

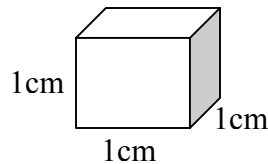
MITOSIS

Why Reproduce?

Why do cells divide? Why can't you exist as a single cell? The largest single cell in the world is the ostrich egg. You, as a human, are composed of a trillion, trillion cells. What gives? Cells reproduce not to perpetuate their DNA, but instead to obtain an effective surface area/volume ratio. It's purely mathematical!

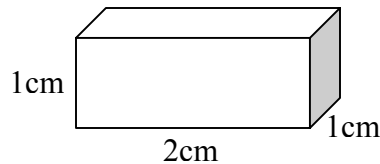
Surface Area/Volume

Assume we have a cell that is cuboidal in shape (not unusual – many cells are cube-shaped). Assign dimensions to the cell. The length of the cell is 1cm, the height is 1 cm and the width is 1cm. What is the total volume of the cell? The formula for volume is: $V = \text{length} \times \text{width} \times \text{height}$. The volume of the cell is thus $1\text{cm} \times 1\text{cm} \times 1\text{cm}$ or 1cm^3 .



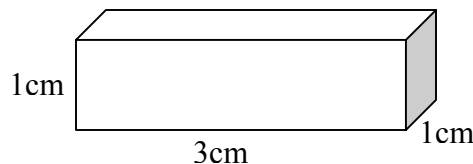
What is the area of the cube? The formula for area is: $A = \text{length} \times \text{width}$. Therefore, the area of the cube is $1\text{cm} \times 1\text{cm}$, right? Wrong! That's the area of one side of a cube, 1cm^2 . A cube has 6 sides, therefore the total area of the cube is 6cm^2 . The ratio of area to volume in the case is $6/1$.

Our cell will now grow, only in length. The new dimensions are 1cm wide, 1cm high, and 2 cm long. The new volume is $1\text{cm} \times 1\text{cm} \times 2\text{cm}$ or 2cm^3 . What is the new area?



The area for four of the six sides is $1\text{cm} \times 2\text{cm}$. That $2\text{cm}^2 \times 4$ sides or 8cm^2 . Two of the sides of the cube have height and width of 1cm or $1\text{cm}^2 \times 2$ sides or 2cm^2 . Add that to the 8 and you have a total area of 10cm^2 . The area to volume ratio is now $10/2$ or reduced to $5/1$.

Continue to grow the cell in length only. The new length is 3cm. The new volume is 3cm^3 . The area of 4 of the sides is 3cm^2 for a total of 12cm^2 . Two of the sides have an area of 1cm^2 or a total of 2cm^2 . The total area of all six sides is 14cm^2 . The area to volume ratio is $14/3$ or $4.6/1$.



As you increase the volume, what is happening to the total surface area of the cell? It is decreasing: $6/1 \rightarrow 5/1 \rightarrow 4.6/1$. The greater the volume, the less the surface area! You cannot exist as a single cell for one of two reasons. You would never be able to get enough food through your membrane and you would die of starvation, or perhaps more grotesquely, you would drown in your own excrement since you could not remove waste products fast enough.

What do cells do which have a poor surface area to volume ratio? They divide and decrease their volume! Cells divide to produce more surface area.

Types of Reproduction

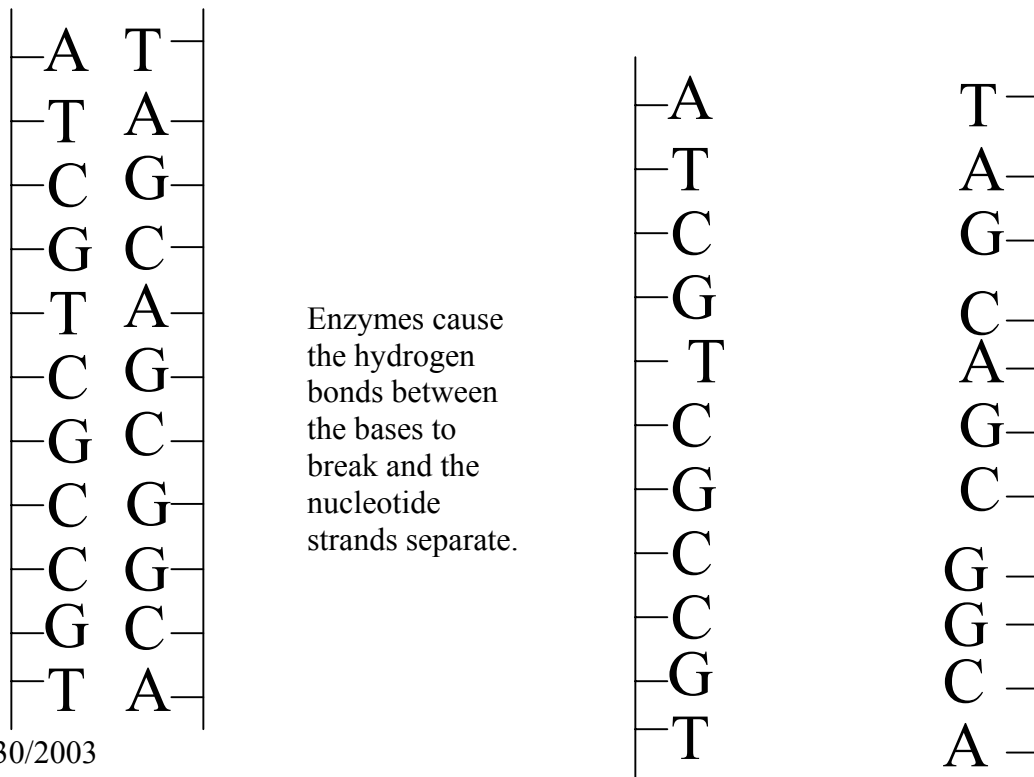
There are two basic types of reproduction in cells: asexual and sexual. There are several ways cells may reproduce asexually: binary fission, vegetative reproduction, budding and mitosis. There is only one way to reproduce sexually – meiosis.

Asexual: Binary Fission

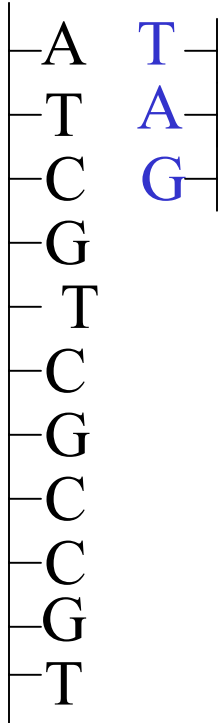
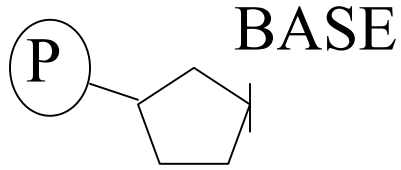
Binary fission occurs in prokaryotic cells such as bacteria and cyanobacteria. Remember the prokaryotic genetic material is a single copy of circular DNA with non-histone proteins. This DNA replicates and makes an exact copy. The bacterium now has two pieces of DNA, both which move apart in the cell. The cell begins to form a cell wall between the two pieces and the cell divides equally in two to produce two cells identical in nature to the “parent” cell.

Replication of DNA

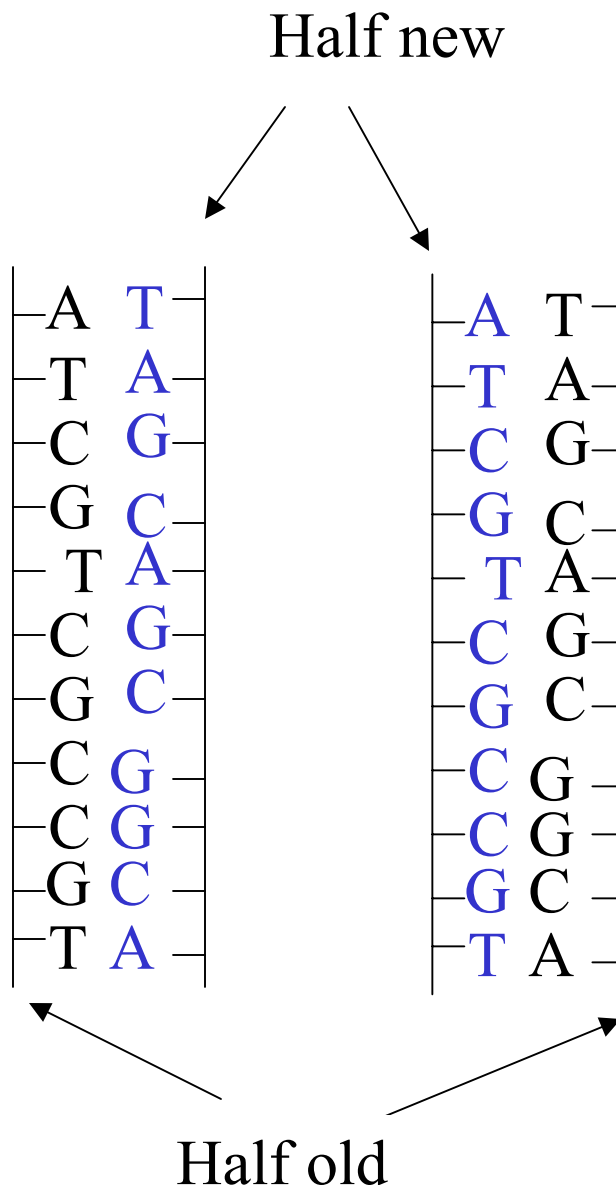
The true nature of reproduction is making copies of DNA. Cells do that by a process known as the semi-conservative theory of replication. Assume a double strand of nucleotides as shown in the diagram.



The next event occurs when individual nucleotides, free in the protoplasm of the cell begin to match up opposite the appropriate base pairs.



One at a time, new base pairs form along each nucleotide sequence to begin the formation of new strands of nucleotides.



As the new strands form along side the old strands, we form two new strands, identical to the parent strand. The term “semi-conservative” comes from the fact half the parent (old) strand is preserved and half of the DNA is “new”.

The examples given in the diagrams represent linear DNA of eukaryotic cells (which also use the semi-conservative theory of replication. Prokaryotic DNA is circular, but it occurs in the same method as shown, except the circle breaks apart.

Vegetative Reproduction

This form of reproduction is also asexual. You probably have practiced a form of this when you have broken off a piece of a plant and rooted it to produce a new plant. In humans, that would be somewhat akin to ripping off a human's arm and planting it to produce a new human. At first, it seems humans don't have this form. However, when you think of platelets in the blood, they are actually vegetatively produced.

Budding

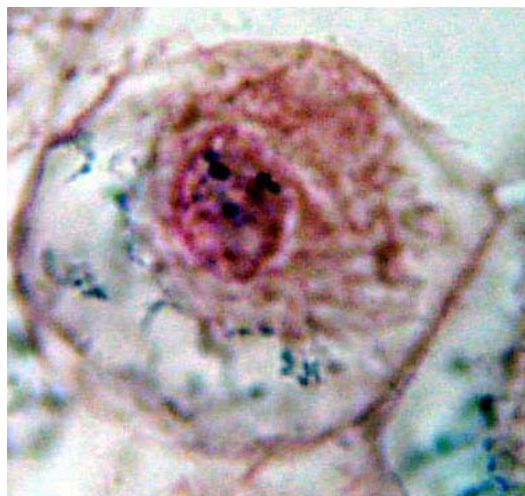
Budding is similar to binary fission except there is an unequal division of the cytoplasm after the nucleus divides. A common life form that buds is yeast.

Mitosis and the Cell Cycle

Cells, like other life forms, go through cycles. The cell cycle revolves around the idea of division of the cell. That is called mitosis. However, before the cell can undergo mitosis, it must prepare. The part of the cell cycle where the DNA replicates (*via* the semi-conservative theory of replication) is called synthesis (S). After synthesis, the cell must prepare for the trauma of dividing in half. It stores food reserves and energy reserves. This phase is called G2 or gap 2. The next event is mitosis. Following the division, there is a recovery phase from division called G1 or gap 1. Gap1, Interphase, and Gap 2 are collectively called interphase.

Interphase

During interphase, particularly G1 and G2 parts of interphase, the cell is pretty much like the basic cell studied earlier. There is the nucleus, the nucleoli, the endoplasmic reticula, the Golgi, and all of the other cell organelles discussed previously. During synthesis, however, the chromosomes duplicate by the semi-conservative theory of replication. In the case of humans, who typically have 46 chromosomes in their nuclei, the number doubles to 92. When a chromosome replicates, it forms two identical copies of the parent chromosome. Each copy is called a chromatid. The chromatids are joined at only one point along their length, called the centromere.



Whitefish blastomere in interphase. Note the nucleoli and nucleus. The individual chromosomes are not distinct.

Mitosis

Mitosis refers to the division of eukaryotic cells. It is divided into two major parts: karyokinesis and cytokinesis. Karyokinesis refers to the division of the nucleus. Cytokinesis refers to the division of the cytoplasm.

Karyokinesis

Karyokinesis is characterized by four events: prophase, metaphase, anaphase and telophase. During the latter part of telophase, cytokinesis begins.

Prophase

During prophase, a series of events take place. The events are not necessarily distinct, but for the purposes of explanation, they will be separated into five steps.

1. The nucleoli disappear
2. The chromosomes coil and become visibly thickened
3. The nuclear membrane degenerates
4. The centrioles divide and move apart
5. A spindle forms. Astral rays are characteristic of animal mitosis.

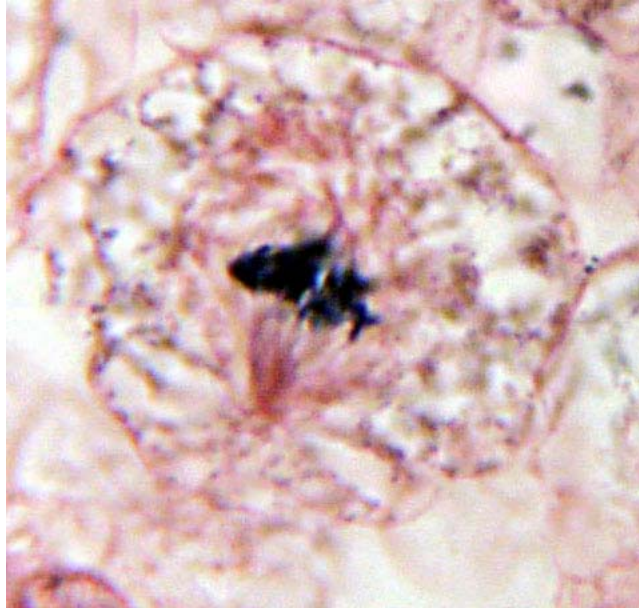
These five events all take place somewhat simultaneously.



Whitefish blastomere in prophase. Note the nucleoli are missing and the chromosomes have become fairly distinct within the nucleus. The nuclear membrane has not begun to degenerate as of yet, so this would be early prophase.

Metaphase

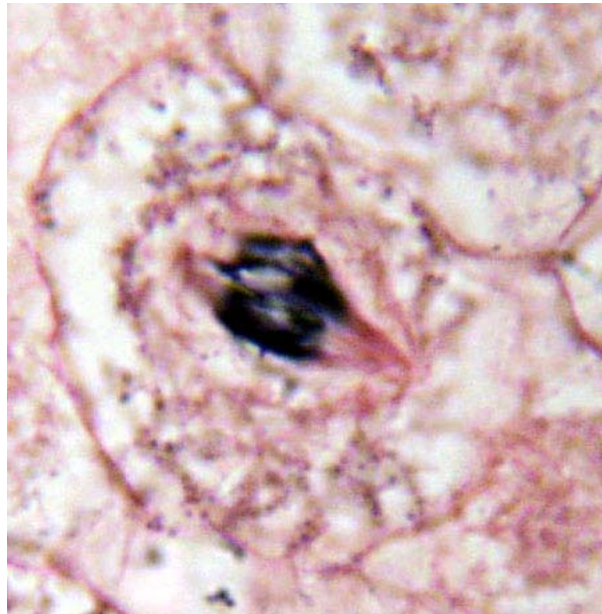
During metaphase, the chromosomes align themselves along the equatorial plane of the spindle.



Whitefish blastomere during metaphase. Note the well developed spindle fibers and the chromosomes which have aligned themselves in the center of the spindle.

Anaphase

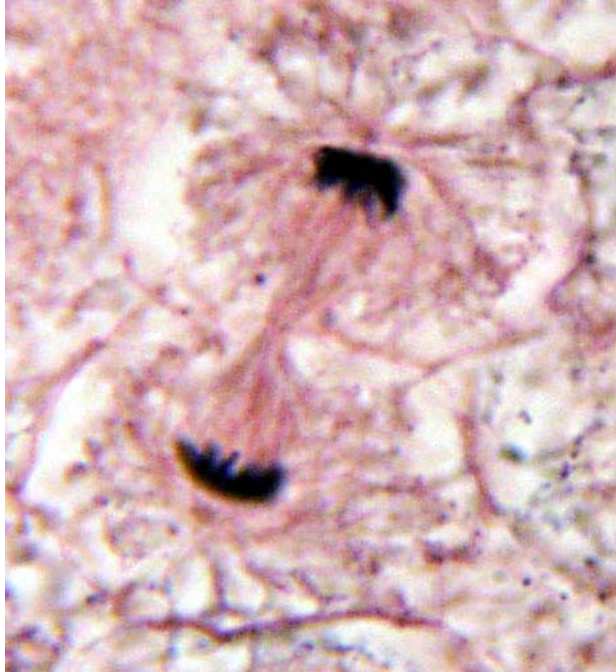
During anaphase, the centromere divides and the chromosomes push past each other on their way to the ends of the spindle.



Whitefish blastomere during early anaphase. The chromosomes seem to be pulled apart, but instead, they push past each other.

Telophase

During telophase, the chromosomes reach the poles and begin to uncoil. A new membrane begins to form around the nuclei and cytokinesis begins by forming a cleavage furrow that pinches the cells into daughter cells.



Whitefish blastomere during telophase. Note the chromosomes have reached the poles and the cells have almost been "cleaved" in two.

The two daughter cells are identical to the parent cell. They simply have a better surface area/volume ratio.

Mitosis in Plants

Mitosis in plants is very similar with a couple of exceptions. Remember, plants do not typically have centrioles, therefore, you will not find centrioles. A spindle does form, however. In addition, plants cannot form cleavage furrows and pinch the cells in two. Instead, a cell plate forms (either from the center or from either edge, depending on the plant species). The events of prophase, metaphase, anaphase, and telophase are otherwise, exactly the same. The images shown are in *Allium* or onion.



Interphase



Prophase



Metaphase



Anaphase



Telophase