Meiosis, gametes and fertilisation

Loci and linkage, meiosis and genetic variation, specialised gametes, and fertilisation in mammals and flowering plants.

Chromosomes, loci and linkage

A **locus** is the position of a gene on a chromosome. Genes on the **same chromosome** are **linked** and tend to be inherited together, unless separated by crossing over. This changes the ratios expected in a dihybrid cross.

Meiosis

Meiosis is a form of nuclear division in which **one diploid cell** produces **four haploid cells** that are genetically **different**. It involves two divisions, **meiosis I** and **meiosis II**, with one round of DNA replication before it.

Stage	What happens
Prophase I	Chromosomes condense. **Homologous chromosomes pair up** (bivalents). **Crossing over**: chromatids of homologues wrap and exchange sections at **chiasmata**, swapping alleles
Metaphase I	Bivalents line up at the equator. Each pair is arranged **randomly** (**independent assortment**)
Anaphase I	**Homologous chromosomes** are pulled apart to opposite poles (the number of chromosomes per cell halves)
Telophase I	Two haploid cells form
Meiosis II	Like mitosis: chromatids separate in anaphase II. Four haploid cells form

Genetic variation

Meiosis ensures variation in the gametes in two ways:

1. **Independent assortment** of homologous chromosomes at metaphase I. In humans, with 23 pairs there are 2^{23} (over 8 million) combinations in a gamete.
2. **Crossing over** between non-sister chromatids in prophase I, producing **new combinations of alleles** on a chromosome.

Further variation comes from **random fertilisation**, and from mutation.

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Don't mix up the two processes: independent assortment shuffles whole chromosomes; crossing over shuffles alleles within a chromosome pair.

Gametes in mammals

Sperm are specialised for reaching and fertilising the egg:

- A **flagellum (tail)** with many **mitochondria** in the mid-piece to provide ATP for movement.
- An **acrosome** at the head, a lysosome-like vesicle containing **hydrolytic enzymes** (e.g. proteases) which digest the egg's coat.
- A **haploid nucleus** with condensed chromatin.

The **egg cell (secondary oocyte)** is large, with a **cytoplasm** rich in nutrients, **cortical granules** (vesicles just under the cell surface membrane), a **zona pellucida** (a glycoprotein layer around the cell) and a cell surface membrane with receptors for sperm.

Fertilisation in mammals

1. Sperm reach the egg and attach to the **zona pellucida**, which has species-specific receptors.
2. The **acrosome reaction**: the acrosome releases its enzymes by exocytosis, digesting a path through the zona pellucida.
3. The sperm membrane fuses with the egg cell membrane, and the sperm nucleus enters.
4. The **cortical reaction**: **cortical granules** release enzymes that make the zona pellucida **hard and impermeable**, preventing entry of other sperm (polyspermy).
5. The egg completes meiosis II, and the **nuclei fuse** to form a diploid **zygote**.

Fertilisation in flowering plants

1. **Pollen** lands on the **stigma** and absorbs sugars; it germinates and grows a **pollen tube** down the style, following chemical signals, digesting a path with enzymes.
2. The pollen grain contains a **tube nucleus** (controls growth) and **two male gametes (nuclei)**.
3. The pollen tube enters the ovule through the **micropyle**.
4. **Double fertilisation**: one male nucleus fuses with the **egg cell nucleus** to form the **diploid zygote**; the other fuses with **two polar nuclei** to form the **triploid endosperm nucleus**, which becomes the nutrient store.

NOTE

A common practical investigation is the effect of sucrose concentration on pollen tube growth. Pollen grains are placed in a range of sucrose solutions, and the percentage germination and tube

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length are measured with a microscope. The sucrose provides nutrient and keeps the water potential suitable.

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