# The Basics of Cell Structure and Cell Division

## Cell Structure

There are two general types of cells based on their structure and complexity; **prokaryotic** and **eukaryotic**. The table below summarizes their characteristics.

<table>
<thead>
<tr>
<th>PROKARYOTIC CELLS</th>
<th>EUKARYOTIC CELLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5 μm in length</td>
<td>&gt; 10 μm in length</td>
</tr>
<tr>
<td>no nucleus</td>
<td>membrane bound nucleus</td>
</tr>
<tr>
<td>homogenous cytoplasm</td>
<td>complex cytoplasm</td>
</tr>
<tr>
<td>“cream of potato soup”</td>
<td>“chunky vegetable”</td>
</tr>
<tr>
<td>contain 16s ribosomes</td>
<td>cytosol + organelles</td>
</tr>
<tr>
<td>usually have a cell wall</td>
<td>18s ribosomes</td>
</tr>
<tr>
<td>bacteria</td>
<td>cell walls in plant cells, fungi</td>
</tr>
<tr>
<td>unicellular</td>
<td>unicellular &amp; multicellular</td>
</tr>
<tr>
<td>bacteria &amp; archaea</td>
<td>All cells, except bacteria &amp; archaea</td>
</tr>
</tbody>
</table>

![Prokaryotic Cell Structure](image1)

![Eukaryotic Cell Structure](image2)

![Generalized Eukaryotic Cell Structure](image3)
Cell structures:
1. **plasma membrane**
   - boundary between the external environment and the inside of the cell
   - composed of a double layer of phospholipids with embedded protein
   - semi-permeable = is able to regulate what enters or leaves the cell

2. **cytoplasm**
   - in *prokaryotic cells*, the cytoplasm is the entire interior of the cell
   - in *eukaryotic cells*, the cytoplasm is the region of the cell between the plasma membrane and the nuclear envelope
     - the cytoplasm of eukaryotic cells consists of
       - **cytosol** = liquid portion of the cytoplasm
       - **organelles** = small, membrane bound structures with specialized functions
       - **cytoskeleton** = an internal system of tiny fibers and microtubules that gives the cell shape, structure, and motility

**Cytoplasmic organelles of eukaryotic cells**

1. **Nucleus** = control center or “brain” of the cell
   - surrounded by a nuclear envelope made up of a double phospholipid bilayer
     - materials move in and out of this protected area through nuclear pores
   - contains the genetic material of the cell, **DNA** (deoxyribonucleic acid)

   - the genetic material in eukaryotic cells is composed of about 50% DNA and 50% associated proteins. The proteins perform many functions, including organizing the DNA in coiled groupings called **nucleosomes** (remember: each of your cells has about 2 meters of DNA....that's approximately 2 yards!!!
   - **chromatin** = when the cell is going about its normal routine, the DNA is organized very loosely so that it can be accessed and read
   - **chromosomes** = when the cell is preparing to divide, the DNA is condensed so as to insure that each new cell gets the correct genetic information
   - **nucleolus** = specialized region of DNA located in the nucleus that is responsible for the production of **RNA**, a molecule involved in protein synthesis and a structural component of ribosomes; most eukaryotic cells contain two to three nucleoli
2. **Ribosomes** = sites of protein synthesis
   - Organelles made up of two subunits and composed of ribosomal RNA and protein
   - Found either free in the cytoplasm or associated with the endoplasmic reticulum

3. **Endoplasmic reticulum** = series of fluid filled channels that run through the cytoplasm from the nuclear envelope to the plasma membrane. Comes in “two flavors” – rough & smooth
   - Rough = rER = the term “rough” refers to ribosomes which are embedded on the outside of these channels. They produce proteins that will be exported either to another part of the cell or out of the cell entirely.
   - Smooth = sER = these channels are major storage sites for calcium ions (Ca^{++}), which are very important in muscle contraction, and also are the part of the cell that assembles fats.

4. **Golgi bodies** or Golgi apparatus = UPS of the cell
   - Modifies cell products, “packages” them, and sorts them by destination

5. **Mitochondria** = powerhouse of the cell
   - Sites of energy production in the cell
     - Temporarily stores the energy from molecules that are broken down. The energy is transferred to **ATP** (adenosine triphosphate), a special molecule that subsequently transfers the captured energy to drive other cellular reactions.
   - Large organelle surrounded by a double membrane
   - Inner membrane is highly folded (folds are called *cristae*)
   - Contains its own DNA and ribosomes (similar to those found in prokaryotic cells.....why?}

6. **Centrioles** = two perpendicular bundles of microtubules located near the nucleus in animal cells only
   - Region in which they are found is called the centrosome
   - Source of the spindle fibers during cell division

7. **Vacuoles** = space surrounded by membrane that can store substances in the cell
   - May store food, water, waste products, etc.

8. **Lysosome** = suicide sacs
   - Vacuoles filled with digestive enzymes
- Can break down ingested particles and make nutrients available to the cell
- Found in large numbers in white blood cells, where they break down ingested viruses and bacteria
- When an organelle is damaged, lysosomes fuse with the organelle and destroy it so that the cell is not wasting resources on something that doesn’t work right
- When the cell is damaged, lysosomes will burst and digest the entire inside of the cell in a process called autophagy, or “self-eating”. That’s why we call them suicide sacs!

**Cell Division**

There are several phases of development in the life of a cell. These phases are referred to as the cell cycle. The two major divisions of the cell cycle are interphase and the M phase.

![Cell Cycle Diagram](image)

**Interphase:**

- **G1** = gap 1 = during this phase of cell life, the cell is growing and metabolizing. At the end of G1, the cell has made a “decision” to divide. It is now going to enter the S phase in preparation for this event.
- **S phase** = synthesis phase = in order to produce a second cell, the DNA has to be copied. This process is called replication. DNA replication occurs in the S phase. In addition, in animal cells, the centrioles are also duplicated.
- **G2** = gap 2 = last minute preparations for division occur. This may include the production of proteins and the assembly of structures involved in cell division.

**M phase:**

This is the phase during which cell division occurs.

There are two types of cell division that occur in eukaryotic cells. The first is mitosis, and the second is meiosis.

**Mitosis** is the type of cell division that occurs when you want to produce cells that are identical to each other and the cell from which they came. These cells are involved in
growth and development, also in repair and replacement of existing cells in multicellular organisms. Organisms that reproduce asexually may also use mitosis for reproduction.

There are four phases in mitosis: prophase, metaphase, anaphase, and telophase. Let’s look at each of these steps individually. Remember: before this division begins, the DNA is copied during the S phase of interphase.

**Prophase:**
- The DNA condenses and becomes visible.
- The nuclear envelope disappears.
- The spindle fibers form.
- The spindle fibers capture each of the chromosomes by the centromeres

Chromosomes in prophase of mitosis look like this:

![chromatid](image)

**Metaphase:**
- The chromosomes line up in the middle of the cell along an imaginary line
**Anaphase:**
Chromatids separate to become independent chromosomes.
Chromosomes move to each pole.

**Telophase:**
This phase is the opposite of prophase.
The nuclear envelope reforms.
The chromosomes decondense and become chromatin.
Cytokinesis occurs (the cytoplasm divides into two separate cells)

**Results:**
2 cells with identical DNA, identical to the original parent cell

**Meiosis** is the type of cell division that occurs in sex cells, or gametes. In humans, the sex cells that are produced are sperm and egg. There are two goals:
1) to produce cells that are genetically different from each other and from the cell from which they came;
2) to produce cells with one complete set of DNA.
Genetically different cells give rise to variation in a population. Variation ensures survival of the species. Cells are needed in sexual reproduction that have only one complete set of DNA because there are two parents and each will contribute a set of DNA to the new organism.

All of this occurs in two separate divisions called meiosis I and meiosis II. Genetic variation occurs in meiosis I due to crossing over of homologous chromosomes organized as tetrads, which occurs in Prophase I, and independent assortment, which occurs in Metaphase I. Meiosis II is very similar to mitosis. DNA replication occurs immediately proceeding meiosis I, but does not occur between meiosis I and II.

Let’s look at the orientation of chromosomes in meiosis first. All of the cells in your body contain the same DNA. We are diploid organisms because we have one complete set of DNA from our mother (which we received from her egg) and one complete set of DNA from our father (which we received from his sperm). When the time comes for us to make our own sex cells, we “shuffle” the DNA from both parents to produce one complete set of chromosomes. In order to do this, we have to have all of the genes on a chromosome that you received from your mom on the same chromosome. A duplicate is made and lines up with this chromosome. All of the genes on a particular chromosome that you received from your dad are on another chromosome. They also duplicate. These homologous chromosomes line up together as a foursome, called tetrads.

**Meiosis I**

**Prophase I**
- The cells begin as diploid cells (2n).
- The DNA replicated in the S phase of interphase before this phase begins.
- The chromosomes condense and arrange as tetrads.
The tetrads attach to the nuclear envelope. The chromosomes cross over and exchange DNA.

The spindle fibers form and attach to the homologous pairs of chromosomes at the centromeres. The nuclear envelope disappears.

**Metaphase I:**
Homologous pairs line up at the equator of the cell.

**Anaphase I:**
Homologous pairs separate and move to opposite poles.
Telophase I:

Chromosomes are at each end of the cell. Cytokinesis occurs as the cell divides into two haploid cells. The cell moves directly into Meiosis II (no DNA replication takes place in interphase).

Results: two genetically different haploid cells.

One more division is needed – meiosis II.

**Meiosis II:**

**Prophase I:**

Spindle fibers reform and attach to the chromosomes at the centromeres.

**Metaphase I:**

Chromosomes line up at the equator.

**Anaphase I:**

Chromosome separate.

**Telophase I:**

Cytokinesis produces four haploid cells, each genetically different. The nuclear envelope reforms and the chromosomes relax to form chromatin.
Spermatogenesis and Oogenesis
Four sperm cells are produced for each dividing spermatogonium. Only one viable egg cell is produced for each dividing oogonium. This is because uneven cytoplasmic division results in one oocyte (egg cell) and three polar bodies, which cannot be used for reproduction.

If you would like to learn more about cell division, you may access the following website http://www.pbs.org/wgbh/nova/miracle/divide.html#

It describes cell division in fairly simple terms and compares mitosis and meiosis. There is a “flash” and “non-flash” version available. The flash player can be installed for free, if you choose to go that route.