are only capable of moving substances from a region of high concentration to a region of lower concentration.

a. **Simple Diffusion:** Diffusion is the movement of molecules from a region of higher concentration to a region of lower concentration until equilibrium is achieved.

b. **Osmosis:** Osmosis is the diffusion of a solvent (in biology, essentially always water) through a selectively permeable membrane.

c. **Passive Transport or Facilitated Diffusion:** Passive transport is the movement of substances through the membrane via a carrier molecule, but with no expenditure of energy. Movement of the carrier is spontaneous.

ii. **Active Processes:** Active processes cost the cell energy. Many substances (like certain carbohydrates, and amino acids) are moved into the cell by both passive and active processes. In conditions of abundance, the passive processes are sufficient to meet the cell's needs. But if the commodity is scarce, the active process is necessary. Active processes are capable of moving substances against the concentration gradient.

a. **Active Transport:** Active movement of substances through the membrane via a carrier molecule is called active transport. This process is very similar in concept to Passive Transport, except that the carrier molecule won't move unless energy is provided. This energy is in the form of ATP's "spent." Since this process is run by an "engine," it is capable of moving passengers against the concentration gradient (from low concentration to high concentration). No passive process is capable of doing this. Besides active nutrient transport systems, an extremely important active transport system (the sodium-potassium pump) is part of the mechanism by which nerve cells are able to transmit electrical signals.

envelope and the plasma membrane, and they may interconnect with each other.

- a. **Smooth Endoplasmic Reticulum (SER):** The surface of the membranes of SER is smooth and featureless. Besides the usual transport functions, SER is often apparently a site of lipid synthesis. SER also generates the new layers of Golgi bodies. SER is frequently tubular in shape.
 - b. **Rough Endoplasmic Reticulum (RER):** In electron micrographs, the surface of the membranes of RER is rough and sandpapery, due to the presence of many small nodules embedded in the surface. These are ribosomes. The function of a ribosome is to perform protein synthesis, so those regions of the ER which have ribosomes on their surfaces are associated with that function. RER is generally in the shape of flattened sacs.
3. **Golgi Apparatus:** The Golgi apparatus of a cell is composed of numerous stacks of hollow membrane discs. Each stack is called a **Golgi body**. These are apparently produced by the endoplasmic reticulum, probably the SER. Each Golgi body is constantly being renewed at one end, while the aging discs at the other end are constantly being eroded away at the edges. At its creation, each of the discs of a Golgi body contains materials in its interior (its cisterna) which were manufactured by the cell's synthetic processes, very likely materials synthesized in association with the ER. Throughout its life, the Golgi disc processes this material and packages it into small, membrane bound fragments of itself called Golgi vesicles. These vesicles are pinched away from the edges of the disc, gradually claiming all of the substance of its structure. Eventually the disc will simply disappear. As long as the Golgi body is active, new discs will be added to replace the ones which disappear. NOTE: Golgi bodies are not in the business of garbage disposal; they are packaging materials intentionally manufactured by the cell.
 4. **Nuclear Envelope:** The nuclear envelope is considered a part of the membrane systems of the cell. It interconnects with the ER, and through them, with the Golgi and probably the plasma membrane.
- c. **Cytoplasm and its Organelles.** The cytoplasm of the cell is all of the material located between the nuclear envelope and the plasma membrane. This region is highly organized place in which a variety of **organelles** ("little organs") are positioned in a fluid matrix called the **cytoplasm**.
 1. **Cytoplasm:** The cytoplasm is a rich organic soup composed primarily of water. In the water, as in the nucleoplasm, are many ions, inorganic and organic compounds. Although the contents of the cytoplasm are, in general, very similar to the contents of the nucleoplasm, there are some important differences related to the different functions which are

performed in the cytoplasm and the nucleus. For instance, the cytoplasm doesn't contain the high concentrations of deoxyribonucleotides and ribonucleotides found in the nucleoplasm, or the enriched numbers of the enzymes necessary for the other general functions required for the DNA and RNA related processes that go on in the nucleus. And the nucleoplasm doesn't contain the high concentrations of amino acids (necessary for protein synthesis, which occurs only in the cytoplasm) found in cytoplasm. The cytoplasm is also rich in sugars and other raw energy compounds.

2. **Non-membrane Bound Organelles** found in the cytoplasm.
 - a. **Ribosomes:** Ribosomes are small structures which are found in great numbers in the cytoplasm of any active cell. Their function is to perform the process of **translation** (protein synthesis). The ribosomes of eukaryotic cells are very similar to those found in prokaryotic cells. They are somewhat larger, and contain a larger number of different proteins and a larger number of different ribosomal RNA's, but their structure is basically the same. A ribosome is composed of two subunits, a large and a small. Each subunit contains a specific assortment of proteins and rRNA's. When the ribosome is not actively synthesizing protein, its two subunits are separate. When the translation process begins, a large and a small subunit will assemble around the message molecule which gives them their instructions. Together, they subunits of a eukaryotic ribosome contain about 80 different kinds of proteins, many of them enzymes necessary for the translation process, as well as five different kinds of rRNA's. Many of these proteins and RNA's are present in multiple copies. (The ribosomes of prokaryotic cells contain only about 50 kinds of proteins and three kinds of rRNA's). Ribosomes are assembled in the **nucleolus** inside the nucleus, using ribosomal RNA's which are transcribed in the nucleus (as are all RNA molecules) and those 80 different kinds of proteins, which were manufactured out in the cytoplasm, traveled through endoplasmic reticulum to the nucleus and entered through a nuclear pore which articulates with the ER. The finished ribosome leaves the nucleus through another nuclear pore.
 - b. **Centriole:** Centrioles come in pairs; any cell which has a centrioles will have two of them. These small structures are composed of **microtubules**—27 of them, arranged in an array described as “nine triplets.” The general shape of the centrioles is rather like a tin can with one end open. The two centrioles are positioned with their long axes at ninety degrees to each other. Centrioles are a source for the production of microtubules in the

cell, for use in several different functions. Centrioles create and organize the microtubules of the cytoskeleton. The basal body which produces and anchors any cilium or flagellum is a copy of a centrioles. In cells with centrioles, the spindle tubules (which are microtubules) generated during mitosis or meiosis are produced by the centrioles. Evidence suggests that a primary function of the centrioles is their role in the generation of cilia and flagella, as the cells of higher plants have no centrioles. There is no stage in the life cycle of a conifer or an angiosperm in which it is necessary to generate cilia or flagella. These plants **do** produce spindle tubules for mitosis and meiosis, despite having no centrioles, which suggests that, while having centrioles is convenient for spindle production, that isn't their primary function.

- c. **Cytoskeleton:** The cytoskeleton is a complex arrangement of **microtubules** and **microfilaments** which ramifies throughout the cytoplasm, providing support and a superstructure for attachment. The entire function of this superstructure is not really understood. Microtubules, which are tiny hollow rods made of the protein **tubulin**, are often found in positions in which they are involved in support and movement. Microfilaments, which are tiny solid rods made of protein, are also frequently implicated in movement functions. For example, the contractile fibers of a muscle cell are composed of two kinds of microfilaments. Whether the cytoskeleton has other functions is not yet known.

3. **Organelles bound by a single membrane.**

- a. **Vesicles:** Primarily Golgi vesicles. These are small membranous packages containing materials produced within the cell, all or mostly by the Golgi apparatus. These vesicles have a variety of fates, depending upon their contents.
 - i. **Microbodies:** These are special vesicles which contain sets of enzymes which have particular types of functions, and which the cell needs to keep confined. The best known of these, and the easiest to understand, is called a **lysosome** [lysis=breakage; soma=body]. The lysosome contains digestive enzymes which, if they were to be released into the cytoplasm, would digest the materials of the cell and kill it. At some times in the life of an organism this may, in fact, be the function of the lysosome (for instance, during the building and breaking down processes of development in an embryo). However, the everyday function of lysosomes is probably more mundane. Their primary function is probably in the digestion of food and waste materials. Since most cells obtain nutrients from materials which are constructed of

essentially the same materials as the cells themselves, the enzymes used to extract those nutrients must, of necessity, be capable of doing the same thing to the cell. They must, therefore, be confined.

- ii. **Secretory Vesicles:** Many of the materials packaged into Golgi vesicles are intended for export from the cell (secretion). These vesicles travel to the plasma membrane (possibly with the help of the cytoskeleton), where they release their contents to the outside of the cell by **exocytosis**. Examples of materials which might be treated this way are hormones and mucous (used to lubricate passages inside the body). [NOTE: **secretion** is performed with materials which the cell intentionally produces to export; the elimination of waste materials is **excretion**.]
- b. **Vacuoles:** “Vacuole” is hard to define. Essentially, a vacuole is a single membrane bound package in the cell which is not a vesicle. This is a very unsatisfactory definition, but vacuoles are diverse, and no more precise definition is really possible. Vacuoles fall into several different categories, some of which have very specific functions. Some of the best known of these are:
 - i. **Food Vacuoles:** A food vacuole is a package of a food substance which the cell acquires by **endocytosis**. Usually, the food vacuole will fuse with a **lysosome**, whose enzymes will break down the food within the vacuole for use by the cell. When a lysosome has assimilated enough food vacuoles, and its enzymes are getting worn out, it will dispose of its contents (the waste left over from digesting the food) by **exocytosis**. The cell can always manufacture new lysosomes using its Golgi apparatus.
 - ii. **Central Vacuole** of plant cells: This is a large vacuole in the center of the mature plant cell. It contains water and a small amount of salt and/or other substances (such as proteins). Along with the non-elastic cellulose cell wall of the plant cell, the central vacuole uses **osmosis** to create **turgor pressure** (osmotic pressure against the inside of the cell wall) to keep the plant cell stiff [turgid=stiff]. This is the means by which delicate plant leaf tissue is kept stiff enough to remain outstretched and able to perform its function as a solar panel.
 - iii. **Contractile Vacuole** in fresh water Protists: This is a specialized structure which functions in osmotic control. In a unicellular organism living in fresh water, the higher water

concentration outside the cell will cause water to tend to osmose into the cytoplasm. The contractile vacuole collects excess water and expels it to the outside of the cell, thus preventing the cell from exploding due to increasing internal pressure. Water can be a very significant force.

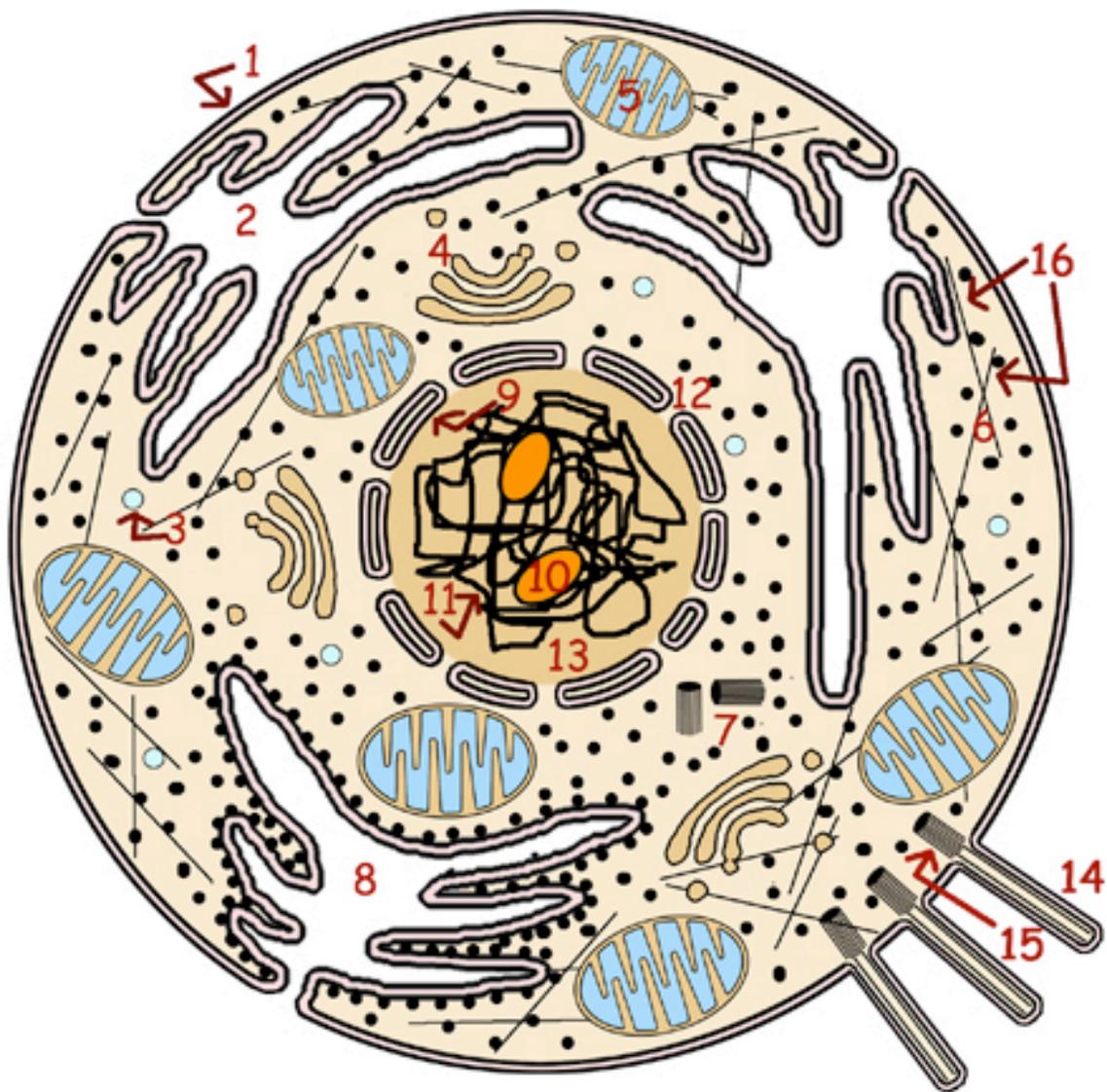
4. **Organelles Bound by a Double Membrane:** There are two organelles which fall into this category. Both of these organelles are large and complex, and both are involved in the cell's energy processing machinery. Because of the complexity of these organelles, and because they contain in their structures so many features which are characteristic of prokaryotic cells, most biologists now believe that the evolutionary origins of these two organelles was through a process of **endosymbiosis**. A symbiotic relationship is a relationship in which two (or more) organisms live in partnership with each other. In many cases, this kind of partnership becomes so vital that neither of the partners can exist without the other. **Endosymbiosis** is a symbiotic relationship in which one of the partners actually lives inside the body of the other. There are many endosymbiotic relationships which are well known to us today, and probably many more not yet discovered. Biologists now believe that mitochondria and chloroplasts are the distant descendants of independently living prokaryotic cells which entered into endosymbiotic partnerships with larger cells.
 - a. **Mitochondrion** (pl. mitochondria). All living eukaryotic cells contain mitochondria—usually many of them. Mitochondria are specialized to perform the function of **aerobic cellular respiration** by which the cell converts its raw energy source (food) into biologically useful energy (**ATP**). The first stage of this process, glycolysis, occurs in the free cytoplasm, but the final stages, the Krebs Cycle and Electron Transport, occur in the mitochondria. Structurally, the mitochondrion is surrounded by two membranes. The **outer membrane** is smooth and uncomplicated, but the **inner membrane** is convoluted into inwardly directed folds or tubes called **crystae** which tremendously increase its surface area. The space between the inner and outer membranes is called the **intermembrane space**. The space inside the inner membrane is filled with another rich organic soup called the **mitochondrial matrix**. Again, this material is mostly water, but contains ions, inorganic and organic substances. The mitochondrial matrix is rich in those enzymes and materials specific to the aerobic process of cellular respiration (Krebs Cycle and Electron Transport). Contained within this matrix are a single circular, naked DNA molecule and many prokaryotic style ribosomes. The DNA contains functional

genes which are not duplicated in the nucleus of the cell. These genes are transcribed and translated in the mitochondrion, using the mitochondrial ribosomes for the translation process. Many of the proteins necessary for aerobic cellular respiration are coded into the mitochondrial DNA. The presence and nature of the DNA and the ribosomes provide the most telling evidence in support of the **endosymbiotic theory of mitochondrial origin**.

- b. **Chloroplast** [chloro=green; plast=object]. Chloroplasts are found only in the cells of plants and eukaryotic algae. They are actually part of a family of interrelated organelles called **plastids**. Other plastids are amyloplasts (starch storage organelles), chromoplasts (colored plastids found in many fruits and flowers), and proplastids (immature plastids). Chloroplasts are specialized to perform **photosynthesis** [photo=light; synthesis=building], the process of manufacturing carbohydrates from inorganic CO₂, using light as an energy source. Again, chloroplasts surrounded by two membranes, and **outer membrane** and an **inner membrane**, with an **intermembrane space** between them. The inner membrane is even more complex than the inner membrane of the mitochondrion. Most of the inner membrane is formed into thin flattened sacs called **thylakoids** (the membrane is referred to as the **thylakoid membrane**). In some places within the chloroplast, the thylakoids are solitary (**frets**) but in many places they are stacked into dense arrays called **grana** [sing. granum=grain]. The green color of chloroplasts is due to a pigment called **chlorophyll** [phyll=leaf] which is part of the thylakoid membranes. The chlorophyll is vital in the light absorption part of the photosynthesis process. The thylakoids run through the inner region of the chloroplast, which is filled with yet another rich organic soup called **stroma**. Once again, this material is mostly water, and contains a variety of ions, inorganic and organic compounds. Stroma is distinguished from the other plasms because it is enriched in the materials necessary for the process of photosynthesis. In the stroma, there is a single circular, naked DNA molecule and many prokaryotic style ribosomes. Again, the DNA of the chloroplast contains genes which are not duplicated in the nucleus, and which code for many of the proteins necessary for the process of photosynthesis.

- D. **Cell Wall** of the Plant Cell: **NOTE: This structure is separate and distinct from the plasma membrane!** Plant cells must, like all other cells, be enclosed in a plasma membrane. However, **in addition to the membrane**, plant cells are also surrounded by a cell wall. This cell wall lies outside the plasma membrane, and is composed primarily of cellulose,

a structural polysaccharide. Cellulose is somewhat flexible, but non-elastic. Therefore, a cell wall will bend and flex, but will not stretch. In some plant cell types the cell wall is supplemented by the deposition of materials like lignin or suberin. Lignin is hard and rigid, and is characteristic of cells like those that makeup the wood in a tree's trunk. Suberin is a wax, and is thus waterproof. It is found in the cell walls of tissues like cork. Cell walls are not capable of functioning as an osmotic or diffusion barrier.



Animal (Eukaryotic) Cell

- | | |
|--------------------------------|----------------------------|
| 1-Plasma Membrane | 9-Double Nuclear Envelope |
| 2-Smooth Endoplasmic Reticulum | 10-Nucleolus |
| 3-Vacuole | 11-Chromosomes (Chromatin) |
| 4-Golgi Body with Vesicles | 12-Nuclear Pore |
| 5-Mitochondrion | 13-Nucleoplasm |
| 6-Ribosomes | 14-Cilium |
| 7-Centrioles | 15-Basal Body |
| 8-Rough Endoplasmic Reticulum | 16-Cytoskeleton |