Mitosis, the cell cycle and stem cells

The cell cycle and mitosis, the root tip squash practical and the mitotic index, and stem cells and their medical use.

The cell cycle

The **cell cycle** is the series of events from one cell division to the next.

Phase	Events
Interphase	The cell grows and carries out its normal functions. It has three stages: **G1** (growth, protein synthesis), **S** (**DNA replication**, so each chromosome has two chromatids) and **G2** (preparation: more growth, checking of DNA)
Mitosis	Nuclear division
Cytokinesis	Division of the cytoplasm

Control: **checkpoints** at the end of G1, G2 and during mitosis stop the cycle if there is DNA damage. If control fails and cells divide uncontrollably, a **tumour** (cancer) can form.

Mitosis

Mitosis produces **two genetically identical diploid daughter cells** from one parent cell. It is used for **growth**, **repair** and **asexual reproduction**.

Stage	What happens
Prophase	Chromosomes **condense** and become visible as two sister **chromatids** joined at the **centromere**. The nuclear envelope breaks down. The **spindle** forms from the centrioles (in animal cells)
Metaphase	Chromosomes line up on the **equator**, attached to spindle fibres by their centromeres
Anaphase	The centromeres divide and **sister chromatids** are pulled to opposite poles by the shortening of the spindle fibres (using ATP)
Telophase	Chromatids reach the poles and **decondense**. Nuclear envelopes reform

Then **cytokinesis**: in animal cells a **cleavage furrow** forms; in plant cells a **cell plate** forms.

> **Mitosis keeps the chromosome number the same (diploid to diploid) and gives genetically identical cells. Meiosis halves the chromosome number and gives variation.**

Note Academy

Core Practical 6: root tip squash

1. Cut about 1 cm from the tip of a root (e.g. onion or garlic), where **cells are dividing** (the meristem).
2. **Hydrolyse** with warm dilute hydrochloric acid (about 60 °C for a few minutes). This softens the cell walls and separates the cells.
3. Place on a slide and add a **stain** (acetic orcein or toluidine blue) that makes the **chromosomes** visible. Leave for a few minutes.
4. Add a coverslip and **squash** gently with a thumb (not twisting) to spread the cells into a single layer.
5. Observe with a light microscope at low then high power, and identify the stages.

Safety: the acid and some stains are hazardous, so wear eye protection and gloves.

The mitotic index

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

It measures the proportion of cells that are dividing. A **high** index shows rapid growth, or a tumour, and a low index shows slow division. It is used to test the effect of drugs on cell division (anti-cancer drugs aim to reduce it).

> **TRY IT**
>
> In a field of view 36 of 240 cells are in mitosis. Find the mitotic index.

$36/240 = 0.15$ (or 15%). Count several fields to make the sample large.

Stem cells

Stem cells are undifferentiated cells that can divide by mitosis and become specialised.

Type	Ability	Where
Totipotent	Can become **any** cell type, including the extra-embryonic (placenta) cells and a whole organism	**Zygote and cells of the early embryo** (up to the **morula**, an 8–16-cell ball)
Pluripotent	Can become any cell of the **body** (not the placenta)	Cells of the inner cell mass of the **blastocyst** (embryonic stem cells)
Multipotent	Can become several related cell types	Adult stem cells (e.g. in bone marrow)

A **morula** is a solid ball of cells formed by division of the zygote. The **blastocyst** is a hollow ball of cells with an inner cell mass.

Note Academy

Using stem cells in medicine

Stem cells are used (or investigated) to treat diseases such as **leukaemia** (bone marrow transplants), **Parkinson's disease**, **diabetes**, spinal injury and heart damage, by replacing damaged tissue.

Society uses scientific knowledge to make decisions about their use:

- **Benefits**: treat conditions that are otherwise incurable and reduce reliance on donors.
- **Issues**: obtaining embryonic stem cells **destroys an embryo**, which is unacceptable to some religious and moral views; **adult** stem cells avoid this, but have **less potential**. There are risks of **tumours**, rejection and cost.
- **Regulation**: laws control the source (for example, using spare embryos from IVF), the age of the embryo (up to 14 days), and cloning.
- **Induced pluripotent stem cells** can be made from adult cells, which avoids using embryos.

Note Academy