How Do Cells Reproduce?

The Cell Cycle
Mitosis
Cytoplasmic Division
Mitotic Clocks
The Cell Cycle Gone Awry
The Cell Cycle

1. A cell spends most of its life in interphase, which includes three stages: G₁, S, and G₂.
2. G₁ is the interval of growth before DNA replication. The cell’s chromosomes are unduplicated.
3. S is the time of synthesis, during which the cell copies its DNA (duplicates its chromosomes).
4. G₂ is the interval after DNA replication and before mitosis. The cell prepares to divide during this stage.
5. The nucleus divides during mitosis, the four stages of which are detailed in the next section. After mitosis, the cytoplasm may divide. Each descendant cell begins the cycle anew, in interphase.
6. Built-in checkpoints stop the cycle from proceeding until certain conditions are met.
Control Over the Cell Cycle

Built-in checkpoints:

- The completion of DNA copying
- DNA damage
- Nutrient availability
Back to Cell Theory

Cells only come from pre-existing cells

Cell division: Reproduction at the cellular level
Reproduction of whole organisms

<table>
<thead>
<tr>
<th>Asexual reproduction</th>
<th>Sexual reproduction:</th>
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<tbody>
<tr>
<td>➢ Offspring are genetically identical to the parent</td>
<td>➢ Requires fertilization of an egg by a sperm</td>
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<tr>
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<td>➢ Offspring have a unique combination of genes from both parents</td>
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<tr>
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<td>➢ No two offspring have the same genetic material (except twins)</td>
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**Homologous chromosomes**
Chromosomes with the same length, shape and genes controlling the same inherited characteristics
One inherited from the mother and one from the father

![Diagram of Two Pairs of Homologous Chromosomes](image)

*The arrows point to corresponding genes.*
A Pair of homologous chromosomes in a cell during G1. Both are unduplicated.

B By G2, each chromosome has been duplicated.

C Mitosis and cytoplasmic division package one copy of each chromosome into each of two new cells.
Mitosis

Nuclear division that conserves the chromosome number by equally distributing the replicated chromosomes to each of the daughter cells.
Significance of Mitosis

- Asexual Reproduction
- Growth and development
- Cell replacement
The Sequence of Events During Mitosis

Cell division is a continuum of dynamic changes
Interphase: Chromosomes are loosened to allow transcription and DNA replication.

Interphase cells are shown for comparison, but interphase is not part of mitosis. The nuclear envelope is intact.

Art, © Cengage Learning; plant cell photos, Michael Clayton/University of Wisconsin, Department of Botany; animal cell photos, ISM/Phototake.
Early prophase: in preparation for nuclear division the chromosomes begin to pack tightly.

- Early Prophase:
  Mitosis begins. Transcription stops, and the DNA begins to appear grainy as it starts to condense. The nuclear envelope begins to break up and the centrosome gets duplicated.
Prophase

The duplicated chromosomes become visible as they condense. One of the two centrosomes moves to the opposite side of the cell as the nuclear envelope breaks up completely. Spindle microtubules assemble and bind to chromosomes at the centromere. Sister chromatids become attached to opposite centrosomes.
### Metaphase

All of the chromosomes are aligned midway between the spindle poles.

<table>
<thead>
<tr>
<th>Plant nucleus</th>
<th>Animal nucleus</th>
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Art, © Cengage Learning; plant cell photos, Michael Clayton/University of Wisconsin, Department of Botany; animal cell photos, ISM/Phototake.
spindle pole
Anaphase

Spindle microtubules separate the sister chromatids and move them toward opposite spindle poles. Each sister chromatid has now become an individual, unduplicated chromosome.
Telophase

The chromosomes reach opposite sides of the cell and loosen up. Mitosis ends when a new nuclear envelope forms around each cluster of chromosomes.
The process of cytokinesis (splitting of the cytoplasm) differs between plant and animal cells.

**Animal cell**

1. In a dividing animal cell, the spindle begins to disassemble after mitosis is completed.
2. At the midpoint of the former spindle, a ring of actin and myosin filaments attached to the plasma membrane contracts.
3. This contractile ring pulls the cell surface inward as it shrinks.
4. The ring contracts until it pinches the cell in two.

**Plant cell**

5. In a dividing plant cell, vesicles cluster at the future plane of division before mitosis ends.
6. The vesicles fuse with each other, forming a cell plate along the plane of division.
7. The cell plate expands outward along the plane of division. When it reaches the plasma membrane, it attaches to the membrane and partitions the cytoplasm.
8. The cell plate matures as two new cell walls. These walls join with the parent cell wall, so each descendant cell becomes enclosed by its own wall.
Telomeres

- Noncoding DNA sequences that occur at the ends of eukaryotic chromosomes
- Telomere sequences provide a buffer against the loss of more valuable internal DNA
A telomere buffer is very important

- Typically, a eukaryotic chromosome shortens by about 100 nucleotides with each DNA replication

- A few normal adult cells retain the ability to divide indefinitely, replacing cell lineages that die out
  - These immortal cells are called *stem cells*

- Stem cells continuously produce enzymes called telomerases
  - Telomerases reverse the telomere shortening that normally occurs after DNA replication
What Happens When Control Over the Cell Cycle Is Lost?

- Checkpoint genes mutate causing the loss-of-function of their protein products

- Controls that regulate checkpoint gene expression fail

- Cells start dividing uncontrollably
Cancer/ Disease of Mitosis

- Neoplasm: accumulation of abnormally dividing cells
  Checkpoint malfunctions passed on to descendant cells
- Tumor: neoplasm that forms a lump
- Oncogene: gene that can transform a normal cell into a tumor cell
- Proto-oncogene: gene that, by mutation, can become an oncogene/ gene encoding proteins that promote mitosis
- Tumor suppressors: gene products that inhibit mitosis
Cells anchor to dish surface and divide.

When cells have formed a complete single layer, they stop dividing (density-dependent inhibition).

If some cells are scraped away, the remaining cells divide to fill the dish with a single layer and then stop (density-dependent inhibition).

After forming a single layer, cells have stopped dividing.

Providing an additional supply of growth factors stimulates further cell division.
Transformed cells do not require a growing surface (no anchorage dependence) and form high density colonies (no density dependent inhibition)
Under controlled conditions, cancer cells are immortal (provided they have enough nutrients)/normal mammalian cells can divide 20-50 times before they stop.

HeLa cells continuously multiplying in culture since 1951.

The immortal cells of Henrietta Lacks/HeLa cells.
Cancer/ Disease of Mitosis

- **Benign:** cells remain at original site/ typically not dangerous

- **Malignant:**
  - cells spread to neighboring tissues/ metastasis
  - dangerous