

Cell Reproduction

The image contains several microscopic views of cells in various stages of division. A central diagram shows a cell cycle with stages labeled: G₁, S (DNA synthesis), G₂, and M (mitosis). The M phase is further divided into prophase, metaphase, anaphase, and telophase.

I. Functions of Cell Division

A. Unicellular- Reproduction
B. Multicellular

1. Growth and development from egg.
2. Replacement of dead or damaged cells.
3. Passes along the **genome** (total DNA per species)
 - a) Precisely replicates its DNA
 - b) Equally distributes DNA to opposite ends of the cell.
 - c) Separates into two identical daughter cells.

Microscopic images showing a cell in the process of binary fission, with DNA being distributed to two daughter cells.

II. How Prokaryotic Cells Divide

A. Prokaryotic Chromosome

1. Is Singular
2. Contains mostly DNA and some associated proteins
3. Less DNA than eukaryotic chromosomes (1/1000).
4. Highly packed and tightly coiled inside the cell.
5. A circular loop attached to plasma membrane.

A microscopic image shows a dense, tangled mass of DNA. Below it, a diagram labeled "Nuclear Zone" shows a circular loop of DNA attached to the plasma membrane.

II. How Prokaryotic Cells Divide

B. Division is by Fission

1. Asexual reproduction requires a single parent
2. Binary fission produces two genetically identical daughter cells.
3. Generation times of *Escherichia coli* is 20 minutes; most bacteria need one hour to a day.

Microscopic image of a rod-shaped bacterium in the process of binary fission, showing two daughter cells forming within the parent cell.

II. How Prokaryotic Cells Divide

C. Binary Fission

1. DNA is replicated so two chromosomes are attached inside the plasma membrane.
2. The two chromosomes separate when cell lengthens and pulls them apart.
3. When cell is approximately twice its original length:
 - a) the plasma membrane grows inward
 - b) a new cell wall forms
 - c) the cell divides into two approximately equal daughter cells.

A series of diagrams illustrating the steps of binary fission: DNA replication, cell elongation, inward growth of the plasma membrane, and the formation of a new cell wall to separate the two daughter cells.

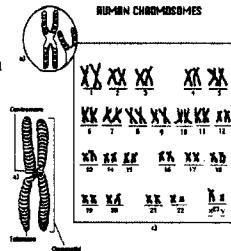
III. Eukaryotic Chromosomes

A. DNA is associated with histones (proteins)
B. Histone proteins organize chromosomes.
C. When not undergoing division, DNA is a tangled mass of threads called chromatin.
D. At cell division, chromatin becomes highly coiled and condensed and visible as chromosomes.
E. Each species has a characteristic number of chromosomes.

The diagram shows the hierarchy of DNA packaging: DNA double helix, nucleosomes, condensed chromatin, and finally metaphase chromosomes. A microscopic image shows a set of condensed chromosomes.

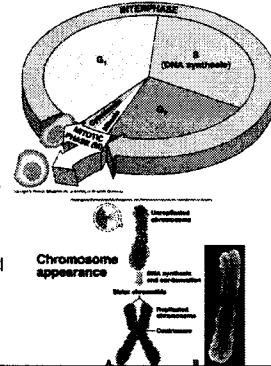
III. Eukaryotic Chromosomes

- F. **Diploid** ($2n$) number includes two sets of chromosomes of each type.
1. Found in all the nonsex cells of an organism's body (with a few exceptions).
 2. Examples include humans (46), crayfish (200), etc.
- G. **Haploid** (n) number contains one of each kind of chromosome.
- H. In many animals, only sperm and egg cells have the haploid number.
- I. Examples include humans (23), crayfish (100), etc



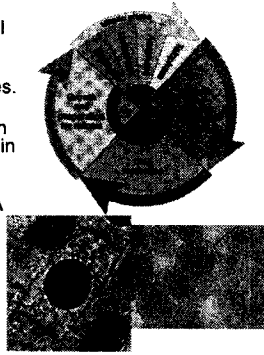
IV. The Cell Cycle

- A. Involves nuclear division and cytokinesis (division of the cytoplasm).
- B. Nuclear division keeps the chromosome number constant.
- C. A chromosome begins cell division with two sister chromatids.
- D. Sister chromatids are two parts of a chromosome.
1. They are attached at a centromere.
 2. Each consists of an identical DNA molecule.



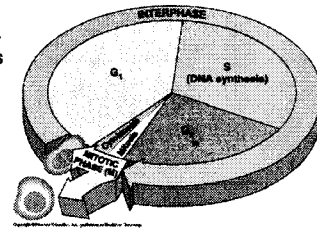
V. Interphase

- A. Considered a "resting state" until DNA replication was detected in the 1950s.
- B. Consists of G₁, S, and G₂ stages.
1. G₁ - just prior to DNA replication, when cell grows in size and organelles increase in number.
 2. S- DNA replication occurs; proteins associated with DNA are also synthesized.
 3. G₂- just prior to cell division; preparation for mitotic cell division (grows).



VI. Mitosis

- A. M stage (M = mitosis) is the entire cell division state, including both mitosis and cytokinesis.
- B. Mitosis (karyokinesis) is divided into phases.

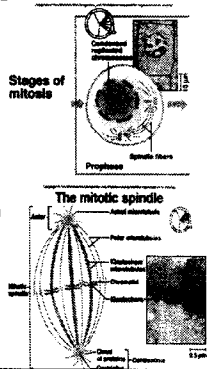


VI. Mitosis

C. Phases of Mitosis

1. Prophase

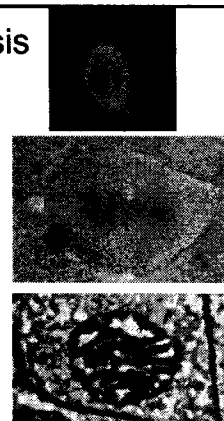
- a) **Chromatin** condenses forming visible **chromosomes** (held together by a **centromere**).
- b) The nucleolus disappears.
- c) Chromosomes have no particular orientation.
- d) Protein complexes (**kinetochores**) develop on each side of centromere.
- e) **Spindle** begins to assemble as pairs of **centrosomes** migrate away from each other.
- f) Short microtubules radiate out from the pair of centrioles located in each centrosome; form starlike **asters**.



VI. Mitosis

2. Prometaphase

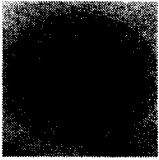
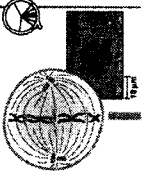
- a) The spindle consists of poles, asters, and fibers that are bundles of microtubules.
- b) Chromosomes attach to the spindle (kinetochore fibers).
- c) Nuclear envelope fragments
- d) Polar fibers (nonkinetochore fibers) span from centrosome to centrosome.
- e) The chromosomes move towards the equator.



VI. Mitosis

3. Metaphase

- Chromosomes, attached to kinetochore fibers, are aligned at the metaphase plate.
- Nonattached spindle fibers (polar, nonkinetochore) fibers, overlap.



Stages of mitosis

Metaphase

VI. Mitosis

4. Anaphase

- Sister chromatids separate at centromere.
- Daughter chromatids, each with a centromere, move to opposite poles.
- Polar spindle fibers lengthen as they slide past each other.
- Kinetochore spindle fibers disassemble at the kinetochores; this pulls daughter chromatids to poles.


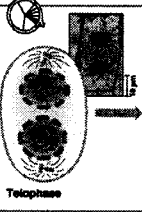
Stages of mitosis

Anaphase

VI. Mitosis

5. Telophase

- Spindle disappears.
- Chromatids decondense and return to chromatin.
- Nuclear envelope reforms.
- Nucleoli reappear

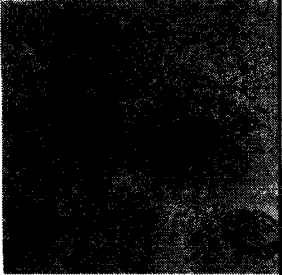
Stages of mitosis

Telophase

VII. Cytokinesis

A. In Animal Cells

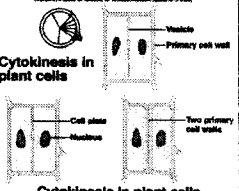

- Cleavage furrow forms between the two daughter nuclei.
- Cytoplasmic cleavage begins as anaphase draws to a close.
- Cleavage furrow deepens as band of actin filaments slowly constricts between the two daughter cells.
- Narrow bridge exists between daughter cells during telophase; then constriction separates the cytoplasm.



VII. Cytokinesis

B. In Plant Cells

- The rigid cell wall that surrounds plant cells does not permit cytokinesis by furrowing.
- Golgi apparatus produces vesicles that move to the midpoint between the daughter cell nuclei.
- Vesicles fuse, forming a cell plate.
- Vesicles also release molecules that signal the formation of plant cell walls.
- Later, walls are strengthened by the addition of cellulose fibrils.

Cytokinesis in plant cells





Cytokinesis in plant cells

Cell plate

10 μm

VIII. Control of the Cell Cycle

- Some cells (e.g., skin cells) divide continuously throughout life.
- Other cells (e.g., skeletal muscle cells and nerve cells) are arrested in the G1 stage.
- Still other cells, such as cardiac muscle cells, are arrested in the G2 Stage.
- Cyclic molecule levels create the **cell cycle control system**

VIII. Control of the Cell Cycle

E. Cell Cycle Checkpoints

- Enzymes known as cyclin-dependent kinases (Cdks) regulate passage of cells through checkpoints
- Three main checkpoints
 - G1
 - Restriction point in animals
 - Three Cdk (cyclin dependent kinase) involved
 - G2 (MPF- maturation promoting factor)
 - M (anaphase is checkpoint)

The diagram shows a circular cell cycle with three main checkpoints: DNA damage checkpoint, Spindle assembly checkpoint, and Restriction checkpoint. A legend indicates that squares represent kinases and triangles represent cyclins.

VIII. Control of the Cell Cycle

F. Cyclin-dependent kinases (Cdks)

- Kinases remove a phosphate group from ATP and add it to another protein.
- The recipient protein (which may be another kinase) becomes activated.
- Enzymes of cell cycle are cyclin dependent because they activate when they combine with cyclin.

The diagram titled 'Cyclins and kinases' shows a central circle with arrows pointing outwards to various proteins, representing the activation of different kinases by cyclins.

VIII. Control of the Cell Cycle

G. Cyclin proteins

- Cycle at different concentrations in cell division
- Activate cyclin-dependent kinases, which in turn activate enzymes; one destroys cyclin (MPF).
- Kinases that combine with cyclins become activated and regulate the passage of cells through the various stages of the cell cycle.

The diagram titled 'Cyclins and kinases' shows a circular cell cycle with arrows indicating the activation and subsequent destruction of cyclins, which in turn activate kinases.

VIII. Control of the Cell Cycle

H. External Factors

- Growth factors (regulatory substances) may be necessary.
- Cell density (density-dependent inhibition)
- Cell size is main indicator of cell division.

The diagram illustrates external factors: growth factors (a flask with a pipette), cell density (cells in a petri dish), and contact inhibition (cells touching and stopping division). A legend indicates that squares represent kinases and triangles represent cyclins.

IX. Cancer

A. Oncogenesis (cancer-causing genes) may code for cyclins that no longer function as they should.

- Growth factors bring about cell growth.
- Ordinarily a cyclin combines with its kinase only when a growth factor is present.
- Cyclin that has gone awry combines with its kinase when growth factor is absent, resulting in a tumor.

The diagram shows a cell with a mutated cyclin (represented by a triangle) that is always active, combining with a kinase (represented by a square) even in the absence of a growth factor, leading to uncontrolled cell growth.

IX. Cancer

B. Tumor-suppressor genes

- Causes production of protein that combines with a cyclin-kinase complex
- Stops that kinase from being active.

C. Transformation is when eukaryotic cells go through unregulated growth.

D. Benign tumors stay at original site.

E. Malignant tumors have the ability to spread to other sites.

F. Spreading of cancer cells is called metastasis.

The diagram shows normal cells (squares) and cancer cells (triangles). A separate diagram shows cancer cells spreading from a primary site to other parts of the body, labeled as metastasis.