Cell Division, Chromosomes, and DNA

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Cell Division, Chromosomes, and DNA

New cells are produced by cell division. The type of division determines whether the new cells are genetically identical to the parent or genetically varied. Understanding this is the foundation for everything in genetics and inheritance.

The DNA ’Chromosome ’Gene ’Allele Hierarchy

Term	What it is
DNA	a long double-stranded molecule carrying genetic information as a sequence of bases
Chromosome	a single piece of tightly coiled DNA associated with proteins; carries many genes
Gene	a specific section of DNA that codes for one protein (or one characteristic)
Allele	one of two or more different versions of a gene (e.g. tall vs short plant height)

Human body cells contain **46 chromosomes** arranged in **23 pairs** of homologous chromosomes. Each pair carries the same genes, but may carry different alleles.

- **Diploid (2n)** — the full set of paired chromosomes; found in body cells (46 in humans)
- **Haploid (n)** — half the chromosome number; found in gametes (23 in humans)

From DNA to allele

Mitosis

Mitosis produces two genetically identical daughter cells from one parent cell. It is used for:

- **growth** of the organism
- **repair** of damaged tissue
- **asexual reproduction** in organisms that reproduce without sex

What happens in mitosis

Before mitosis begins, DNA is replicated — each chromosome makes an exact copy of itself. The cell then divides:

- 1. **Prophase** — chromosomes condense and become visible; nuclear envelope breaks down
- 2. **Metaphase** — chromosomes line up along the centre of the cell
- 3. **Anaphase** — copies of each chromosome are pulled to opposite ends of the cell
- 4. **Telophase / Cytokinesis** — nuclear envelopes reform around each set; cell divides

Outcome: 2 diploid cells, each genetically identical to the original.

Diagram showing the stages of mitosis: Interphase, Prophase, Prometaphase, Metaphase, Anaphase, and Telophase & Cytokinesis

> **Helpful but not required: prometaphase**
> **Prometaphase** is extra detail beyond the standard stage sequence expected here. If you see it on the diagram, treat it as part of late prophase: the nuclear envelope breaks down and chromosomes prepare to line up at the centre of the cell.

Asexual Reproduction and Mitosis

In asexual reproduction, all offspring come from a single parent by mitosis. Because mitosis produces genetically identical cells, all offspring are clones — they are genetically identical to the parent. This is an advantage when conditions are stable and the parent is well-adapted, but a disadvantage if conditions change, as there is no variation to select from.

Meiosis

Meiosis produces four haploid cells from one diploid parent cell. It occurs in the gonads (testes and ovaries) to produce gametes (sperm and eggs).

Why meiosis is necessary

During fertilisation, a sperm (n = 23) fuses with an egg (n = 23) to produce a zygote (2n = 46). If gametes were produced by mitosis, they would have 46 chromosomes, and fertilisation would double the chromosome number each generation. Meiosis halves the chromosome number, ensuring the correct number is restored after fertilisation.

What happens in meiosis

Meiosis consists of **two divisions** (Meiosis I and Meiosis II):

Meiosis I — separation of homologous pairs

- Homologous chromosomes pair up
- **Crossing over** occurs — sections of DNA exchange between chromosomes, creating new allele combinations
- Homologous pairs separate to opposite poles

Meiosis II — separation of sister chromatids

- Similar to mitosis; the two cells from Meiosis I divide again
- Sister chromatids separate

Outcome: 4 haploid cells, each genetically different from the others.

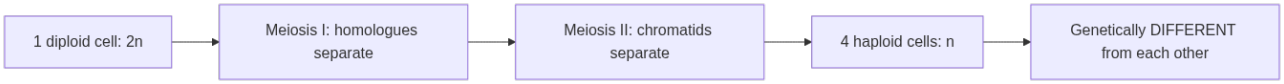
Meiosis I Stage Detail

Past papers have asked for events in named stages of Meiosis I:

Stage	Key events
Prophase I	chromosomes condense; homologous chromosomes pair; crossing over may occur
Metaphase I	homologous pairs line up at the centre of the cell
Anaphase I	homologous chromosomes separate and move to opposite poles; sister chromatids remain joined
Telophase I	two nuclei/cells form, each with half the original chromosome number

The most important distinction is that **Meiosis I separates homologous chromosomes**, while **Meiosis II separates sister chromatids**.

Diagram showing the stages of meiosis: Prophase I, Metaphase I, Anaphase I, Telophase I & Cytokinesis, Prophase II, Metaphase II, Anaphase II, and Telophase II & Cytokinesis



Overview of meiosis

Sources of Genetic Variation in Meiosis

Two mechanisms create variation:

- 1. **Crossing over** — during Meiosis I, homologous chromosomes exchange segments. This shuffles alleles, creating chromosomes with new combinations not present in either parent.
- 2. **Independent assortment** — the orientation of each homologous pair at the cell centre is random. This means each gamete receives a random mix of maternal and paternal chromosomes.

These two mechanisms together produce enormous diversity in the gametes, even from the same two parents.

Mitosis vs Meiosis — Comparison

Feature	Mitosis	Meiosis
Purpose	growth, repair, asexual reproduction	production of gametes (sexual reproduction)
Number of divisions	one	two
Cells produced	2	4
Chromosome number in products	diploid (2n)	haploid (n)
Genetic identity of products	identical to parent	genetically varied
Where it occurs	all body (somatic) cells	gonads (testes and ovaries)
Crossing over	does not occur	occurs during Meiosis I

> 📝 **Exam Tip**
> A common exam question asks you to compare mitosis and meiosis. Focus on: number of divisions, chromosome number in daughter cells, and whether products are genetically identical or varied. These three points capture the key differences.

Link to Inheritance

The gametes produced by meiosis each carry one allele for every gene. When two gametes fuse at fertilisation, the zygote receives one allele from each parent — this is the basis of the inheritance patterns covered in the Heredity and Genetics page.

PRACTICE — CELL DIVISION, CHROMOSOMES, AND DNA

DNA
A double-stranded molecule made of nucleotides; carries genetic information as a sequence of bases.

Chromosome
Coiled DNA associated with proteins; each chromosome carries many genes.

Gene
A section of DNA that codes for one protein or characteristic.

Allele
One version of a gene; different alleles of the same gene may produce different phenotypes.

Diploid
Having two complete sets of chromosomes (2n); found in body cells.

Haploid
Having one set of chromosomes (n); found in gametes.

Mitosis
Cell division producing two genetically identical diploid daughter cells; used for growth and repair.

Meiosis
Cell division producing four genetically varied haploid cells; used to produce gametes.

Crossing over
Exchange of segments between homologous chromosomes during Meiosis I; creates new allele combinations.

Independent assortment
Random orientation of chromosome pairs during meiosis; produces diverse gametes.

Clone
An organism genetically identical to its parent; produced by asexual reproduction or mitosis.