CELL DIVISION

INTRODUCTION

All living things "start" as a single cell.

A cell is the smallest most fundamental unit of life. Cells are a very complex, highly organized form of matter.

The instructions to build a cell are coded as **genetic information** in its **genes**. **Cell numbers increase by cell division.**

All cells are descendants from cells that have divided and cells must divide to produce ancestors. **Descendants** "follow" (kids follow parents so kids are descendants of their parents) but **ancestors** "precede" (parents are ancestors to their children).

By definition a **mother cell** divides into two **daughter cells**. Each cell division is a cellular "generation" in which a parent (mother cell) gives rise to offspring (two daughter cells).

UNICELLULAR AND MULTICELLULAR ORGANISMS

Some organisms are nothing more than a single cell "all their life" so we call them **unicellular** (organisms). These organisms make up most of the life on Earth. Cell division is a cell's way of reproducing. The cell divides into two cells that usually look identical. For this reason, cell division is sometimes called **"binary fission"** to emphasize that a cell has split into two exact copies. After cell division the two unicellular organisms usually drift apart.

Organisms such as you and I are a collection of many cells, so we are called **multicellular** (organisms). We have specialized cells performing specialized functions but almost every cell in our body has the same genetic information. The differences among our cells are due to how they use that information. Some multicellular organisms reproduce by a method very similar to simple cell division - they just split into two pieces. But most multicellular organisms reproduce by a more complicated method

It is important to understand that all **multicellular organisms start as a single cell.** We become multicellular by a series of cell divisions very similar to the way unicellular organisms reproduce, but instead of drifting apart as two separate cells, most of our cells stick together and eventually organize themselves into a specialized "colony" that grows into a multicellular organism

There are about 100 trillion (10^{14}) cells in your body. All of these cells were derived from multiple cell divisions and, with minor exceptions, every cell in your body contains the same genetic information. Each cell inherited that genetic information from a previous cell and we can track that information all the way back to your first cell when you where nothing more than a "zygote". A zygote is a single cell created by the union of two sex cells which are called gametes.

Each cell grows in size between each cell division. This "growth phase" is an important time for a cell because during growth a cell feeds and increases in size. If there were no cell growth between divisions the cells would divide and divide until nothing remained.

Genetic information is contained in a very long molecule called **DNA.** That stands for "DeoxyriboNucleic Acid". Like letters in a word or words in a sentence, DNA's message provides information for the cell.
DNA is often described as a cell's "blueprint". Long stretches of DNA are organized into **chromosomes.** During cell division it is extremely important that the daughter cells inherit the correct and complete chromosome(s) from their mother cell.

EUCARIOTIC AND PROKARIOTIC CELLS

Eukaryotes are organisms that hold their chromosomes in a nucleus. Most species are eukaryotes. In fact, eukaryotes have many other things (organelles) in them beside a **nucleus** but, by definition, all eukaryotes have a nucleus. People are eukaryotes.

Prokaryotes do not have a nucleus so their genetic material is free to float around throughout the cell. All bacteria, including "blue-green algae", are prokaryotes. Everything else that's alive is a eukaryote. (Viruses are not alive.)

All prokaryotes have a single, "naked" [no bound proteins - just naked] (double) strand of DNA, as a circular chromosome. Prokaryotes have only one type of cell division - fission. It's really nothing more than cell division but let's discuss the specifics of fission as it applies to prokaryotes. Before fission the cell makes a copy of its DNA so that it now has two copies of its genetic material.

One copy is distributed to each half of the cell. One copy of DNA goes to each side o f the cell. Then a membrane and cell wall form dividing the cell in two. Any other materials inside the cell are distributed between the two halves at random. What matters is that both cells end up with identical copies of genetic information. That's why there are mechanisms in place to ensure that each cell gets a copy of the chromosome DNA.

Eukaryotic cells have a more complex genetic system - complex in terms of how they package their DNA and complex in terms of how they distribute it in cell division.
Eukaryotes package their genetic information in chromosomes that are very different from prokaryotic chromosomes. Each eukaryotic chromosome contains a linear length of (double-stranded) DNA. Eukaryotic chromosomes also contain a lot of protein. This complex of DNA and protein is called **chromatin**. So a eukaryotic chromosome is made of chromatin (DNA and proteins) but a prokaryotic chromosome is just "naked" DNA.

Obviously, the proteins that condense the DNA are very important to pack all that information into a nucleus. During most stages of cell divisions we see the chromosomes as X-shaped objects composed of two "chromatids". The ends of the chromatids are called **telomeres** ("telos" is Greek for "end)" and the point were they are joined is called a **centromere** although it isn't always at the center.It is important to understand that these X-shaped chromosomes are made of two identical pieces of (double-stranded) DNA. That is, the "left side" is identical to the "right side". Because they are identical the two **chromatids** on the same chromosomes are called sister chromatids.

CELL DIVISION IN EUKARYOTES

Cell division in eukaryotes is more complicated that cell division in prokaryotes because eukaryotes have:

a nucleus
more than one chromosome
two types of nuclear division - **mitosis and meiosis.**

Mitosis and meiosis refer to the **division of the nucleus** and this is only a part of cell division. **Mitosis produces identical nuclei** ("nuclei" is plural for nucleus) so it is similar to prokaryote fission BUT it is not the same in detail. Mitosis is the dominant type of nuclear division and its purpose is to increase the number of nuclei. This usually leads to an increase in cell numbers, with each cell containing one nucleus, Most mitosis is followed by cell division so most of the time mitosis increases cell numbers but **mitosis only increases the number of nuclei**. Mitosis is used in **asexual reproduction** - reproduction without sex. (Vegetative propagation, cloning, budding, etc.).

Meiosis produces diverse nuclei and that makes meiosis "doubly complicated" to most Meiosis is a very specialized type of nuclear division occurring only in cells that will become gametes (sex cells). **So meiosis is required for sexual reproduction**; reproduction using gametes.

THE CELL CYCLE

Eukaryotic cells go through a **cell cycle** as their "life history". The cell cycle is a series of stages through which the cell passes between divisions and it is composed of three stages:

1**. Interphase** is the period between divisions when nothing seems to be happening.

2. **Nuclear Division** is when the genetic material is dividing and you can see the chromosomes. As you know eukaryotic cells have two types of nuclear division - mitosis and meiosis. Therefore this is often called **M phase.** During M phase one mother nucleus becomes two daughter nuclei.

3. **Cytokinesis** divides the cytoplasm of the mother cell into two daughter cells and this is very obvious under the microscope. It is during cytokinesis that one mother cell becomes two daughter cells.

THE INTERPHASE

Interphase dominates the cell cycle and it is often called the "gap phase" in the cell cycle because it represents a period in which nothing seems to be happening. We often abbreviate it as G phase to distinguish it from M phase. Today, interphase is subdivided into these three subphase:

3**. G1** (**or Gap 1)** occurs after cytokinesis, the last cell division, but before the start of DNA synthesis.

4. **S phase** (or Synthesis phase) is the time when DNA is synthesized. It is during S phase that DNA replicates.
5. **G2 (or Gap 2)** occurs after S phase but before the next M phase.

G1 is "early interphase" and cells in G1 have only one centrosome. The centrosome is not easy to see but its location is usually found by following the microtubule filaments that radiate from it later in M phase. Microtubules are tiny tubular structures made of protein. They act like tiny molecular "strings" for the cell, maintaining the cell's shape and they are responsible for most of the cell's movements as well as the movement of internal organelles and chromosomes. In most species the centrosome is made up of a pair of **centrioles -** one centriole is larger than the other and they are at right angles to each other.

Of course after G1 comes S phase when the DNA duplicates itself. During S phase each single chromatid (inherited from the previous nuclear division) is duplicated to give us the identical sister chromatids. During G2 the centrosome is duplicated so by late G2 the cell has two centrosomes.

Regardless of whether a cell has centrioles or not - they all have one centrosome during G1 and two centrosomes by late G2. The centrosome count is "diagnostic" (tells us) if we are nearing M phase.

It is crucial that the centrosome replicates during G2 because a cell must have two centrosomes to guide the chromosomes during the M phase that follows. Any cell with two centrosomes has successfully completed S phase and is in late G2. (or M phase if you can see the chromosomes).

MITOSIS

Mitosis is specifically designed to distribute chromosomes equally. Mitosis distributes exact copies of genetic material so the daughter nuclei are genetically identical to each other and identical to the mother nucleus from which they came. The main function of mitosis is to increase the number of identical nuclei. When followed by cytokinesis, as it usually is, mitosis increases cell numbers.

Many species, including some multicellular species, can reproduce by mitosis and when they do so they produce exact copies of the parents. These are called **clones** and this method of reproduction is called **asexual reproduction** often called **vegetative** reproduction or vegetative **propagation**. All asexual reproduction (cloning, vegetative reproduction and vegetative propagation) is mitotic reproduction.

We humans reproduce via meiosis BUT, once the zygote is formed, mitosis dominates and is responsible for making EVERY nucleus in your body except the gametes (sperm and egg cells).

Mitosis is a flow of events but we have divided it into four obvious stages:

1. Prophase
2. Metaphase
3. Anaphase
4. Telophase

Prophase is the first phase of mitosis but it's named "pro" which is Greek for "before". Prophase is composed of a series of very important yet subtle events. During prophase the chromatin condenses into chromosomes. Also early in prophase, the centrosomes come "alive" with activity. They move to opposite sides of the cell and develop spindle fibers - long chains of microtubules that will be used in the next phases to move chromosomes around. During prophase, as the chromosomes continue to condense, the centrosomes move to opposite "poles" dragging their spindles along.
Once the microtubules attach to the chromosome they act as a "rope" allowing the centrosome to orchestrate the movements of chromosomes in the next two phases.

Metaphase is well named because "meta" is Greek for between. All the chromosomes come to line up midway between the two centrosomes. More specifically, when all the chromosomes' centromeres are lying on a plane perpendicular to a line connecting the two centrosomes, the cell has entered the part of mitosis called metaphase. The plane upon which the centromeres are arranged is called the metaphase plate. This phase lasts for about an hour.

At **anaphase** the centromere of each chromosome breaks down the middle and the two sister chromatids move to opposite centrosomes. It is at anaphase that "true" genetic division. Somehow, all the chromosomes are able to coordinate the breaking of their centromeres very well and the speed at which the chromatids move is impressive. Not only is anaphase an important part of mitosis, it is also a critical stage in the way we name chromosomes and chromatids.
When the two chromatids come apart, when the centromere breaks at anaphase, the two chromatids become chromosomes. The moment the chromosome's centromere splits, during anaphase, each kinetochore acts as the center for the creation of a new centromere. By definition a chromosome has a centromere - it's a one to one correspondence. Therefore, during anaphase, each chromosome becomes two

separate chromosomes at that moment of chromatid separation and we now have two chromosomes from each chromosome

That means, during anaphase and indeed until cytokinesis occurs, the cell has twice as many chromosomes as "normal". But they are all "half-chromosomes" made of just one chromatid.

Once the newly created chromosomes reach their poles, anaphase is over and we enter the next and last phase of mitosis – telophase. Telos" is Greek for "end". **Telophase** is the point in mitosis when the new nuclei are formed. A nuclear membrane forms around both bundles of chromosomes at each pole. This creates two nuclei. Also, the chromosomes begin to unwind (decondense) until eventually they are nothing more than a dim coloring of chromatin with a few nucleoli (clumps of chromatin). Each nucleus eventually takes on the appearance of an interphase nucleus and once that is done the cell has completed telophase and mitosis.

CYTOKINESIS

As a cell enters cytokinesis it has two nuclei formed by nuclear division during M phase. **During cytokinesis the cytoplasm is divided.** Most cells divide their cytoplasm pretty evenly but not all cells are so "fair" in their allocation of the cytoplasm. Mitosis ensures that both nuclei have exactly equal genetic information, but cytokinesis distributes the organelles (mitochondria, ribosomes, etc.) and cytoplasm randomly. That's OK as long as enough organelles are present so the cell will be viable.
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