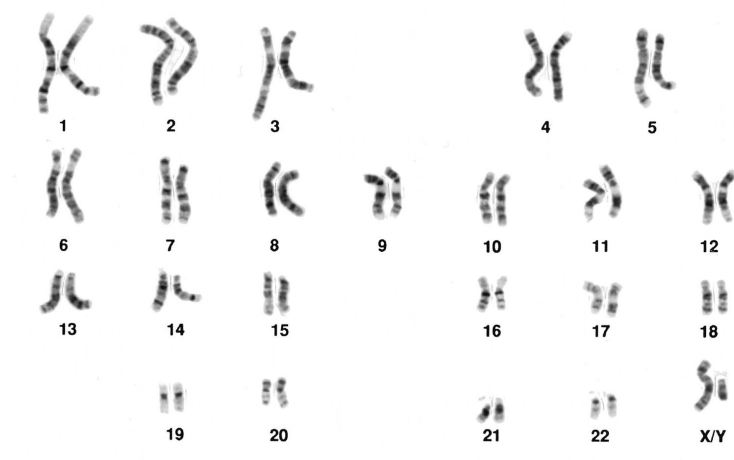


Heredity

AP Biology

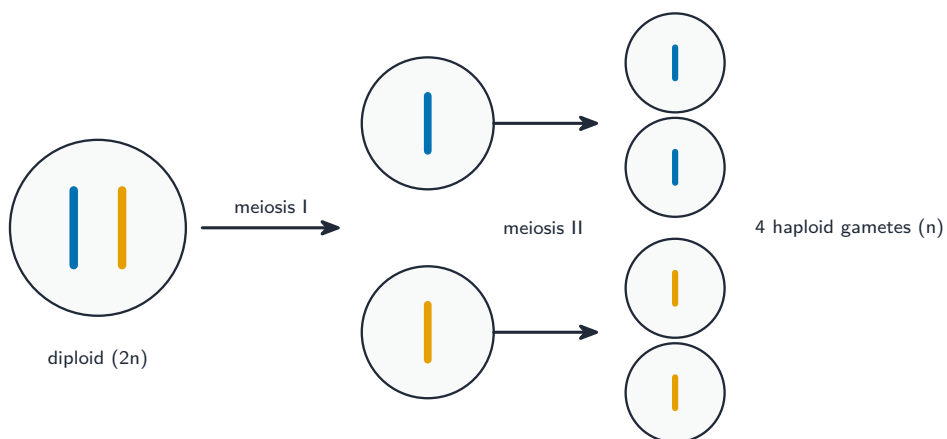
Meiosis



Normal Karyotype

A human karyotype: 22 pairs of autosomes plus the sex chromosomes

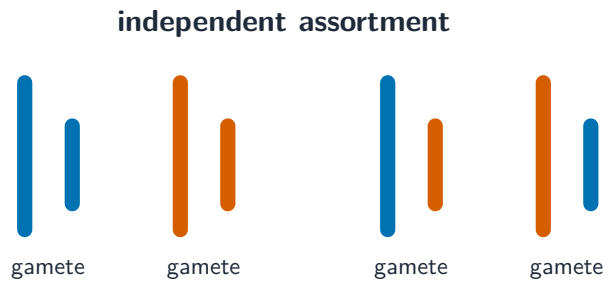
Meiosis 减数分裂 makes **gametes** 配子 (eggs and sperm) with **half** the chromosome number, so fertilization restores the full set. One diploid cell divides **twice** to give four haploid cells. Meiosis I separates **homologous chromosomes** 同源染色体 (reducing the number); meiosis II separates sister chromatids (like mitosis).



Meiosis halves the chromosome number in two divisions

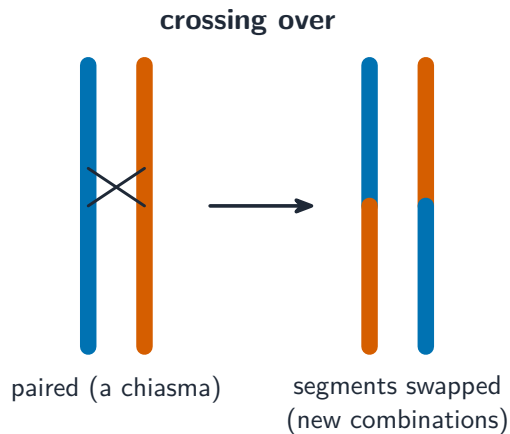
Meiosis and Genetic Diversity

Meiosis shuffles genes three ways, so offspring differ from parents and each other:



the pairs line up in a random order, so each gamete gets a random mix

Independent assortment produces many gamete combinations



Crossing over swaps segments between homologous chromosomes

- **Crossing over** 交叉互换: homologous chromosomes swap segments in meiosis I.
- **Independent assortment** 自由组合: each homologous pair lines up and separates randomly.
- **Random fertilization**: any sperm can meet any egg.

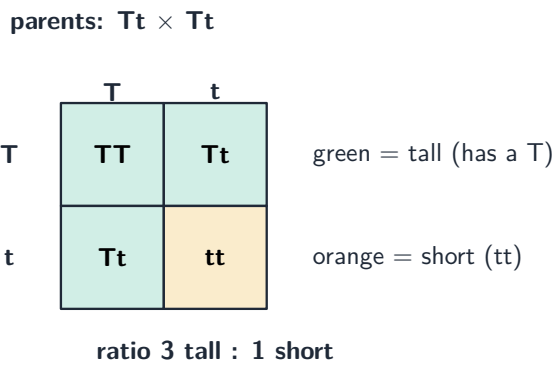
Together these create enormous variation – the raw material for evolution.

Mendelian Genetics



Natural variation in snail shell banding — heritable differences selection can act on

A gene’s alternative versions are **alleles** 等位基因. An organism’s **genotype** 基因型 (its alleles) produces its **phenotype** 表型 (its traits). Mendel’s rules: a **dominant** 显性 allele masks a **recessive** 隐性 one; the two alleles **segregate** into different gametes (law of segregation); genes for different traits assort **independently**. A **Punnett square** 庞纳特方格 predicts offspring ratios (a heterozygous cross gives 3:1). **Homozygous** 纯合 means two identical alleles; **heterozygous** 杂合 means two different.



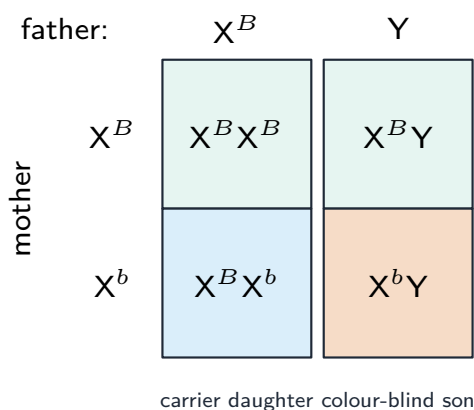
A monohybrid Punnett square giving a 3:1 ratio

Worked example. For a **dihybrid** cross of two independent genes, $AaBb \times AaBb$, use the multiplication rule instead of a 16-box square. Each gene alone gives $\frac{3}{4}$ dominant, so the chance an offspring shows **both** dominant traits is $\frac{3}{4} \times \frac{3}{4} = \frac{9}{16}$, and the chance

of the fully recessive $aabb$ is $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$. Multiplying two independent 3:1 ratios is what produces the classic 9:3:3:1 pattern.

Non-Mendelian Genetics

Many traits do not follow simple dominance:



Sex linkage gives different results for sons and daughters

- **Incomplete dominance** 不完全显性: heterozygotes are a blend (red $\times$ white $\rightarrow$ pink).
- **Codominance** 共显性: both alleles show fully (AB blood type).
- **Multiple alleles, polygenic** 多基因 traits (many genes, like height), **pleiotropy** (one gene, many effects), and **sex-linked** 伴性 genes (on the X chromosome) all give more complex ratios.

Worked example (chi-square test). To check whether real data fit a predicted ratio, use $\chi^2 = \sum \frac{(o - e)^2}{e}$. A monohybrid cross predicts 3:1, so of 80 offspring you expect 60 dominant and 20 recessive, but you observe 55 and 25. Then $\chi^2 = \frac{(55 - 60)^2}{60} + \frac{(25 - 20)^2}{20} = \frac{25}{60} + \frac{25}{20} = 0.42 + 1.25 = 1.67$. With 1 degree of freedom the critical value at $p = 0.05$ is 3.84; since $1.67 < 3.84$, we **fail to reject** the null hypothesis – the deviation is within chance.

Environmental Effects on Phenotype

Phenotype is not set by genes alone – the **environment** also matters. Temperature, nutrition, and other factors can change how genes are expressed (a Himalayan rabbit's dark fur where it is cold, a plant's height with more sunlight). So identical genotypes can give different phenotypes in different conditions.

Exam tips

- Contrast mitosis (2 identical, full chromosome number) with **meiosis** (4 non-identical gametes, half the number).
- Explain variation from **crossing over, independent assortment, and random fertilisation**.
- Use the multiplication rule for dihybrid crosses (each gene's 3:1 multiplied), and a **chi-square** test ($\chi^2 = \sum \frac{(o-e)^2}{e}$) to judge observed vs expected ratios.
- Keep **genotype** (the alleles) separate from **phenotype** (what you see) — AA and Aa can look the same.
- Recognise non-Mendelian patterns: incomplete dominance, codominance, and sex linkage.