Mitosis cell division:



In [cell biology](https://en.wikipedia.org/wiki/Cell_biology), mitosis is a part of the [cell cycle](https://en.wikipedia.org/wiki/Cell_cycle) in which replicated [chromosomes](https://en.wikipedia.org/wiki/Chromosomes) are separated into two new nuclei. Cell division gives rise to genetically identical cells in which the total number of chromosomes is maintained. Therefore, mitosis is also known as equational division. In general, mitosis (division of the nucleus) is preceded by the S stage of [interphase](https://en.wikipedia.org/wiki/Interphase) (during which the DNA is replicated) and is often followed by [telophase](https://en.wikipedia.org/wiki/Telophase) and [cytokinesis](https://en.wikipedia.org/wiki/Cytokinesis); which divides the [cytoplasm](https://en.wikipedia.org/wiki/Cytoplasm), [organelles](https://en.wikipedia.org/wiki/Organelle) and [cell membrane](https://en.wikipedia.org/wiki/Cell_membrane) of one cell into two new [cells](https://en.wikipedia.org/wiki/Cell_%28biology%29) containing roughly equal shares of these cellular components.  The different stages of Mitosis altogether define the mitotic (M) phase of an animal cell cycle—the [division](https://en.wikipedia.org/wiki/Cell_division) of the mother cell into two daughter cells genetically identical to each other.

The process of mitosis is divided into stages corresponding to the completion of one set of activities and the start of the next. These stages are [prophase](https://en.wikipedia.org/wiki/Prophase), [prometaphase](https://en.wikipedia.org/wiki/Prometaphase), [metaphase](https://en.wikipedia.org/wiki/Metaphase), [anaphase](https://en.wikipedia.org/wiki/Anaphase), and [telophase](https://en.wikipedia.org/wiki/Telophase). During mitosis, the chromosomes, which have already duplicated, condense and attach to spindle [fibers](https://en.wikipedia.org/wiki/Spindle_apparatus%22%20%5Co%20%22Spindle%20apparatus) that pull one copy of each chromosome to opposite sides of the cell.  The result is two genetically identical daughter nuclei. The rest of the cell may then continue to divide by cytokinesis to produce two daughter cells. The different phases of mitosis can be visualized in real time, using [live cell imaging](https://en.wikipedia.org/wiki/Live_cell_imaging). Producing three or more daughter cells instead of the normal two is a mitotic error called tripolar mitosis or multipolar mitosis (direct cell triplication / multiplication). Other errors during mitosis can induce [apoptosis](https://en.wikipedia.org/wiki/Apoptosis) (programmed cell death) or cause [mutations](https://en.wikipedia.org/wiki/Mutation). Certain types of [cancer](https://en.wikipedia.org/wiki/Cancer) can arise from such mutations.[[](https://en.wikipedia.org/wiki/Mitosis#cite_note-10)

Mitosis occurs only in [eukaryotic](https://en.wikipedia.org/wiki/Eukaryote) cells. [Prokaryotic](https://en.wikipedia.org/wiki/Prokaryote) cells, which lack a nucleus, divide by a different process called [binary fission](https://en.wikipedia.org/wiki/Binary_fission)[[citation needed](https://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)]. Mitosis varies between organisms. For example, [animal](https://en.wikipedia.org/wiki/Animal) cells undergo an "open" mitosis, where the [nuclear envelope](https://en.wikipedia.org/wiki/Nuclear_envelope) breaks down before the chromosomes separate, whereas [fungi](https://en.wikipedia.org/wiki/Fungi) undergo a "closed" mitosis, where chromosomes divide within an intact cell nucleus.[[12]](https://en.wikipedia.org/wiki/Mitosis#cite_note-DeSouza2007-12) Most animal cells undergo a shape change, known as [mitotic cell rounding](https://en.wikipedia.org/wiki/Mitotic_cell_rounding), to adopt a near spherical morphology at the start of mitosis. Most human cells are produced by mitotic cell division. Important exceptions include the [gametes](https://en.wikipedia.org/wiki/Gamete) – [sperm](https://en.wikipedia.org/wiki/Sperm) and [egg](https://en.wikipedia.org/wiki/Ovum) cells – which are produced by [meiosis](https://en.wikipedia.org/wiki/Meiosis).

Phases of mitosis :

Interphase:

The mitotic phase is a relatively short period of the [cell cycle](https://en.wikipedia.org/wiki/Cell_cycle). It alternates with the much longer [interphase](https://en.wikipedia.org/wiki/Interphase), where the cell prepares itself for the process of cell division. Interphase is divided into three phases: [G1 (first gap)](https://en.wikipedia.org/wiki/G1_phase), [S (synthesis)](https://en.wikipedia.org/wiki/S_phase), and [G2 (second gap)](https://en.wikipedia.org/wiki/G2_phase). During all three parts of interphase, the cell grows by producing proteins and cytoplasmic organelles. However, chromosomes are replicated only during the [S phase](https://en.wikipedia.org/wiki/S_phase). Thus, a cell grows (G1), continues to grow as it duplicates its chromosomes (S), grows more and prepares for mitosis (G2), and finally divides (M) before restarting the cycle.[[33]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Blow2005-33) All these phases in the cell cycle are highly regulated by [cyclins](https://en.wikipedia.org/wiki/Cyclins), [cyclin-dependent kinases](https://en.wikipedia.org/wiki/Cyclin-dependent_kinases), and other cell cycle proteins. The phases follow one another in strict order and there are "[checkpoints](https://en.wikipedia.org/wiki/Cell_cycle_checkpoint)" that give the cell cues to proceed from one phase to another.[[35]](https://en.wikipedia.org/wiki/Mitosis#cite_note-35) Cells may also temporarily or permanently leave the cell cycle and enter [G0 phase](https://en.wikipedia.org/wiki/G0_phase) to stop dividing. This can occur when cells become overcrowded ([density-dependent inhibition](https://en.wikipedia.org/wiki/Density-dependent_inhibition)) or when they [differentiate](https://en.wikipedia.org/wiki/Cellular_differentiation) to carry out specific functions for the organism, as is the case for [human heart muscle cells](https://en.wikipedia.org/wiki/Cardiac_muscle_cell) and [neurons](https://en.wikipedia.org/wiki/Neurons). Some G0 cells have the ability to re-enter the cell cycle.

DNA double-strand breaks can be [repaired](https://en.wikipedia.org/wiki/DNA_repair) during interphase by two principal processes.[[36]](https://en.wikipedia.org/wiki/Mitosis#cite_note-36) The first process, [non-homologous end joining](https://en.wikipedia.org/wiki/Non-homologous_end_joining) (NHEJ), can join the two broken ends of DNA in the [G1](https://en.wikipedia.org/wiki/G1_phase), [S](https://en.wikipedia.org/wiki/S_phase) and [G2](https://en.wikipedia.org/wiki/G2_phase) phases of interphase. The second process, [homologous recombinational](https://en.wikipedia.org/wiki/Homologous_recombination) repair (HRR), is more accurate than NHEJ in repairing double-strand breaks. HRR is active during the S and G2 phases of interphase when [DNA replication](https://en.wikipedia.org/wiki/DNA_replication) is either partially accomplished or after it is completed, since HRR requires two adjacent [homologs](https://en.wikipedia.org/wiki/Chromatids).

Interphase helps prepare the cell for mitotic division. It dictates whether the mitotic cell division will occur. It carefully stops the cell from proceeding whenever the cell's DNA is damaged or has not completed an important phase. The interphase is very important as it will determine if mitosis completes successfully. It will reduce the amount of damaged cells produced and the production of cancerous cells. A miscalculation by the key Interphase proteins could be crucial as the latter could potentially create cancerous cells.[[](https://en.wikipedia.org/wiki/Mitosis#cite_note-37)

Prophase:

During prophase, which occurs after G2 interphase, the cell prepares to divide by tightly condensing its chromosomes and initiating mitotic spindle formation. During interphase, the genetic material in the nucleus consists of loosely packed [chromatin](https://en.wikipedia.org/wiki/Chromatin). At the

onset of prophase, chromatin fibers condense into discrete chromosomes that are typically visible at high magnification through a [light microscope](https://en.wikipedia.org/wiki/Light_microscope). In this stage, chromosomes are long, thin, and thread-like. Each chromosome has two chromatids. The two chromatids are joined at the centromere.

[Gene transcription](https://en.wikipedia.org/wiki/Gene_transcription) ceases during prophase and does not resume until late anaphase to early G1 phase.[[40]](https://en.wikipedia.org/wiki/Mitosis#cite_note-40)[[41]](https://en.wikipedia.org/wiki/Mitosis#cite_note-41)[[42]](https://en.wikipedia.org/wiki/Mitosis#cite_note-42) The [nucleolus](https://en.wikipedia.org/wiki/Nucleolus) also disappears during early prophase.[[43]](https://en.wikipedia.org/wiki/Mitosis#cite_note-43)

Close to the nucleus of animal cells are structures called [centrosomes](https://en.wikipedia.org/wiki/Centrosome), consisting of a pair of [centrioles](https://en.wikipedia.org/wiki/Centriole) surrounded by a [loose collection of proteins](https://en.wikipedia.org/wiki/Pericentriolar_material). The centrosome is the coordinating center for the cell's [microtubules](https://en.wikipedia.org/wiki/Microtubule). A cell inherits a single centrosome at cell division, which is [duplicated by the cell](https://en.wikipedia.org/wiki/Centrosome_cycle) before a new round of mitosis begins, giving a pair of centrosomes. The two centrosomes polymerize [tubulin](https://en.wikipedia.org/wiki/Tubulin) to help form a [microtubule spindle apparatus](https://en.wikipedia.org/wiki/Spindle_apparatus). [Motor proteins](https://en.wikipedia.org/wiki/Motor_proteins) then push the centrosomes along these microtubules to opposite sides of the cell. Although centrosomes help organize microtubule assembly, they are not essential for the formation of the spindle apparatus, since they are absent from plants,[[38]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Lloyd-38) and are not absolutely required for animal cell mitosis.

Metaphase:

After the microtubules have located and attached to the kinetochores in prometaphase, the two centrosomes begin pulling the chromosomes towards opposite ends of the cell. The resulting tension causes the chromosomes to align along the metaphase plate or equatorial plane, an imaginary line that is centrally located between the two centrosomes (at approximately the midline of the cell).[[49]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Winey1995-49) To ensure equitable distribution of chromosomes at the end of mitosis, the [metaphase checkpoint](https://en.wikipedia.org/wiki/Spindle_checkpoint) guarantees that kinetochores are properly attached to the mitotic spindle and that the chromosomes are aligned along the metaphase plate.[[51]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Chan2003-51) If the cell successfully passes through the metaphase checkpoint, it proceeds to anaphase.

Anaphase:

During anaphase A, the [cohesins](https://en.wikipedia.org/wiki/Cohesin%22%20%5Co%20%22Cohesin) that bind sister chromatids together are cleaved, forming two identical daughter chromosomes.[[52]](https://en.wikipedia.org/wiki/Mitosis#cite_note-FitzHarris-52) Shortening of the kinetochore microtubules pulls the newly formed daughter chromosomes to opposite ends of the cell. During anaphase B, polar microtubules push against each other, causing the cell to elongate.[[53]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Miller2000-53) In late anaphase, [chromosomes](https://en.wikipedia.org/wiki/Chromosome) also reach their overall maximal condensation level, to help [chromosome segregation](https://en.wikipedia.org/wiki/Chromosome_segregation) and the re-formation of the nucleus.[[54]](https://en.wikipedia.org/wiki/Mitosis#cite_note-54) In most animal cells, anaphase A precedes anaphase B, but some vertebrate egg cells demonstrate the opposite order of events.

Telophase:

Telophase is a reversal of prophase and prometaphase events. At telophase, the polar microtubules continue to lengthen, elongating the cell even more. If the nuclear envelope has broken down, a new nuclear envelope forms using the membrane vesicles of the parent cell's old nuclear envelope. The new envelope forms around each set of separated daughter chromosomes (though the membrane does not enclose the centrosomes) and the nucleolus reappears. Both sets of chromosomes, now surrounded by new nuclear membrane, begin to "relax" or decondense. Mitosis is complete. Each daughter nucleus has an identical set of chromosomes. Cell division may or may not occur at this time depending on the organism.

Cytokinesis:





Cilliate undergoing cytokinesis, with the [cleavage furrow](https://en.wikipedia.org/wiki/Cleavage_furrow) being clearly visible

Cytokinesis is not a phase of mitosis, but rather a separate process necessary for completing cell division. In animal cells, a [cleavage furrow](https://en.wikipedia.org/wiki/Cleavage_furrow) (pinch) containing a contractile ring, develops where the metaphase plate used to be, pinching off the separated nuclei.[[55]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Glotzer2005-55) In both animal and plant cells, cell division is also driven by vesicles derived from the

[Golgi apparatus](https://en.wikipedia.org/wiki/Golgi_apparatus), which move along microtubules to the middle of the cell.[[56]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Albertson2005-56) In plants, this structure coalesces into a cell plate at the center of the [phragmoplast](https://en.wikipedia.org/wiki/Phragmoplast) and develops into a cell wall, separating the two nuclei. The phragmoplast is a microtubule structure typical for higher plants, whereas some green algae use a [phycoplast](https://en.wikipedia.org/wiki/Phycoplast%22%20%5Co%20%22Phycoplast) microtubule array during cytokinesis.[[39]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Raven_2005-39):64–7, 328–9 Each daughter cell has a complete copy of the genome of its parent cell. The end of cytokinesis marks the end of the M-phase.

There are many cells where mitosis and cytokinesis occur separately, forming single cells with multiple nuclei. The most notable occurrence of this is among the [fungi](https://en.wikipedia.org/wiki/Fungus), [slime molds](https://en.wikipedia.org/wiki/Slime_mold), and coenocytic algae, but the phenomenon is found in various other organisms. Even in animals, cytokinesis and mitosis may occur independently, for instance during certain stages of [fruit fly](https://en.wikipedia.org/wiki/Drosophila_melanogaster) embryonic development.[[57]](https://en.wikipedia.org/wiki/Mitosis#cite_note-Lilly2005-57)

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An abnormal (tripolar) mitosis in a precancerous lesion of the stomach. H&E stain
Although errors in mitosis are rare, the process may go wrong, especially during early cellular divisions in the zygote. Mitotic errors can be especially dangerous to the organism because future offspring from this parent cell will carry the same disorder.
In nondisjunction, a chromosome may fail to separate during anaphase. One daughter cell will receive both sister chromosomes and the other will receive none. This results in the former cell having three chromosomes containing the same genes (two sisters and a homologue), a condition known as trisomy, and the latter cell having only one chromosome (the homologous chromosome), a condition known as monosomy. These cells are considered aneuploid, a condition often associated with cancer. Occasionally when cells experience nondisjunction, they fail to complete cell division and retain both nuclei in one cell, resulting in binucleated cells.
Mitosis is a demanding process for the cell, which goes through dramatic changes in ultrastructure, its organelles disintegrate and reform in a matter of hours, and chromosomes are jostled constantly by probing microtubules. Occasionally, chromosomes may become damaged. An arm of the chromosome may be broken and the fragment lost, causing deletion. The fragment may incorrectly reattach to another, non-homologous chromosome, causing translocation. It may reattach to the original chromosome, but in reverse orientation, causing inversion. Or, it may be treated erroneously as a separate chromosome, causing chromosomal duplication. The effect of these genetic abnormalities depends on the specific nature of the error.



