Cells/Cytology

The cell is the fundamental structure and functional unit of the body.

Cellular function is referred to as metabolism, and in order for cells to remain alive certain requirements must be met.

Each cell must have:
1) access to nutrition
2) access to oxygen
3) a mechanism to eliminate waste products

All of this is achieved through interaction with the circulatory system and its interaction with other body systems.

Cellular Diversity

Although all cells in the body come from a single cell, through the process of differentiation they form different cell types. Once a cell has specialized it cannot digress back to an earlier cell type. (there are some exceptions to this).

Cells vary in size and shape. This is closely tied to the central tenet of anatomy: "form follows function."

cells are measured in micrometers, often referred to as microns. 1 micron = 1/1000th mm

Red Blood Cell = 7.5 microns

White Blood Cell = 10 - 12 microns

Ovum = 140 microns

Some nerve cells, although microscopic in diameter, may be more than a meter in length

Cell shapes vary according to function. Think about this for Discussion. Remember, form follows function.

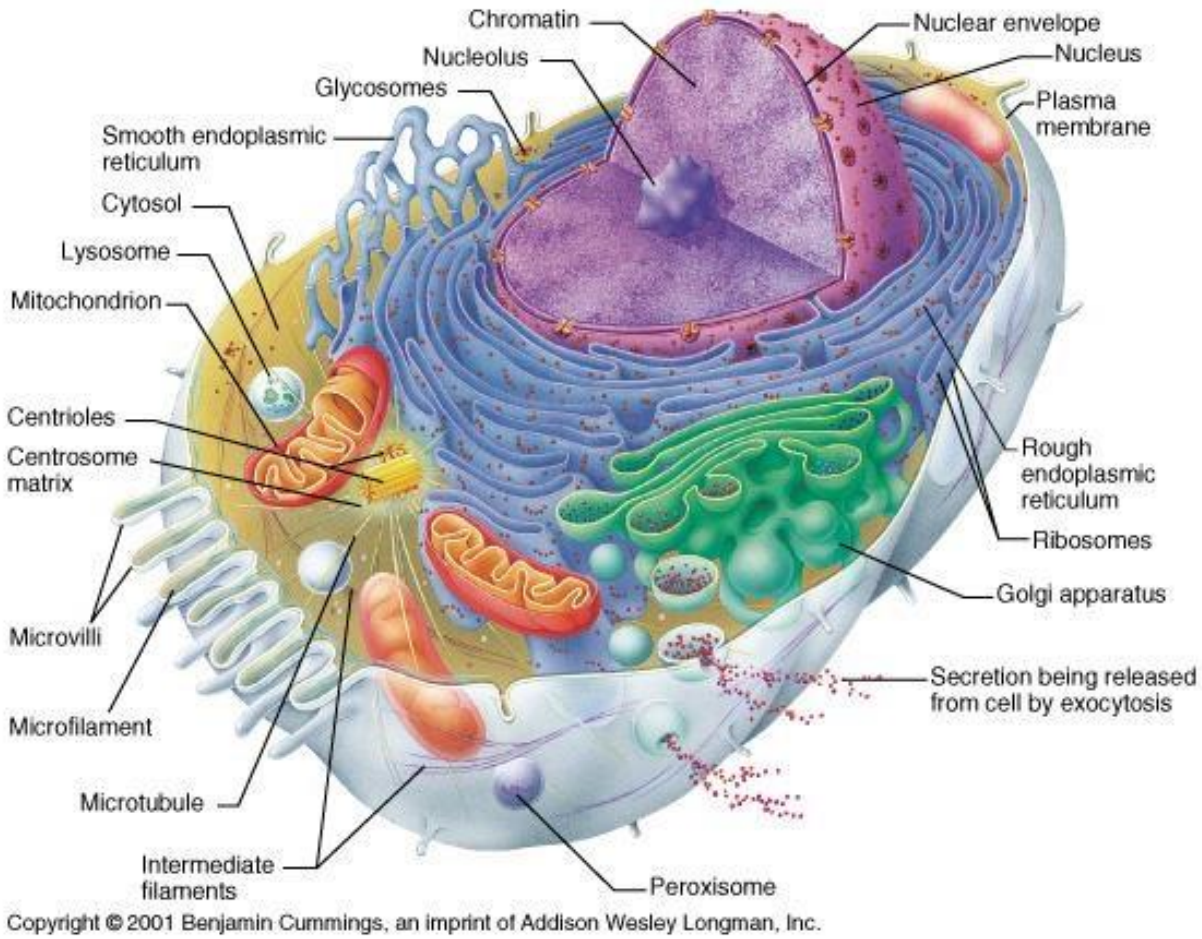
Some cells also have some surface specialization's, i.e. cilia, flagella, microvilli, gelatinous coats

Keep in mind that each cell is essentially a small chemistry lab and all the processes that occur within the cell must adhere to the rules of chemistry. From this concept came the study of biochemistry.

Cell Structure

There are 3 principle parts to a cell:

1) cell (plasma) membrane
2) cytoplasm with organelles
3) nucleus



Let us take a look at some of the various structures of a typical cell.

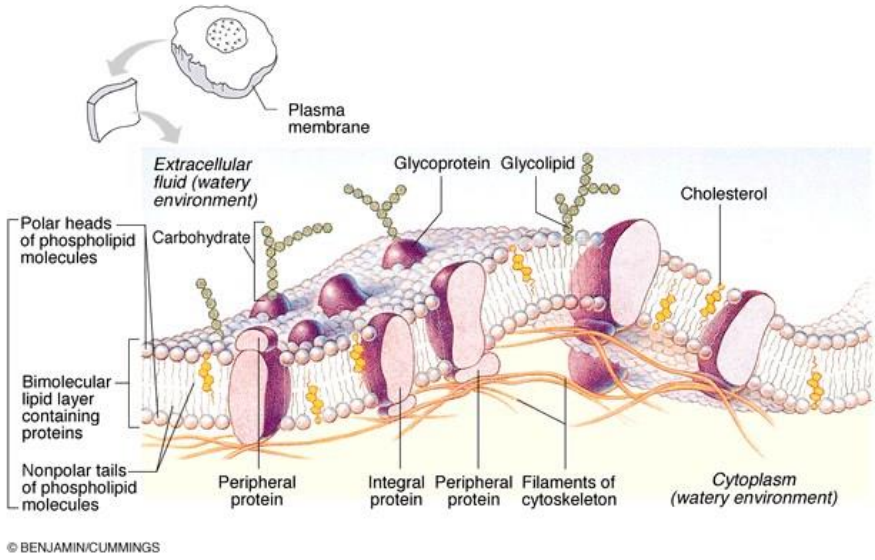
Plasma membrane

This structure is only7.5 - 10 nm (nanometers – not micrometers) thick and therefore is not visible with the light microscope.

This membrane is described as a fluid mosaic model, comprised of a bilipid layer, with integral proteins. The plasma membrane is roughly 50 % lipid and 50 % proteins, but is still referred to as a bilipid layer for functional reasons.

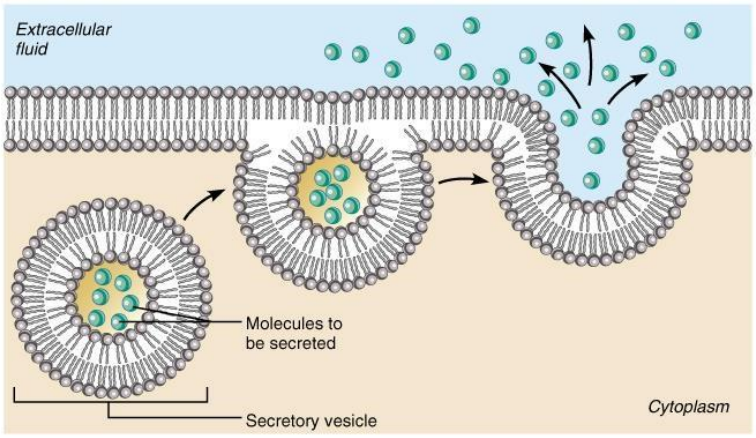
The lipids comprising this membrane are phospholipids. Due to their biochemical nature they are described as having a head region that is described as hydrophilic (essentially water loving) and a tail region that is described as hydrophobic (essentially afraid of water). This is due to the polarity of the molecules. This means that the "head" of the phospholipid molecule will freely interact with water molecules, while the "tail" end will not interact with water molecules. By placing these phospholipid molecules in a "bilipid layer" with the head regions oriented to the surfaces of the layer we create a membrane that will freely interact with water molecules along either surface of the membrane, but will not allow passage of water through the membrane. This is ideally suited for keeping water (and dissolved solutes) either inside or outside of the cell. However, there are times when we need substances to pass from the outside of the cell to the inside or vice versa. Some substances, due to their chemical nature, cannot pass through the bilipid membrane. If these

substances are small enough they may pass through special pores located in some of the integral proteins embedded in the membrane. If they are too large to pass through specialized pores in the membrane they can bind to peripheral proteins and via active transport, be carried across the membrane. It is important to recall that lipids are readily miscible (will freely interact) with other lipids. Or more simply put, lipids can dissolve in other lipids. This means that lipid soluble molecules can readily pass through the phospholipid bilayer.



The fact that lipids are readily miscible with other lipids allows for restructuring of cellular membranes with very little expenditure of energy. Some examples are:

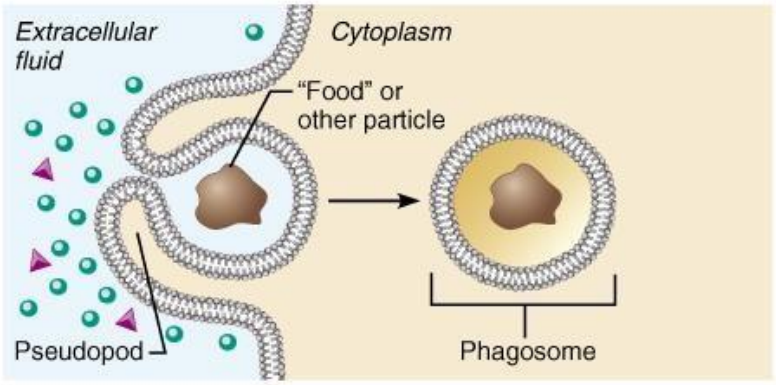
Exocytosis: expelling materials from the cell to the extracellular environment. Note that a secretory vesicle is also composed of a bilipid layer. This allows for the vesicle to fuse with and become part of the plasma membrane of the cell. This will result in the contents of the vesicle being deposited outside of the cell with very little expenditure of energy.



(a)

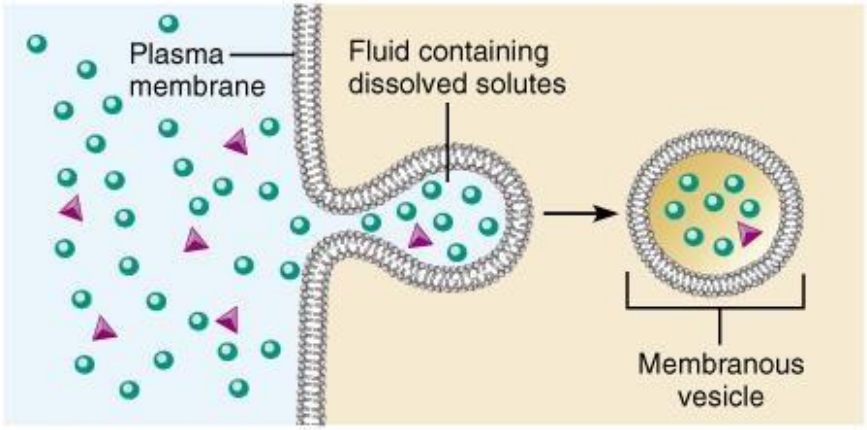
Endocytosis: is the process of taking material into the cell. This comes in three different forms,

1. **phagocytosis**: is the equivalent of cell eating. In this process the cell encounters a particle of debris that is much too large to bring through the plasma membrane. The cell will send out extensions (called pseudopods) of its plasma membrane and engulf the "food" particle. Because lipids are readily miscible with lipids, a new portion of the plasma membrane is formed and the old, invaginated portion of the plasma membrane becomes the wall of a structure termed a phagosome. The phagosome can be acted upon by the cells version of a digestive system.



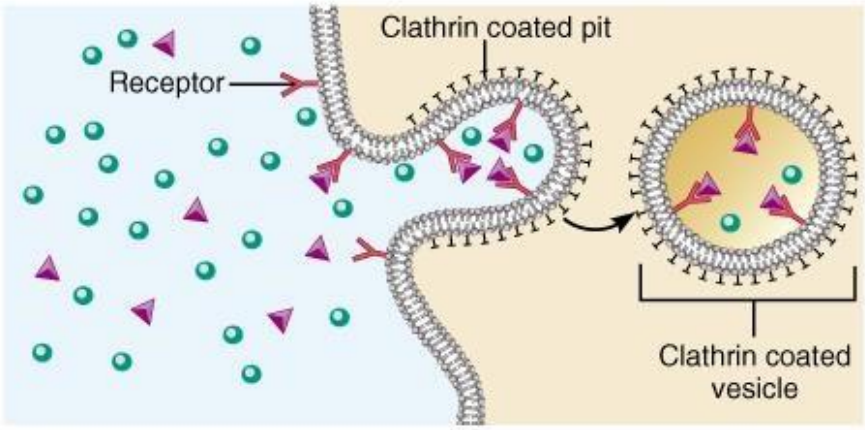
(a) Phagocytosis

2. **pinocytosis**: (often referred to as bulk phase endocytosis) is the equivalent of cell drinking. In this process an invagination of the plasma membrane forms and the fluid surrounding the cell (and any substances dissolved in that fluid) move into the invagination. Again, because lipids are readily miscible with lipids, a new portion of the plasma membrane is formed and the old, invaginated portion of the plasma membrane becomes the wall of a membranous vesicle. This vesicle can be acted upon by the cells version of a digestive system.



(b) Bulk-phase endocytosis

3. **receptor mediated endocytosis**: is a process of taking in molecules for which the cell has specific receptors. In this process, when the receptors have bound their respective substance the cell begins an invagination process that is very similar to that seen in pinocytosis. The result is an internalized vesicle that contains the substance for which the receptors showed specificity as well as some of the extracellular fluid and its dissolved substances.



(c) Receptor-mediated endocytosis

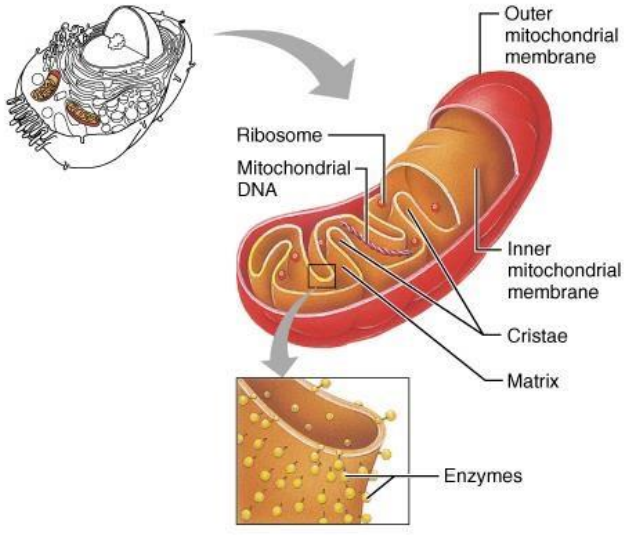
Cytoplasm

Cytoplasm refers to the material within the cell yet outside the nucleus. Inside the nucleus we have nucleoplasm. This includes the organelles of the cell, the intracellular fluid (cytosol), and other structures such as inclusion bodies and free ribosomes.

Mitochondrion

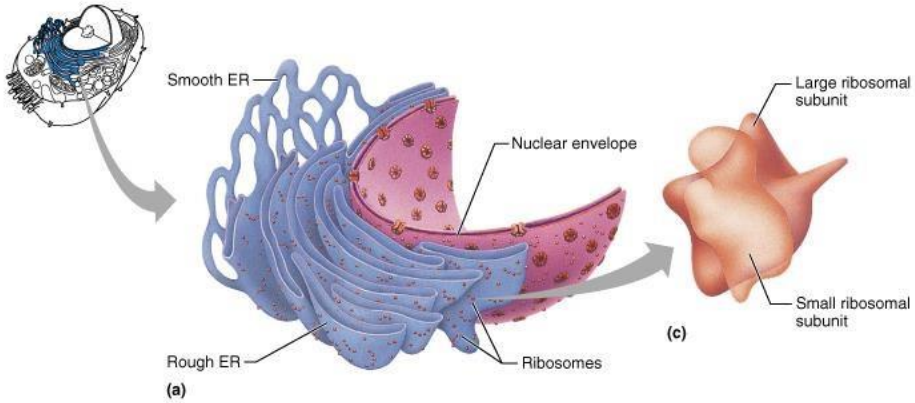
The mitochondrion (mitochondria – pleural) is often referred to as the powerhouse of the cell. Itfunctions to provide energy for the cell by conversion of an adenosine molecule between two forms. Adenosine diphosphate (ADP) is an adenosine molecule with two phosphate groups attached. When cells have "eaten," the energy gained from the food is used to bind a third phosphate molecule to the ADP thus converting it into Adenosine Triphosphate (ATP), which is a high energy molecule. When the cell needs energy, an ATP molecule can be broken down into ADP and an inorganic phosphate. The energy released by this process provides the energy to power the cell.

Mitochondria are double membrane organelles. There is an outer, smooth membrane and an inner, folded membrane. These folds are called cristae and they provide for more surface area. On these cristae we find elementary particles (oxysomes), which is where the ADP/ATP conversion takes place. If we return to "form follows function" it makes sense that if energy conversion occurs at oxysomes and oxysomes are found on the surface of the inner mitochondrial membrane, and the inner mitochondrial membrane has a large surface area due to the cristae (folds), the more power conversion is possible.



Endoplasmic reticulum (ER)

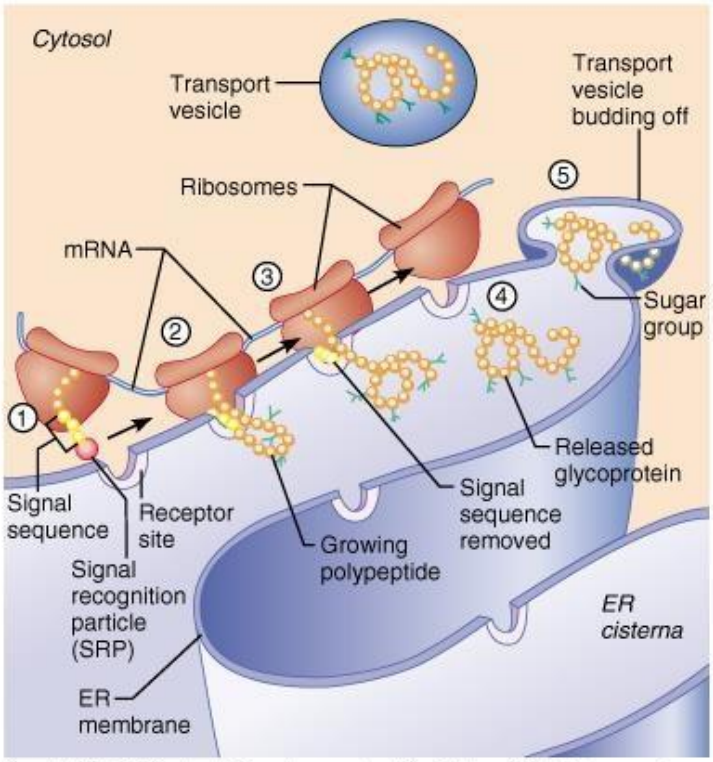
In the simplest terms, the endoplasmic reticulum can be viewed as the production (assembly) line of the cell, although it has many functions which relate to the specific type of cell in which it is located. There are two types of endoplasmic reticulum 1) Rough Endoplasmic Reticulum (RER) and 2) Smooth Endoplasmic Reticulum (SER).



RER is studded along its surface with ribosomes (discussed later). RER resembles a complex stack of double membranes forming a tube between the membranes. This system of membranes is continuous with the nuclear envelop. Very seldom are they connected to the plasma membrane (cell membrane). The RER is generally involved in the production of proteins.

SER is not associated with ribosomes. It is very abundant in steroid producing cells. It functions in synthesis, transport, and storage of lipids, metabolism of carbohydrates, and detoxification of substances. As expected, it would be found in abundance in cells that play a major role in detoxification, such as in the liver.

SER in striated muscle cells is called **sarcoplasmic reticulum**. Here it may help to conduct impulses, and has specialized areas that act a calcium storage sites. This is vital to the physiology of muscle contraction.



Ribosomes

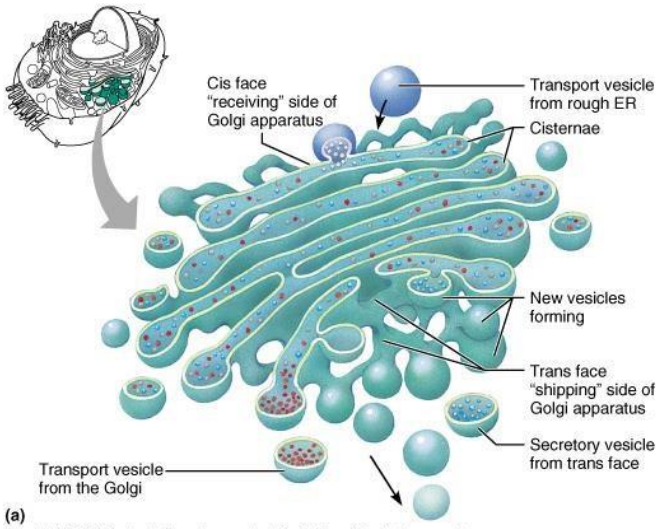
Robosomes are small, dark staining granules made of proteins and ribosomal RNA. They are produced in an organelle known as the nucleolus, which is found in the nucleus. Each ribosome is made of two globular subunits, a large ribosomal subunit and a small ribosomal subunit.

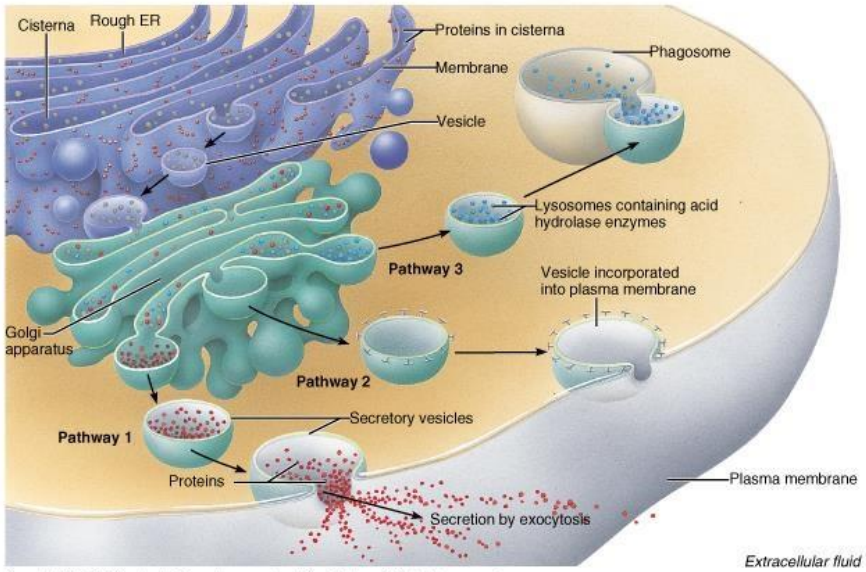
Ribosomes are sites of protein synthesis and they may float freely in the cytosol or they may be attached to the endoplasmic reticulum. Free ribosomes make soluble proteins that will function in the cytosol. Membrane bound ribosomes function to read the messenger RNA (mRNA) code and are mainly involved in synthesizing protein products destined for cellular membranes or for export from the cell. They may be viewed as the workers along the assembly line.

Golgi

Golgi (also called the golgi complex of golgi apparatus) are usually located near the nucleus and are continuous with the endoplasmic reticulum. Golgi function in concentration and packaging of proteins for eventual export from the cell in secretory granules or for incorporation into the plasma membrane. Basically the golgi act as quality control centers in the cell.

It is important to note that golgi do not appear to be involved in the synthesis of carbohydrates.





Lysosomes

Lysosomes are small spherical bodies that contain lytic enzymes for digestion of proteins and carbohydrates. These enzymes were produced in the RER.

Lysosomes function as the cells demolition sites for; 1. digesting particles ingested by endocytosis, 2. degrading worn out, non-functional organelles, 3. metabolic functions such as the breakdown of stored glycogen and the release of thyroid hormone from its storage form in thyroid cells, and 4. breakdown of non-useful tissues such as the webbing between the fingers and toes in fetal development, or the uterine lining during menstruation. Another function is to aid the osteoclast in the breakdown of bone to release calcium into the blood. Because lysosomes essentially constitute the digestive system of the cell they are common in phagocytic cells.

Peroxisomes

Peroxisomes act on free radicals such as superoxide ion (O2-) and hydroxyl radical by converting them to hydrogen peroxide. Hence peroxisomes are especially numerous in liver and kidney cells which are very active in detoxification. They alsocontain enzymes that produce peroxides that can be used to fight infectious portions of ingested cells. In addition, they contain an enzyme, catalase, which breaks down the excess hydrogen peroxide into water and oxygen.

Centrioles, Fibrils, Microtubules, Cilia, and Flagella

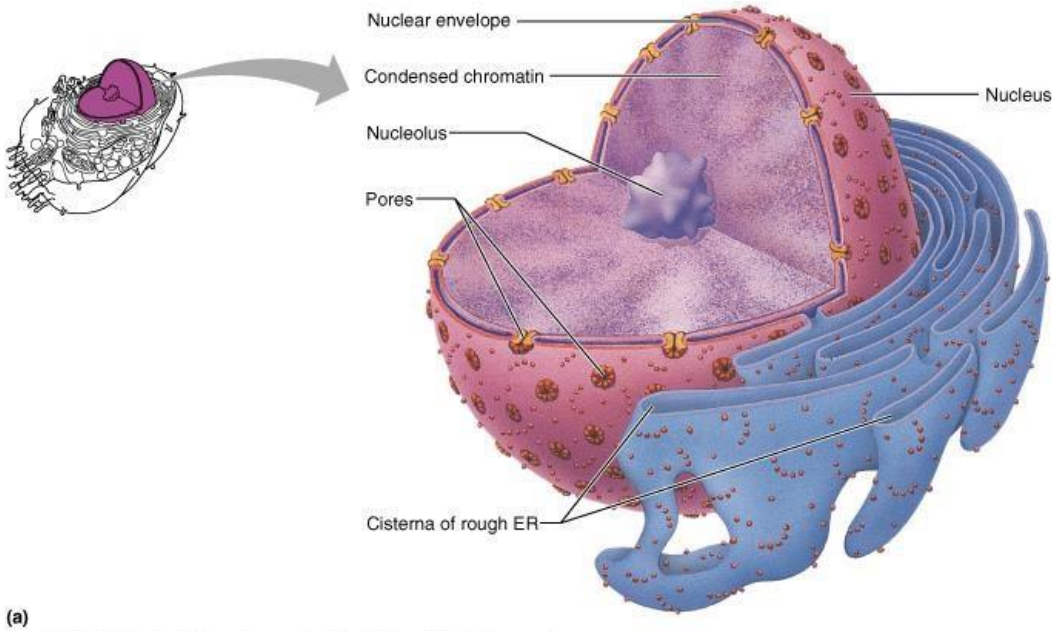
read about on your own. We will not deal with these structures in this course.

Nucleus

The nucleus is the largest structure of the cell. It contains the genetic material that determines cellular structure and controls cellular activity. The nucleus is enclosed by a double walled nuclear membrane which encloses the nucleoplasm. The space between the double walls is referred to as the perinuclear cisterna. The membrane has small pores which allow cytoplasmic continuity.

The Nucleus also contains Nucleoli which are small non-membranous bodies composed of protein and RNA. These are believed to function in the production of ribosomes.

The Nucleus contains Chromatin, which is a coiled, threadlike mass consisting mainly of DNA. During cellular reproduction the chromatin shortens and thickens into rod shaped chromosomes.



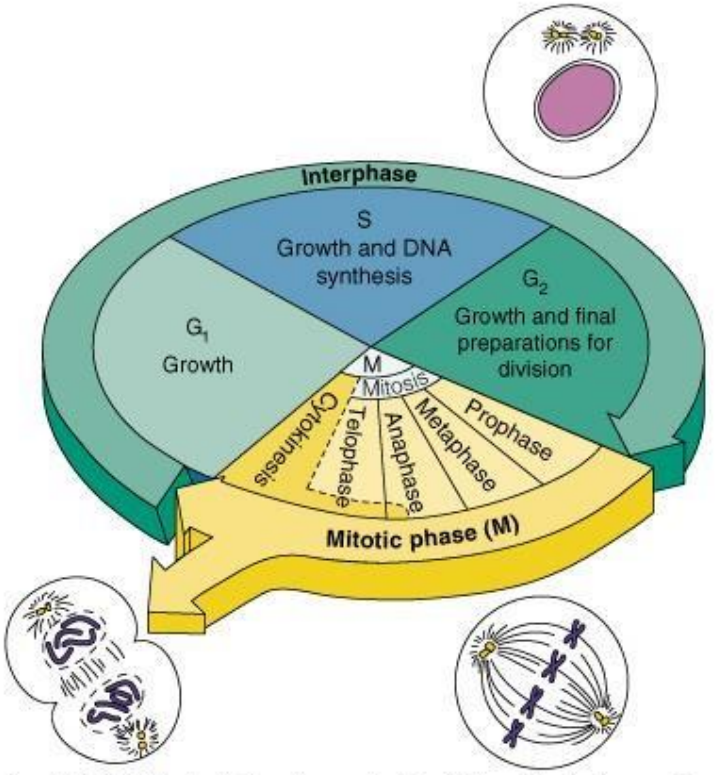
(a)

Cell Cycle

The cell cycle can be divided into two main phases

1) Interphase

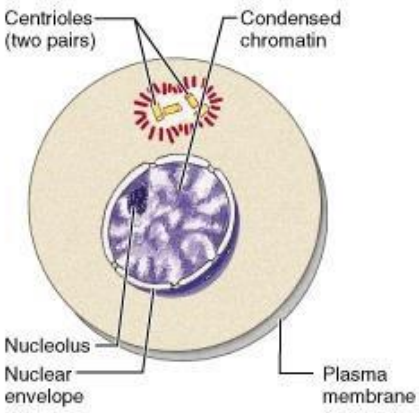
2) Mitotic Phase



Interphase can be divided into three stages

1) G1: G1 is the first cell growth phase. In this phase the cell grows rapidly and is metabolically active. There will also be replication of the centrioles.
2) S (synthetic phase): The name of this phase is derived from the fact that the cell is synthesizing a second copy of its DNA. This produces enough genetic material for two daughter cells. It is important to note that the cell is still metabolically active during this phase.
3) G2: G2 is the second growth phase. During this phase the cell prepares for mitosis by producing the necessary proteins and enzymes. It is important to note that the cell is still metabolically active during this phase.

A quick examination of a cell in interphase reveals no visible chromosomes within the nucleus. What is seen is loosely coiled DNA referred to as condensed chromatin. It is this chromatin that will be tightly coiled to form chromosomes during the appropriate time of the cell cycle.



Interphase

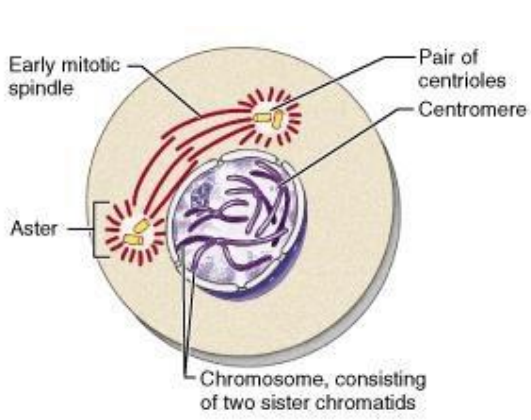
Mitotic Phase

The mitotic phase represents actual cell division and is divided into Mitosis and Cytokinesis

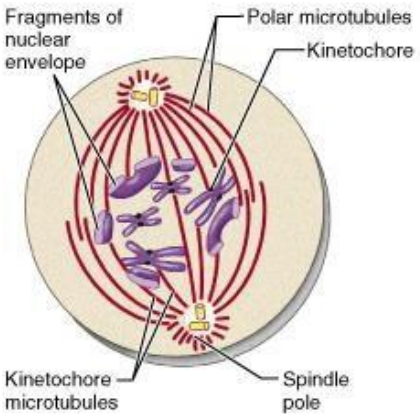
Mitosis

Mitosis is subdivided into 4 stages.

1) Prophase: in prophase the chromatin tightly coils and forms chromosomes that consist of two sister chromatids. These chromosomes begin to move toward the midline of the cell. At the same time the nuclear envelope breaks up. The centrioles also begin to move to opposite pole of the cell.

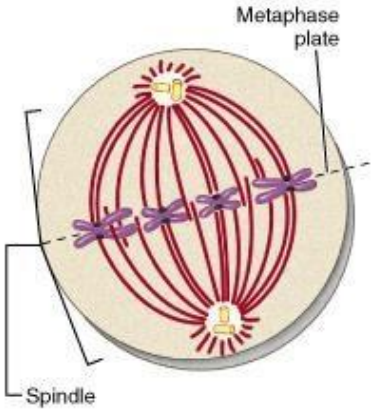


Early prophase



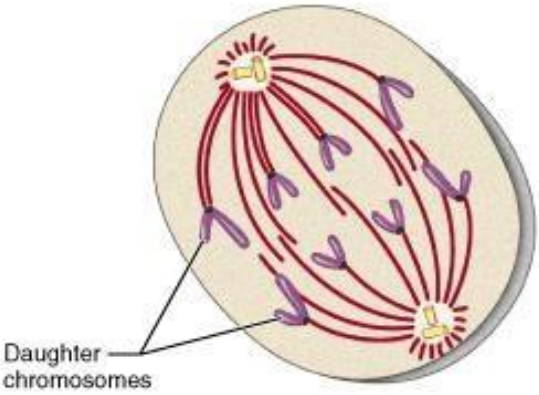
Late prophase

2) Metaphase : in metaphase the nuclear envelope is no longer visible and the chromosomes have moved to the midline (equator) of the cell.



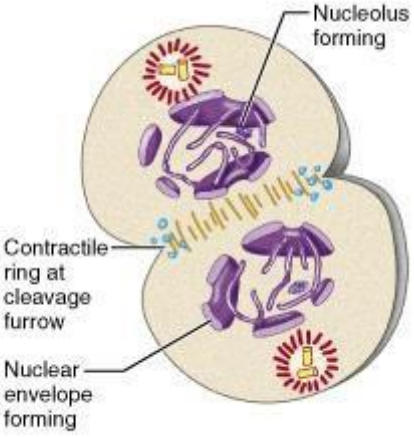
Metaphase

3) Anaphase: in anaphase the sister chromatids split into daughter chromosomes which begin moving to opposite poles of the cell.



Anaphase

4) Telophase: in telophase the daughter chromosomes decondense and the nuclear envelopes begin to form.



Telophase and cytokinesis

Cytokinesis is the constriction to form two new cells It generally overlaps with the last few phases of mitosis, beginning late in anaphase and lasting until the end of telophase.

If we apply a little bit of what we have learned along with some common sense, we can draw some inferences about the cell cycle. It was previously stated that the cell is metabolically active during all three phases of interphase. It was also noted that a second copy of the DNA was being produced during the S subphase of interphase. In order for a cell to be metabolically active, the ribosomes must be able to read the mRNA code. The mRNA is produced by transcribing it from the genetic code of the DNA. If the DNA is tightly coiled into chromosomes, it is not in a "readable" state. In addition, if the DNA is tightly coiled into chromosomes, it would be virtually impossible to make another "copy" of it. Imagine trying to photocopy a chapter from a book without opening the book. So, if you look at the nucleus of the cell and do not see chromosomes, it means that the cell is currently metabolically active (it is doing it particular cell job). If you can see chromosomes you know that the cell is not currently metabolically active, but rather it is busy undergoing cell division (mitosis).

You can also easily distinguish the 4 phases of mitosis at a glance by looking at the nucleus, or lack of nucleus. If you can see sister chromatids (chromosomes that look like Xs) that appear to be randomly scattered throughout the nucleus, the cell is in prophase. If those same X shaped chromosomes are lined up in a row, the cell is in metaphase. If you see daughter chromosomes (chromosomes that look like Vs), the cell is in anaphase. If it is hard to make out any chromosomes or a nucleus and there appears to be a constriction squeezing the cell into two smaller cells, the cell is in telophase.