Cell cycle. Mitosis

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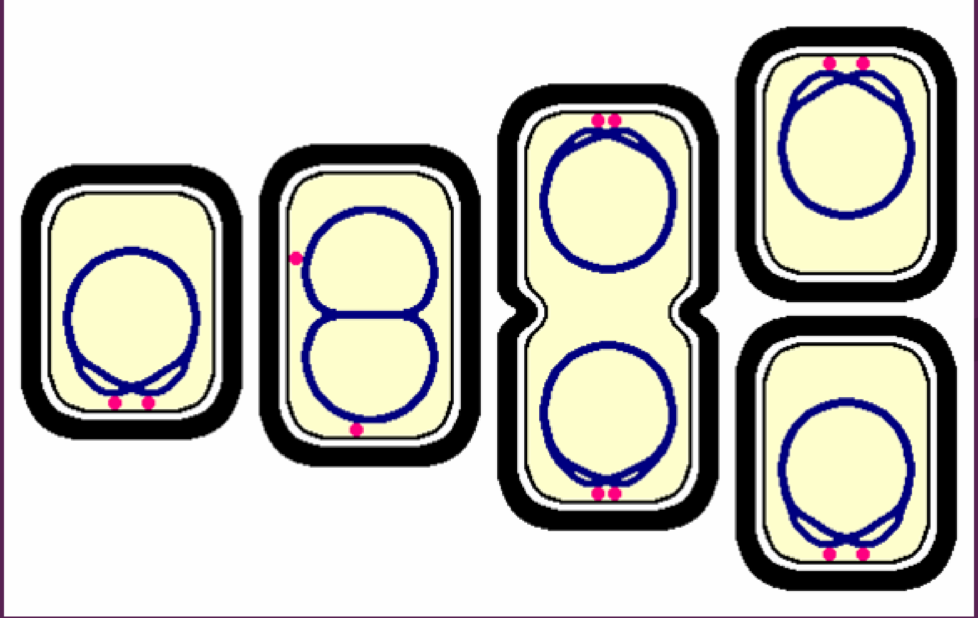
Every multicellular organism begins its individual existence as a single cell – zygote. By multiple cell divisions tissues and organs of the organism are formed. Later, in the adult organism, a lot of somatic cells age and die. Dead cells are displaced by cell division. The division increases the number of cells and transmits genetic information from the maternal cell to daughters. Carriers of genetic information are chromosomes, that's why their behavior is crucial during cell division.

Mitosis is an universal mechanism of cell division for eukaryotes. For prokaryotic cell division usually the term binary fission is used. This is because prokaryotes have no nucleus and they never organize mitotic spindle to segregate genetic material. When bacterial chromosome is duplicated, the copies bind to the cell membrane by special proteins. These proteins pull duplicated chromosome apart to separate them in daughter cells.

Bacterial cell division



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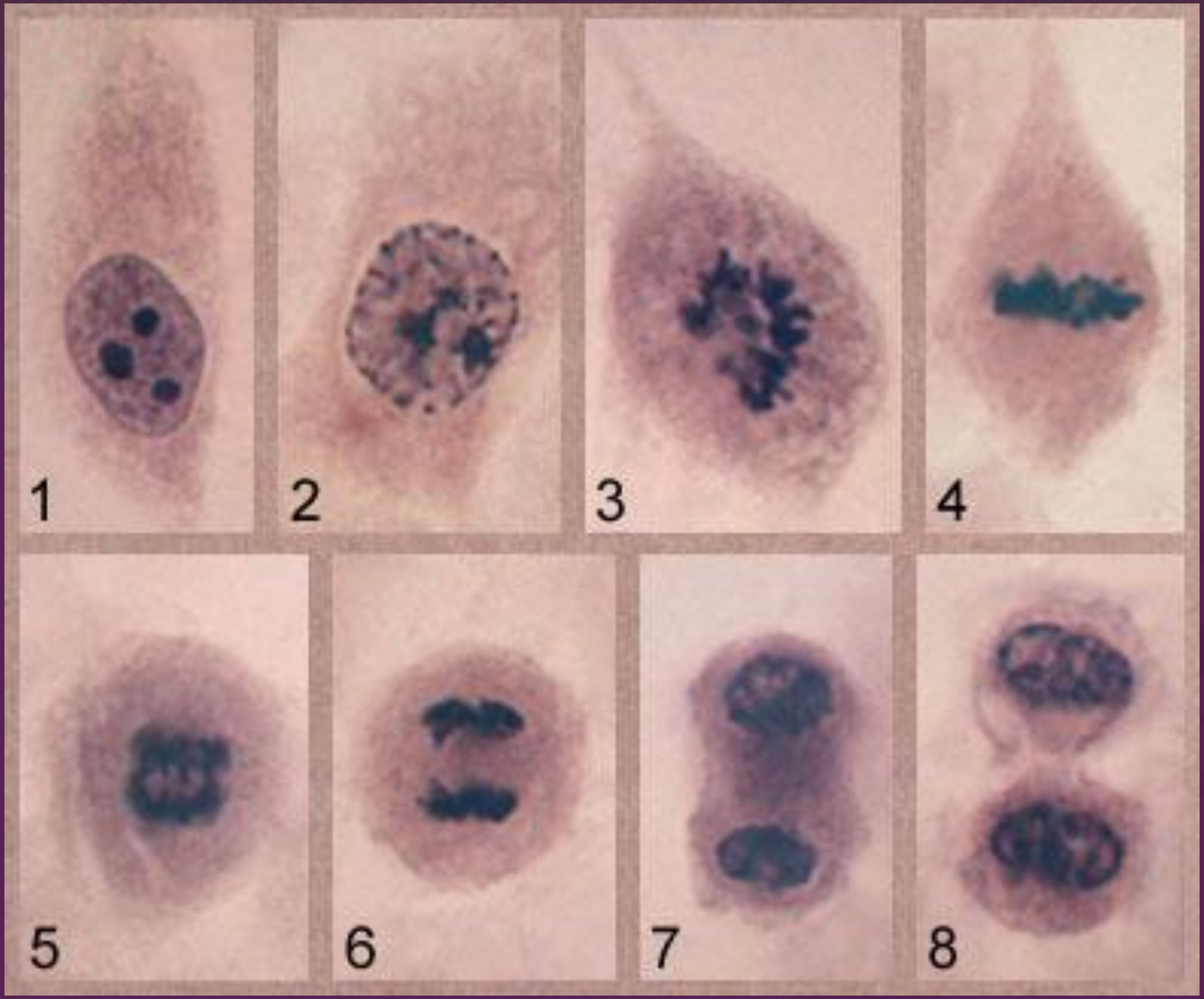
Cell ploidy

When we talk abut cell division, we have to define the cell ploidy.

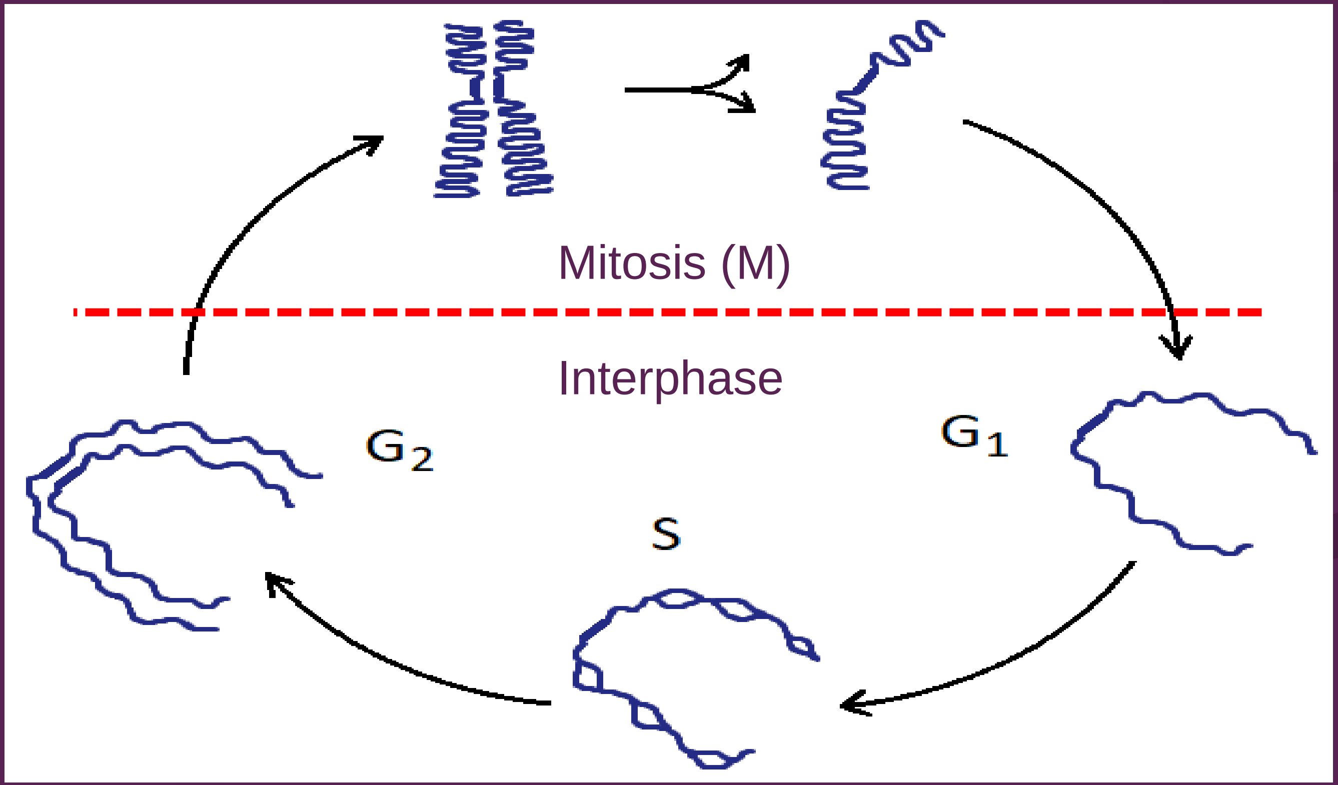
- One cell is haploid if it possesses one copy of each chromosome. Bacteria normally are haploid – they have only one copy of their nucleoid (bacterial chromosome) in the cytoplasm. Because in favorable conditions bacteria divide very fast, it is possible to have two copies of the chromosome. Those copies are product of replication and they will be separated in daughter cells.
- Gametes are haploid eukaryotic cells. They are product of special cell division – meiosis. Each spermatozoa and oocyte contains one copy of each chromosome – maternal or paternal. Human gametes possess 23 chromosomes. Diploid chromosomal number recovers during fertilization when the gametes fuse.
- The term genome defines the haploid number of chromosomes of the species. One haploid set of chromosomes = one genome.
- Somatic cells of eukaryotes are diploid. Each somatic cell contains two copies of each chromosome. One of them is maternal, the other is paternal. Those chromosomes are called homologous. All of eukaryotes are diploid. Eukaryotes needs that, because their complicated genomes require sexual reproduction. Sexual reproduction cleans the genome from deleterious mutation because of exchanging of genes between different individuals. Diploid cells have the advantage to keep silent some pathological allele, because the homologous chromosome carries the normal one. The homologous is used as a template for DNA repair, if in the chromosome is induced double stranded break.

The division of eukaryotic cells is called mitosis



To be precise, the division of *chromosomes* is called mitosis; the division of the cell body is called cytokinesis.

The state of non-dividing cells is called interphase. During interphase each chromosome consist of one chromatid only. These two sister chromatids, which we know from the schemes in school books, are product of DNA replication. Sister chromatids are absolutely identical. They appear after the S-period of interphase. The chromosome has two sister chromatids from the end of S-phase to the beginning of anaphase where sisters separate in order to move to the opposite poles. After anaphase each chromatid is individual chromosome in the newly formed cells.



Preparing for cell division

During mitosis the cell have to produce two identical copies of itself. That's why is necessary to have preparation for this complicated process. Preparing for cell division is called interphase.

Interphase is an ambiguous term in the Cell biology. Sometimes interphase means preparing for cell division. Otherwise interphase denotes the normal cell life, in which the cell is not dividing. This confusion comes from the scientists who discover cell division. They were thought every cell starts preparing for a new division immediately after finishing previous one. That's why they describe the cell cycle as a preparing for a division, division and preparing again.

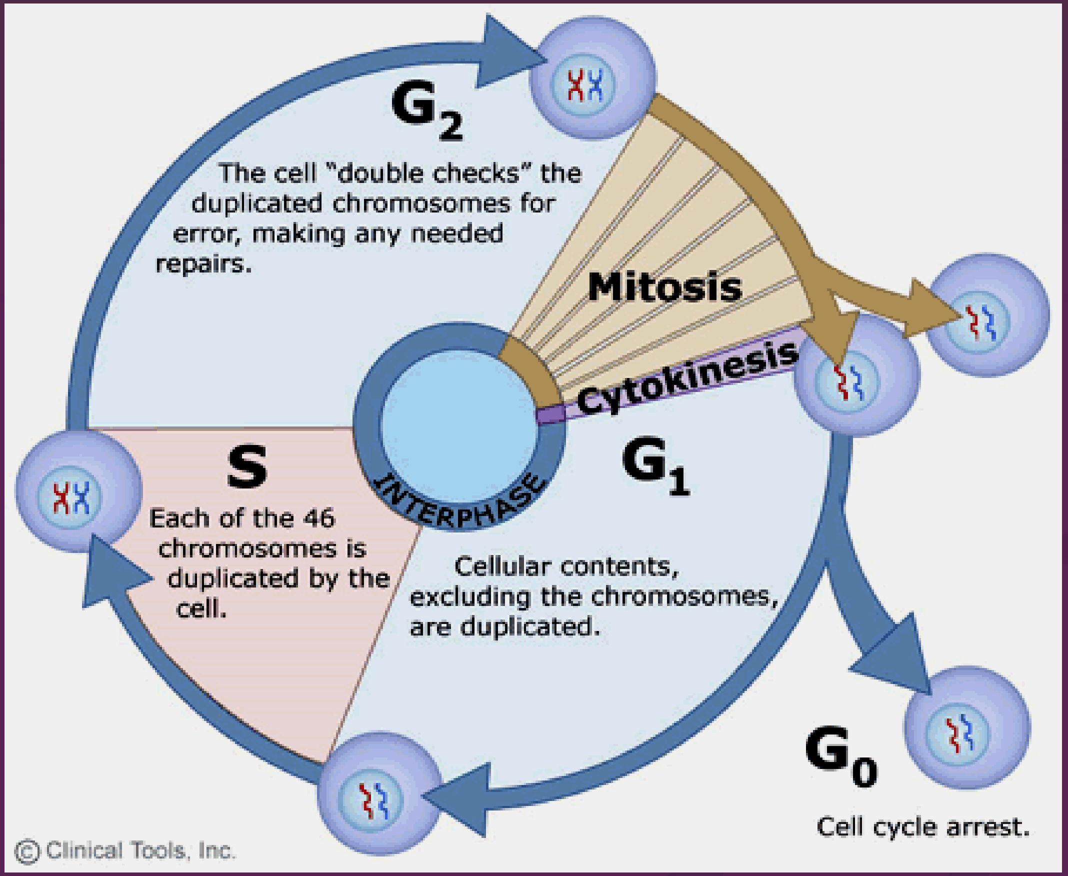
Nowadays we know it is not valid for all of cells. Some of them differentiate after mitosis and are not divided any more. Examples of that are muscle cells and neurons. They are permanently in interphase - in G0 – period.

Despite this confusion, the term interphase is used in both of meanings nowadays.

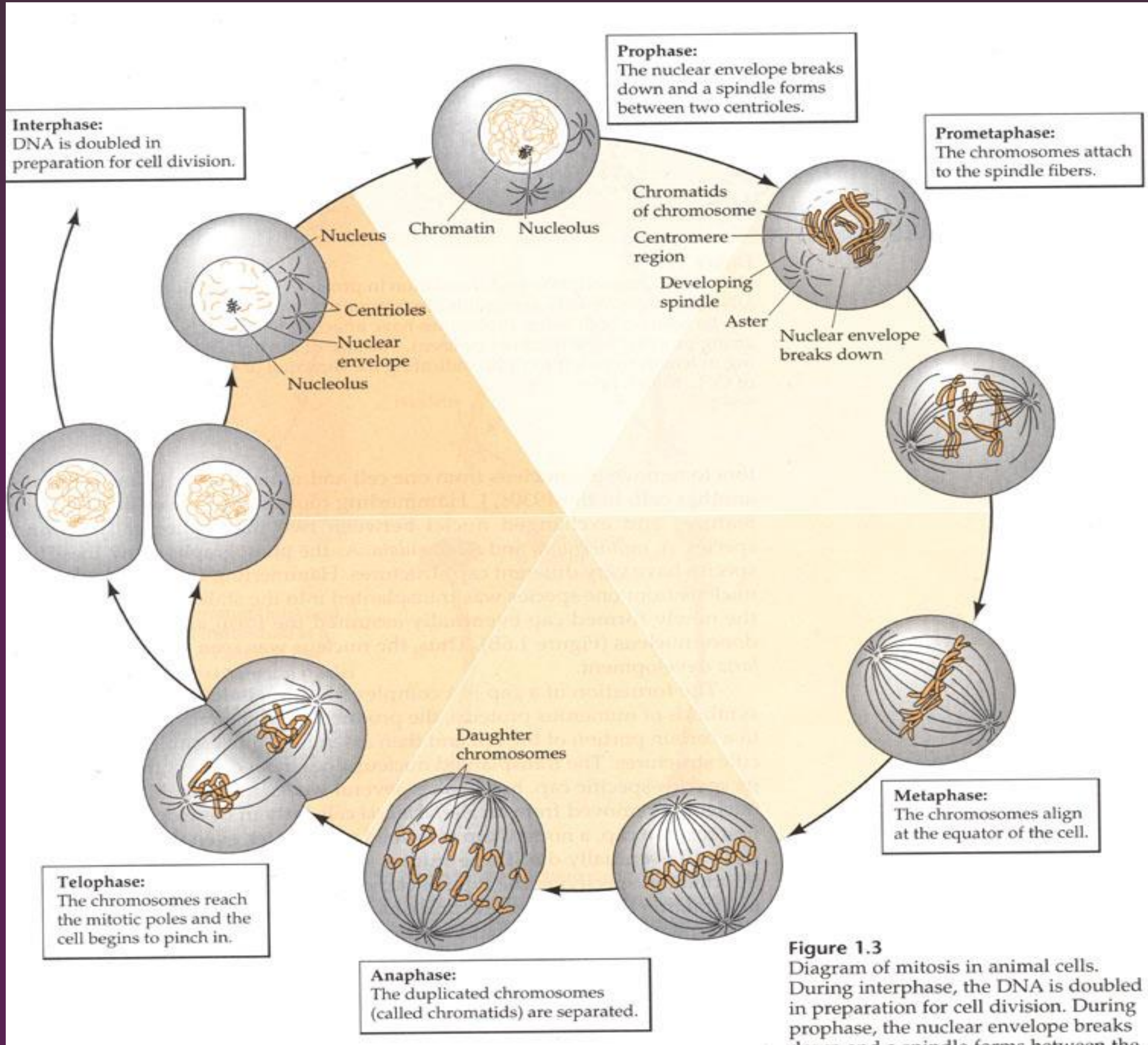
If we talk about preparing for cell division, the interphase is subdivided into three periods – G1, S and G2. Interphase is the longest phase in the cell cycle. Duration of mitosis if different for the different cells. Mitosis of a human cell in a culture lasts 20 hours. 19 hours of them is the interphase and only one hour mitosis.

- G1 phase. Metabolic changes prepare the cell for division. At a certain point - the restriction point - the cell is committed to division and moves into the S phase.
- S phase (syntetic). This is the time for DNA replication. Then each chromosome consists of two sister chromatids.
- G2 phase. Metabolic changes assemble the cytoplasmic materials necessary for mitosis and cytokinesis.
- M phase. A nuclear division (mitosis) followed by a cell division (cytokinesis).
- The period between mitotic divisions - that is, G1, S and G2 - is known as interphase.
- G1 is transformed into G0, if the cell has no stimulus for division – it just do its everyday job.

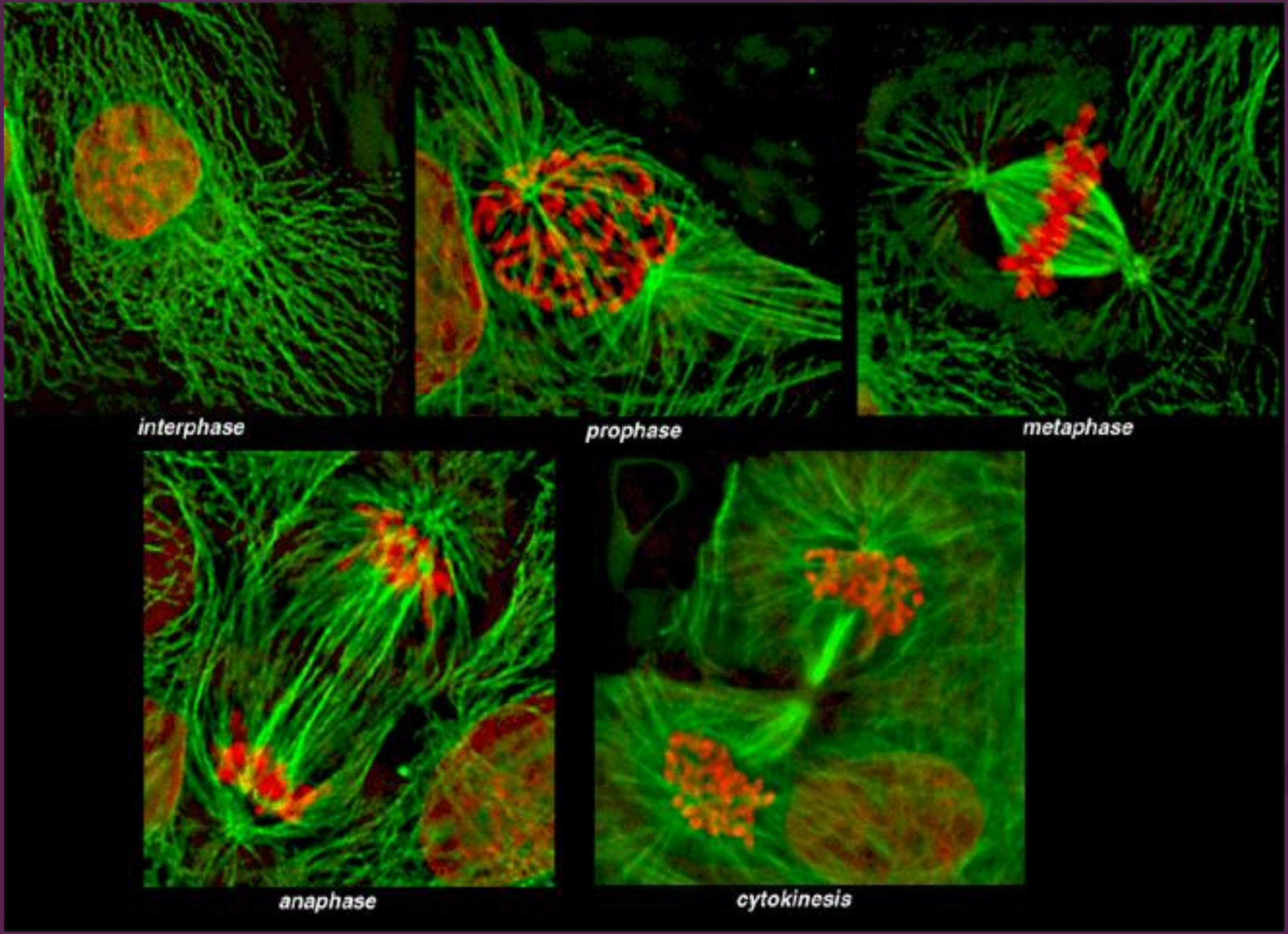
Cell cycle



Phases of mitosis



Chromosomes (red) cannot move on their own and are pulled by the mitotic spindle (green)



Events during the cell cycle

Interphase:

Cell growth, replication of DNA

Prophase:

Chromosomes condense, mitotic spindle starts to form; At the end (prometaphase) nuclear envelope breaks down

Metaphase:

Chromosomes align at the spindle equator

Anaphase:

Sister chromatids separate and are now called chromosomes. The spindle pulls them to the poles

Telophase:

Chromosomes decondense, nuclear envelopes form around them, cytokinesis takes place

Cytokinesis – division of the cytoplasm

Cytokinesis happens after telophase in order to separate the cytoplasm between daughter cells.

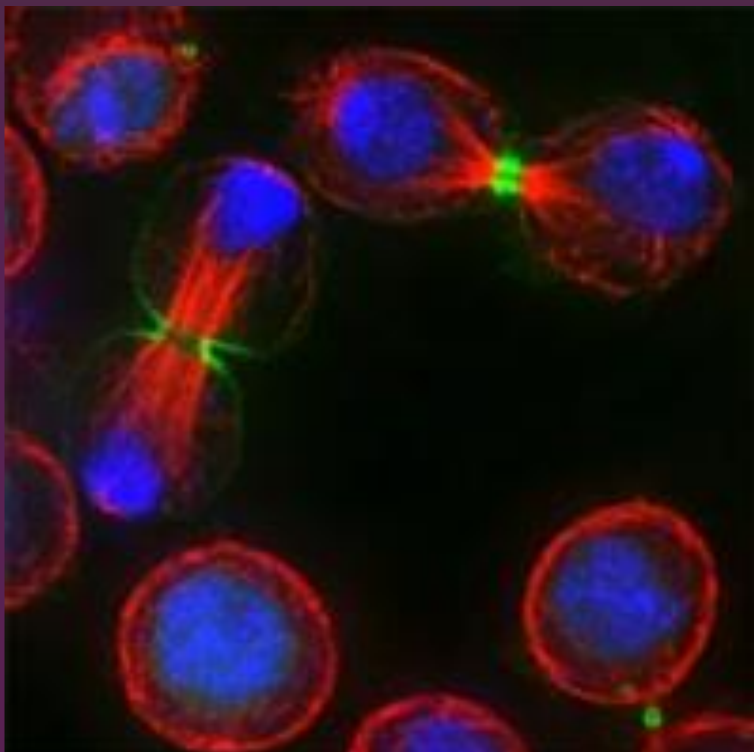
Cytokinesis differs for plant and animal cells.

Animal cytokinesis occurs by forming of a cleavage furrow between cells. This furrow is made of microfilaments of the cell. Microfilaments consist of the protein actin and its motor myosin. Together they form contractile ring (in green on the next left photo). The ring constricts and makes the border between cells narrower to the moment they separate.

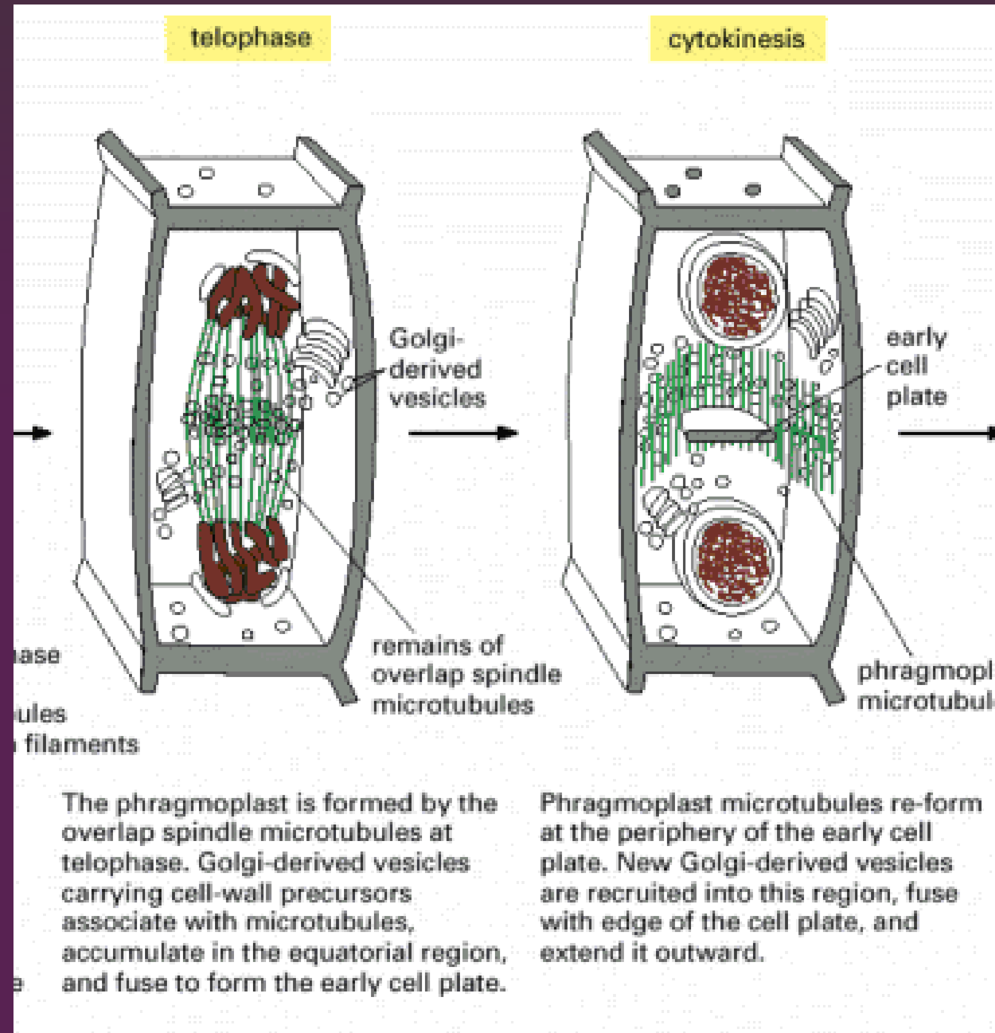
Plant cell can not divide by a cleavage furrow, because plants possess very hard cell wall. The wall can not constrict. That's why during plant cytokinesis a new cell wall is built. Golgi complex synthesizes materials for the cell wall.

After that Golgi-derived vesicles have to travel to the space between daughter cells. This traveling is made by a structure, named phragmoplast. The phragmoplast is formed by microtubules of the destroying spindle. These microtubules serve as a road network for movement of the vesicles from Golgi. In the center between the cells these vesicles fuse to form a border between daughters (look at the photo on the right).

Cytokinesis



Animal cells



Plant cells

https://www.webdepot.umontreal.ca/Usagers/hicksong/MonDepotPublic/Labwebsite/Cytokinesis.html

Control of mitosis

- There are special controlling mechanism which manage the progress of the cell during its division.
- The aim of this control machine is to stop cell division in crucial moments to check something before transition to the next phase. In this way the cell never pass in a stage for which it is not prepared.
- There are three main checkpoints during mitosis. The first is between G1 and S. to overcome it the cell has to have growing cytoplasm and not damaged DNA.
- Second one is between G2 and the real mitosis. Here the quality of replicated chromosomes is the most important think.
- The last checkpoint is between metaphase and anaphase. Here the structure of the spindle is checked, because the cell can not finish mitosis if chromosomes are detached from the spindle fibers.
- The cell can be arrested for a long time in one phase, trying to solve the problem. If the defect couldn't be repaired, the cell dies.

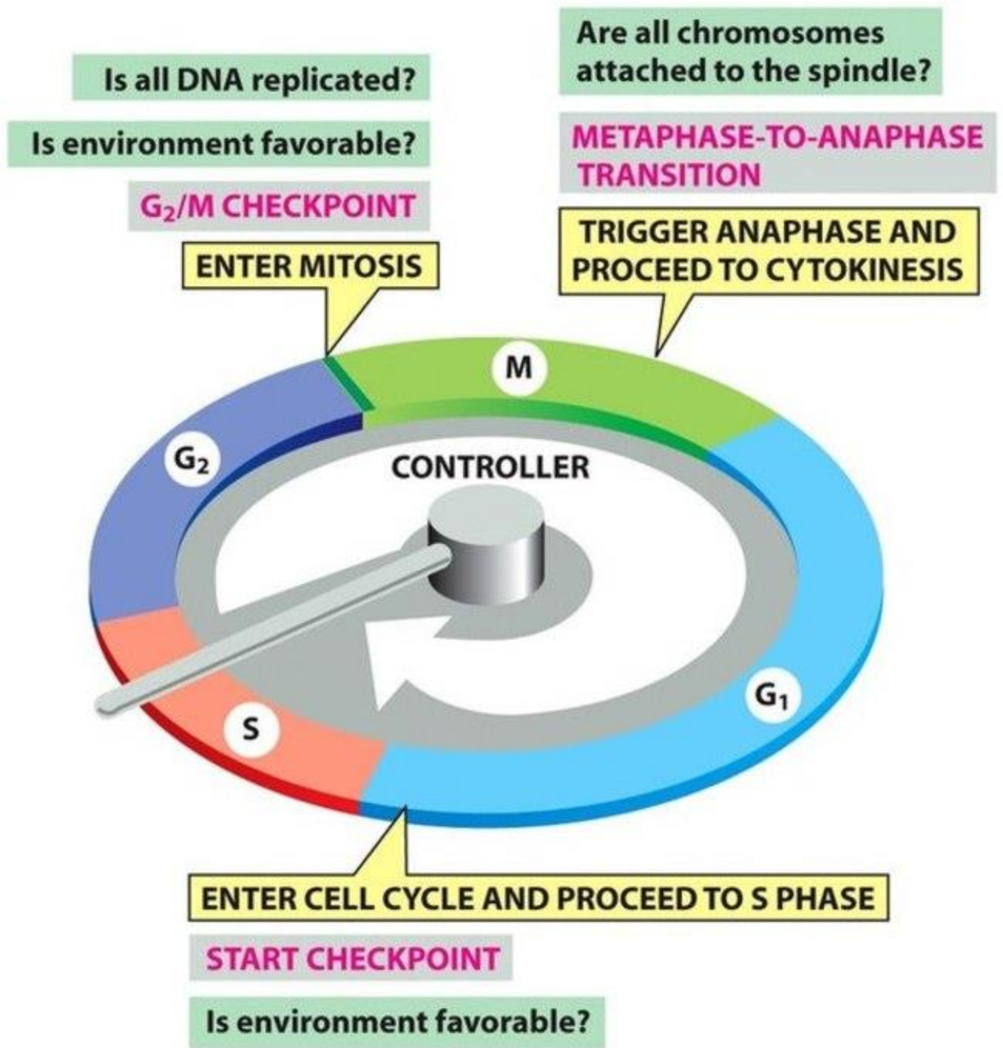


Figure 17-14 Molecular Biology of the Cell 5/e (© Garland Science 2008)