MITOSIS AND MEIOSIS AND THEIR SIGNIFICANCE

PART - I

MITOSIS

- Mitosis occurs only in eukaryotes. Prokaryotes (i.e., archaea and bacteria) divide via binary fission. Mitosis is the process by which the somatic cells of all multicellular organisms multiply. Somatic cells are the nonreproductive cells of which an organism is composed.

- In addition, plants produce gametes by mitosis. Gametes are sexual reproductive cells, that is, there are two types, male and female. In sexual reproduction, a male gamete combines with a female gamete and the resulting, merged cell then divides repeatedly by mitosis to eventually produce a mature organism. Plants also make asexual reproductive cells called spores (by *meiosis*, not mitosis). One spore does not have to combine with another spore for reproduction to occur. A single spore, produced by meiosis, develops into a mature organism by *mitosis*.

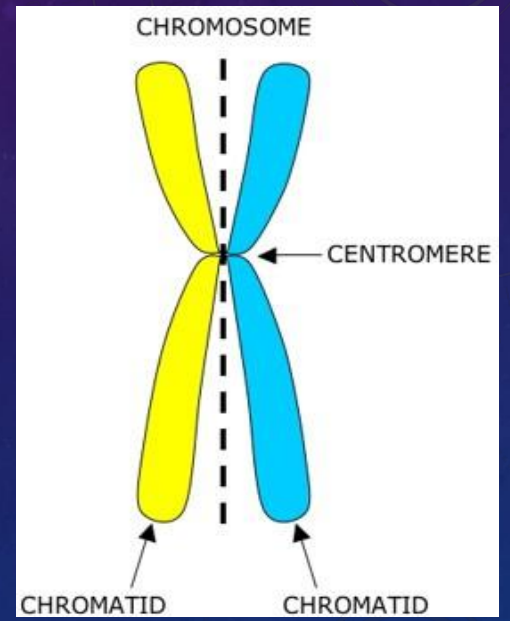
WHY MITOSIS?

1. Growth. The number of cells within an organism increases by mitosis and this is the basis of growth in multicellular organisms.
2. Cell Replacement. Cells are constantly sloughed off, dying and being replaced by new ones in the skin and digestive tract. When damaged tissues are repaired, the new cells must be exact copies of the cells being replaced so as to retain normal function of cells.
3. Regeneration. Some animals can regenerate parts of the body, and production of new cells are achieved by mitosis.
4. Vegetative Reproduction. Some plants produce offspring which are genetically similar to themselves. These offspring are called **clones**.

CONSEQUENCE OF MITOTIC DIVISION

- **No variation** in genetic information
- No variation in chromosome number due to the **semi-conservative replication** of DNA and **equal distribution** of DNA.
- The cell divides **once**.
- Two **identical daughter cells** are formed.
  - Mitosis produces two daughter cells that are identical to the parent cell. If the parent cell is haploid (N), then the daughter cells will be haploid. If the parent cell is diploid, the daughter cells will also be diploid.
    - $N \rightarrow N$
    - $2N \rightarrow 2N$

- A chromatid is one of the two halves of a replicated chromosome (see diagram at right). The two chromatids that make up a chromosome are called "sister chromatids," They are joined at the centromere and are genetically identical because, during interphase, one sister of each chromatid pair is produced by directly copying the other, pre-existing sister. They therefore contain identical alleles at all loci. In contrast, two homologous chromosomes (chromosomes that have the same set of loci in the same order) usually do not have identical alleles at all loci. They are inherited from different parents and are not direct copies of each other.



- The two sister chromatids of each chromosome are segregated into separate cells in both mitosis and meiosis, but they remain together throughout meiosis I. It is only during the second meiotic division (meiosis II) that they finally are separated and distributed into separate cells. As soon as the joined chromatids are separated they are no longer called sisters because they are no longer connected to each other. Instead they are now called unreplicated chromosomes.

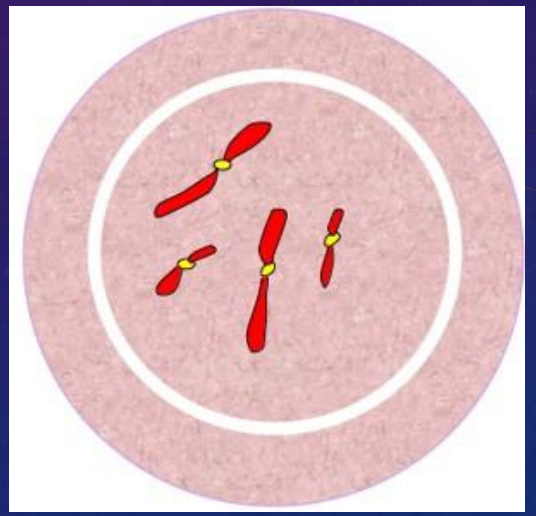
STAGES OF MITOSIS

- The process of mitosis is divided into 6 stages.
  - •Interphase
  - •Prophase
  - •Metaphase
  - •Anaphase
  - •Telophase and
  - •Cytokinasis.

INTERPHASE

- At Interphase, there is only one cell, but after cytokinasis there are two identical cells. Before mitosis can take place, the cell need to store enough energy to drive the chemical processes during the cell division. During this period of time, there is intense cellular activity. The cell grows in size. The length of the grow phase varies between a few hours to a few months. We the cell has stored enough energy, it is ready to divide itself.

- The interphase, or growth, period of the cell cycle alternates with the mitotic phase of the cycle. It's the period when the cell is *not* undergoing mitotic division. So it is *not* part of mitosis. When it begins, the chromosomes (red) have not yet replicated (i.e., each chromosome has a single chromatid), but by the beginning of prophase replication is complete. Thus, the picture shown here represents the chromosomes as they are in the first stage of interphase before replication has occurred, G_1 phase (G_1 stands for first gap). During the next stage, S phase (synthesis), the chromosomes replicate, and by the beginning of the third, G_2 phase (G_2 stands for second gap), replication is complete.

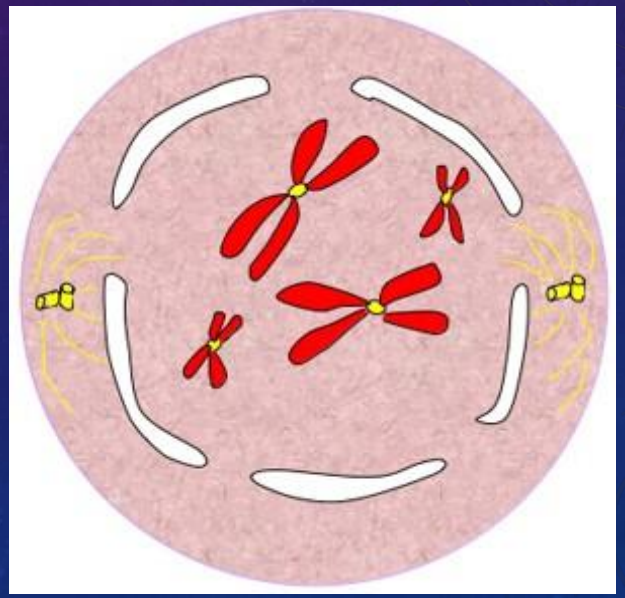


Parent Cell (Interphase – G_1

In this diagram the chromosomes are shown as if they were visible, simply to show that they have not replicated. However, during G_1, S, and G_2 they are not actually visible under a light microscope, both because they are uncondensed and because they are still enclosed in the nuclear membrane.

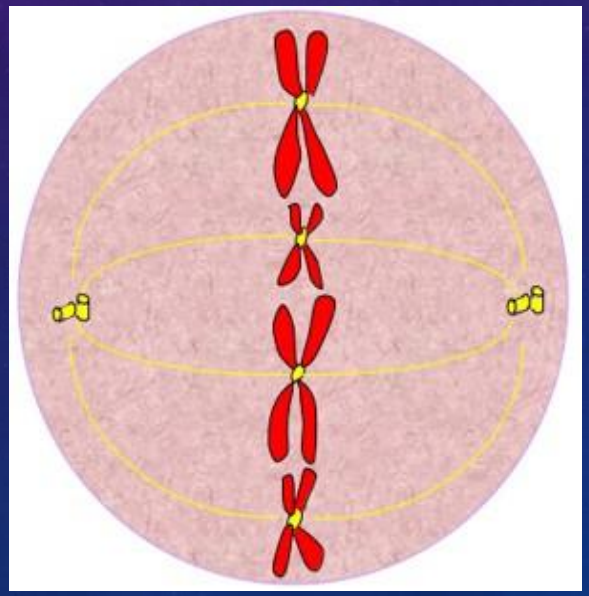
PROPHASE

- Prophase is the first of the four stages of mitosis. Early during this stage the chromosomes (shown in red in the diagram) become visible with a light microscope as they condense (i.e., as they shorten, coil, and thicken). Also, the spindle (yellow strands) begins to extend outward from each of two centers of extension. This starlike configuration is called an *aster*. In animal cells one pair of centrioles (represented by the yellow cylinders in the diagram) is present at each centers of extension. As prophase progresses, the nuclear membrane (white) begins to break up and disappear. Each chromosome has been duplicated and so is composed of two *sister chromatids* containing identical genetic information.



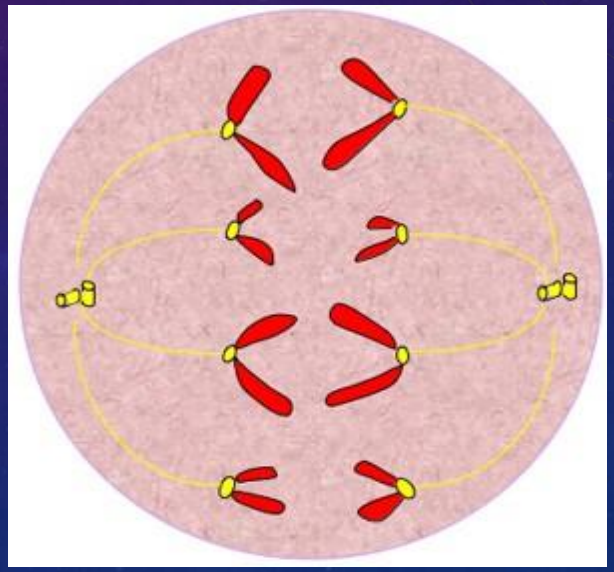
METAPHASE

- During this, the second stage of mitosis, the chromosomes line up in the middle of the cell, halfway between the centrioles on an imaginary plane called the "metaphase plate" The spindle fibers (yellow strands) attach to the centromeres (shown as yellow ovals).



ANAPHASE

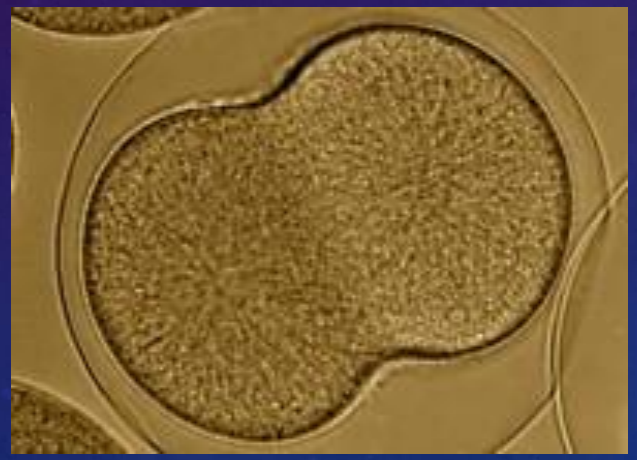
- During the third of the four stages of mitosis, the two chromatids of each chromosome are pulled apart by the spindle and dragged toward opposite poles of the cell (i.e., toward the opposite centrioles). The arms of each chromosome can be seen dragging behind as the it is dragged along by its centromere.

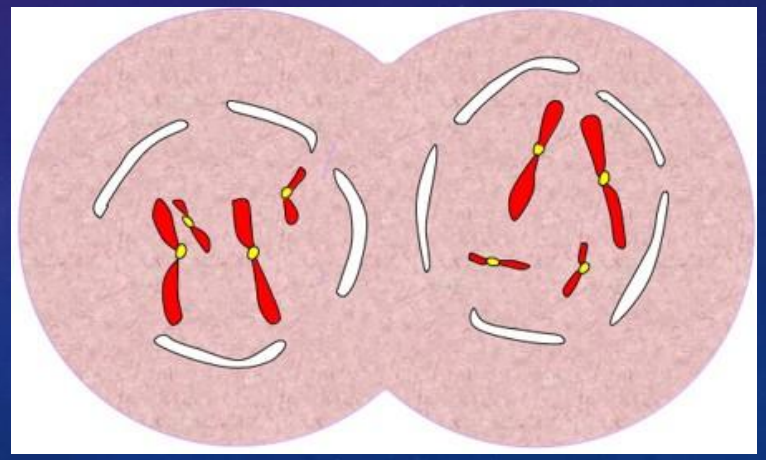


Note: To be called a chromatid, a chromatid must be attached to its sister. When the chromosomes divide at the beginning of anaphase, the sister chromatids are no longer sisters because they are no longer connected. Once they are separated, they are called unreplicated chromosomes. Unreplicated chromosomes will come up again in the Interphase section below.

TELOPHASE

- During the last of the four stages of mitosis, telophase, the chromosomes have reached the poles and the nuclear membrane begins to appear. During telophase in animal cells, a cleavage furrow appears (see photo below). By the end of this stage of mitosis, the cell has divided in two along the plane defined by the furrow. In most plants, instead of a cleavage furrow, a "cell plate" forms, dividing the cell into two daughter cells.





CYTOKINESIS

- While cytokinesis is one of the steps in the cell cycle, it is *not* one of the phases of mitosis. It is the division of the cytoplasm, as opposed to karyokinesis, which is division of the nucleus (the cytoplasm is all of the contents of the cell outside the nucleus). Division of the cytoplasm occurs in both mitosis and meiosis.
- After mitosis, the cell returns to interphase, which recall, is the growth stage of the cell cycle between successive mitoses (interphase is the stage during which DNA synthesis, or replication, occurs). Cytokinesis and karyokinesis are now complete and there are two daughter cells. The nuclear membrane has reformed. The chromosomes have decondensed once again and are now re-enclosed in an intact nuclear membrane.

SIGNIFICANCE OF MITOSIS

- The significance of mitosis is its ability to produce daughter cells which are exactly the same a the parent cell. It is important for three reasons:

1. **Growth**

- If a tissue wants to get bigger by growth needs new cells that are identical to the existing ones. Cells division must therefore be by mitosis.

2. **Repair**

- Damaged cells have to be replaced by exact copies of the organism so that it repairs the tissues to their former condition. Mitosis is the means by which this is achieved.

3. **Asexual reproduction**

•If a species is good at colonizing a habitat, there might be no point, in producing offspring which are different from the parents, because they might be less effective at survival. Therefore it might be better, in the short term, to make a colony which is similar to the parents. In simple animals and most plants this is achieved by mitotic division.

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