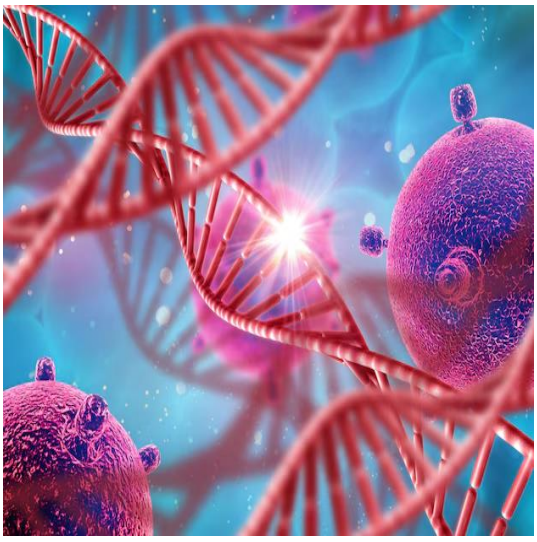
Lecture 14

General Biology & Cytology Course 2301130



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Cell cycle

The learning outcomes of Lecture 14:

1.Understanding the Role of Cell Division

2.Cell Division and the Cell Cycle.

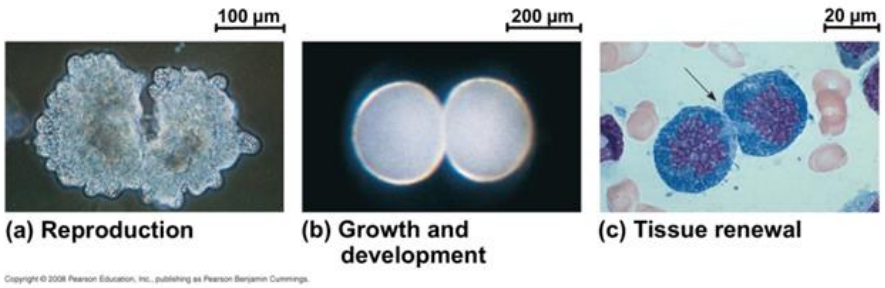
3.Genetic Material and Chromosome Organization.

4.Processes of Mitosis.

5.Mechanisms of Chromosome Distribution.

6.Cell Cycle Regulation.

- In unicellular organisms, division of one cell reproduces the entire organism
- Multicellular organisms depend on cell division for:
  - Development from a fertilized cell
  - Growth
  - Repair



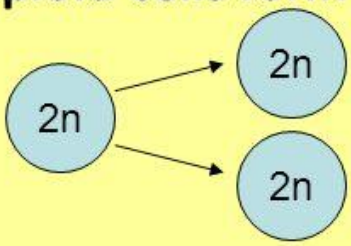
Cell division results in geneticallyidentical daughter cells

- The ability of organisms to reproduce best distinguishes living things from nonliving matter
- The continuity of life is based on the reproduction of cells, or **cell division**
- Most cell division results in daughter cells with identical genetic information, DNA
- A special type of division produces nonidentical daughter cells (gametes, or sperm and egg cells)

Two Types of Cell Division

MITOSIS (IPMAT)

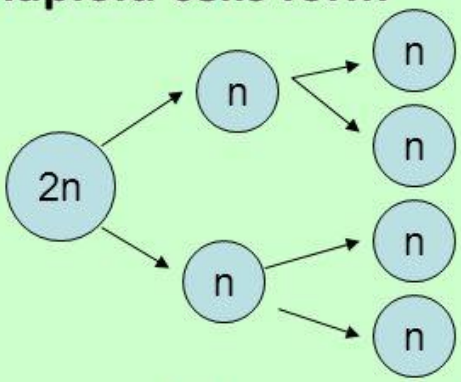
- For growth, maintenance & repair
- 2n cell → 2n cells (46 chromosomes → 46 chromosomes) Diploid
- 2 diploid cells form



- Occurs in somatic cells in the human body!

MEIOSIS (IPMATPMAT)

- For gamete formation
  - sperm & egg
- 2n cell → n cells haploid. (46 chromosomes → 23 chromosomes)
- 4 haploid cells form

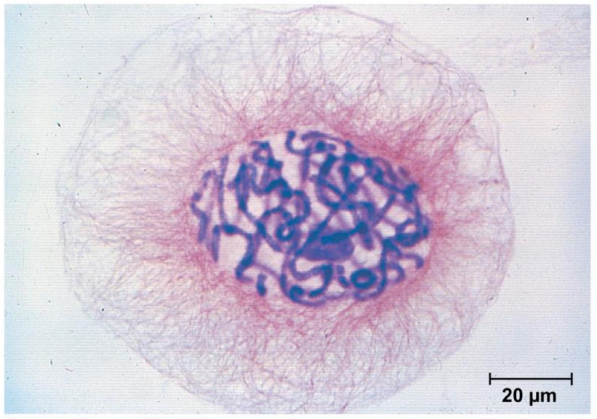


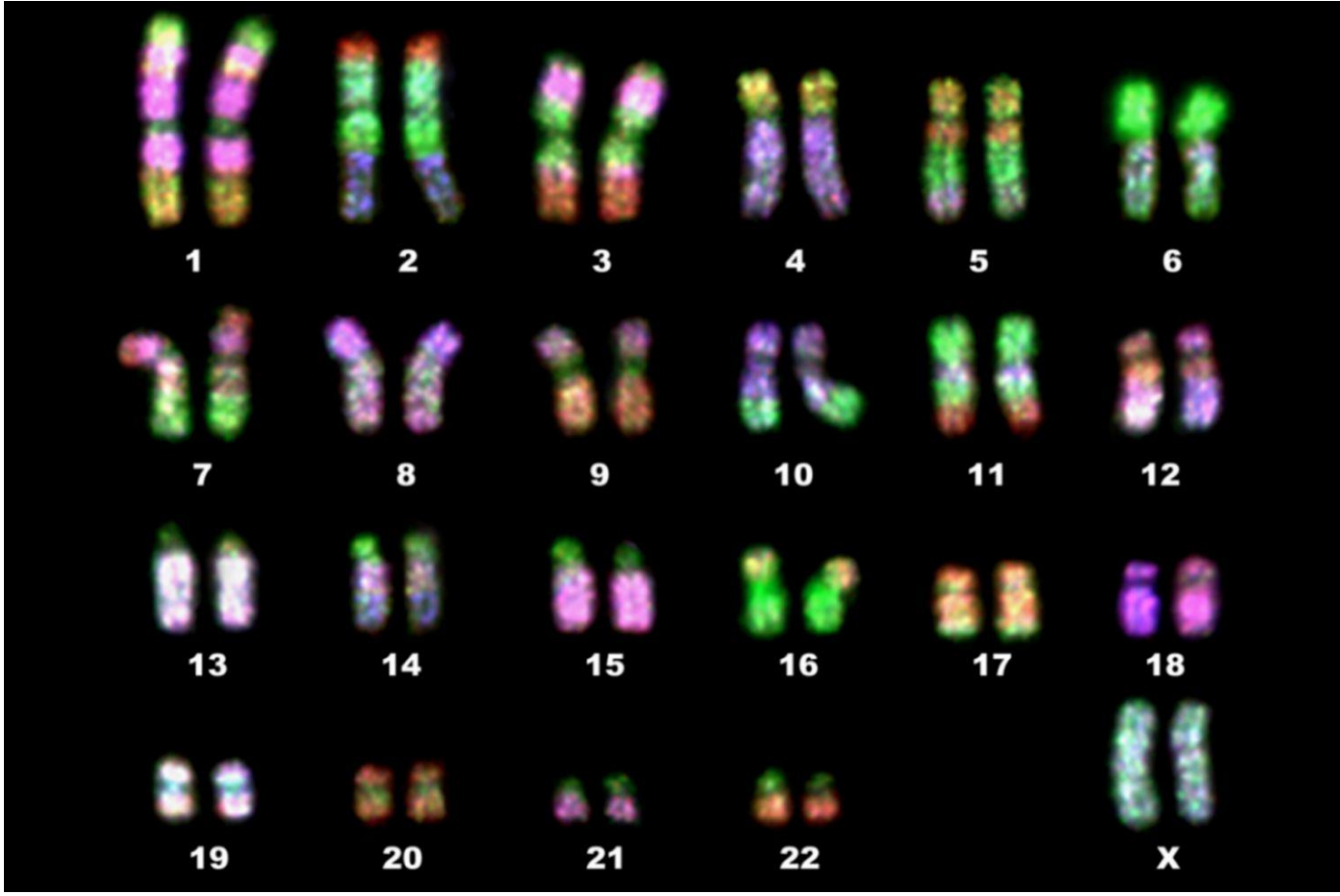
- Occurs only in gonads (ovaries and testes)
- Cause of most existing genetic variation

Cellular Organization of the Genetic Material

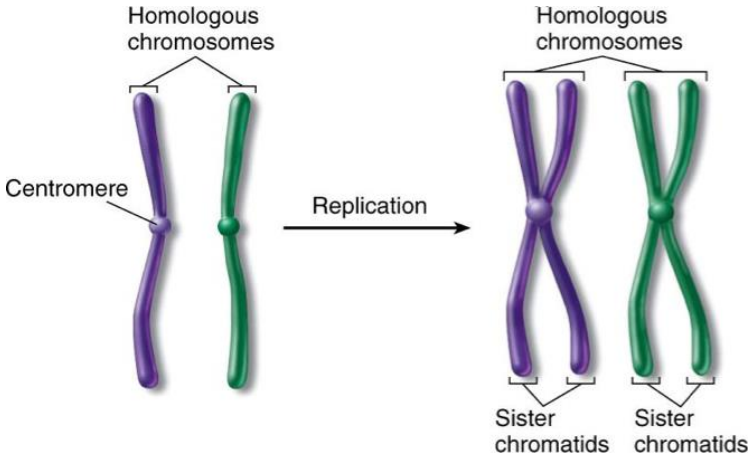
- All the DNA in a cell constitutes the cell's **genome**
- A genome can consist of a single DNA molecule (common in prokaryotic cells) or a number of DNA molecules (common in eukaryotic cells)
- DNA molecules in a cell are packaged into **chromosomes**
- **DNA** molecule of chromosome carries several hundred to few thousand of genes
- Eukaryotic chromosomes consist of **chromatin**, a complex of DNA and protein that condenses during cell division

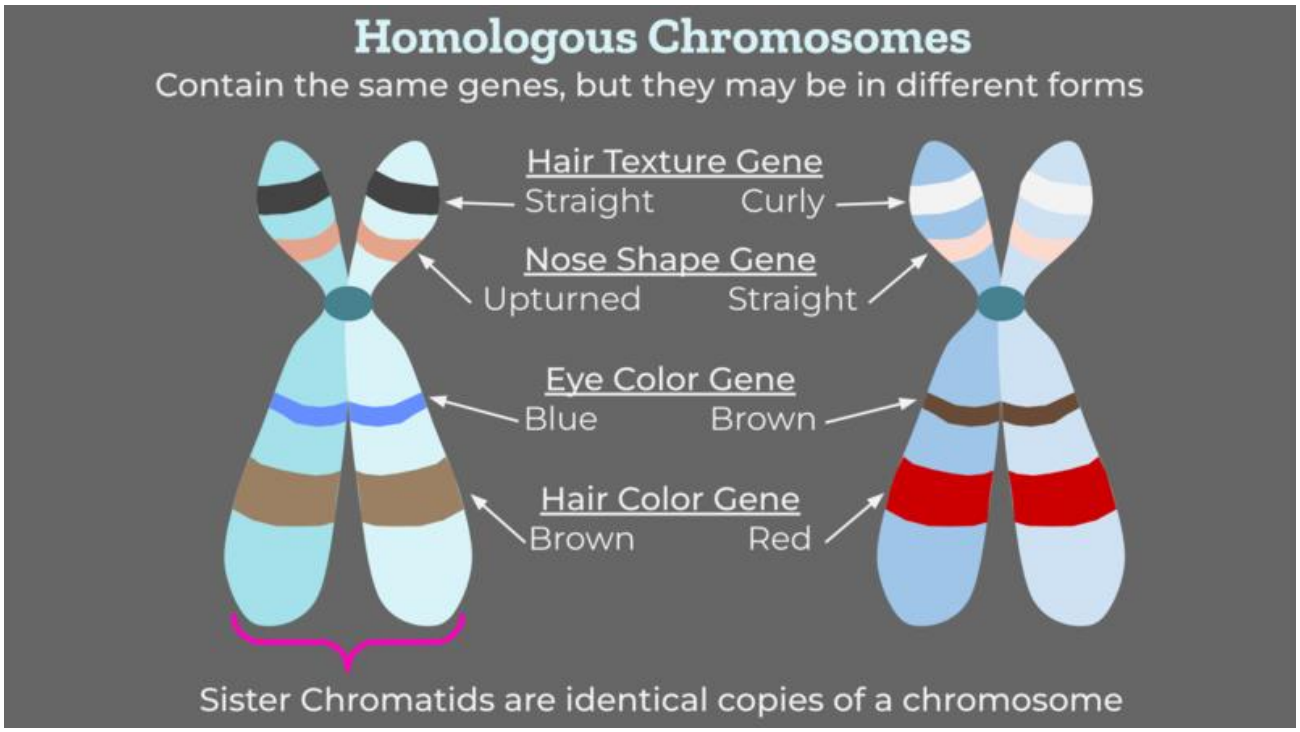
Fig. 12-3





A **karyotype** is the complete set of chromosomes in a cell, organized and displayed visually, typically as a photograph or diagram. It is used to study the number, size, shape, and structure of chromosomes in an organism.

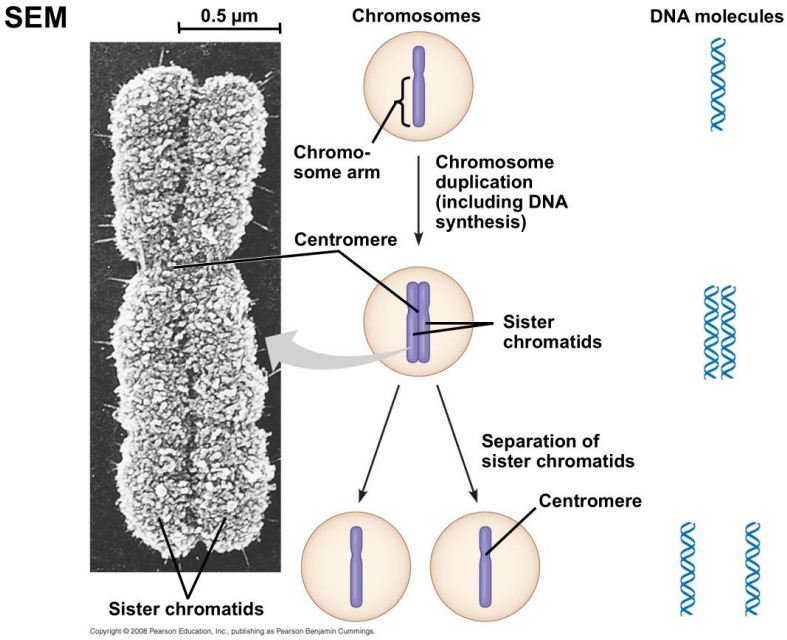

Homologous chromosomes
Centromere
Replication
Homologous chromosomes
Sister chromatids
Sister chromatids


Homologous Chromosomes
Contain the same genes, but they may be in different forms
Hair Texture Gene
Straight
Curly
Nose Shape Gene
Upturned
Straight
Eye Color Gene
Blue
Brown
Hair Color Gene
Brown
Red
Sister Chromatids are identical copies of a chromosome

- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells

Distribution of Chromosomes During Eukaryotic Cell Division

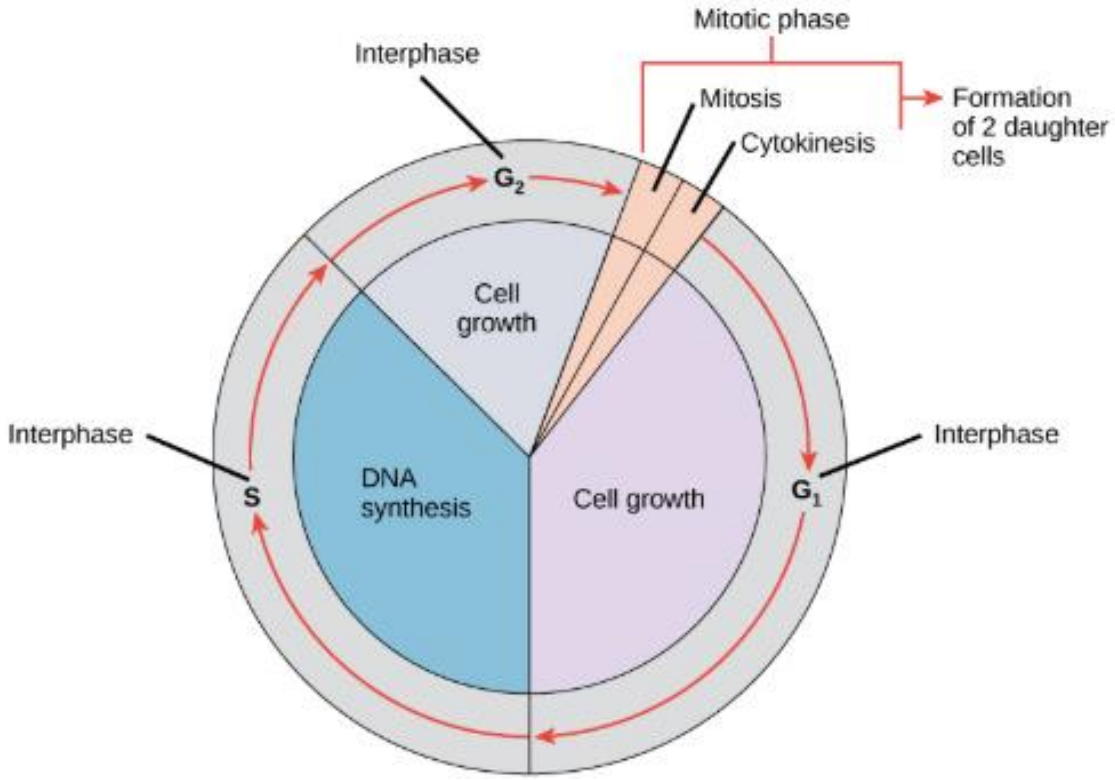
- In preparation for cell division, DNA is replicated and the chromosomes condense
- Each duplicated chromosome has two **sister chromatids**, which separate during cell division
- The **centromere** is the narrow “waist” of the duplicated chromosome, where the two chromatids are most closely attached



Phases of the Cell Cycle

- The cell cycle consists of
  I. **Interphase** (cell growth and copying of chromosomes in preparation for cell division), it takes the 90% of the cell cycle time.
  II. **Mitotic (M) phase** (mitosis and cytokinesis) and take approximately 10% of cell cycle time line.
- Eukaryotic cell division consists of:
  - **Mitosis**, the division of the nucleus
  - **Cytokinesis**, the division of the cytoplasm
- Gametes are produced by a variation of cell division called **meiosis**
- Meiosis yields nonidentical daughter cells that have only one set of chromosomes, half as many as the parent cell

*The cell cycle is composed of **interphase** (G_1, S, and G_2 phases), followed by the **mitotic phase** (mitosis and cytokinesis), and **G_0 phase**.*



I. Interphase

Three steps :

➢ **G1 phase:** (46 single chromosome)

- The longest period of cell cycle, 9-12h.
- RNA and protein synthesis.
- The cell attains its full size.
- The cell performs its function.
- Duplication of centrosomes.

➢ **S phase.** 7.5-10h

- Replication of DNA, amount of DNA is double but not the total chromosomal number. For instance, each chromosome contain one molecule of DNA in S phase become (46 double chromosome)

➢ **G2 phase.** 3.5-4.5h

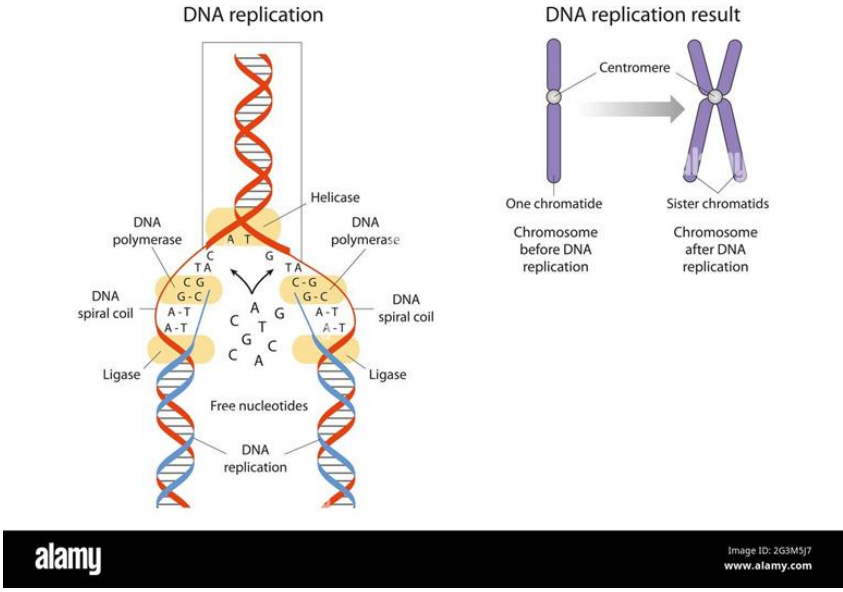
During the second gap phase, the cell grows more, makes proteins and organelles, and begins to reorganize its contents in preparation for mitosis. G2 phase ends when mitosis begins. During this phase:

- Store energy and proteins for mitosis.
- Duplication of centrosome is completed.

Type of chromosomes

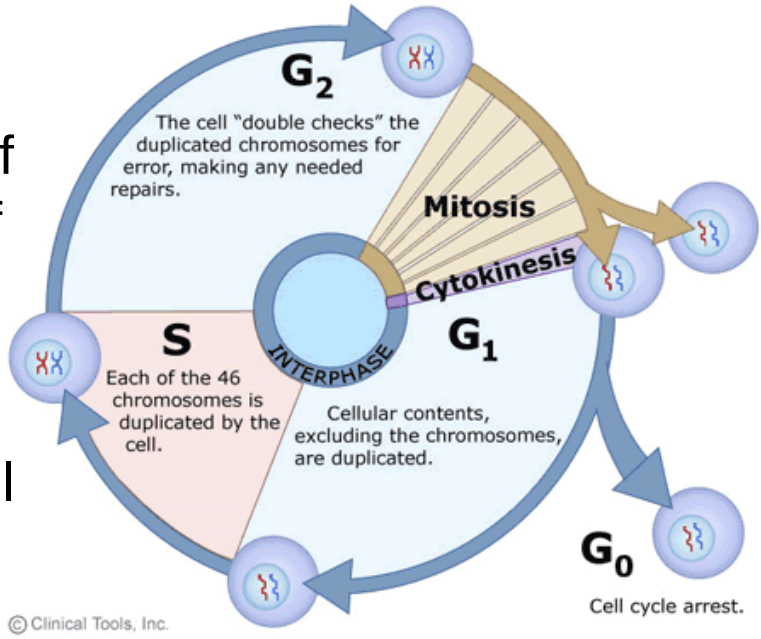
1. Single chromosome made of one DNA molecule.
   S- chromosome= chromatid or chromatin

1. Double chromosome or mitotic chromosome, formed during S phase



G_0 phase

- This depends on what type of cells they are. Some types of cells divide rapidly, and in these cases, the daughter cells may immediately undergo another round of cell division.



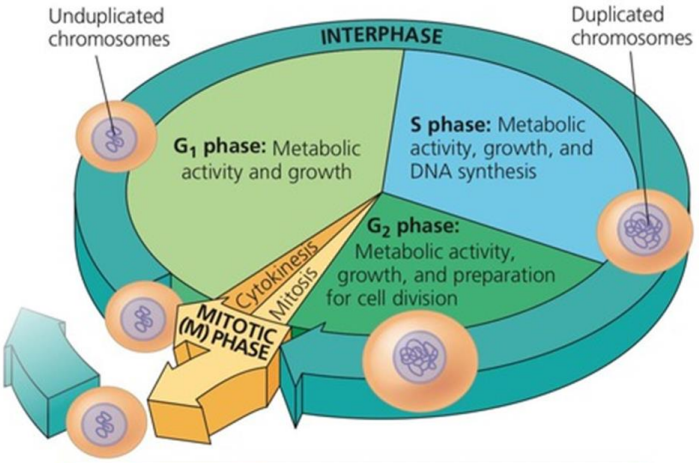
- Other type of cells divide slowly or not at all, exiting the G_1 phase into a resting state called G_0.
- In G_0, may be permanent (neurons) and cardiac muscle cells perform their functions, like conducting signals or temporary (liver cells).

I. **Interphase** (about 90% of the cell cycle) can be divided into sub-phases:
   - **G_1 phase** (“first gap”)
   - **S phase** (“synthesis”)
   - **G_2 phase** (“second gap”)

- The cell grows during all three phases, but chromosomes are duplicated only during the S phase

1. Increase in size
2. Performs its functions
3. DNA replication

▼ **Figure 12.6 The cell cycle.** In a dividing cell, the mitotic (M) phase alternates with interphase, a growth period.



MITOTIC (M) PHASE:
Mitosis: Distribution of chromosomes into two daughter nuclei
Cytokinesis: Division of cytoplasm, producing two daughter cells. Each daughter cell can start a new cell cycle.

Late Interphase (G_2 Phase):

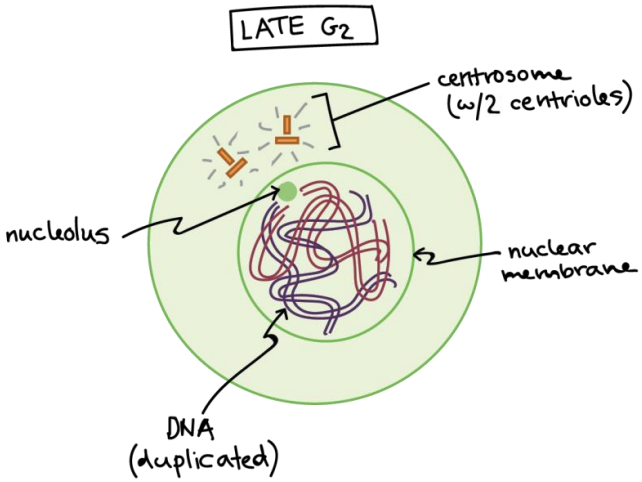
1. The cell is preparing to begin mitosis.

2. DNA has already been copied, forming two identical sister chromatids for each chromosome. (Douple 46 chromosome)

3. Chromosomes remain in a decondensed, long, and stringy form, making them hard to see clearly.

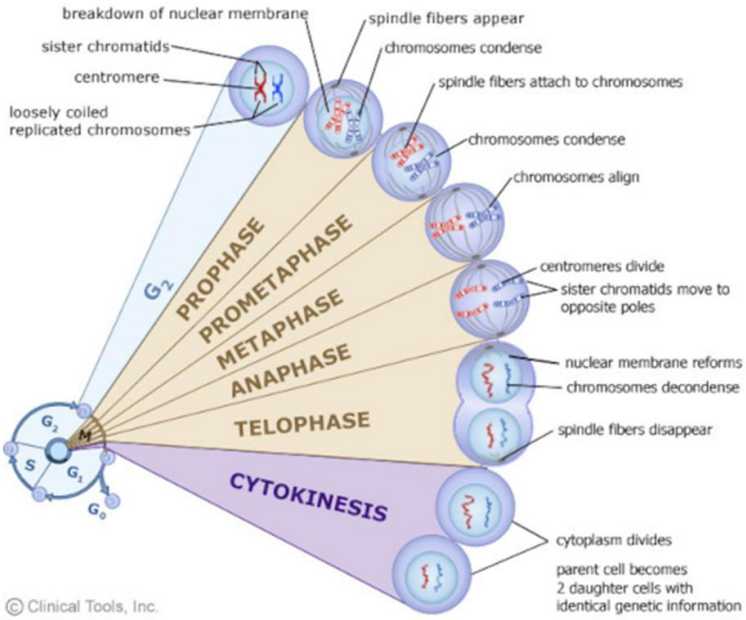
4. The cell has duplicated its centrosome, a key organelle for mitosis.

5. In animal cells, two centrosomes with centrioles are present.



II. Mitotic (M) phase (Mitosis) is conventionally divided into five phases: (1 h). **Please Please Make Another Two cells**

1. **Prophase**
2. **Prometaphase**
3. **Metaphase**
4. **Anaphase**
5. **Telophase**



1. Prophase:

❖ **Prophase occupies over half of the time required for mitosis.**

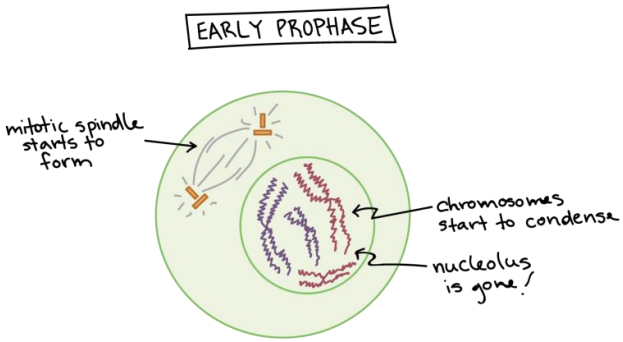
1.Nuclear Membrane Breakdown

2.The nucleolus disappear and becomes non-visible.

3.Centrosome Duplication and Migration to opposite ends (poles) of the cell forming Spindle Fibers.

4.Formation of Sister Chromatids or chromosome condensation

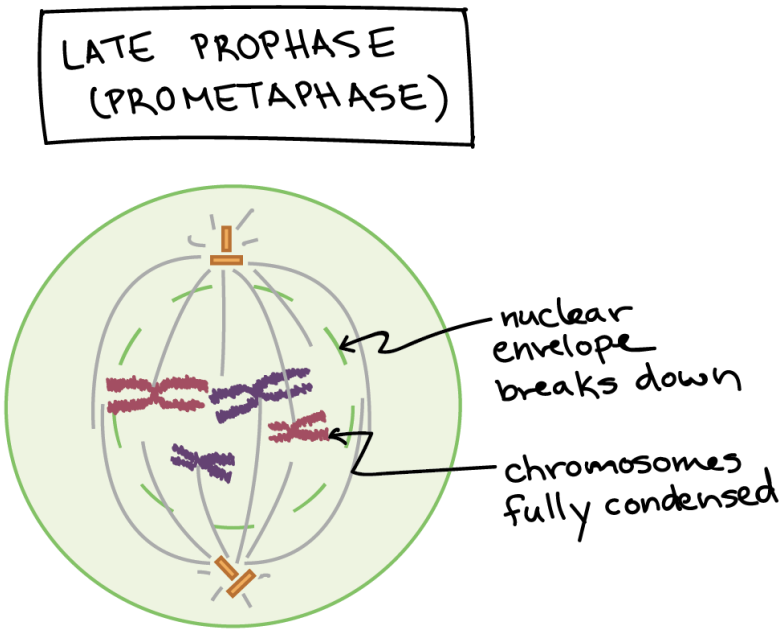
- **Each replicated chromosome consists of two identical chromatids (sister chromatids).**
- **The chromatids are held together by the centromere.**



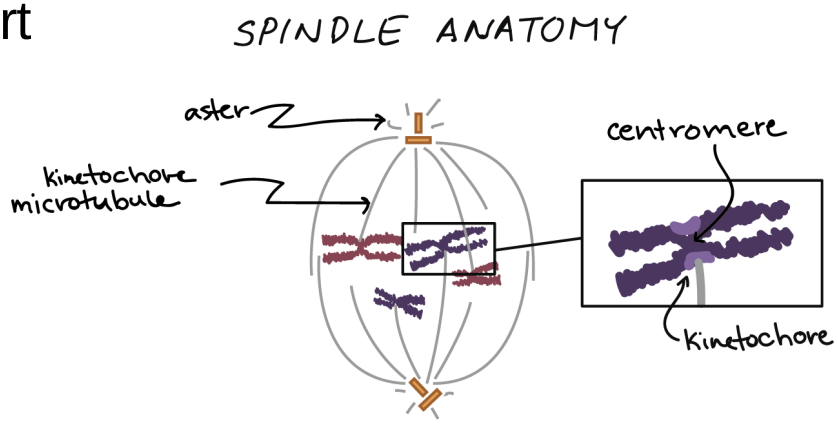
2. Late Prophase (Prometaphase):

1. The mitotic spindle begins to capture and organize chromosomes.
2. Chromosomes condense further, becoming highly compact.
3. The nuclear envelope breaks down, releasing the chromosomes into the cytoplasm.
4. The mitotic spindle continues to grow, with some microtubules attaching to chromosomes.

- ✓ Microtubules can bind to chromosomes at the **kinetochore**, a protein patch on the centromere of each sister chromatid.
- ✓ Microtubules that attach to kinetochores are called **kinetochore microtubules**.
- ✓ **Non-kinetochore microtubules** bind to microtubules from the opposite pole, stabilizing the spindle.
- ✓ Additional microtubules extend from each centrosome toward the cell edges, forming a structure called the **aster**.



Aster (a radial array of short microtubules) extends from each centrosome



3. Metaphase:

1.The spindle captures all chromosomes and aligns them at the cell's center, preparing for division.

2.Chromosomes align at the metaphase plate (an imaginary plane, not a physical structure). The midway point between the spindle's two poles.

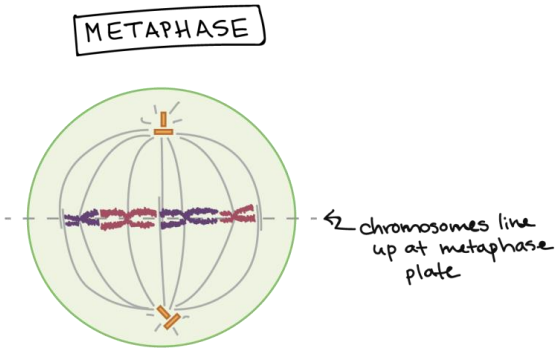
3.Each chromosome's two kinetochores attach to microtubules from opposite spindle poles.

4.The cell performs a **spindle checkpoint** to ensure: All chromosomes are at the metaphase plate.

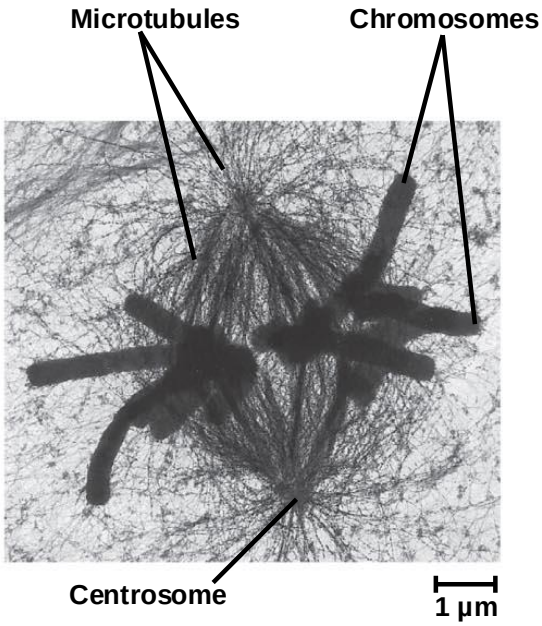
- Kinetochores are correctly attached to microtubules.

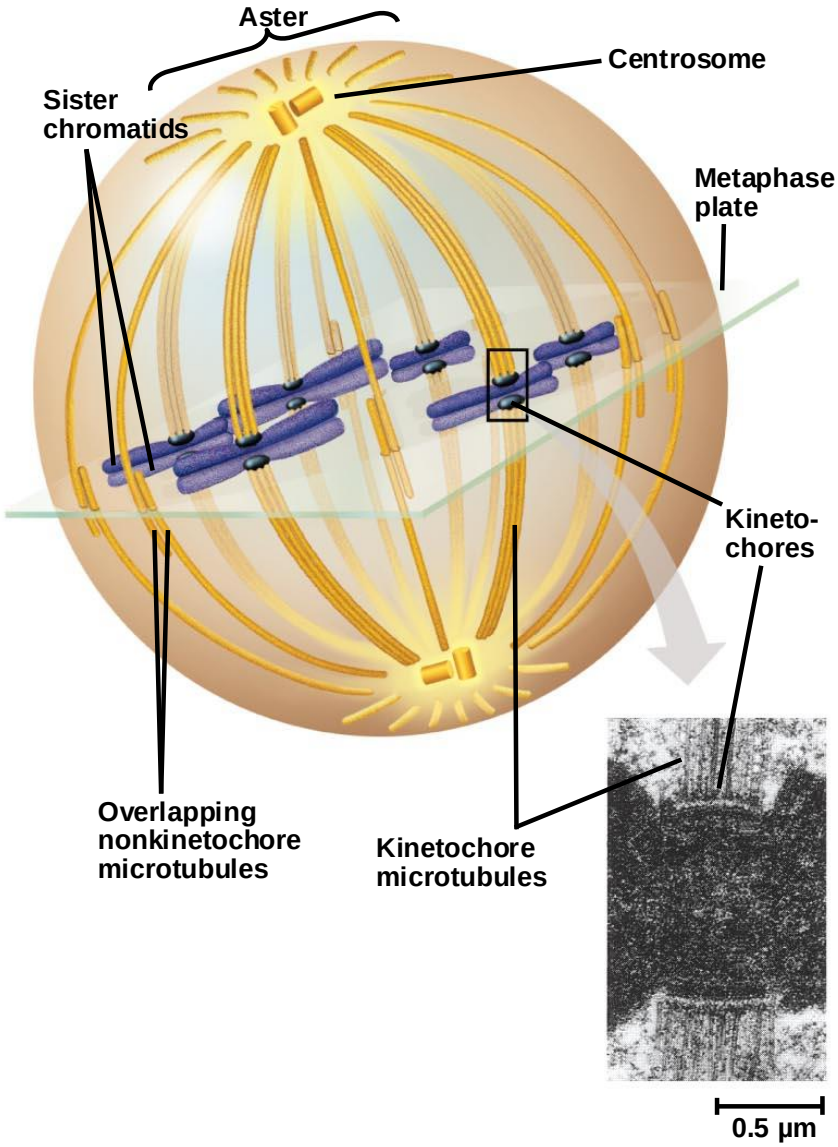
5.If alignment or attachment is incorrect, the cell halts division until the issue is resolved.

Exap: if not work will form **Aneuploidy (**Down syndrome, extra copy of chromosome 21), Turner syndrome, commonly known as 45 chromosome)



*****karyotype done at Metaphase**



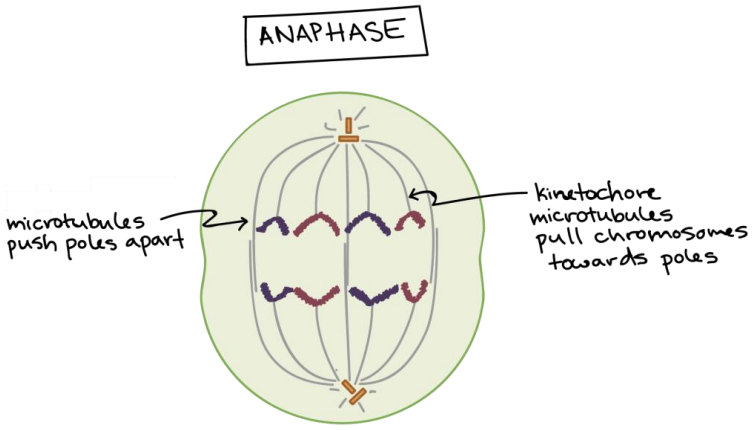


4. Anaphase:

1. Sister chromatids separate and move along the kinetochore microtubules toward opposite ends of the cell. 46 chromatids to each end.
2. The microtubules shorten and chromosomes are pulled toward opposite poles of the cell.

3. Non-attached microtubules elongate and push apart, increasing the cell's length.

4. In late Anaphase the cleavage furrow develop



5. Telophase:

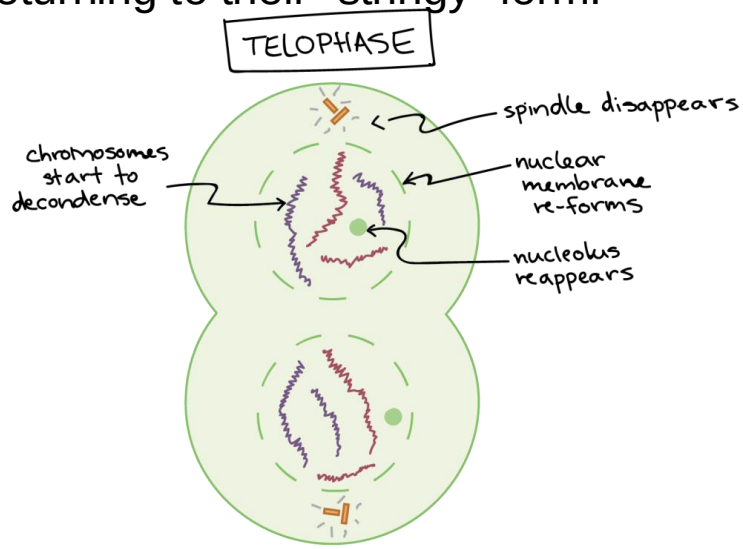
1.The cell nears completion of division as cytokinesis (division of cell contents) begins.

2.The mitotic spindle breaks down into its building blocks.

3.Two new nuclei form, one for each set of chromosomes, genetically identical daughter nuclei form at opposite ends of the cell

4.Nuclear membranes and nucleoli reappear.

5.Chromosomes begin to decondense, returning to their "stringy" form.



Cytokinesis:

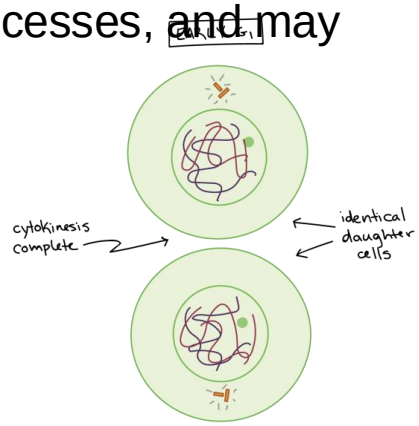
1.Cytokinesis is the division of the cytoplasm to form two new cells and overlaps with the final stages of mitosis.

2.Cytokinesis may start in anaphase or telophase, depending on the cell, and finishes shortly after telophase.

3.In animal cells, cytokinesis is contractile, with a band of **actin filaments (Microfilaments)** (drawstring) forming a **cleavage furrow** to pinch the cell into two.

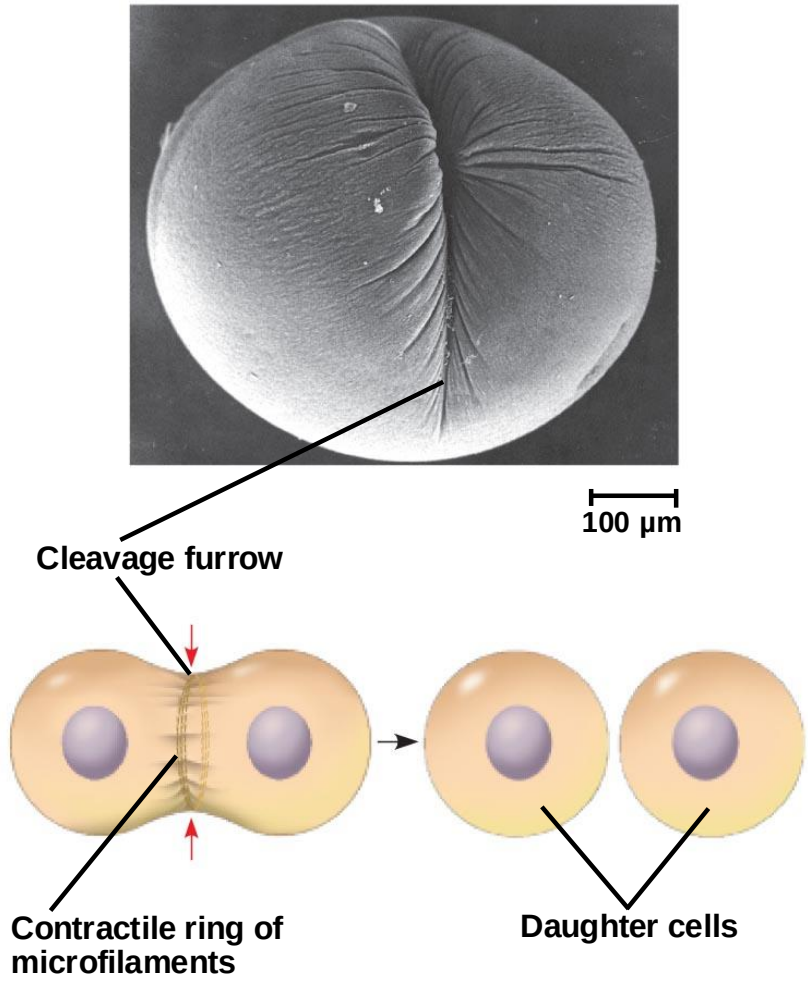
4.Upon completion of cytokinesis, two new cells are formed, each with an identical set of chromosomes. **S- chromosome**

5.The daughter cells can begin their own cellular processes, and may undergo mitosis again when they grow.

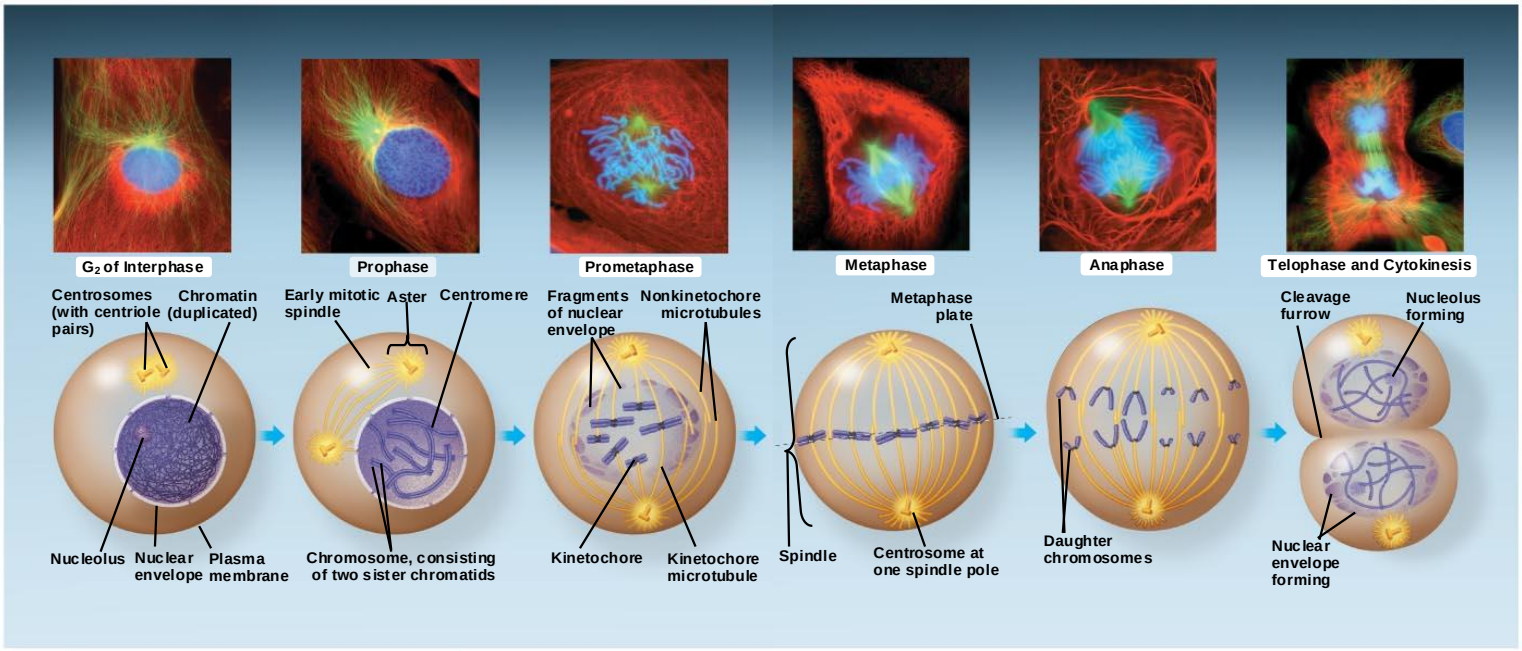


The chromosome segregation checkpoint in Telophase

- **Prevent cytokinesis until all chromosomes have correctly separated**

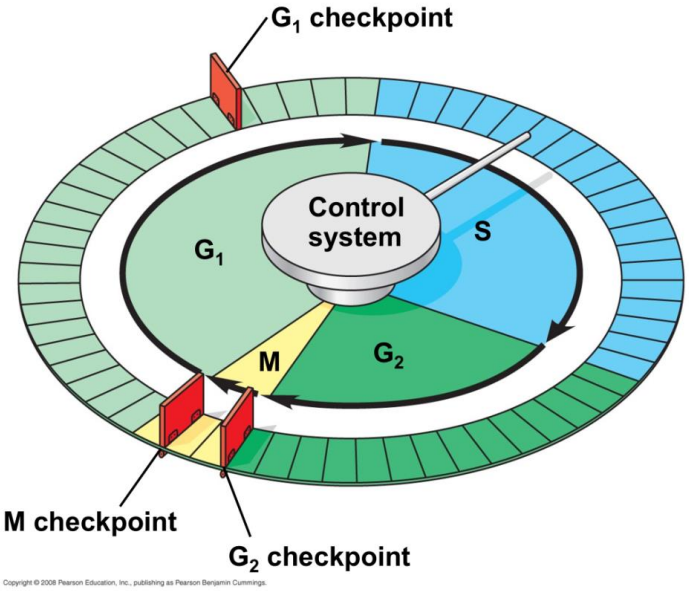


(a) Cleavage of an animal cell (SEM)

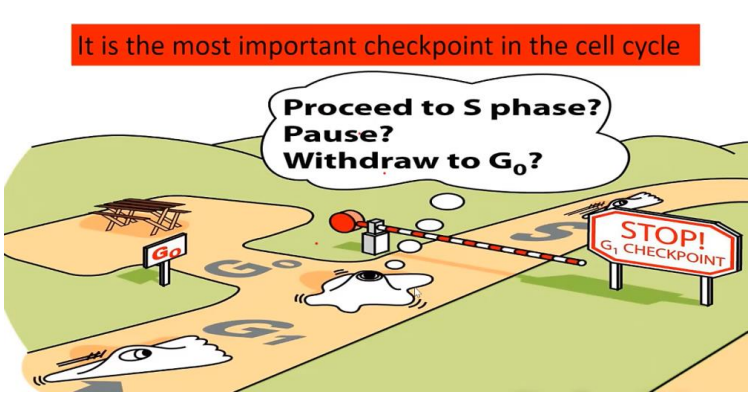


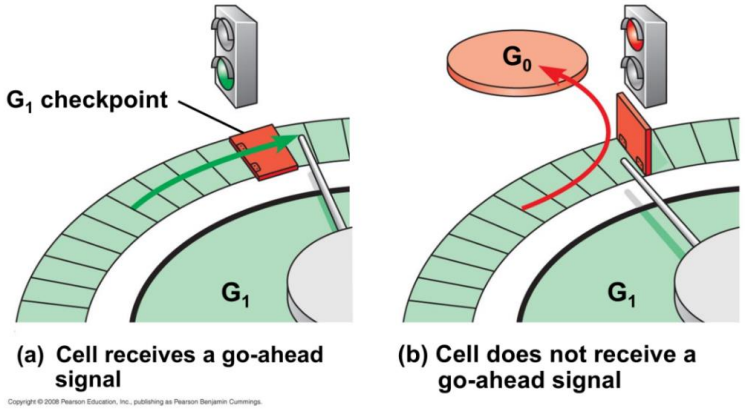
The Cell Cycle Control System

- The sequential events of the cell cycle are directed by a distinct **cell cycle control system**, which is similar to a clock
- The cell cycle control system is regulated by both internal and external controls
- The clock has specific **checkpoints** where the cell cycle stops until a go-ahead signal is received

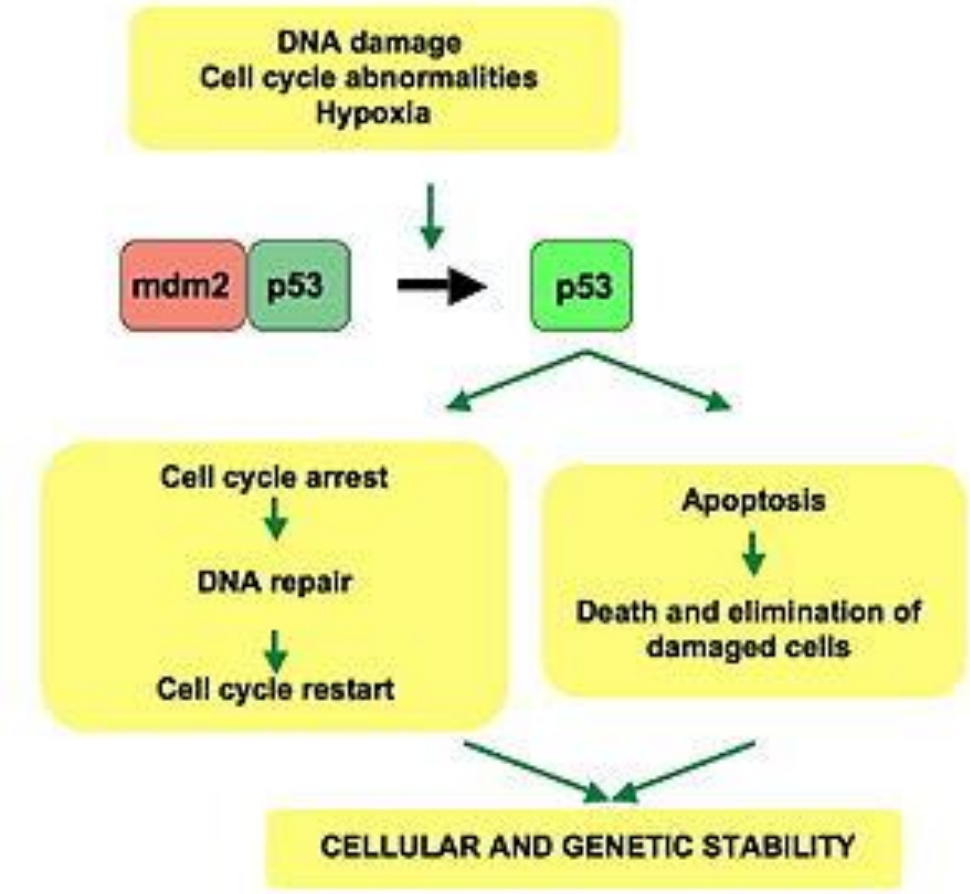


- For many cells, the **G_1** checkpoint seems to be the **most important one.** To detect cell size and interacts with surrounding environment (have a signal to divide). This checkpoint called Restriction checkpoint
- If a cell receives a go-ahead signal at the G_1 checkpoint, it will usually complete the S, G_2, and M phases and divide
- If the cell does not receive the go-ahead signal, it will exit the cycle, switching into a nondividing state called the **G_0 phase**
- **DNA damage checkpoint:** It occurs in G1,S, and G2 phase



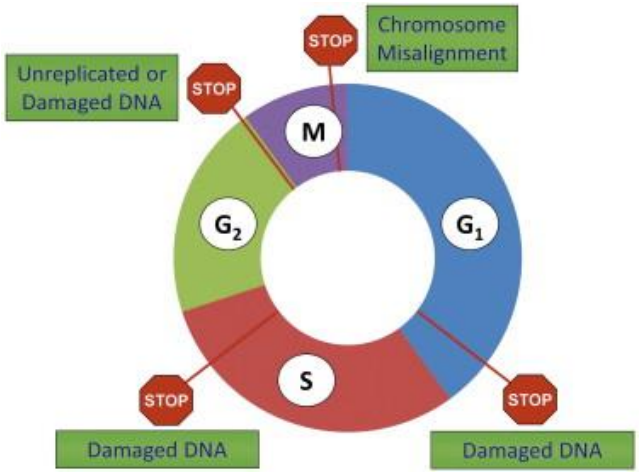


Tumor suppressor protein p53



Unreplicated DNA checkpoint

- **It occurs in G2 phase**
- **It prevents progression into mitosis before completed DNA synthesis**



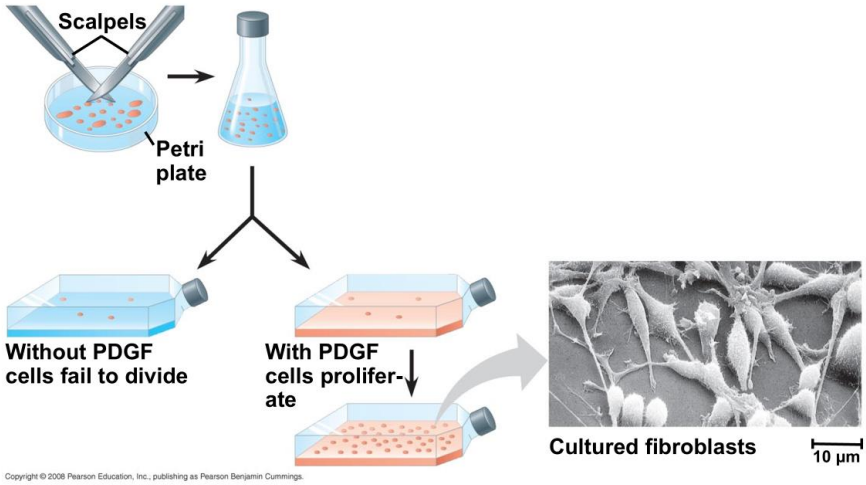
The Cell Cycle Clock: Cyclins and Cyclin-Dependent Kinases

- Two types of regulatory proteins are involved in cell cycle control: **cyclins** and **cyclin-dependent kinases (Cdks)**
- The activity of cyclins and Cdks fluctuates during the cell cycle
- **MPF** (maturation-promoting factor) is a cyclin-Cdk complex that triggers a cell's passage past the G_2 checkpoint into the M phase

Stop and Go Signs: Internal and External Signals at the Checkpoints

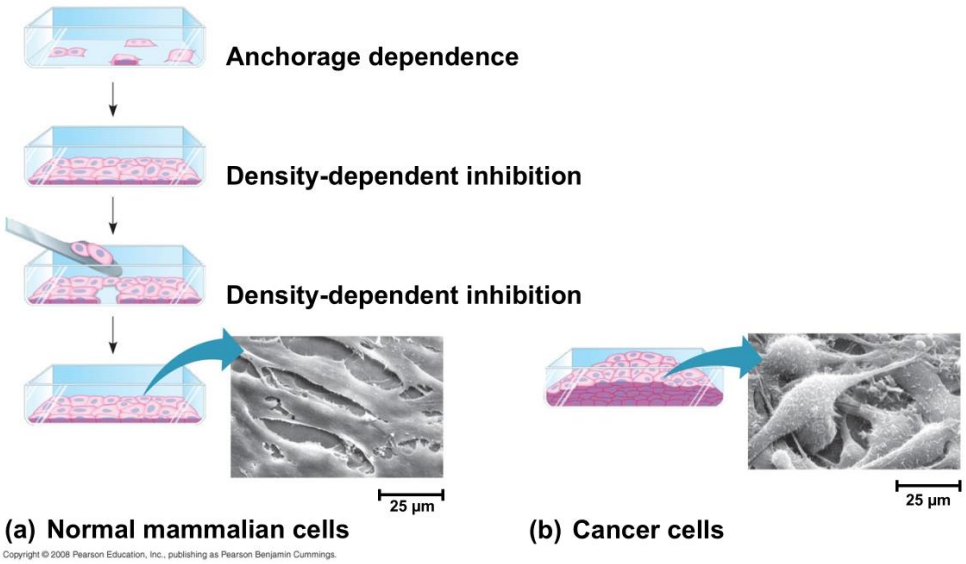
- An example of an internal signal is that kinetochores not attached to spindle microtubules send a molecular signal that delays anaphase
- Some external signals are **growth factors**, proteins released by certain cells that stimulate other cells to divide
- For example, platelet-derived growth factor (PDGF) stimulates the division of human fibroblast cells in culture

Fig. 12-18



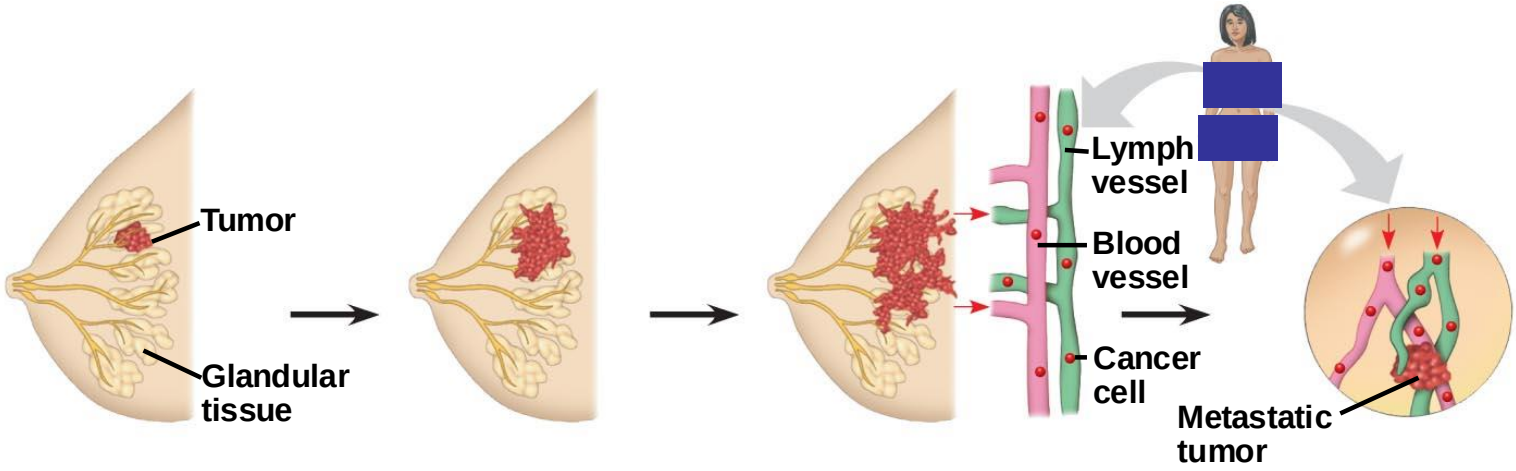
- Another example of external signals is **density-dependent inhibition**, in which crowded cells stop dividing
- Most animal cells also exhibit **anchorage dependence**, in which they must be attached to a substratum in order to divide.

✓ Cancer cells exhibit neither density-dependent inhibition nor anchorage dependence



Loss of Cell Cycle Controls in Cancer Cells

- Cancer cells do not respond normally to the body's control mechanisms
- Cancer cells may not need growth factors to grow and divide:
  - They may make their own growth factor
  - They may convey a growth factor's signal without the presence of the growth factor
  - They may have an abnormal cell cycle control system
- A normal cell is converted to a cancerous cell by a process called **transformation**
- Cancer cells form tumors, masses of abnormal cells within otherwise normal tissue
- If abnormal cells remain at the original site, the lump is called a **benign tumor**
- **Malignant tumors** invade surrounding tissues and can **metastasize**, exporting cancer cells to other parts of the body, where they may form secondary tumors



1. A tumor grows from a single cancer cell.
2. Cancer cells invade neighboring tissue.
3. Cancer cells spread to other parts of the body.
4. Cancer cells may survive and establish a new tumor in another part of the body.