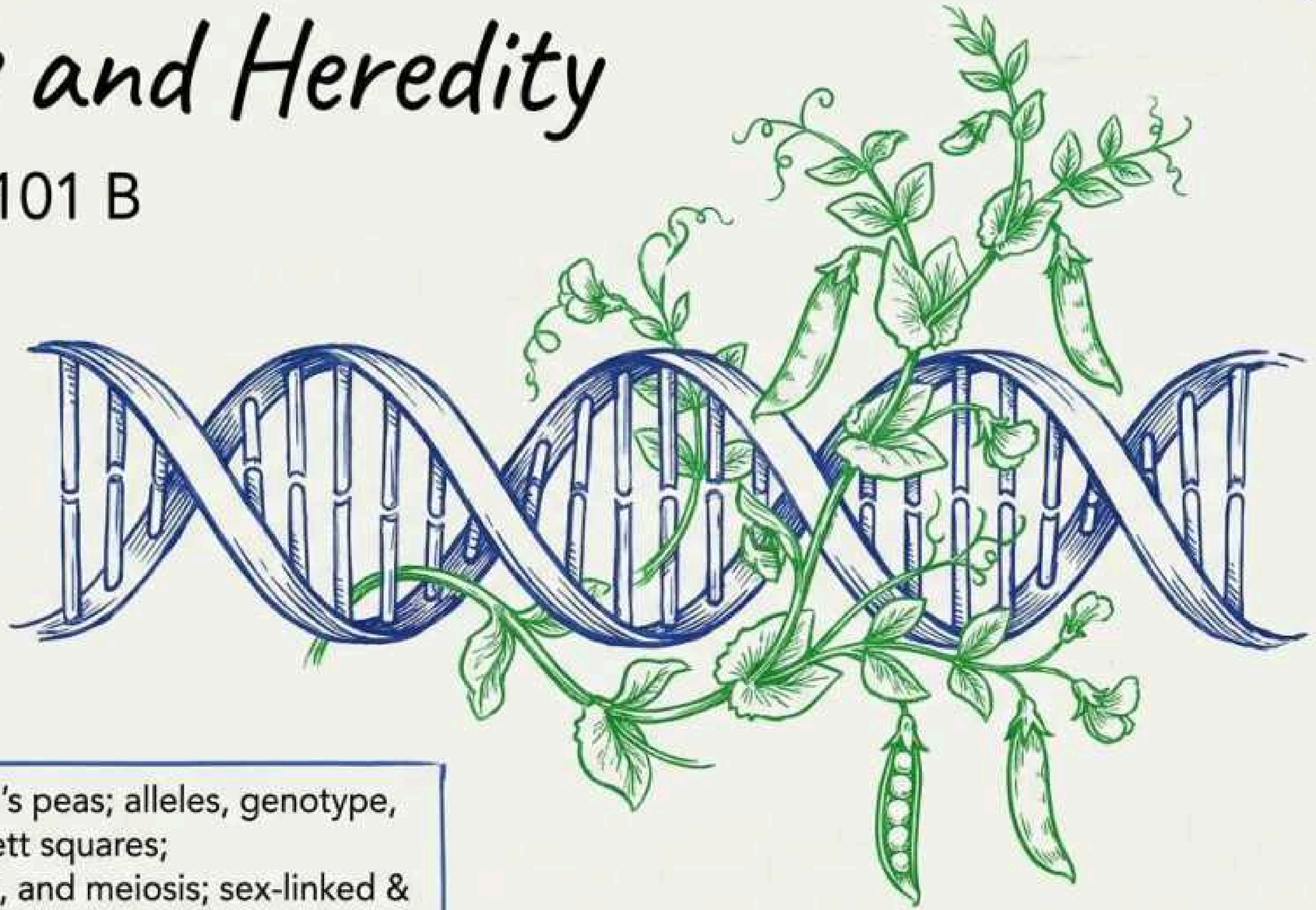
¶ 4.1

Genetics and Heredity

Course: BIO 101 B
Lecture 4

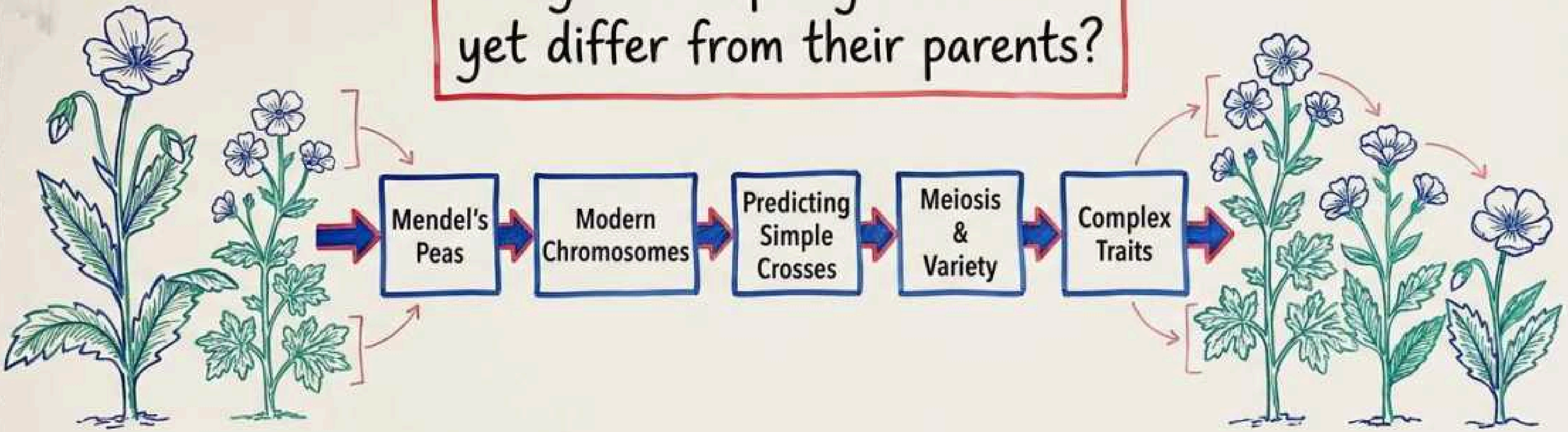


At a glance — Mendel's peas; alleles, genotype, and phenotype; Punnett squares; chromosomes, mitosis, and meiosis; sex-linked & complex traits; inherited conditions and ethics.

¶ 4.2

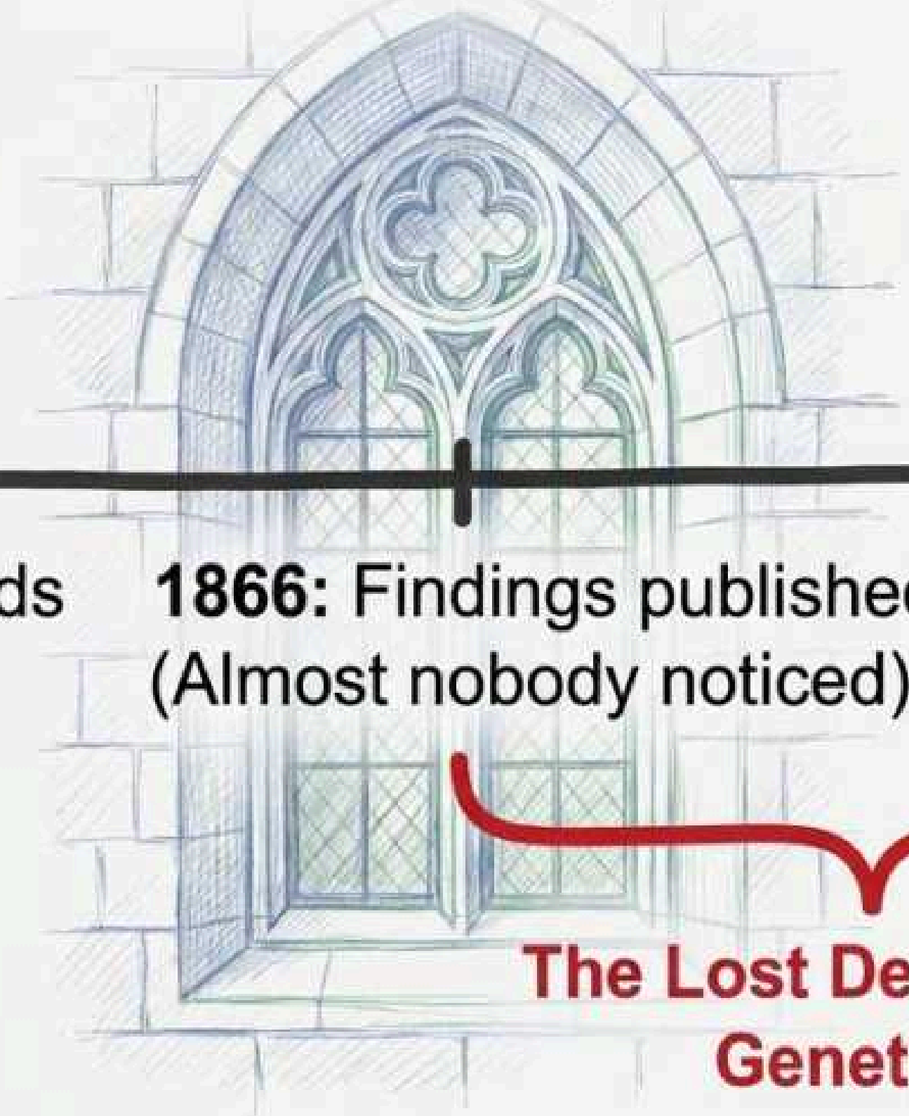
The Core Paradox of Heredity

Why do offspring resemble yet differ from their parents?



¶ 4.3

Gregor Mendel (1822–1884)



1860s: Bred thousands of pea plants & counted results.

1866: Findings published (Almost nobody noticed).

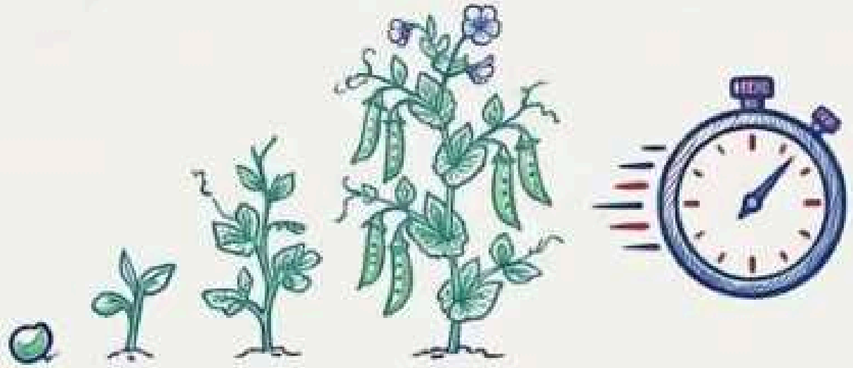
~1900: Work rediscovered.

The Lost Decades of Genetics

Experimental Design: Why Peas?

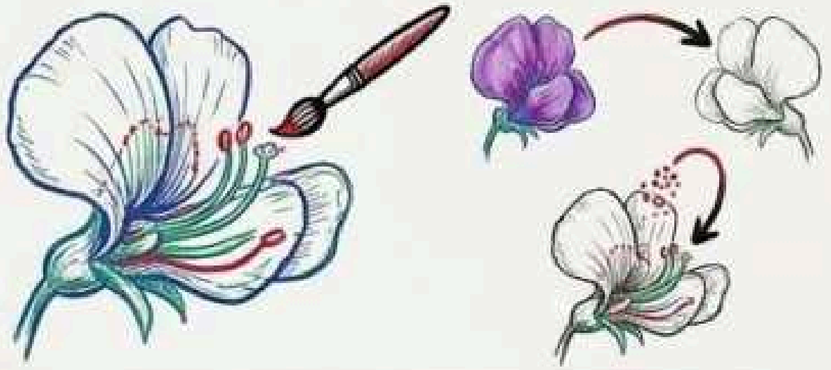
¶ 4.4

Fast growth & high offspring yield

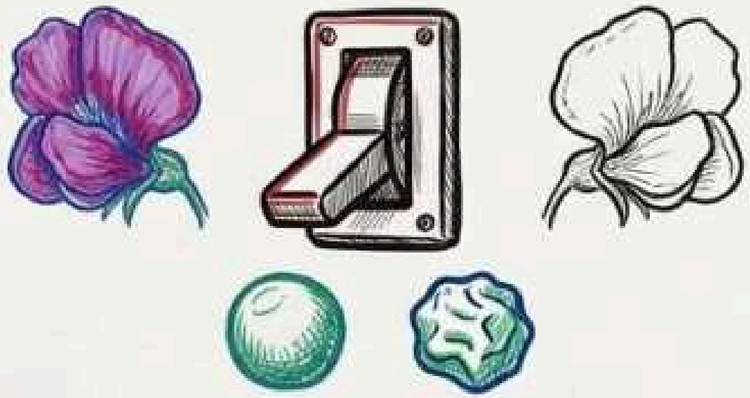


Fast growth & high offspring yield.

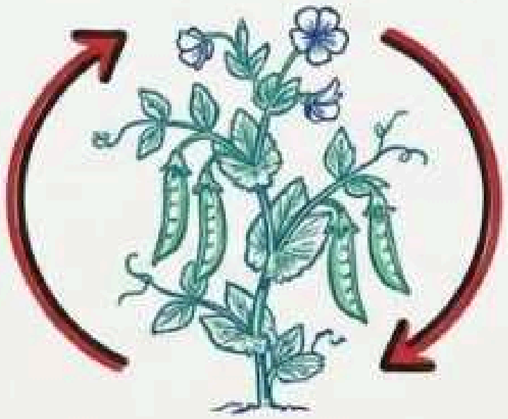
Controlled mating
(self-pollination vs. cross-pollination).



Clear either-or traits
(Purple vs. White flowers; Round vs. Wrinkled seeds)

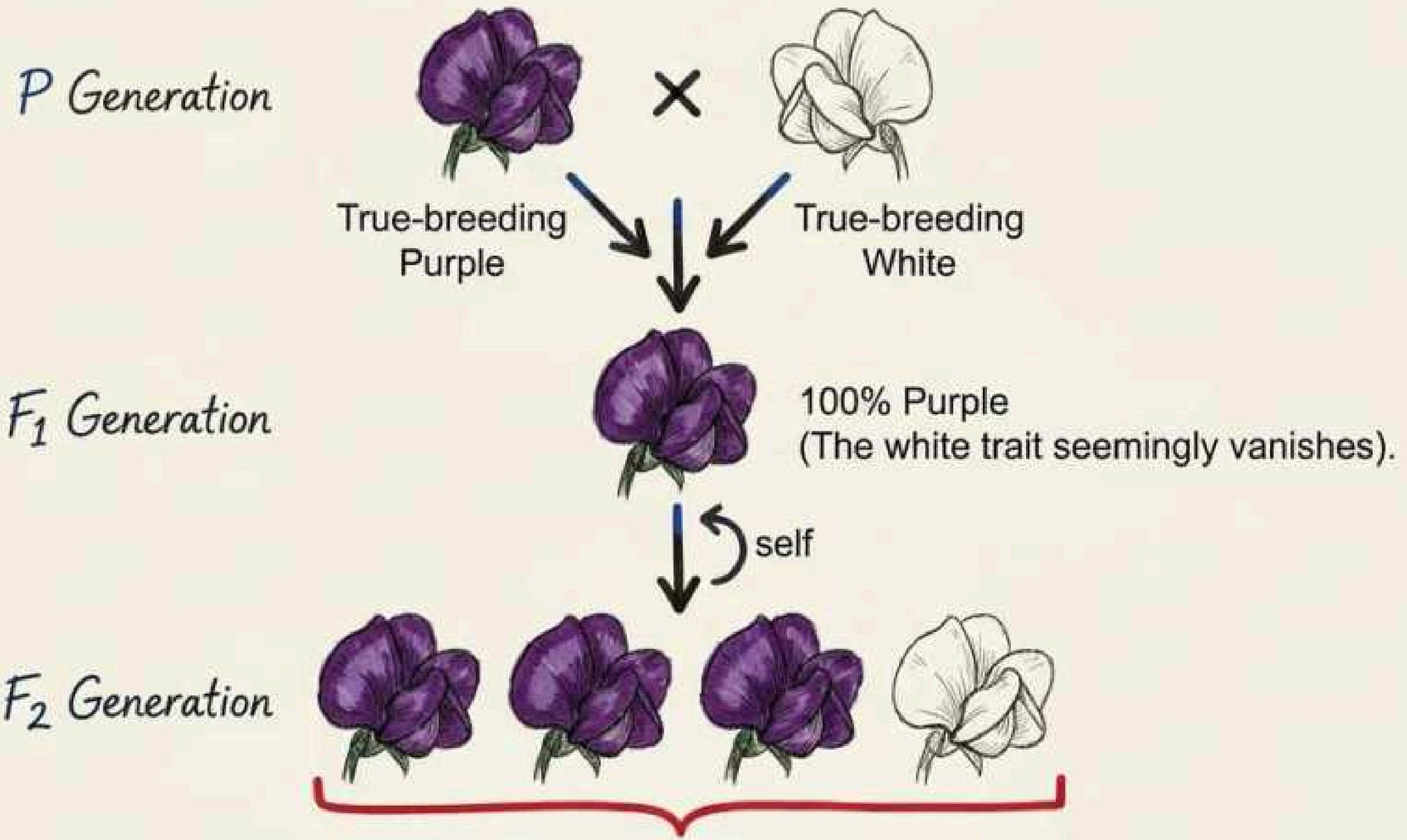


True-breeding baseline
(Produces the exact same trait when self-crossed).



The Foundational Cross

¶ 4.5



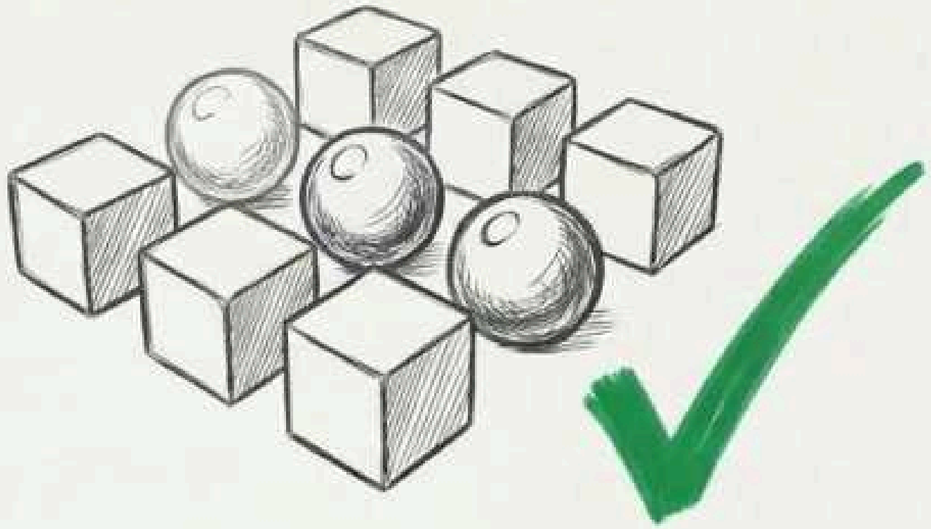
Self-fertilized F1 produces offspring in a precise ratio of 3 Purple : 1 White. (The white trait returns)

Discrete Units vs. Blending

¶ 4.6



Flawed Theory:
Blended inheritance (like mixing paint—traits merge and dilute).



Mendel's Proof:
Heredity passes on discrete units.

Conclusion: The white trait in the F1 generation was merely hidden, not destroyed, allowing it to return unchanged in the F2 generation.

¶ 4.7

The Lexicon of Heredity

$$Trait = Allele_1 + Allele_2$$

Allele: A variant of a factor (one inherited from each parent).

Dominant: Shows up when present.

Recessive: Shows only when two copies are present.

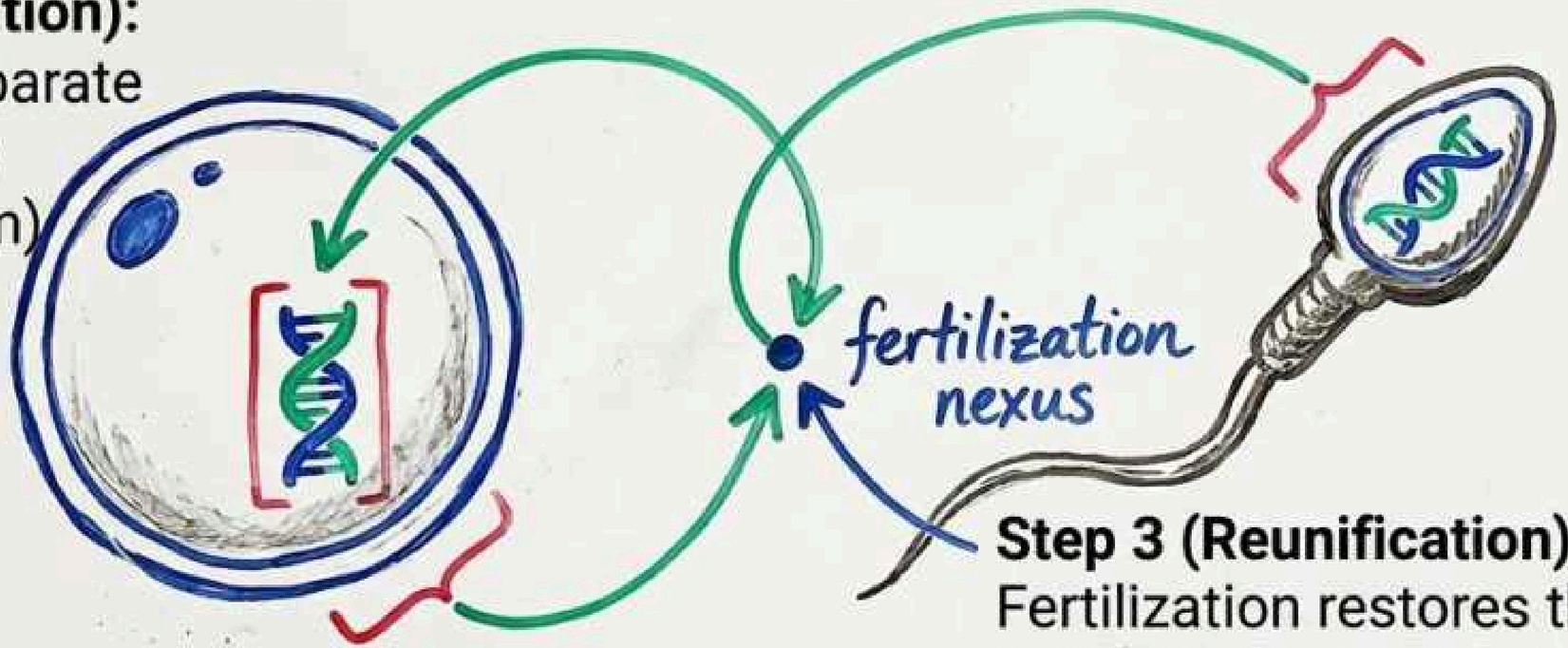
Genotype — The hidden allele pair.

Phenotype — The visible, expressed trait.

The Law of Segregation

¶ 4.8

Step 1 (Separation): Allele pairs separate when gametes (egg and sperm) are formed.



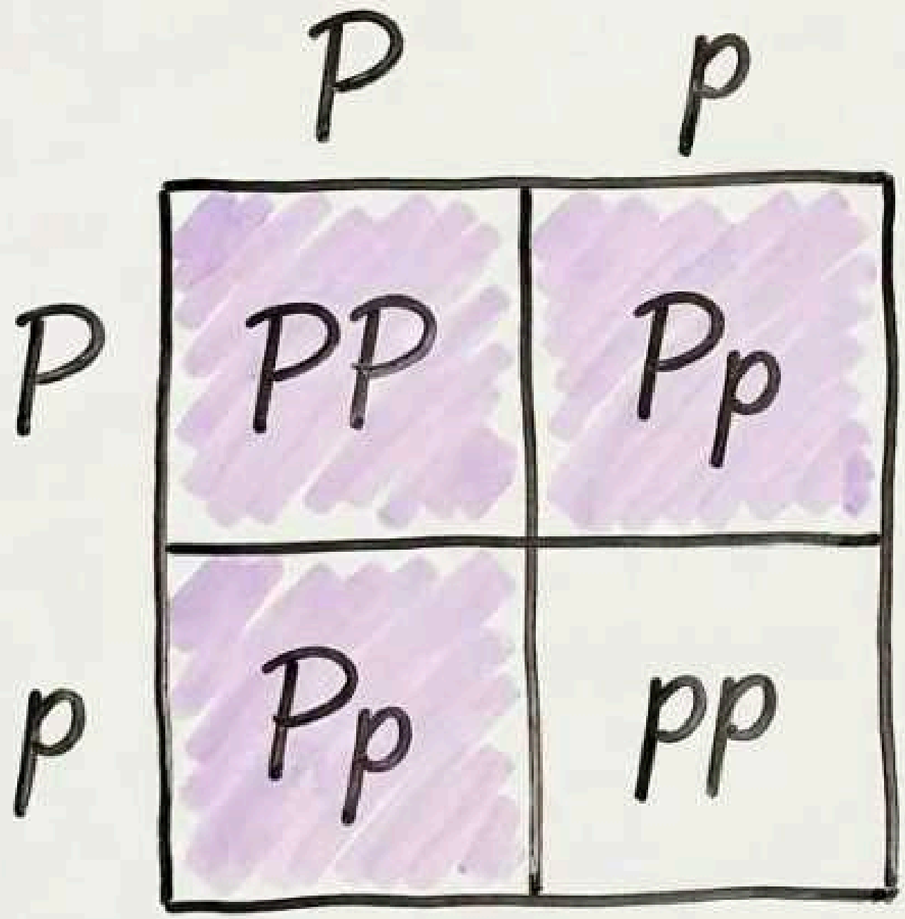
Step 3 (Reunification): Fertilization restores the pair (one from each parent).

Step 2 (Isolation): Each gamete carries exactly n = 1 allele.

Result: This mechanism allows a hidden recessive allele to pass silently through a generation.

Predictive Math: The Punnett Square

¶ 4.9



Input: Cross of Heterozygous (Pp) × Heterozygous (Pp).

Mathematical Output:

P(Purple) = 3/4,
P(White) = 1/4.
} Proh ratio.

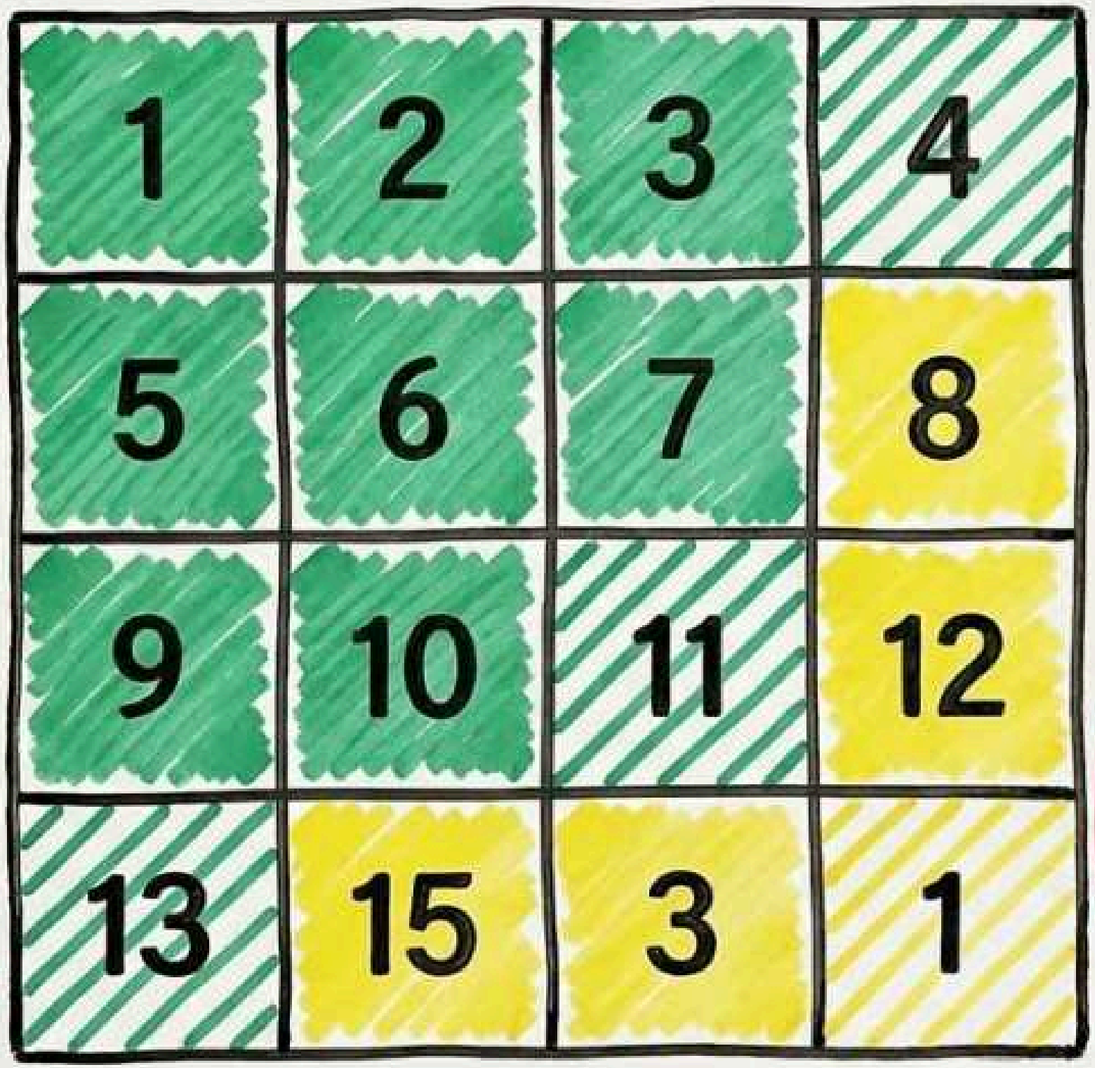
Matches Mendel's exact 3:1 ratio.

Independent Assortment

¶ 4.10

Concept: Alleles for one trait sort into gametes independently of those for another.

Example: Tracking seed shape and seed color simultaneously.



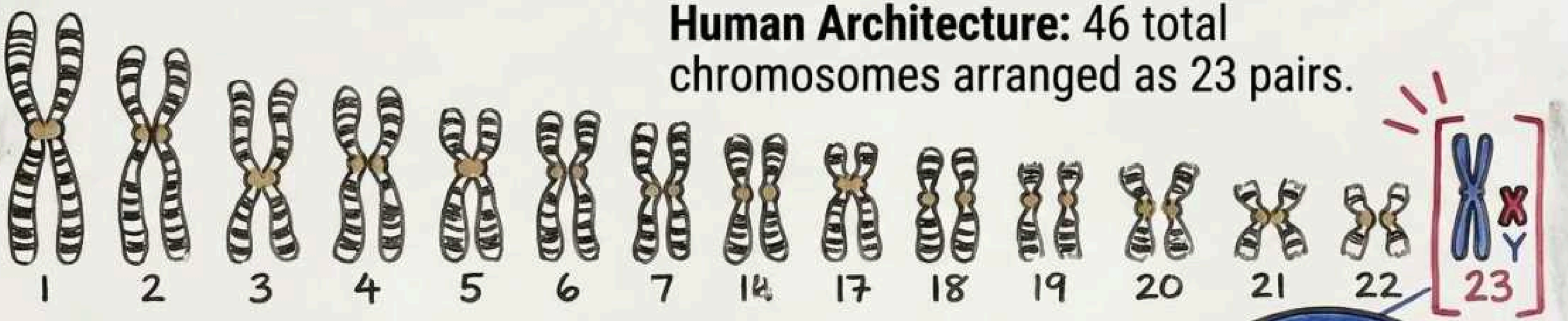
Mathematical Output: Ratio of 9 : 3 : 3 : 1 (from doubly heterozygous parents).

Crucial Condition: This rule holds true when genes sit on different chromosomes.

The Physical Home of Genes

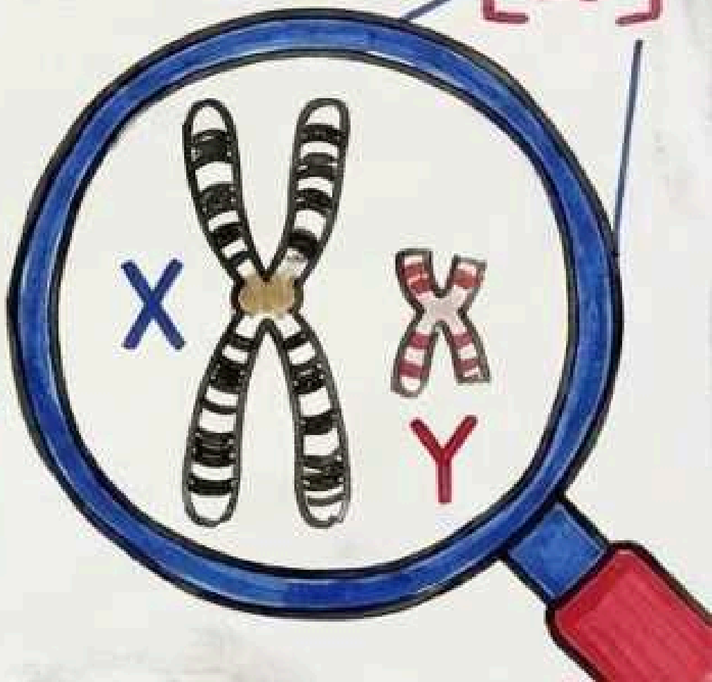
¶ 4.11

Human Architecture: 46 total chromosomes arranged as 23 pairs.



Discovery:
Walter Sutton & Theodor Boveri (1902) proposed the Chromosomal Theory.

Breakdown:
- 22 pairs of Autosomes.
- 1 pair of Sex Chromosomes (Two X chromosomes usually make a female; an X and a Y usually make a male).

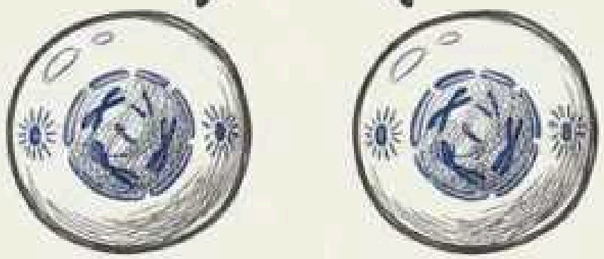


¶ 4.12

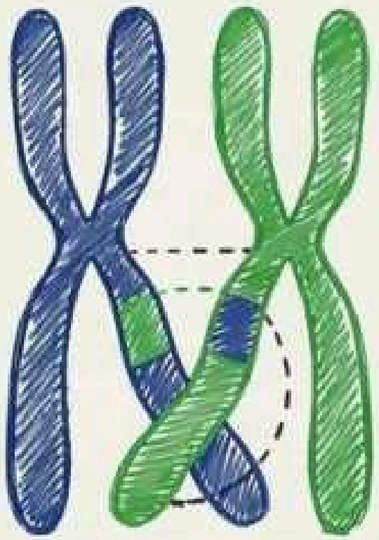
Cellular Division: Mitosis vs. Meiosis



Daughter cells

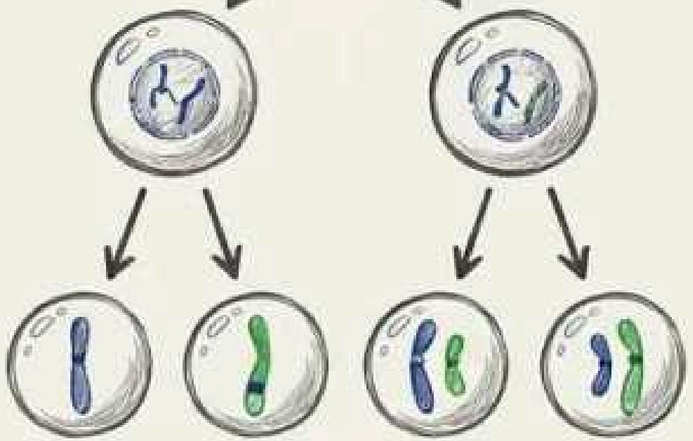


Mitosis Pathway:
1 cell -> divides once -> 2 identical copies.
(Purpose: Growth and repair)



Key Mechanism:
Crossing over—matching chromosomes swap segments, giving each gamete a random mix.





Meiosis Pathway:
1 cell -> divides twice -> 4 distinct gametes, each with half the chromosomes.
(Purpose: Reproduction)

The Mathematics of Uniqueness

Formula 1 (Random Shuffling): $2^{23} > 8{,}000{,}000$ possible gametes from one person.

Formula 2 (Fertilization):

$[\text{Egg } (>8\text{M}) \times \text{Sperm } (>8\text{M})] \approx$ **64 Trillion** unique chromosome combinations.

Formula 3 (Crossing Over):

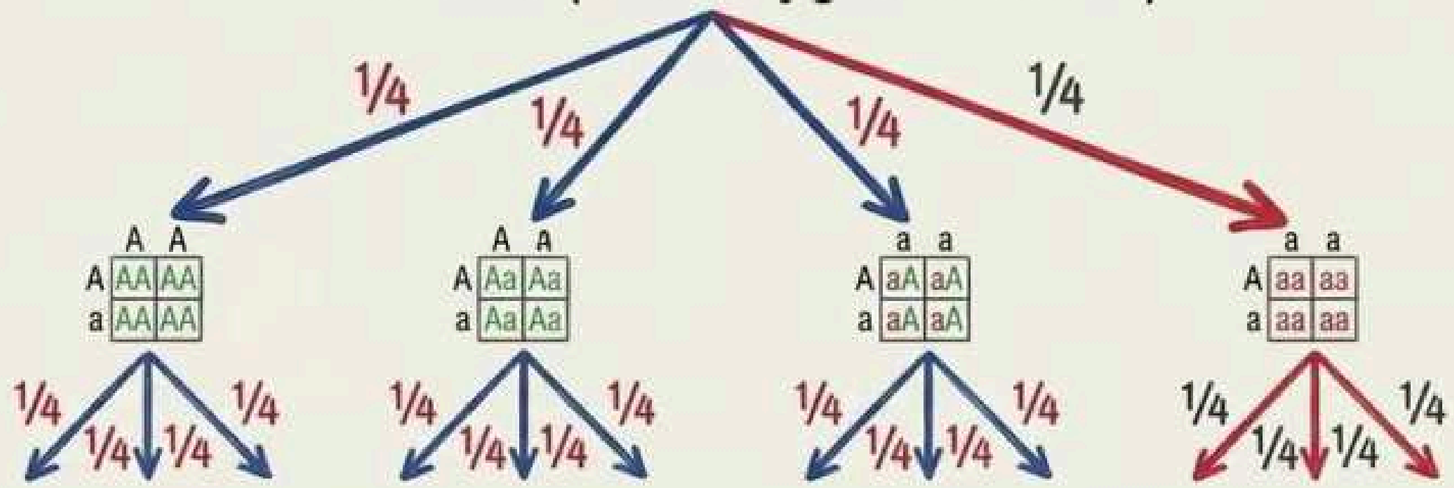
64 Trillion $\times \infty$ (Crossing over) = Genetic Uniqueness.

Conclusion: This math explains why siblings differ, and why, apart from identical twins, every person is genetically unique.

Probabilities, Not Promises



The Metaphor: Like a coin that has landed heads three times, the next toss is still fair.



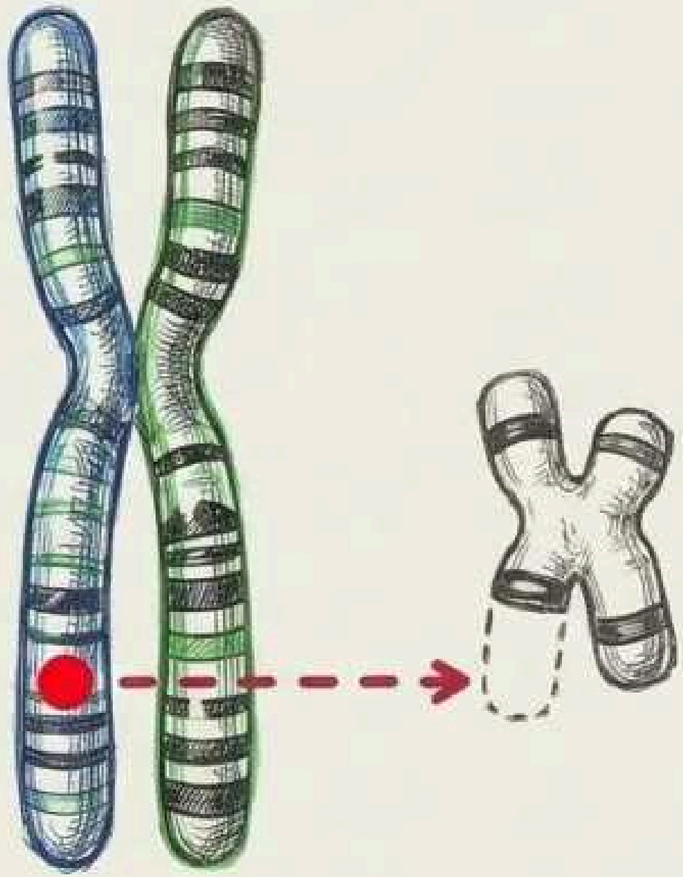
The Rule of Independence: Each child is a completely independent statistical event.

The Math: P(recessive) = 1/4 every single time for heterozygous parents, regardless of earlier children.

The Reality: A single family can defy the average (having four children with a trait, or none), but large populations always follow the Mendelian ratio.

Sex-Linked Traits

The Asymmetry:
The X chromosome carries many genes that the short Y chromosome lacks.



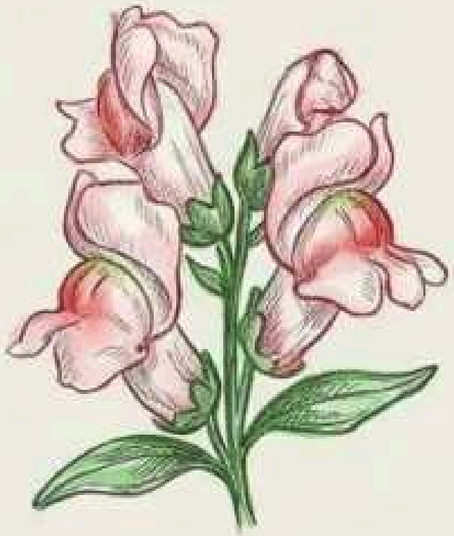
The Consequence:
Males (XY) will show a recessive trait if they inherit just one copy their single X chromosome.

Examples: Red-green color blindness and haemophilia are X-linked, making them far more common in males.

¶ 4.16

Beyond Mendelian Dominance

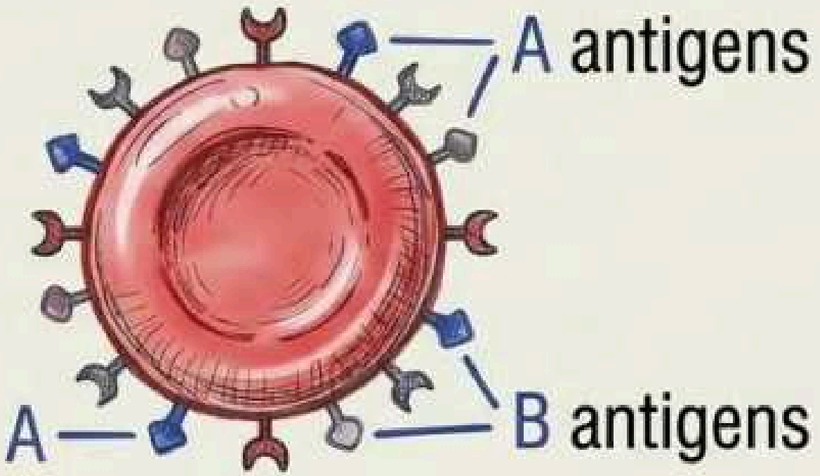
Incomplete Dominance



The heterozygote falls in between the parents.

Example: Red + White parents → Pink snapdragons.

Codominance



Both alleles show fully at the same time.

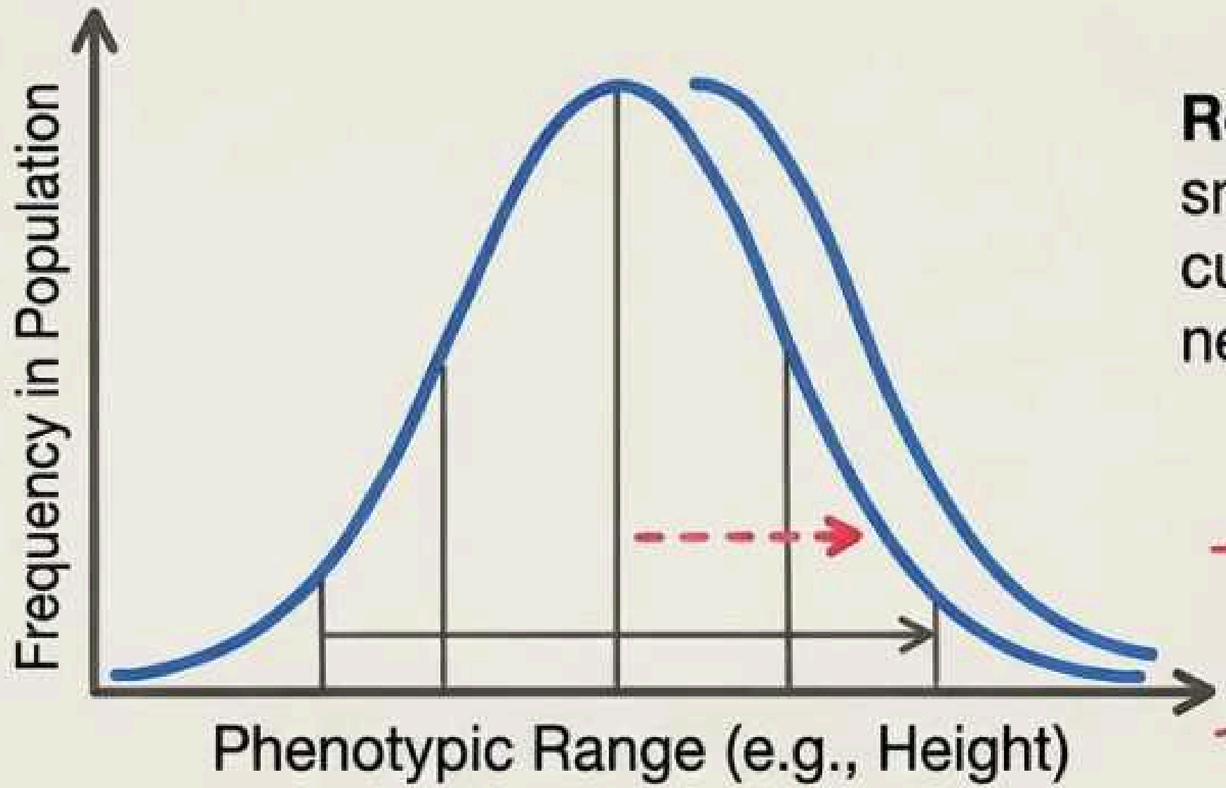
Example: Human ABO blood groups (3 alleles exist in the population, but a single person carries 2).

¶ 4.17

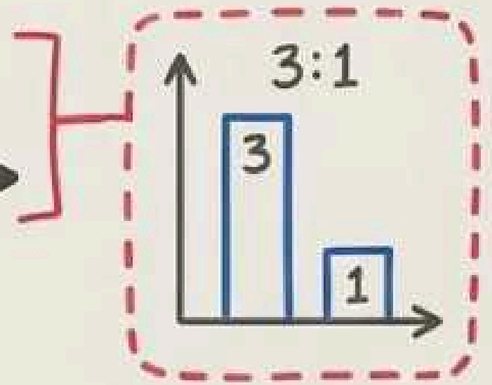
Polygenic Traits & Environment

Definition: Traits influenced by many genes, each with a small effect.

Examples: Human height and skin color.



Result: Traits form a smooth range (bell curve) rather than a few neat categories.

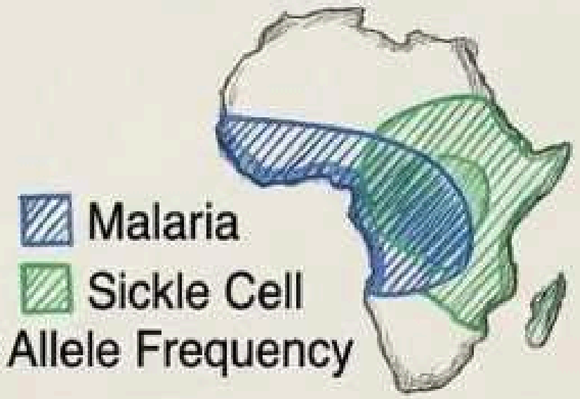


The Environmental Variable:
External factors (like nutrition) add more variation, shifting the curve.

¶ 4.18

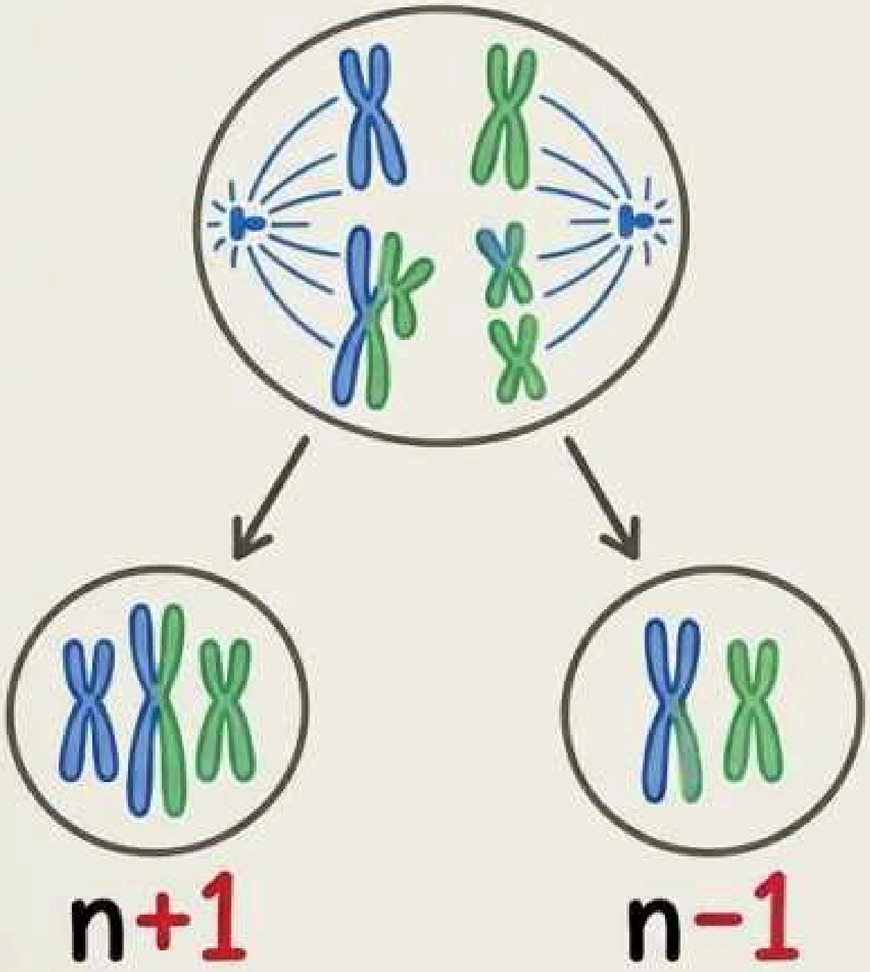
Mendelian Patterns in Humans

Recessive Conditions	Dominant Conditions	Carrier Dynamics
Cystic fibrosis. Requires 2 copies of the allele to express the disease.	Huntington's disease. 1 copy is enough to express the disease.	People with 1 copy of a recessive allele are carriers. **Evolutionary Advantage:** Carriers of the sickle cell allele have protection against malaria, explaining why the allele persists.



¶ 4.19

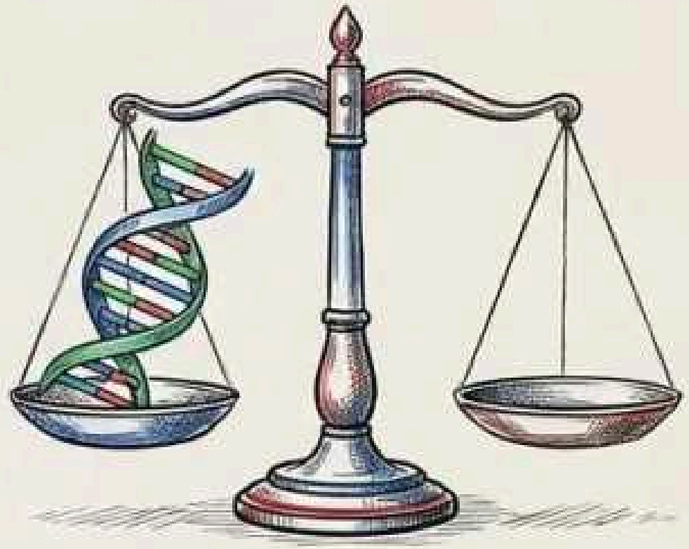
Nondisjunction & Chromosome Number



- **The Error:** Chromosomes fail to separate properly during meiosis.
- **The Result:** Gametes carry an extra or missing chromosome.
- **Example:** Down syndrome (usually resulting from three copies of chromosome 21).
- **Clinical Application:** Genetic counsellors help families understand these risks and interpret what tests can and cannot tell them.

¶ 4.20

The Ethics of Genetics



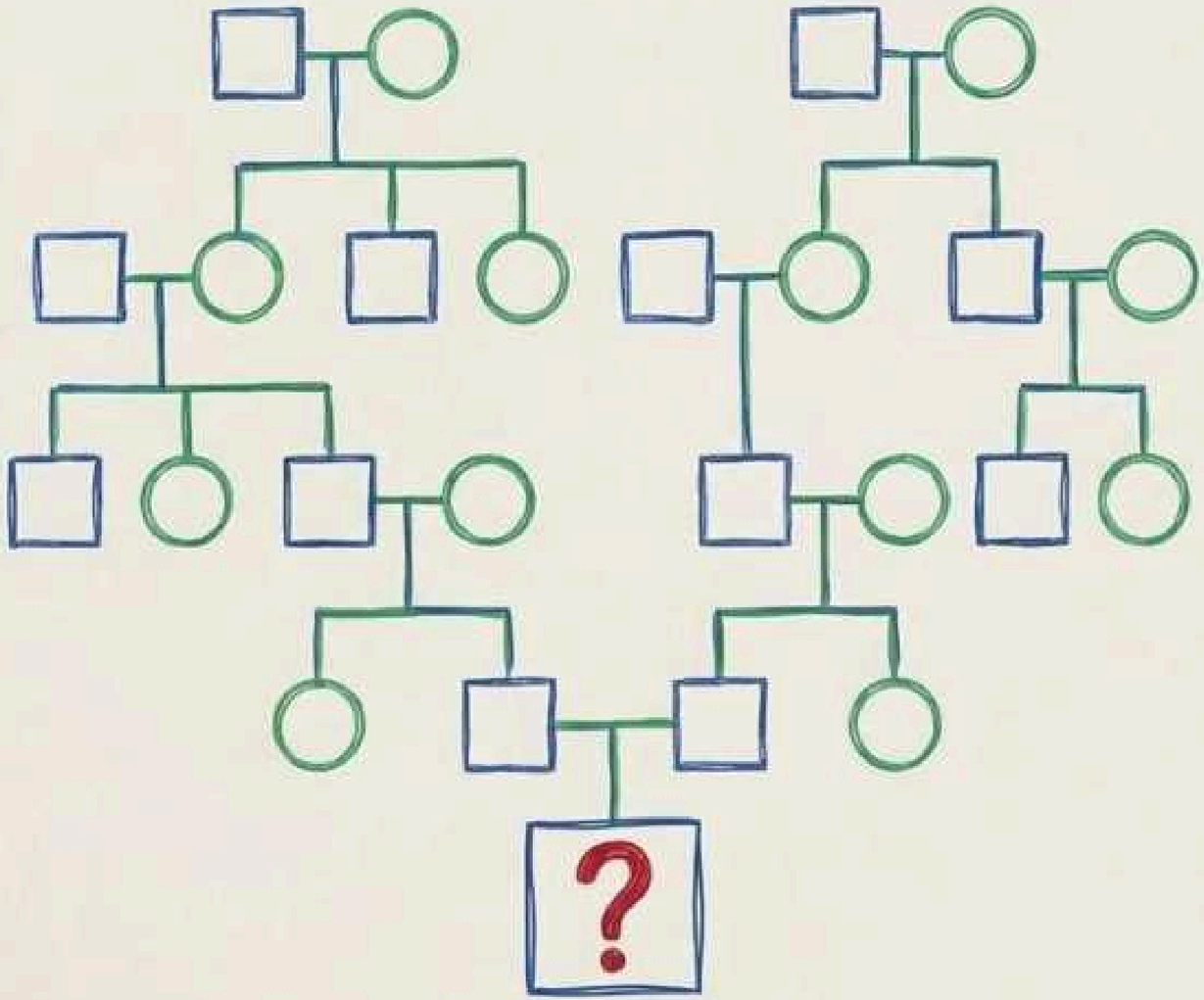
Key Questions:

- Should embryos be screened for disease?
- Should anyone edit the genes of future children?
- Who owns your genetic data, and who may use it?

Science can tell us what is possible.
It cannot, by itself, tell us what we should do.

¶ 4.21

Application: Your Genetic Blueprint

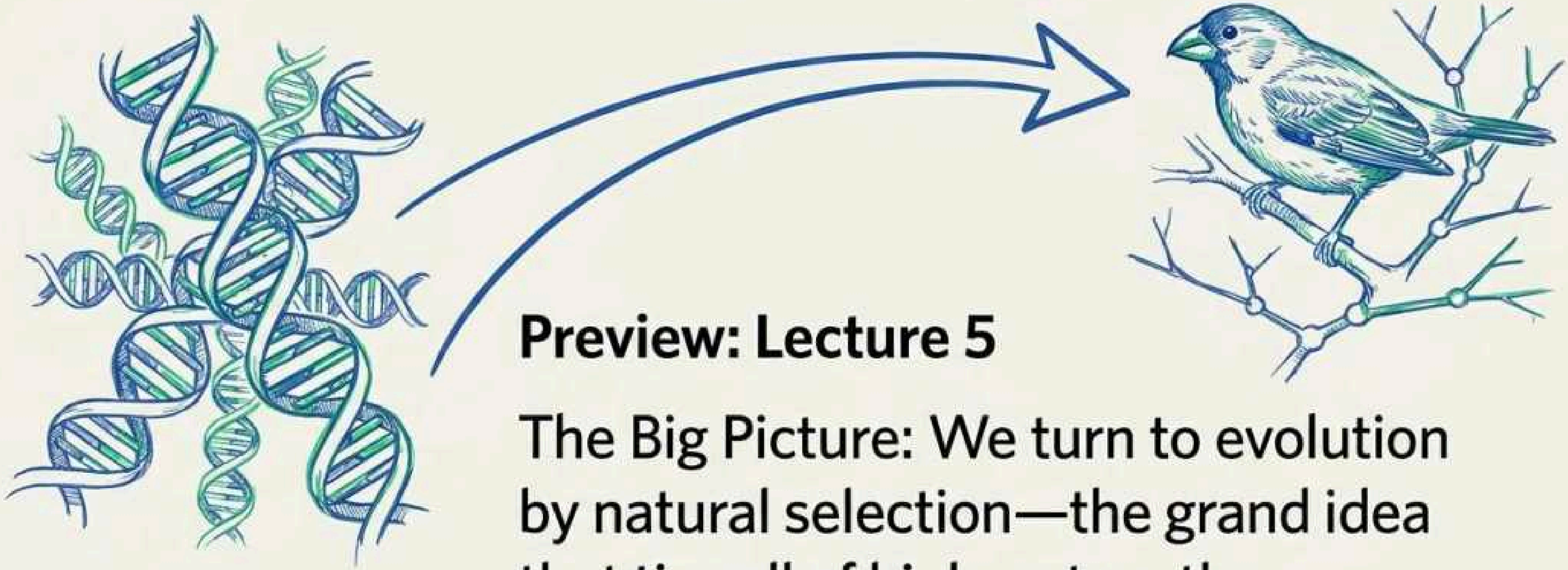


The Challenge: Choose one trait in your own family (eye color, a blood type, or a specific talent).

Analytical Prompt 1: Is it likely to be controlled by one gene or many?

Analytical Prompt 2: How might the environment play a part in its expression?

Next: Natural Selection



Preview: Lecture 5

The Big Picture: We turn to evolution by natural selection—the grand idea that ties all of biology together.