

How cells divide

The vast majority of cells that make up the human body divide on a regular basis. This occurs not only during periods of growth, but also when worn out cells need to be replaced.

All tissues are made up of cells, microscopic membrane-bounded compartments. New cells are made by cell division, during which a cell replicates its genetic material and then separates its contents into two daughter cells. The process of cell division occurs continuously throughout the body, both during the development of the fetus and throughout adulthood.

WHY DO CELLS DIVIDE?

Cells divide when body tissue is growing, or when the cells in that tissue wear out and need to be replaced. Division is carefully regulated and must occur in accordance with the needs of the surrounding tissue, as well as in time with the internal cell growth cycle.

Cells that divide out of control can become cancers. Most chemotherapy is based around regimens that kill dividing cells, but which have less of an effect on non-dividing cells.

EMBRYONIC CELLS

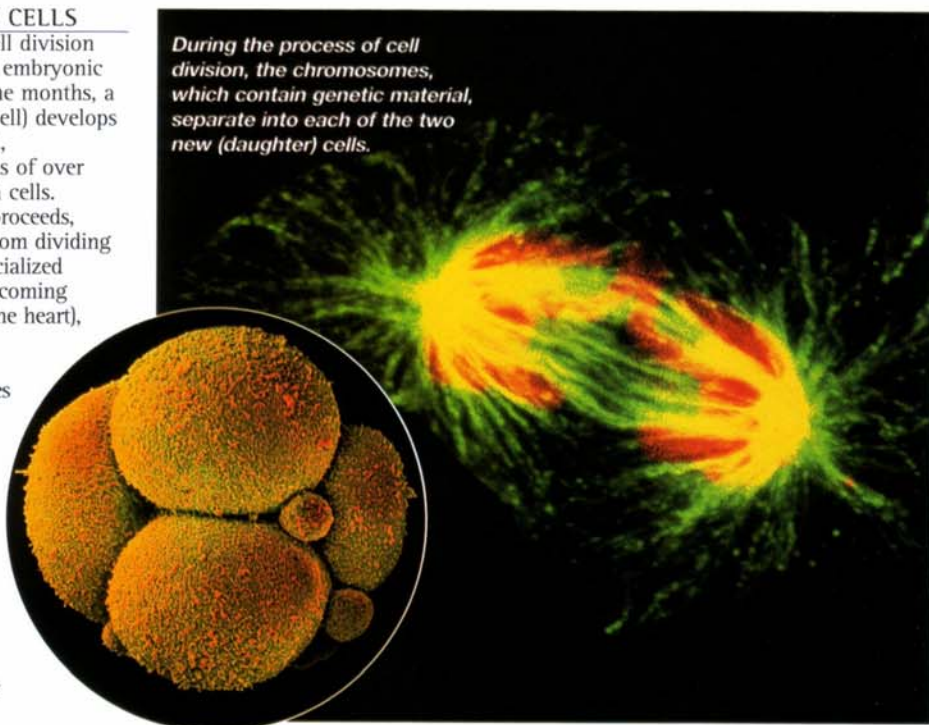
The most prolific cell division occurs during early embryonic development; in nine months, a fertilized egg (one cell) develops into an embryo and, subsequently, a fetus of over 10 thousand million cells.

As development proceeds, many cells switch from dividing to performing a specialized function (such as becoming pacemaker cells in the heart), a process called differentiation.

In almost all tissues there are stem cells, which are cells that are not fully differentiated, but which can divide and differentiate in response to stimuli or wounding.

Once an egg cell is fertilized, it divides progressively; this human embryo is at the four cell stage.

During the process of cell division, the chromosomes, which contain genetic material, separate into each of the two new (daughter) cells.



The life cycle of a cell

The cell division cycle is the process by which one cell doubles its genetic material and then divides into two identical daughter cells. The cycle is divided into two main stages: interphase, when the cell's components are replicated, and mitosis, when the cell divides into two.

Interphase is divided into two

gap phases (G_1 and G_2) and a synthesis (S) phase.

During the first gap phase (G_1), the cell produces carbohydrates, lipids and proteins. Slow-growing cells, such as liver cells, may remain in this phase for years, whereas fast-growing cells, such as those in bone marrow, spend only 16–24 hours in the G_1 phase.

If a cell is not actively dividing, it exits the cell cycle during G_1 and enters a state called G_0 . For example, in adults many highly specialized cells, such as neurones (nerve cells) and heart muscle cells, do not divide and remain in phase G_0 . This makes healing and regeneration in these tissues slow and sometimes impossible.

REPLICATING CHROMOSOMES

The next period of interphase – which is known as the S phase – sees the replication of the chromosomes so that the cell temporarily has 92 chromosomes instead of the normal 46. Proteins are also synthesized during the S phase, including those that form the spindle structures that pull the chromosomes apart. In most human cells, the S phase lasts between 8 and 10 hours.

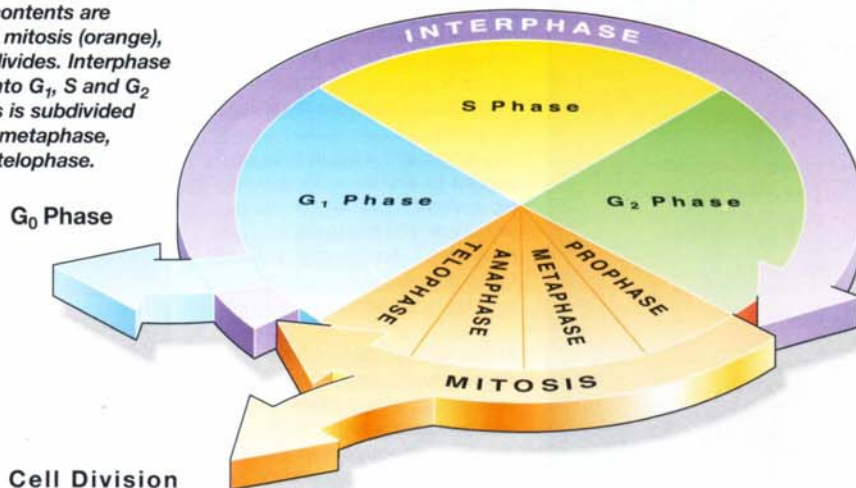
Additional proteins are synthesized in the second gap phase, G_2 .

The cell divides into two daughter cells during a process called mitosis. Mitosis is subdivided into four phases: prophase, metaphase, anaphase and telophase.

The duration of a complete cell cycle varies from a day to a year, depending on the type of cell concerned. Examples of the rates of replacement for different cell types are:

- Liver cells: 12 months
- Red blood cells: 80–120 days
- Skin cells: 14–28 days
- Intestinal mucosa: 3–5 days.

Cell division is divided into two stages: interphase (purple), when the cell contents are replicated, and mitosis (orange), when the cell divides. Interphase is subdivided into G_1 , S and G_2 phases. Mitosis is subdivided into prophase, metaphase, anaphase and telophase.



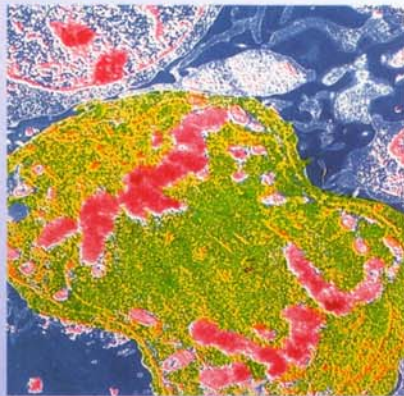
The four stages of mitosis

1 Prophase
During prophase, the DNA condenses into recognizable chromosomes, the nucleus disbands and the nuclear contents enter the cytoplasm.



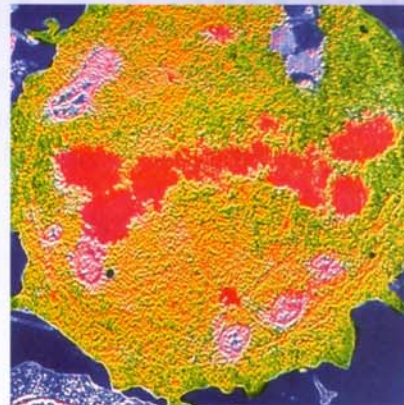
This scanning electron micrograph (SEM) shows the condensed chromosomes (red), nuclear membrane (orange) and cytoplasm (green).

3 Anaphase
During anaphase, the chromosomes are pulled away from each other by the mitotic apparatus in the cell. Half of the chromosomes go to each side of the cell.



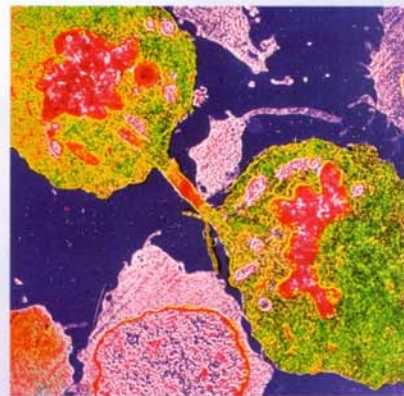
This SEM shows the first stages of anaphase, when the chromosomes separate and the cell membrane becomes indented.

2 Metaphase
During metaphase the chromosomes attach to the mitotic apparatus, a series of specially synthesized protein filaments anchored to opposite sides of the cell.



Here, the cell is in late metaphase: the nuclear membrane has disappeared and the chromosomes (red) are aligned along the centre of the cell.

4 Telophase
During telophase, the nuclear membranes re-form, the cell's contents are redistributed and the membrane 'pinches off' to form two cells.



The cell is in late telophase in this SEM: the two newly-formed cells are still joined by a narrow bridge containing elements of the mitotic apparatus.

Cell death and cell suicide

There are two ways that cells can die: they can be killed by injurious agents, a process called necrosis; or they can be induced to 'commit suicide', a mechanism that scientists call apoptosis.

NECROSIS

When the body is exposed to mechanical or chemical damage, cells may die simply because they are no longer able to

function properly. This process, called necrosis, happens when the cell's integrity is violated, or when molecules or structures essential to the cell's survival are no longer available or functional. For example, after a person dies, nutrients and oxygen are unavailable to all of the cells of the body, which then undergo necrosis and die. Gangrene is another example of

necrosis – the dead tissue turns black due to the action of certain bacteria on haemoglobin, which is broken down to produce dark iron sulphide deposits.

APOPTOSIS

The majority of cells have an in-built programme which makes them commit suicide. Scientists believe that this programme is as intrinsic to the cell as mitosis.

There are two main reasons why a cell would commit suicide. First, programmed cell death is often needed for the proper development of the human body. For example, the formation of the fingers and toes of the fetus requires the removal of the tissue between them by apoptosis.

Second, cell suicide may be needed to destroy cells that represent a threat to the organism. For example, defensive T-lymphocyte cells kill virus-infected cells by inducing apoptosis in them.

In the early stages of fetal development, fingers are connected, giving them a webbed appearance. This webbing disappears as the fetus develops, due to apoptosis.



Meiosis

Meiosis is a special form of cell division that only occurs during the formation of sperm and eggs. During meiosis, there are two cycles of division, but only one duplication of chromosomes, so that sperm and eggs end up with only 23 chromosomes. Meiosis is unique, since 'crossing-over' occurs between paired chromosomes. As a result, the chromosomes that are in the sperm and eggs are not identical to the chromosomes from the parent.



Meiosis is the process that creates both sperm and eggs. Unlike all the other cells in the body, these gametes (sex cells) contain only 23 – rather than 46 – chromosomes