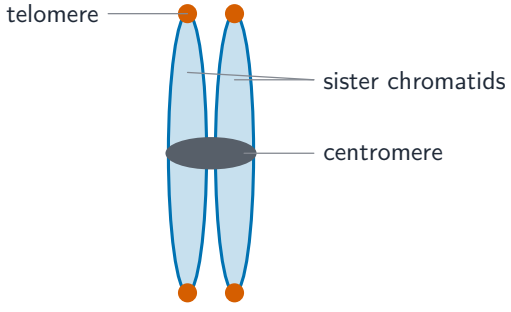
The mitotic cell cycle

A-Level Biology

The structure of a chromosome

A **chromosome** 染色体 is one very long molecule of DNA wound tightly around special **proteins** 蛋白质 called **histones** 组蛋白. Winding the DNA like this lets a huge length fit inside the nucleus and keeps it tidy.

Before a cell divides, its DNA is copied (this copying is called **replication** 复制). After copying, each chromosome is made of two identical copies joined together. These two copies are the **sister chromatids** 姐妹染色单体, and they are held together at a point called the **centromere** 着丝粒. The tips of each chromosome are capped by **telomeres** 端粒, which protect the ends.



one chromosome = two identical copies after DNA replication

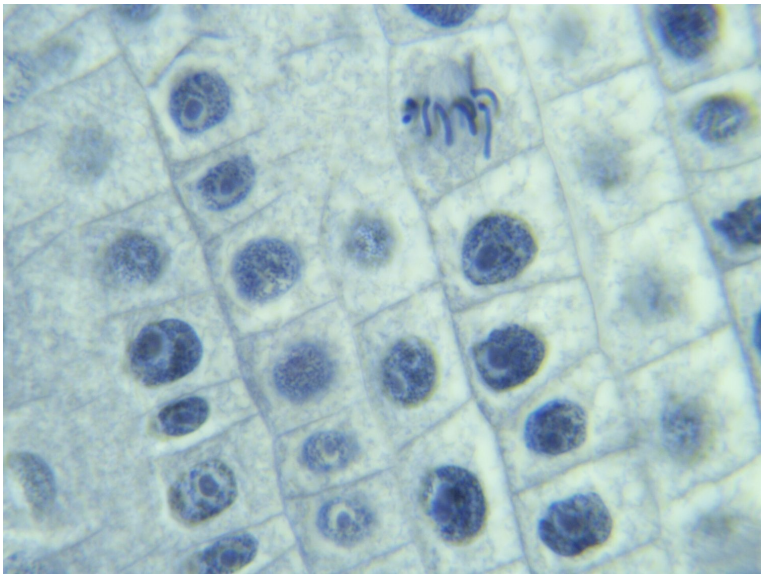
After replication a chromosome is two sister chromatids joined at the centromere, with telomeres at the tips

Why mitosis matters

Mitosis 有丝分裂 is a type of nuclear division that makes two **daughter cells** 子细胞 that are **genetically identical** — they carry exactly the same **genes** 基因 as the parent cell and as each other.

This matters for:

- **growth** of **multicellular** 多细胞 **organisms** 生物体 (making more cells).
- **replacement** of damaged or dead cells.
- **repair** of **tissues** 组织 by making new cells.
- **asexual reproduction** 无性生殖 (one parent makes identical offspring).

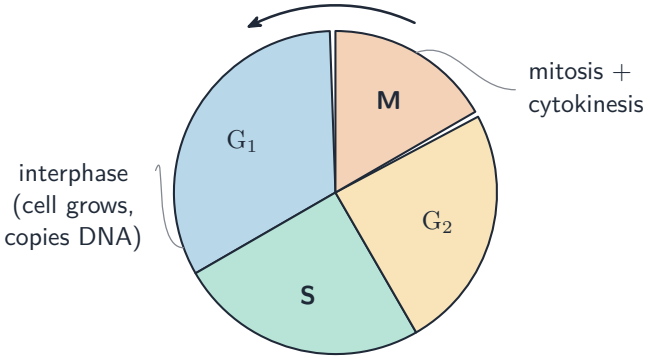


Onion root tip at metaphase: mitosis produces identical body cells for growth and repair

The mitotic cell cycle

The **cell cycle** 细胞周期 is the full life of a cell from one division to the next. It has three parts:

1. **interphase** 间期 — the longest part. The cell grows in the $\mathbf{G_1}$ phase, copies its DNA in the **S** phase (replication), and grows again and prepares to divide in the $\mathbf{G_2}$ phase.
2. **mitosis** — the nucleus divides into two identical nuclei.
3. **cytokinesis** 胞质分裂 — the rest of the cell splits, giving two separate daughter cells.



Most of the cycle is interphase (G_1, S, G_2); mitosis (M) and cytokinesis are a short part

The mitotic index

The mitotic index is the fraction of cells in a sample that are in mitosis. You find it by counting cells under a microscope:

$$\text{mitotic index} = \frac{\text{number of cells in mitosis}}{\text{total number of cells}}.$$

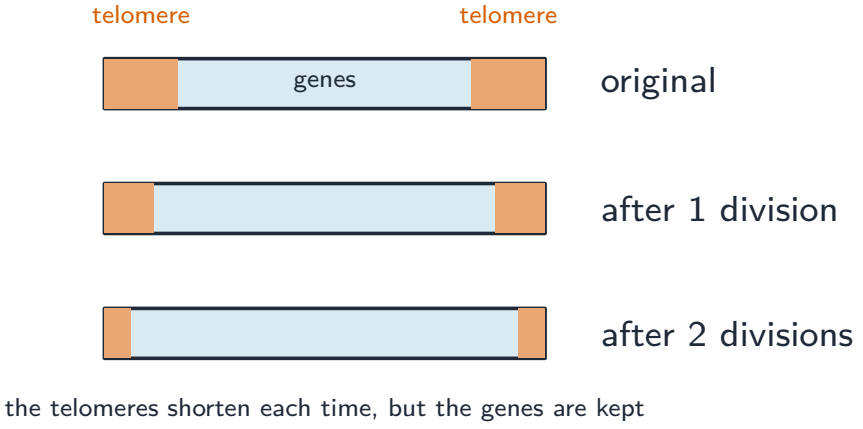
Worked example. In a root-tip sample, 8 of the 50 cells seen are in mitosis. Find the mitotic index.

$$\text{mitotic index} = \frac{8}{50} = 0.16.$$

A high mitotic index means many cells are dividing quickly — normal in a growing root tip, but in adult animal tissue it can be a warning sign of uncontrolled growth.

Telomeres and the ends of chromosomes

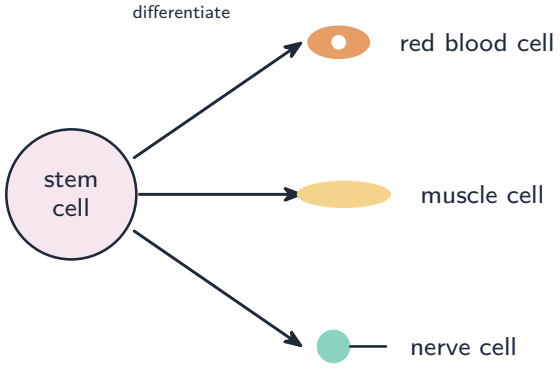
When DNA is replicated, the copying cannot reach the very end of the molecule, so a little is lost each time. Telomeres are short, repeated lengths of DNA at the ends that carry **no genes**. Because the telomeres are shortened instead, no important genes are lost during replication.



The telomeres (which carry no genes) shorten a little at each division, so the genes in the middle are never lost

Stem cells

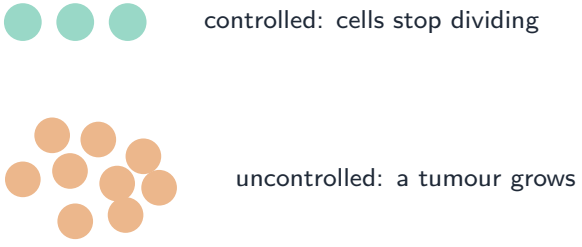
A **stem cell** 干细胞 is an unspecialised cell that can keep dividing by mitosis and can **differentiate** 分化 (change) into different specialised cell types. Stem cells are the source of new cells for replacing lost cells and repairing tissues.



One unspecialised stem cell can differentiate into many specialised cell types

Uncontrolled division and tumours

The cell cycle is normally tightly controlled, so cells divide only when needed. If this control is lost, a cell may divide again and again without stopping. This uncontrolled division produces a lump of cells called a **tumour** 肿瘤.

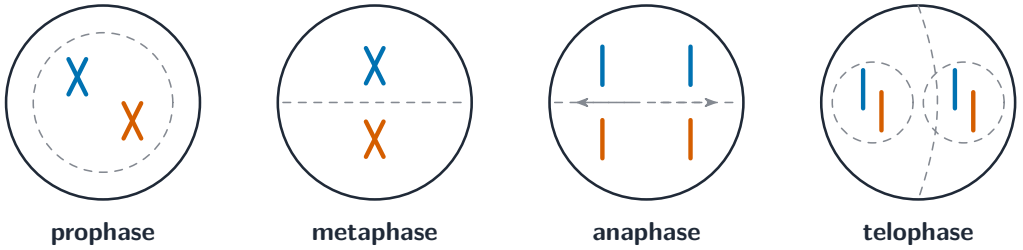


Normally cells stop dividing when they should; if that control is lost, they keep dividing into a tumour

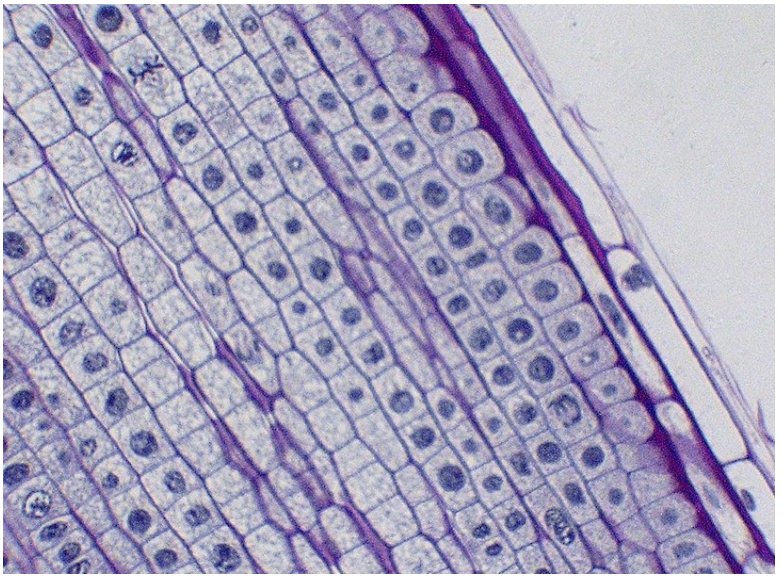
The stages of mitosis

Mitosis runs through four stages. You should be able to recognise them in photomicrographs and slides.

Stage	What happens
prophase 前期	chromosomes coil up and become visible as two sister chromatids; the **nuclear envelope** 核膜 breaks down; a **spindle** 纺锤体 of fibres forms across the cell
metaphase 中期	chromosomes line up along the middle (the **equator** 赤道); spindle fibres attach to each centromere
anaphase 后期	the centromeres split; the sister chromatids are pulled to opposite ends (poles) of the cell
telophase 末期	a set of chromosomes reaches each pole; a new nuclear envelope forms around each set, making two nuclei



The four stages: prophase, metaphase, anaphase, telophase



A real onion root tip: in a growing tip many cells are caught dividing

Cytokinesis then follows. In an animal cell the cell surface membrane pinches inwards to split the cell; in a plant cell a new wall forms across the middle. The result is two genetically identical daughter cells.

Exam tips

- Learn the stages **in order** (prophase, metaphase, anaphase, telophase) with one key event each; interphase (G1, S, G2) is **not** part of mitosis.
- Mitosis gives **two genetically identical diploid** cells — for growth, repair and asexual reproduction.
- **Mitotic index** = cells in mitosis ÷ total cells; a high value means rapid division.
- Link **uncontrolled mitosis** to tumours and telomere shortening to the limit on the number of divisions.