Heredity

AP Biology ▪ Unit 5

AP Biology

	B	b
B	BB	Bb
b	Bb	bb

What we will cover

1. Meiosis
2. Meiosis and genetic diversity
3. Mendelian genetics
4. Non-Mendelian patterns
5. Environment and phenotype

	B	b
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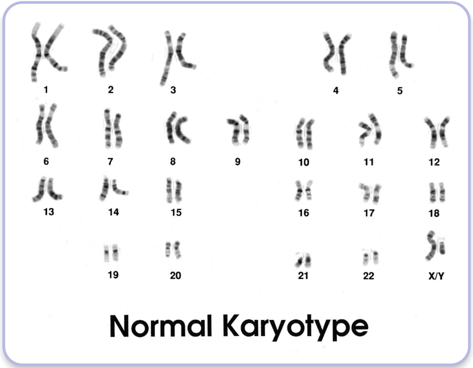
1 Meiosis

Meiosis

Meiosis 减数分裂 turns one **diploid** 二倍体 cell into four **haploid** 单倍体 **gametes** 配子 – halving the chromosome number.

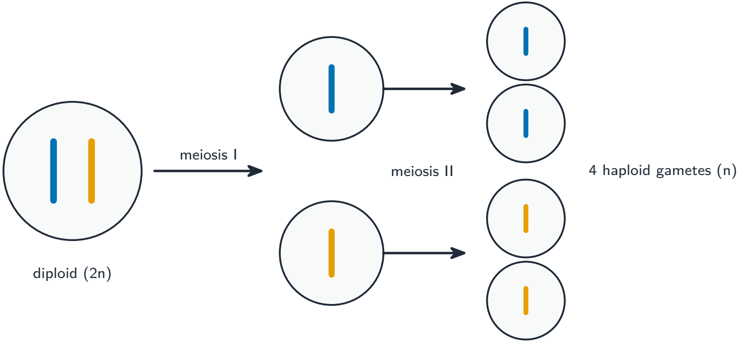
- **meiosis I** separates **homologous** 同源染色体 pairs (halving)
- **meiosis II** separates the copies

> Two haploid gametes join at fertilization to restore the diploid number.



Meiosis halves chromosome sets for gametes

Meiosis halves the chromosome number in two



Meiosis halves the chromosome number in two divisions

2

Diversity

Meiosis and genetic diversity

Three shuffles make every gamete unique:

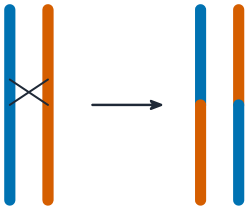
- **Crossing over 交叉互换** – homologs swap pieces
- **Independent assortment 自由组合** – pairs line up at random
- **Random fertilization 随机受精** – any sperm, any egg

> Independent assortment alone gives 2^{23} human gamete types – **genetic diversity** 遗传多样性 is insurance.

Variation among offspring is not noise – it is insurance

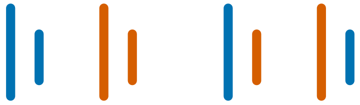
Crossing over swaps segments between homologous

crossing over



Crossing over swaps segments between homologous chromosomes

independent assortment



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

Where meiosis gets its variation

crossing over 交叉互换	homologous chromosomes swap segments in prophase I – new combinations *within* a chromosome
independent assortment 自由组合	each homologous pair lines up independently at metaphase I – 2^{23} combinations in humans
random fertilisation	any sperm with any egg, multiplying the possibilities again
together	these create enormous variation – the raw material evolution acts on
homozygous 纯合 / heterozygous 杂合	two identical alleles, or two different ones, at a locus

> Mutation *creates* new alleles; meiosis *recombines* the existing ones. Both are needed, and they are not the same source.

3

Mendelian

Mendelian genetics

The **law of segregation** 分离: alleles separate, so each gamete carries one. A **Punnett square** 庞纳特方格 predicts the cross.

- **genotype** 基因型 (Bb) vs **phenotype** 表型 (trait)
- **dominant** 显性 (capital) hides **recessive** 隐性

$Bb \times Bb \Rightarrow$ phenotype ratio 3:1. Test the fit with $\chi^2 = \sum \frac{(O-E)^2}{E}$.

	B	b
B	BB	Bb
b	Bb	bb

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Non-Mendelian

Non-Mendelian patterns

Many traits break Mendel's simple dominant/recessive rule:

Incomplete dominance 不完全显性: red+white → pink

Codominance 共显性: AB blood (both show)

Multiple alleles 复等位基因: I^A, I^B, i

Sex-linked 伴性遗传: colour blindness

Polygenic 多基因遗传 & **epistasis** 上位效应: a smooth range

Non-Mendelian patterns, continued

	father: X^B	Y
mother X^B	X^BX^B	X^BY
mother X^b	X^BX^b	X^bY

carrier daughter colour-blind son

- **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 – the chi-square test

A monohybrid cross predicts $3:1$. Of 80 offspring, 55 show the dominant trait and 25 the recessive. Do the data fit?

- expected: 60 and 20
- $\chi^2 = \sum \frac{(o-e)^2}{e} = \frac{25}{60} + \frac{25}{20} = 0.42 + 1.25 = 1.67$
- $df = 2 - 1 = 1$; the critical value at $p = 0.05$ is 3.84
- $1.67 < 3.84$, so do not reject the null hypothesis – the data fit

The null hypothesis is that any difference is chance alone. Failing to reject it is not proof the ratio is right, only that the deviation is unremarkable.

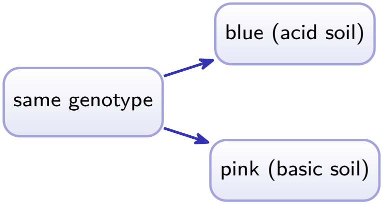
5 Environment

Environment and phenotype

Genes are not the whole story – the **environment** 环境 shapes the phenotype too.

- temperature (dark fur on cool paws)
- nutrition, light

> **Phenotypic plasticity** 表型可塑性: one genotype, a range of phenotypes – nature sets the options, the environment chooses.



Hydrangea: the soil decides the colour.

Phenotype is not set by genes alone

the claim	the environment also shapes how a genotype is expressed
temperature	Siamese cat coat colour, and temperature-dependent sex determination in some reptiles
nutrition	height and mass in almost every organism
density and crowding	can change growth form in plants and behaviour in animals
the general point	a genotype specifies a range of possible phenotypes, not one outcome

> Identical twins are the standard evidence: the same genome, and measurably different phenotypes. That is what the term *norm of reaction* names.

Mendelian Genetics, continued

parents: Tt × Tt

	T	**t**
T	**TT**	**Tt**
t	**Tt**	**tt**

green = tall (has a T)

orange = short (tt)

ratio 3 tall : 1 short

> A monohybrid Punnett square giving a 3:1 ratio

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.

6 Recap

Unit 5 – key takeaways

1 **Meiosis**

diploid $\rightarrow$ four haploid gametes; halves chromosomes

2 **Diversity**

crossing over, independent assortment, random fertilization

3 **Mendel**

$Bb \times Bb \Rightarrow 3{:}1$; test fit with χ^2

4 **Beyond Mendel**

incomplete dominance, codominance, plasticity

Check yourself

1. How many cells, and what ploidy, does meiosis produce?
2. What phenotype ratio comes from $Bb \times Bb$?
3. Red + white flowers give pink – which inheritance pattern?
4. Two identical clones differ in colour – what is this called?

BB	Bb
Bb	bb

Answers **1.** four haploid cells **2.** 3:1 **3.** incomplete dominance **4.** phenotypic plasticity