Cell division

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Cell cycle division

The **cell cycle**, or **cell-division cycle**, is the series of events that take place in a cell that cause it to divide into two daughter cells. These events include the duplication of its DNA (DNA replication) and some of its organelles, and subsequently the partitioning of its cytoplasm and other components into two daughter cells have the same characteristic of parent's cells (first cells)

- In cells with nuclei (eukaryotes), the cell cycle is divided into two main cycles (mitosis and meiosis), these two cycles divided into two main stages: interphase and the mitotic or meiosis (M) phase (including karyokinesis and cytokinesis). During interphase, the cell grows, accumulating nutrients needed for mitosis, and replicates its DNA and some of its organelles. During the mitotic phase, the replicated chromosomes, organelles, and cytoplasm separate into two new daughter cells. To ensure the proper replication of cellular components and division, there are control mechanisms known as cell cycle checkpoints after each of the key steps of the cycle that determine if the cell can progress to the next phase.
- In cells without nuclei (prokaryotes), the cell cycle is divided into the B, C, and D periods. The B period extends from the end of cell division to the beginning of DNA replication. DNA replication occurs during the C period. The D period refers to the stage between the end of DNA replication and the splitting of the bacterial cell into two daughter cells. This called binary fission
- The cell-division cycle is a vital process by which a single-celled fertilized egg develops into a mature organism, as well as the process by which hair, skin, blood cells, and some internal organs are renewed.
- So, we can say that continuity of life depends on this cell cycle.

Cell cycle in Eucaryotic cells.

The cell cycle in eucaryotic cells divided into two main type

1. Mitosis (Asexual reproduction cycle)

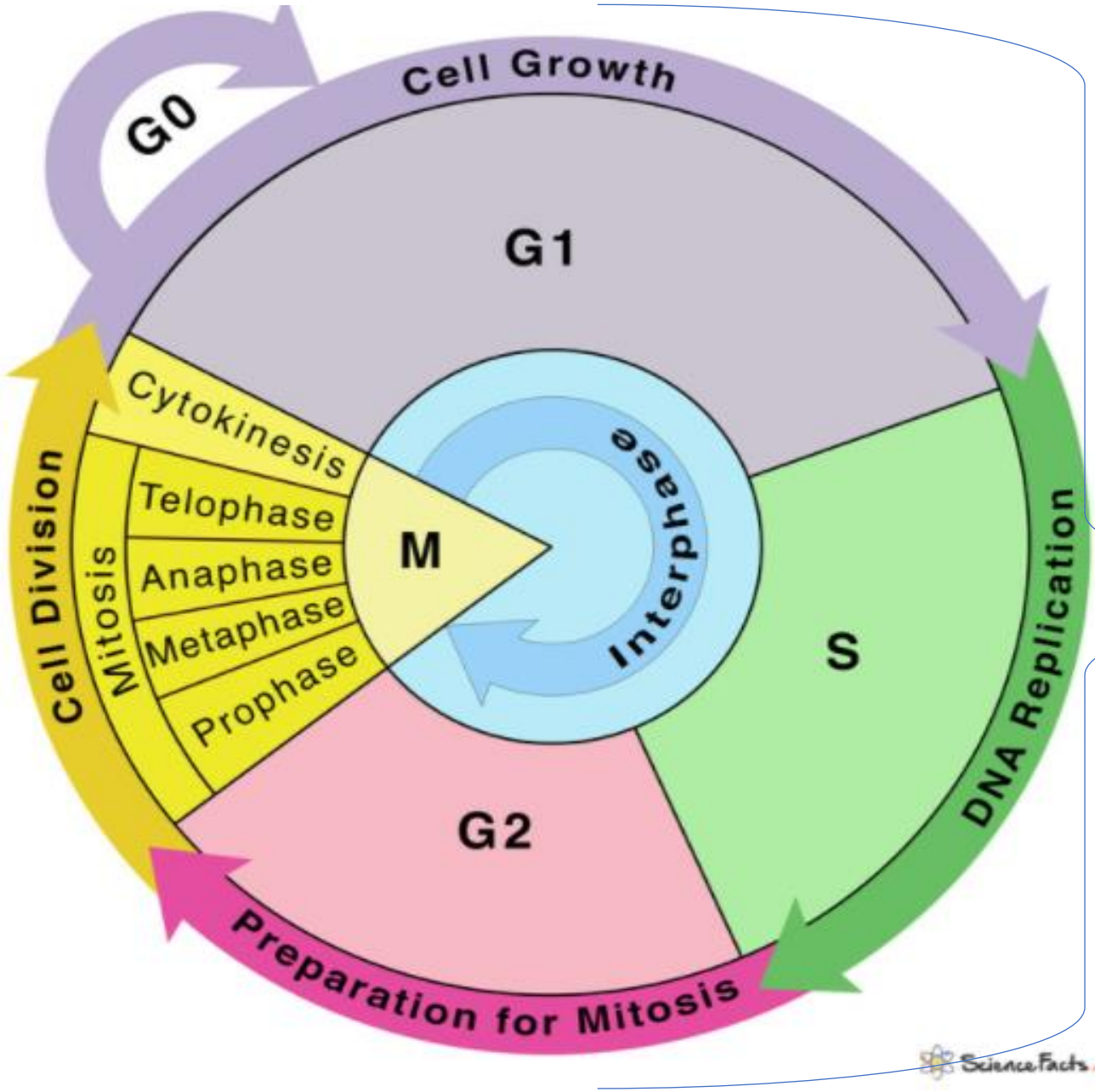
Is the process in which the nucleus of a cell divides to create two new nuclei, each containing an identical copy of DNA (somatic cells). Mitosis allows the cells in to divide and regenerate, your hair to grow, your skin to heal after being wounded. Almost all the DNA duplication is carried out through mitosis.

2. Meiosis (Sexual reproduction cycle)

Is the process by which certain sex cells (gametocytes) are created. In the male, the body uses meiosis to create sperm cells; in the female, it uses meiosis to create egg cells.

For example; in human while all other cells in the body contain 46 chromosomes (23 from father and 23 from mother), the egg (or sperm) cells contain only half that number—a total of 23 chromosomes. When an egg and sperm unite to make a fertilized egg, the chromosomes add up to equal 46.

***More explanation**
Humans are diploid, meaning we have two copies of each chromosome. We inherited one copy of each chromosome from our mother, and one copy of each from our father. Gametes (sperm cells or egg cells) are haploid, meaning that they have just one complete set of chromosomes.
Chromosomes that do not differ between males and females are called **autosomes**, and the chromosomes that differ between males and females are the **sex chromosomes**, X and Y for most mammals. Humans most commonly have 22 pairs of autosomes and 1 pair of sex chromosomes (XX or XY), for a total of 46 chromosomes.


G0
Cell Growth
G1
Cytokinesis
Telophase
Anaphase
Metaphase
Prophase
Mitosis
Cell Division
M
Interphase
S
DNA Replication
G2
Preparation for Mitosis
ScienceFacts

Interphase

Mitosis (Asexual reproduction cycle)

- **Interphase**: It is the first phase of the cell cycle, recognized by the growth period where the chromosome gets duplicated as the cell prepares for division. Interphase happens between one cell division or mitotic (M) phase and the next. It is the longest part of the cell cycle involving three sub-phases. The typical duration of this phase is 23 hours (About 90 percent of a cell's time in the normal cell cycle may be spent in interphase).

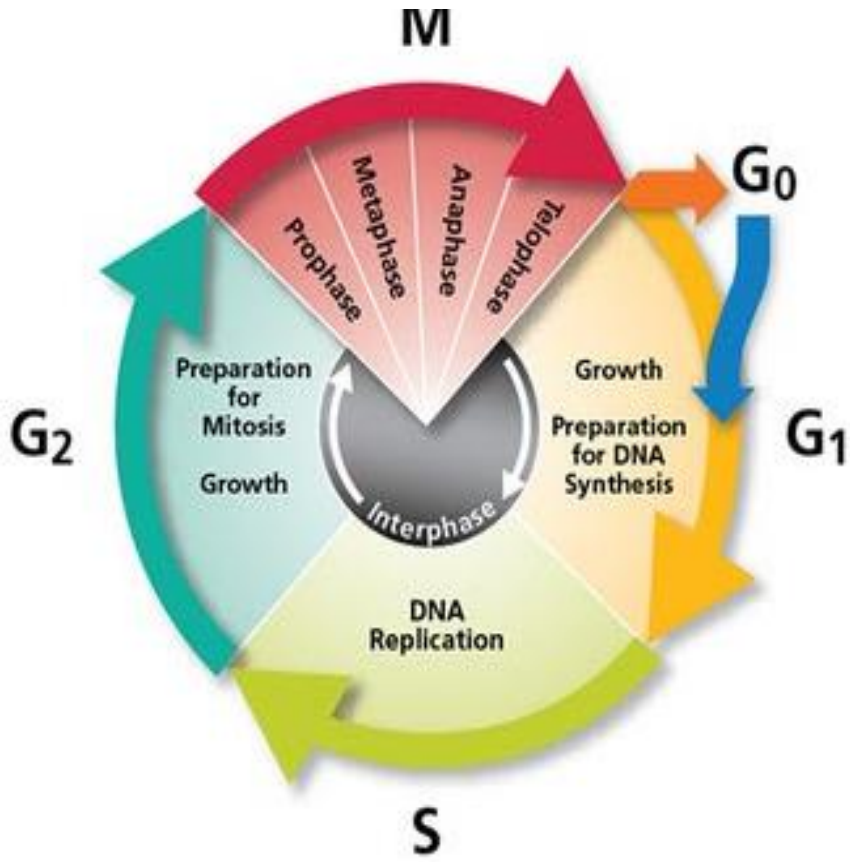
a. G1-phase: Also known as the first-gap phase, during this period, the cells grow, synthesize cell organelles and other macromolecules such as proteins that serve as the building block of the cell. The cells also accumulate sufficient energy required for division.

b. S-phase: Also known as the synthesis phase, the existing DNA is copied within the nucleus. This process of DNA synthesis is also known as DNA-replication. The centrosome is also duplicated during this phase and gives rise to spindle fibers. The entire S-phase requires energy expenditure to proceed.

c. G2-phase: This is the second gap phase and is somewhat like the G1- phase. During this period, the cells grow further in size, making more proteins and organelles. All preparation for mitosis get completed before the cells enter the mitotic phase.

- **G0-phase**

- Some cells do not immediately enter another round of preparatory phase or interphase following the division or mitosis. Instead, they exit the G1 growth phase and enter a resting stage called G0-phase. Thus, G0 is also called the alternative phase of the cell cycle. Some cells enter the G0-phase temporarily until an outside signal triggers the onset of G1. In contrast, other cells that either never divide or seldom (rare) divide, such as nerve cells or cardiac cells, remain in G0-phase permanently.



- **Mitotic (M) Phase**

This period is also known as the cell division phase and occurs just after the G2-phase. Here, the cell divides its genetic material (DNA) and cytoplasm to form two new cells. The M-phase involves two different critical processes that unfold in the following order:

a) Mitosis or Karyokinesis

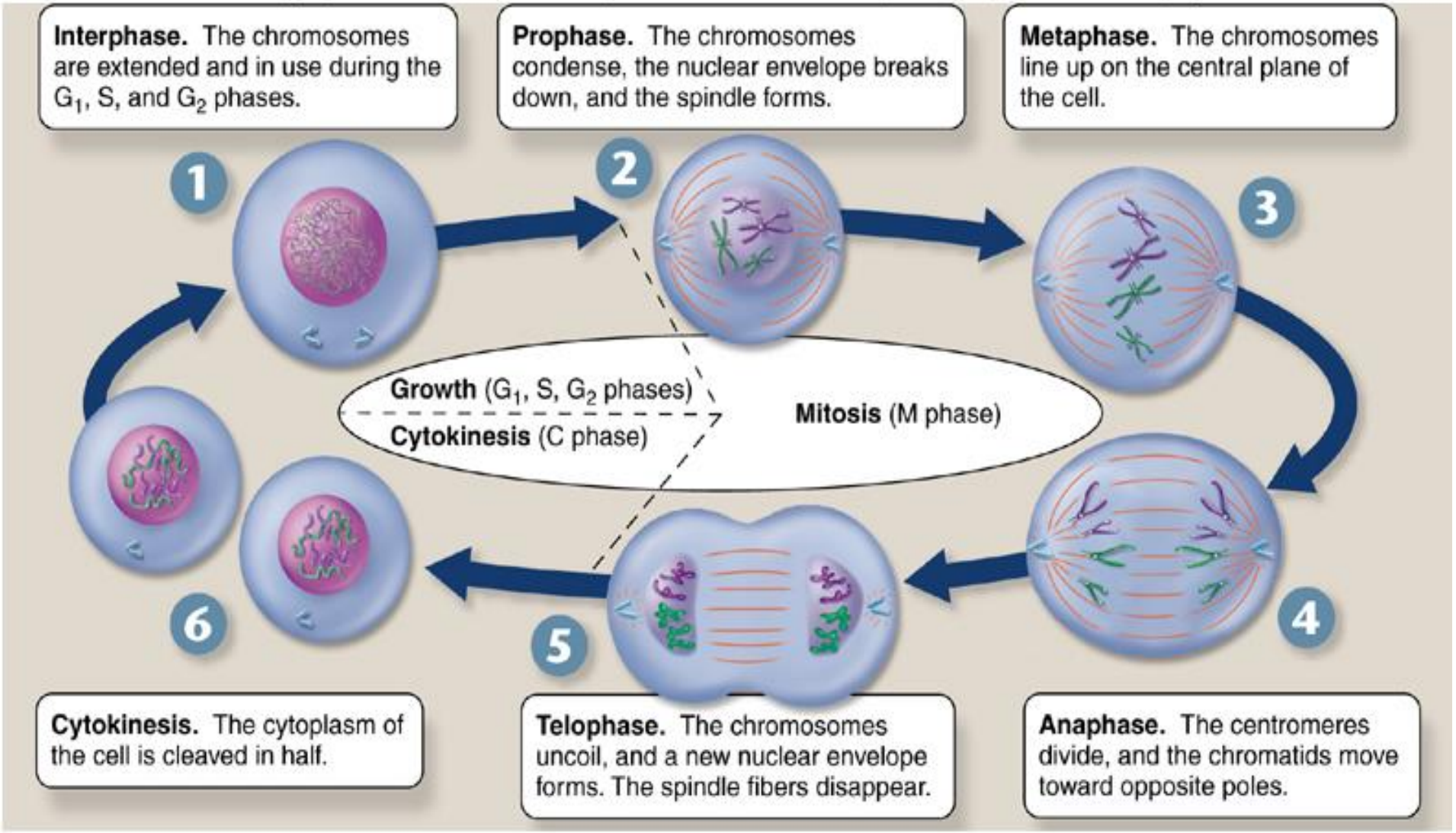
It is the nuclear division period and consists of four sub-phases: prophase, metaphase, anaphase, and telophase. During this phase, the cell divides the nucleus and gets separated into two daughter cells, where each daughter cell receives a complete set of chromosomes.

1. **Prophase** – This is the first step in mitosis which brings many structural changes in the cells such as condensation of chromosomes. The condensation helps chromosomes to easier separate from each other in later stages. The chromosomes begin to migrate toward the cell center.
2. **Metaphase** – In this phase, the chromosomes start to align in a plane called the metaphase plate. The cell also makes sure that, the process of alignment is correct before moving to the next stage. In case there is an issue with the alignment, the cell will not be able to move towards the next stage of the division until the issue is solved.
3. **Anaphase** – The chromosomes which were aligned in metaphase plate start to separate from each other as chromatids and move towards the opposite direction towards the poles of the cell. At the end of anaphase, each pole will get one set of daughter chromosomes. Also known as migratory phase.
4. **Telophase** – In this phase, most parts of the cell are divided into two daughter cells. After this, the daughter cells start to normalize their structure to survive as separate cells. Two nuclei are formed at the end of telophase. Both the nuclei have the same number of chromosome as parent cell. Also known as reorganization phase.

b) Cytokinesis

It is the process by which the cytoplasm of the cell splits to form two independent cells. The phase of cytokinesis begins towards the end of mitosis During cytokinesis, many granular matrix formed by the golgi body and endoplasmic reticulum accumulates in the equatorial region. These granular matrix form cell plate. This plate divides the cell and by the end of telophase, cytokinesis is completed. Cytokinesis is the shortest phase of the cell cycle.

- **The end result is Two individual daughter cells are formed, each having identical copies of the genetic material.**


Interphase. The chromosomes are extended and in use during the G_1, S, and G_2 phases.
Prophase. The chromosomes condense, the nuclear envelope breaks down, and the spindle forms.
Metaphase. The chromosomes line up on the central plane of the cell.
1
2
3
Growth (G_1, S, G_2 phases)
Cytokinesis (C phase)
Mitosis (M phase)
4
5
6
Cytokinesis. The cytoplasm of the cell is cleaved in half.
Telophase. The chromosomes uncoil, and a new nuclear envelope forms. The spindle fibers disappear.
Anaphase. The centromeres divide, and the chromatids move toward opposite poles.

Functions OF MITOSIS:

- Mitosis produces 2 genetically identical cells, so mitosis maintains the genetic stability of organisms.
- DNA remains constant, so mitosis keeps the chromosomes number constant in a species.
- Mitosis helps in the development of multicellular organism.
- Mitosis helps to replacement of old, dead or damaged cells by new one.
- It helps in the recovery of wounds and injury of the body by formation of new cells.
- In unicellular organisms like Yeast, *Paramecium* , mitosis is a means of asexual reproduction.
- Mitosis causes maturation and multiplication of germ cells and makes them ready for meiosis.

Meiosis (Sexual reproduction cycle)

- Almost all of body's cells divide by mitosis. Meiosis is used to produce only one type of cell, and those are the ***gametes.*** During meiosis, a ***diploid cell*** divides to produce four, non-identical ***haploid daughter cells,*** each containing a single set of chromosomes. In humans, these are sperm and egg cells.
- Unlike mitosis, meiosis involves two rounds of cell division. These happen across two stages: Meiosis I, and Meiosis II. Each stage of meiosis can be further divided into four phases: prophase, metaphase, anaphase, and telophase.

The Stages of Meiosis

Before the first round of cell division begins, the cell's DNA is replicated (duplicated) during the interphase of the cell cycle

1. Meiosis I

Like mitosis, meiosis I takes place across four stages.

- Prophase I

During prophase I, the chromosomes condense and form homologous pairs. Each homologous pair of chromosomes lines up carefully so their genes are aligned. Next, the chromosomes swap genetic material with one another, in a process known as crossing over. This ensures that each sister chromatid is no longer genetically identical.

- Metaphase I

The homologous chromosome pairs line up along the metaphase plate in the middle of the cell.

- Anaphase I

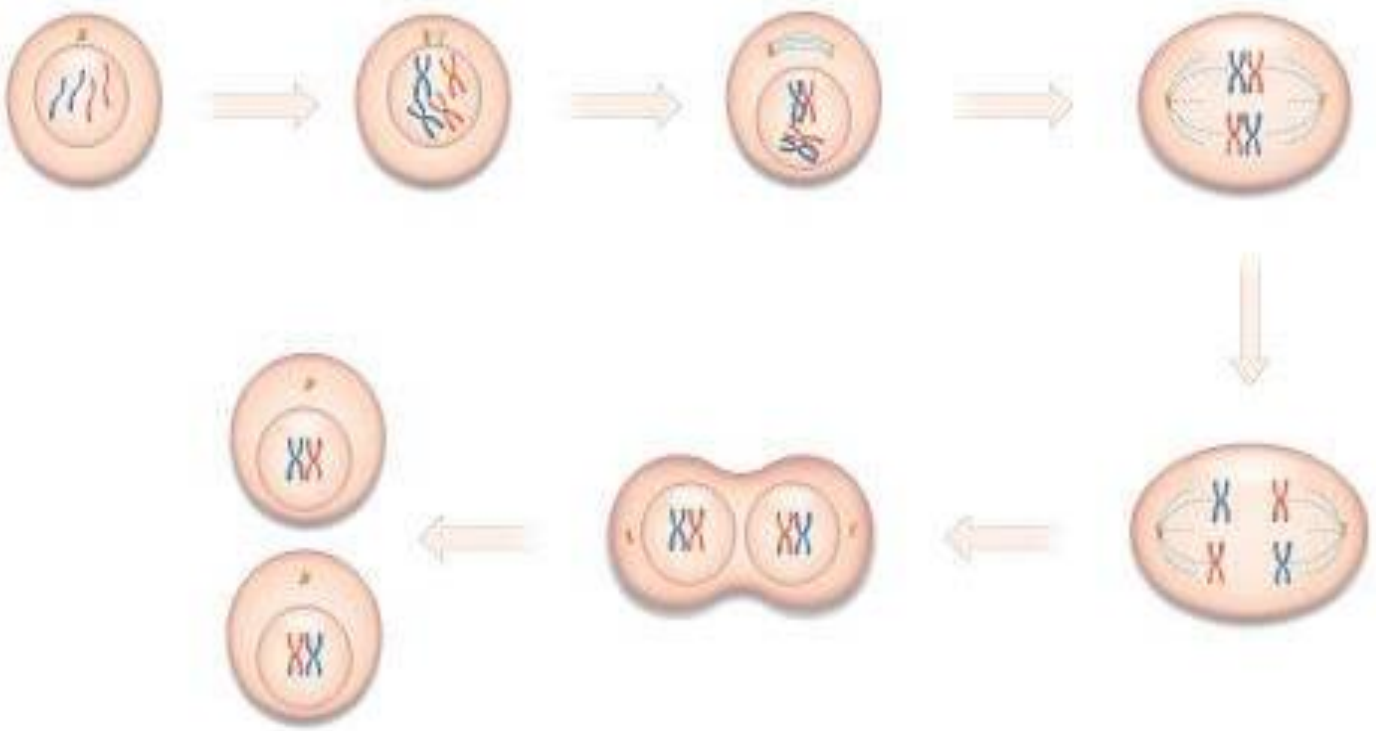
The homologous pairs are separated by the microtubules and are pulled to opposite ends of the cell. The homologous pairs line up and are separated at random in a process known as independent segregation. This is done to further increase genetic diversity among daughter cells.

- Telophase I

The chromosomes arrive at opposite ends of the cell, and the cytoplasm is split by cytokinesis.

- The first round of cell division is complete. The two non-identical, haploid daughter cells now enter the second stage of meiosis.

MEIOSIS I



2. Meiosis II

Meiosis II is very similar to the process of mitosis, except it involves two haploid cells rather than one diploid cell.

- Prophase II

During prophase II, the chromosomes condense.

- Metaphase II

The chromosomes line up along the metaphase plates.

- Anaphase II

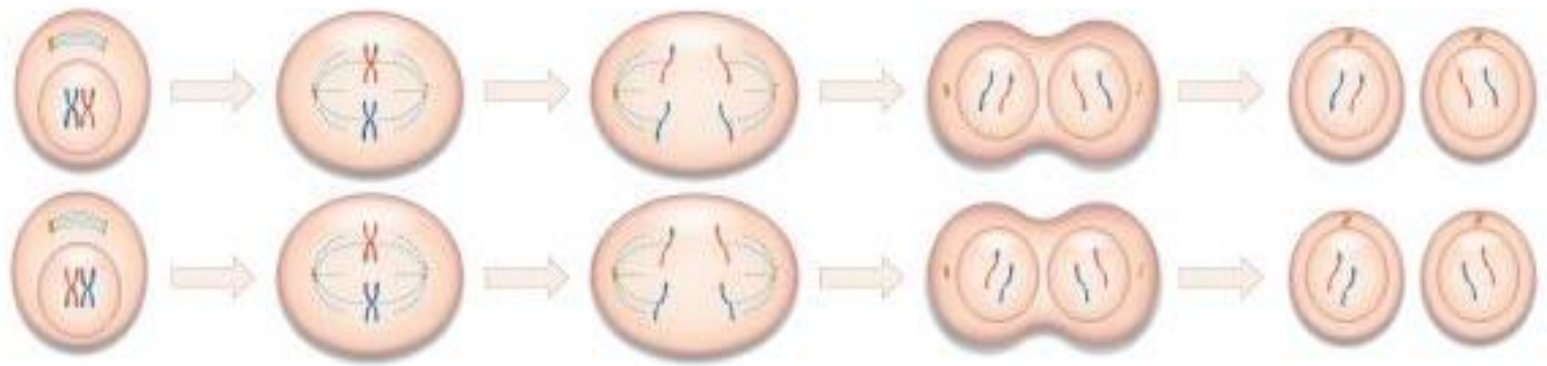
The chromosomes are pulled apart by microtubules. The non-identical sister chromatids are pulled to opposite ends of the cells.

- Telophase II

The sister chromatids reach opposite ends of the cells. The cells are divided by cytokinesis, and four non-identical, haploid daughter cells are produced.

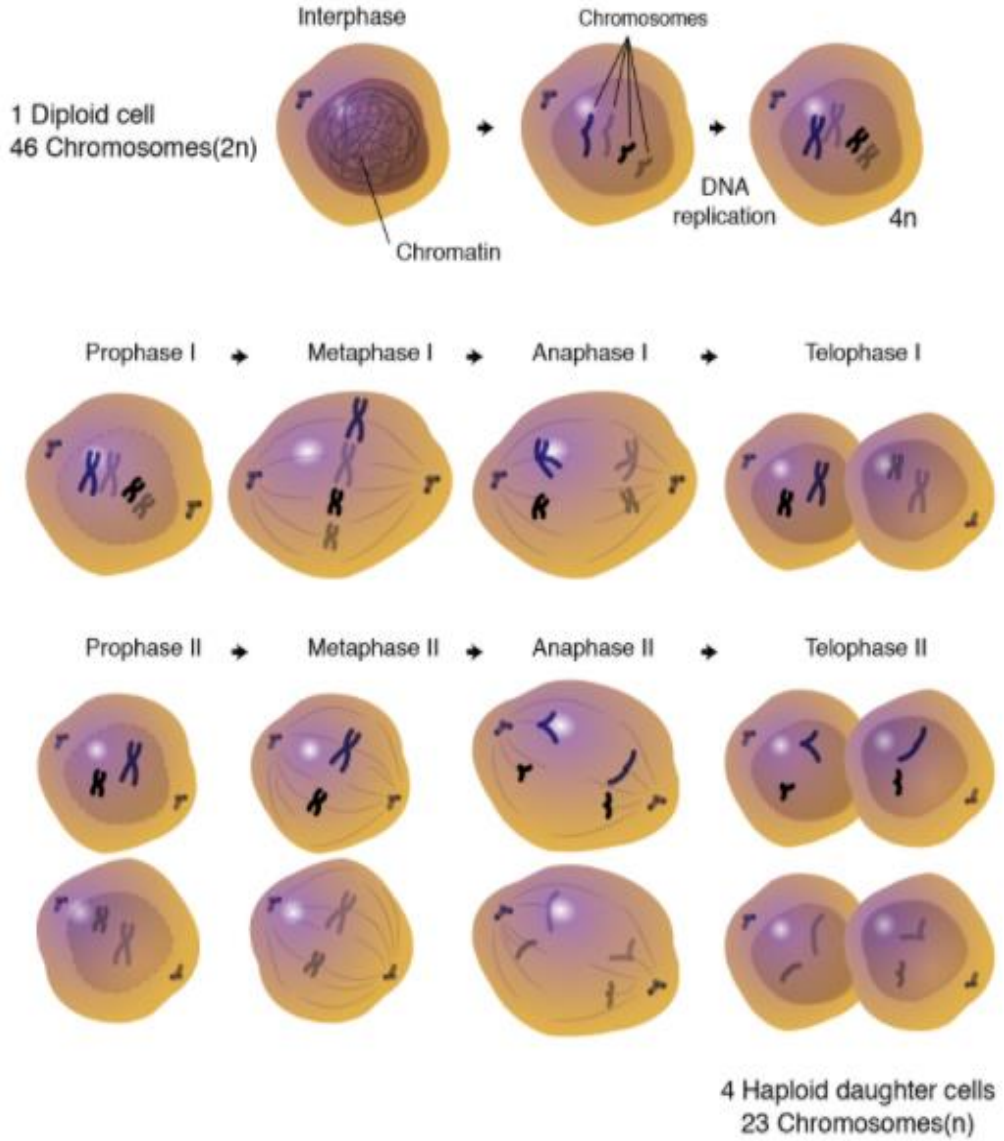
- This means there are 4 copies of each gene, present in 2 full sets of DNA, each set having 2 alleles.

MEIOSIS II



Miosis I

Miosis II



Function of Meiosis

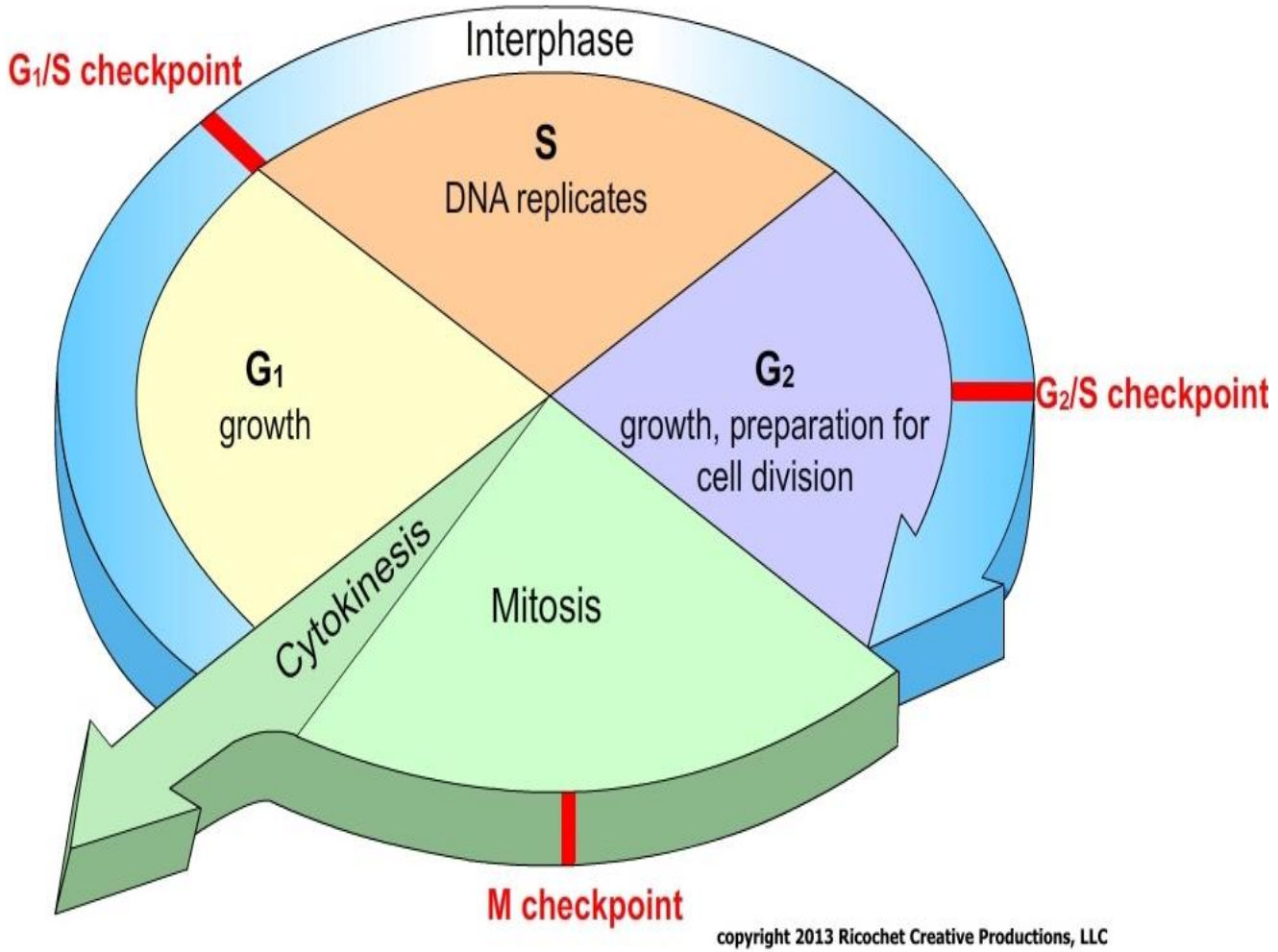
- Meiosis is necessary for many sexually-reproducing animals to ensure the same number of chromosomes in the offspring as in the parents. The act of fertilization includes two cells fusing together to become a new zygote. If the number of alleles of each gene is not reduced to 1 in the gametes that produce the zygote, there will be 4 copies of each gene in the offspring. In many animals, this would lead to many developmental defects.
- In other organisms, polyploidy is common, and they can exist with many copies of the same gene. However, if the organism cannot survive if they are polyploidy, meiosis must occur before reproduction. Meiosis occurs in two distinct divisions, with different phases in each.

Regulation of Cell Cycle

The cell cycle occurs in an orderly and natural manner. A group of proteins called regulatory proteins ensures an error-free process. There are some checkpoints whose purpose is to control the system and determine whether the cell will start or delay the next phase of the cell cycle. The main checkpoints are:

- G1-checkpoint: Present just before the entry into S-phase, it makes the critical decision whether the cell will enter the S-phase. The decision is based on whether the cell is big enough and has synthesized proteins necessary for DNA synthesis.
- G2-checkpoint: Checks errors in the DNA-synthesis phase and, based on the result, bars the entry into the M-phase. This checkpoint helps to prevent the occurrence of cancer in higher animals. Suppose there is an error in DNA replication. In that case, the G2 checkpoint prevents the cell from progressing further in the cell cycle and checks the error in the newly formed DNA.
- M-checkpoint: This occurs near the end of the metaphase stage. It checks whether all sister chromatids are correctly attached to the spindle fibers. The M-checkpoint ensures that equal division of chromosome occurs between the two daughter cells.

In case the above cell cycle regulators do not function properly, the organism may end up with too few or too many cells. Apart from the above checkpoints, many growth factors and chemicals stimulate the cell to progress through the cell cycle.


Interphase
G1/S checkpoint
S
DNA replicates
G1
growth
G2
growth, preparation for
cell division
G2/S checkpoint
Cytokinesis
Mitosis
M checkpoint
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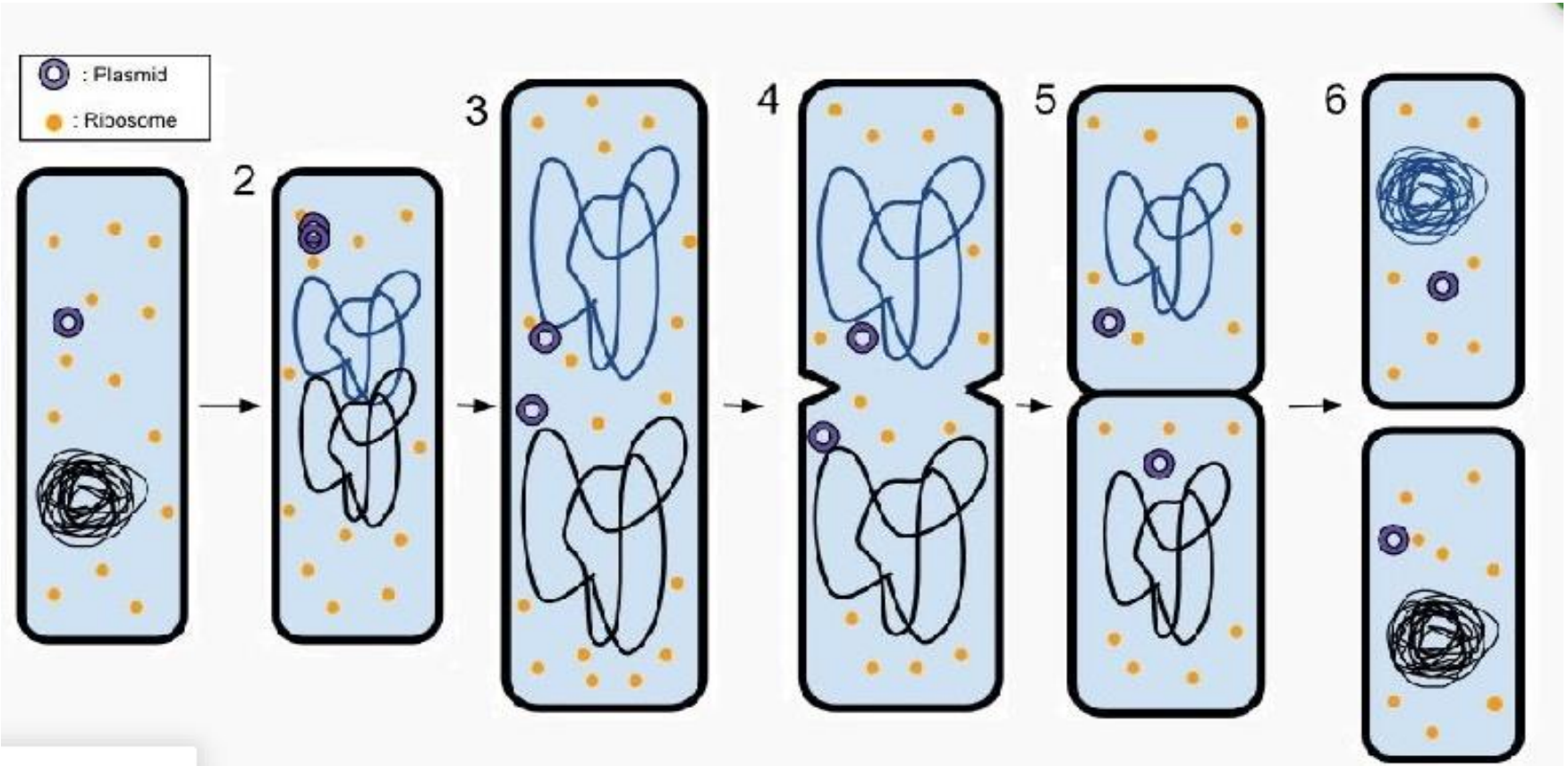
Binary fission

- Binary fission is the process through which asexual reproduction happens in prokaryotic cells (bacteria and archaea). During binary fission, a single organism becomes two independent organisms.
- Binary fission is a relatively simple process, compared to mitosis, because binary fission does not involve reproducing organelles or complex chromosomes. **The process starts with the replication of the DNA within the cell.**
- Then, the DNA is separated into alternate ends of the single cell. The plasma membrane pinches the cell apart, and one cell becomes two. With a fully-functioning DNA molecule, each cell is then capable of all the functions of life. Therefore, the cells become independent organisms.

Binary Fission Steps

Binary fission of a prokaryote, has 5 steps:

- Step 1, a prokaryote's DNA is tightly wound. Sometimes, the prokaryote will carry small *plasmids*, which are small rings of DNA that carry extra genetic information.
- Step 2, the DNA is unraveled. As it is unraveled, specialized proteins gain access to the DNA, which then works to replicate the ring of DNA. The same proteins work on the plasmids in the cell, duplicating them as well.
- Step 3, both the DNA and plasmids have been duplicated. The individual copies of DNA attach themselves to different parts of the cell membrane. As the cell elongates in preparation for division, the DNA molecules are pulled to different sides of the cell.
- Step 4, a cleavage furrow appears in the cell membrane, as the cell wall and membrane start to pinch off and create two new cells.
- Finally, in step 5, the cells become completely separated from one another as a new bacterial cell wall forms. The final step includes breaking any additional proteins or other molecules that still connect the two cells. Each cell now has everything it needs to continue the functions of life independently.


: Plasmid
: Ribosome
2
3
4
5
6

Homework

- Why is Cancer considered as Cell Cycle Disease?
- What are the differences between Meiosis and mitosis?
- What are the differences between mitosis and binary fission?
- Can binary fission happen in eukaryotic cells?(yes or no), if yes where and when?

Good lack

Thanks for attention

Questions