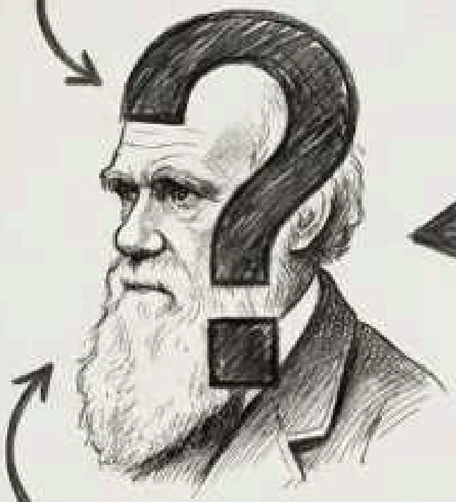
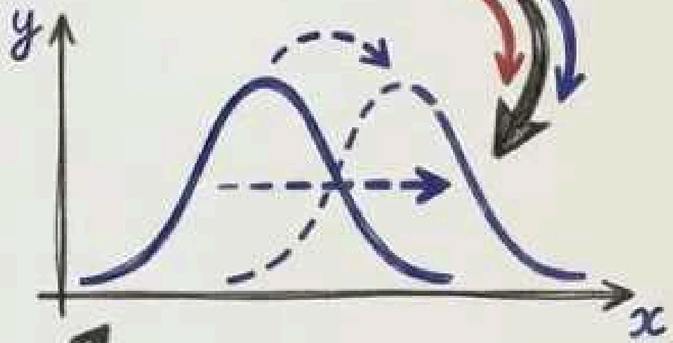
Lecture 2: Genes and Evolution

¶ 2.1

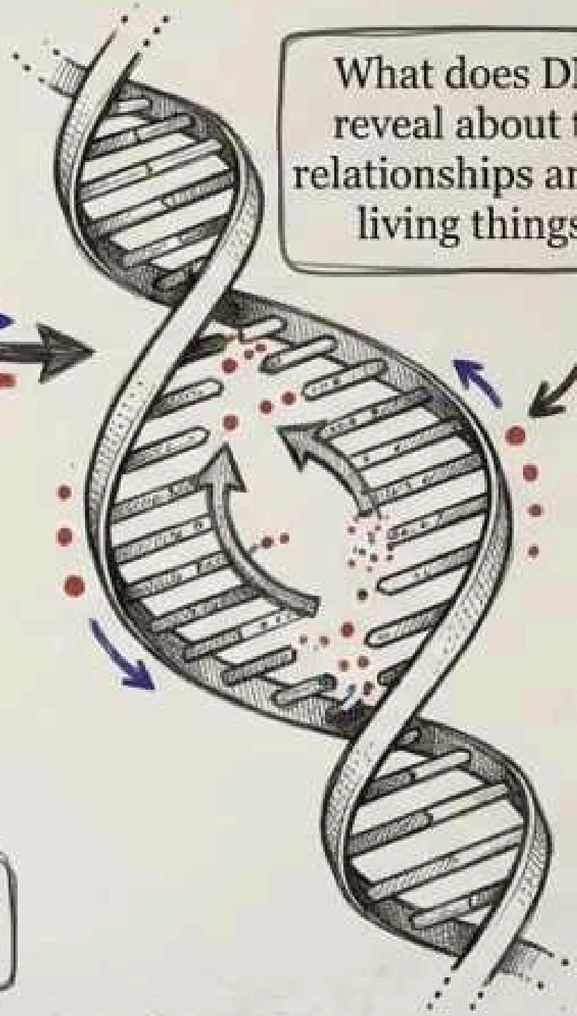
How does inheritance work, and why did it puzzle Darwin?



How does inheritance work, and why did it puzzle Darwin?



What forces change the genetic makeup of populations?



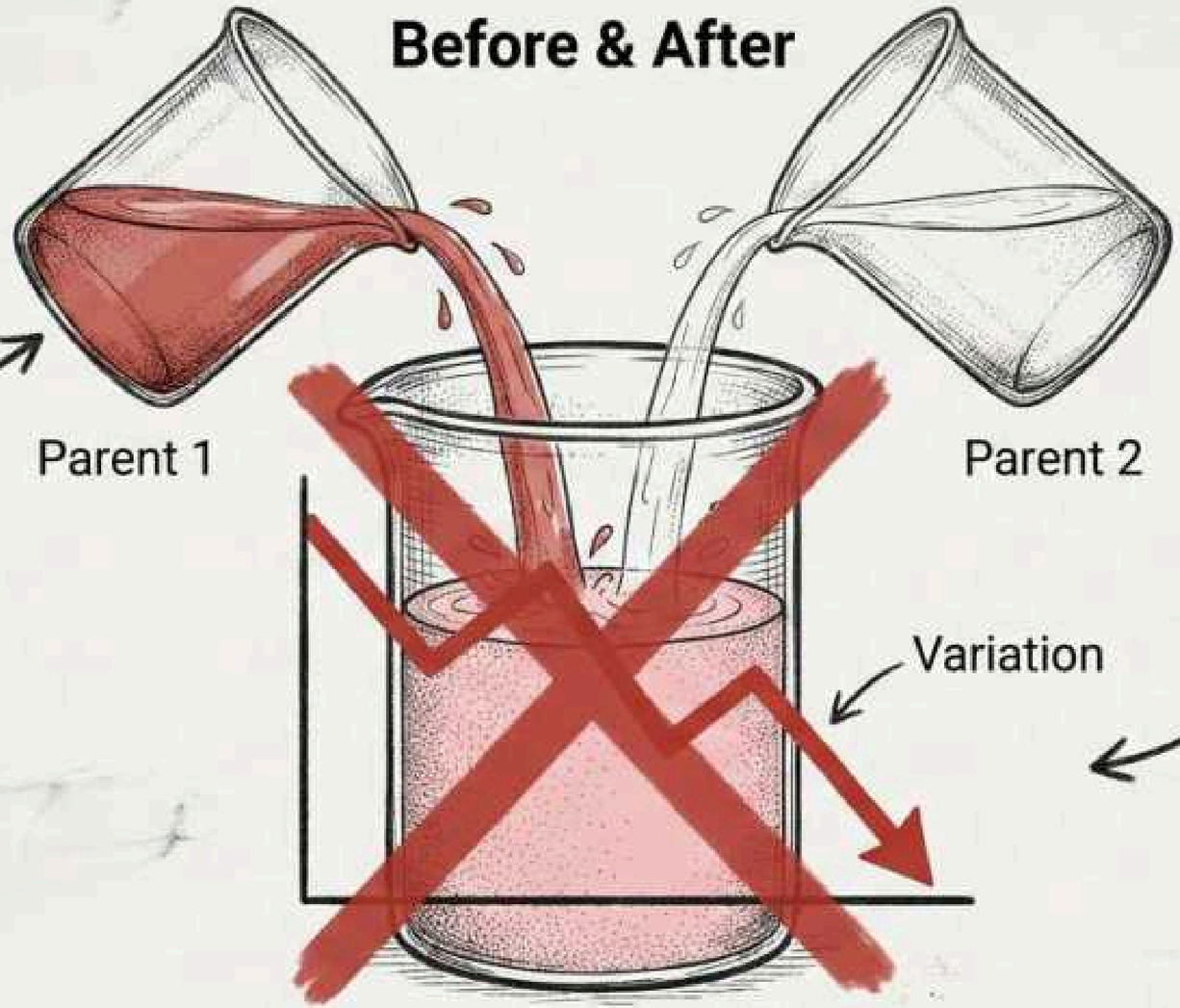
What does DNA reveal about the relationships among living things?

Blending inheritance mathematically erases variation

¶ 2.2

The 19th-century belief:

Offspring are a smooth mix of parents, like mixing paint.



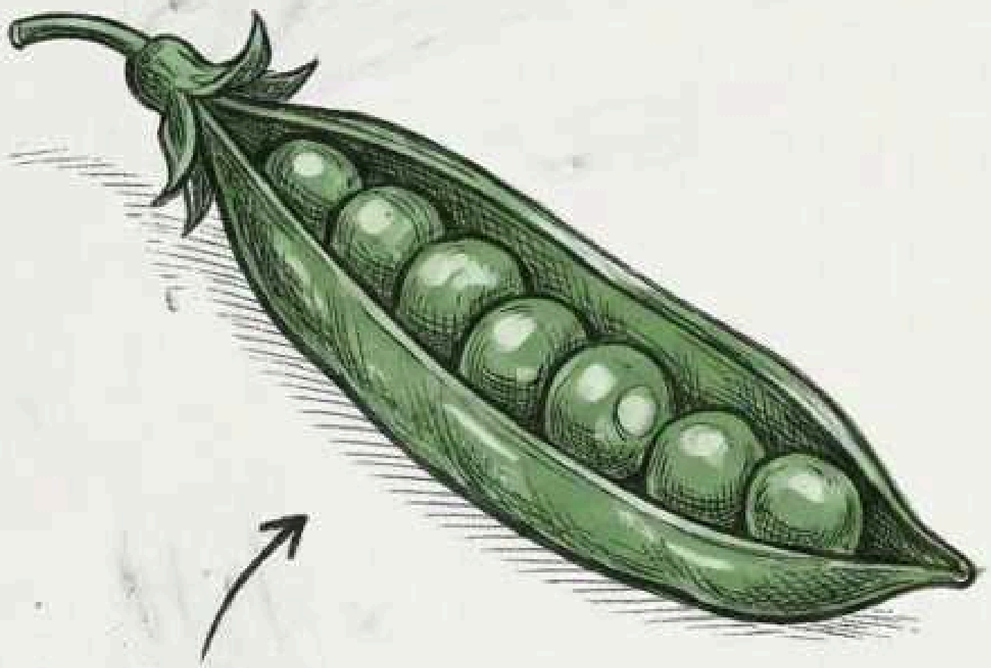
The Paradox for Darwin:

Blending quickly erases variation.

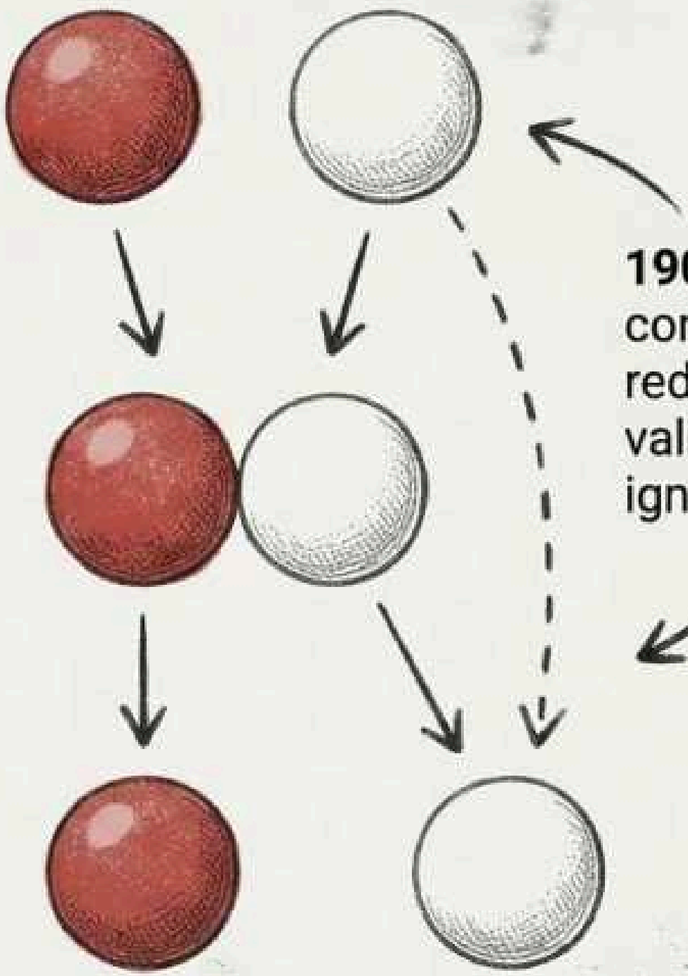
Without variation, natural selection has absolutely nothing to work on.

Mendel discovered that traits are passed on as separate units

¶ 2.3



1866 (Brno): Monk Gregor Mendel publishes results proving traits do not blend. They are separate units (genes). Recessive traits can disappear and reappear intact.



1900: The scientific community rediscovers and validates Mendel's ignored work.

¶ 2.4

Forging the Modern Synthesis in the 20th Century

1930s and 1940s

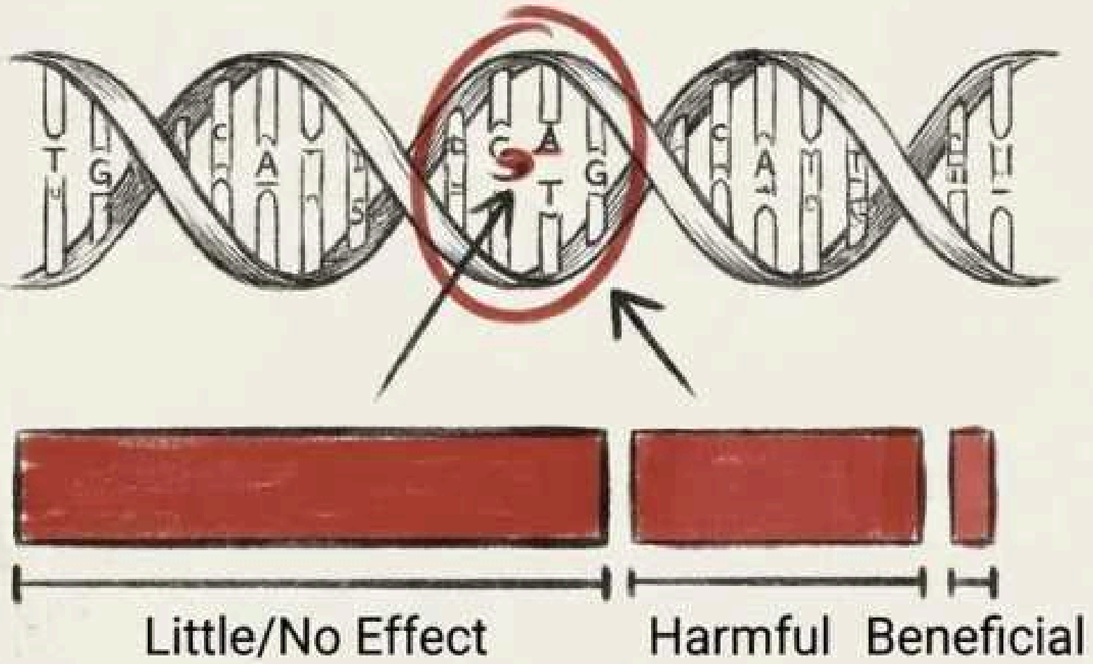
[Darwin's Natural Selection] + [Mendel's Genetics] + [The Mathematics of Populations] = The Modern Synthesis

The architects of the synthesis:
Ronald Fisher, J. B. S. Haldane, Sewall Wright, Theodosius Dobzhansky, and Ernst Mayr.

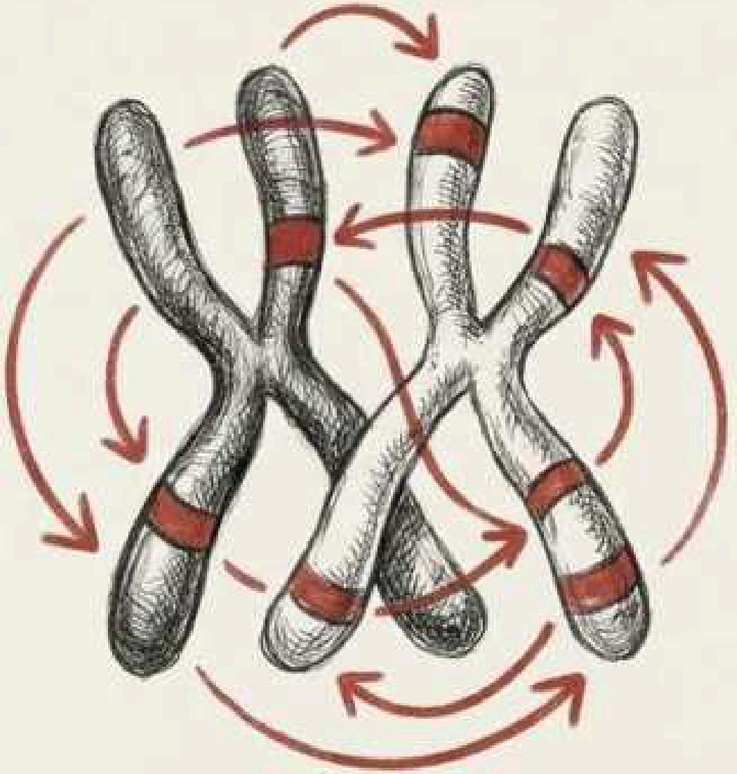
This combination remains the absolute foundation of evolutionary biology today.

¶ 2.5

The origin and arrangement of genetic variation



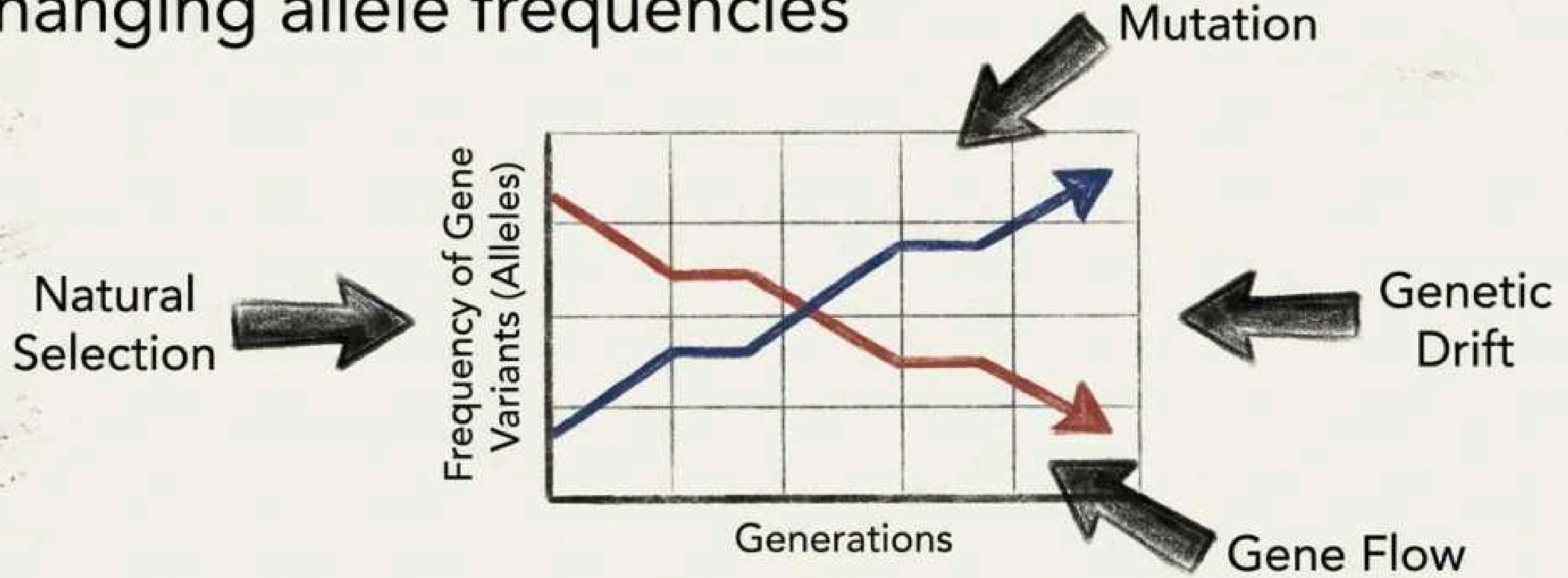
Mutation: The ultimate source of new variation (changes in the DNA sequence).



Reproduction: Shuffles existing variation into novel combinations, providing raw material for selection.

Evolution is mathematically defined by changing allele frequencies

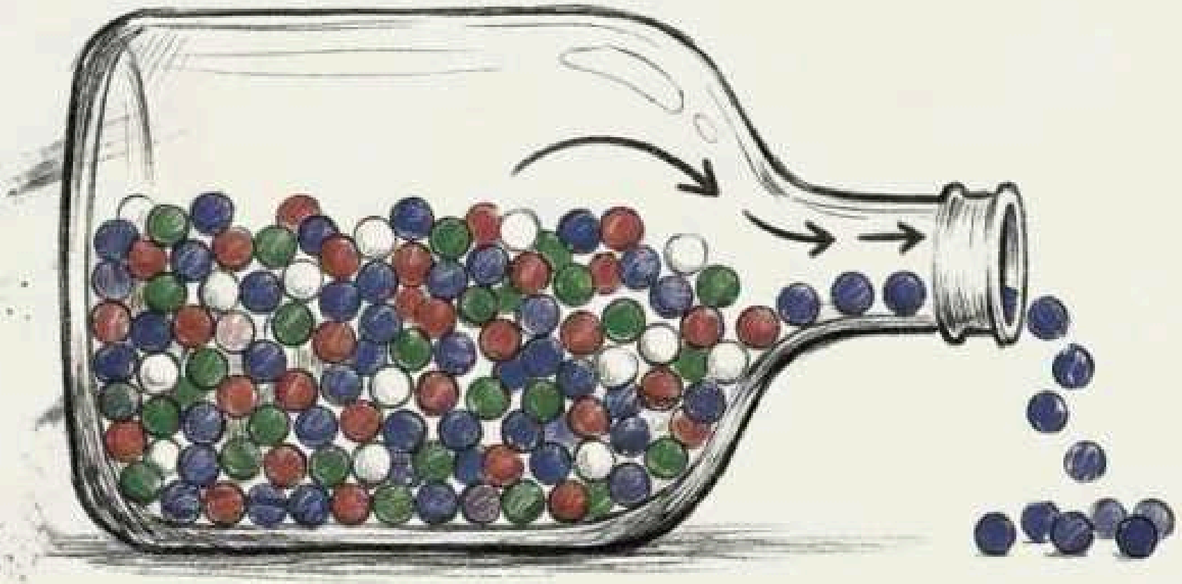
¶ 2.6

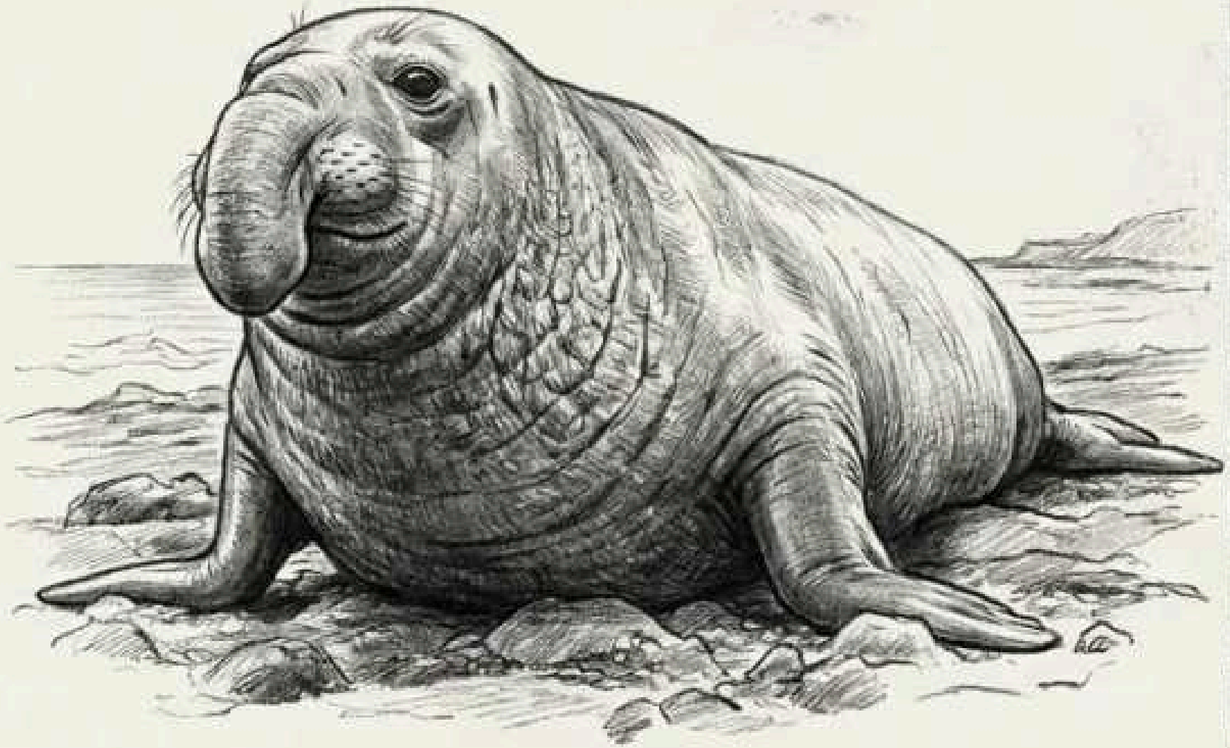


Evolution = A change in the frequency of alleles in a population over generations.

Genetic drift and the vulnerability of bottlenecks

¶ 2.7



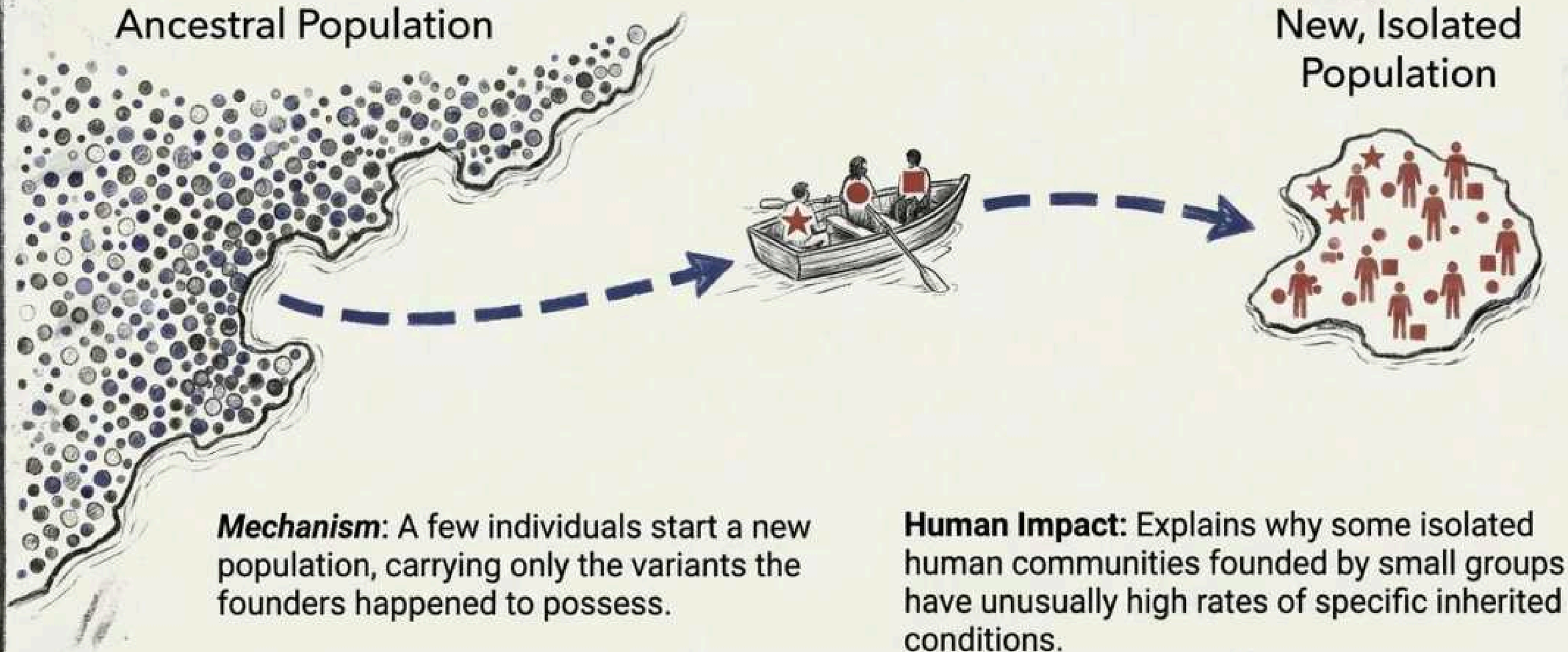


Drift Definition: Random change in allele frequencies due entirely to chance (who happens to reproduce). Strongest in small populations.

The Elephant Seal Case: Hunted to just 20–100 individuals in the 1890s. Today, the population is well over 100,000, but they possess almost zero genetic diversity due to the historic bottleneck.

The Founder Effect locks in random initial variations

¶ 2.8



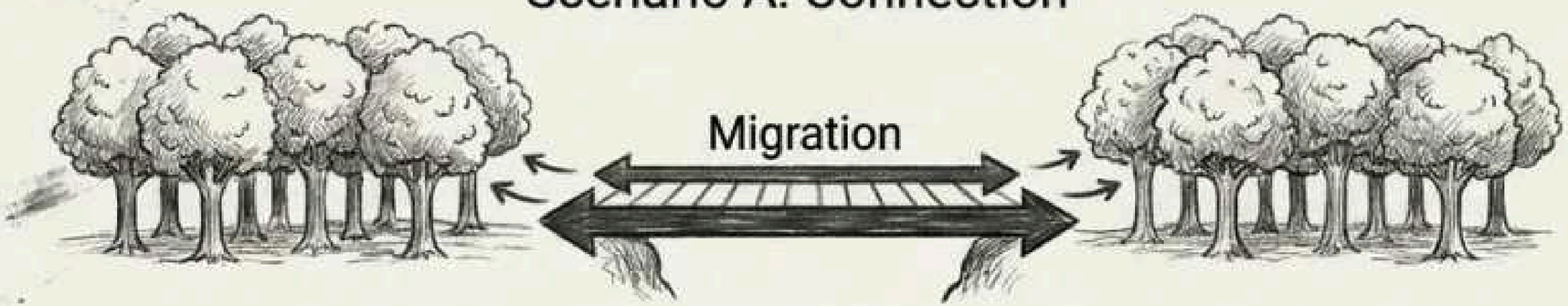
Mechanism: A few individuals start a new population, carrying only the variants the founders happened to possess.

Human Impact: Explains why some isolated human communities founded by small groups have unusually high rates of specific inherited conditions.

Gene flow homogenizes; severance creates species

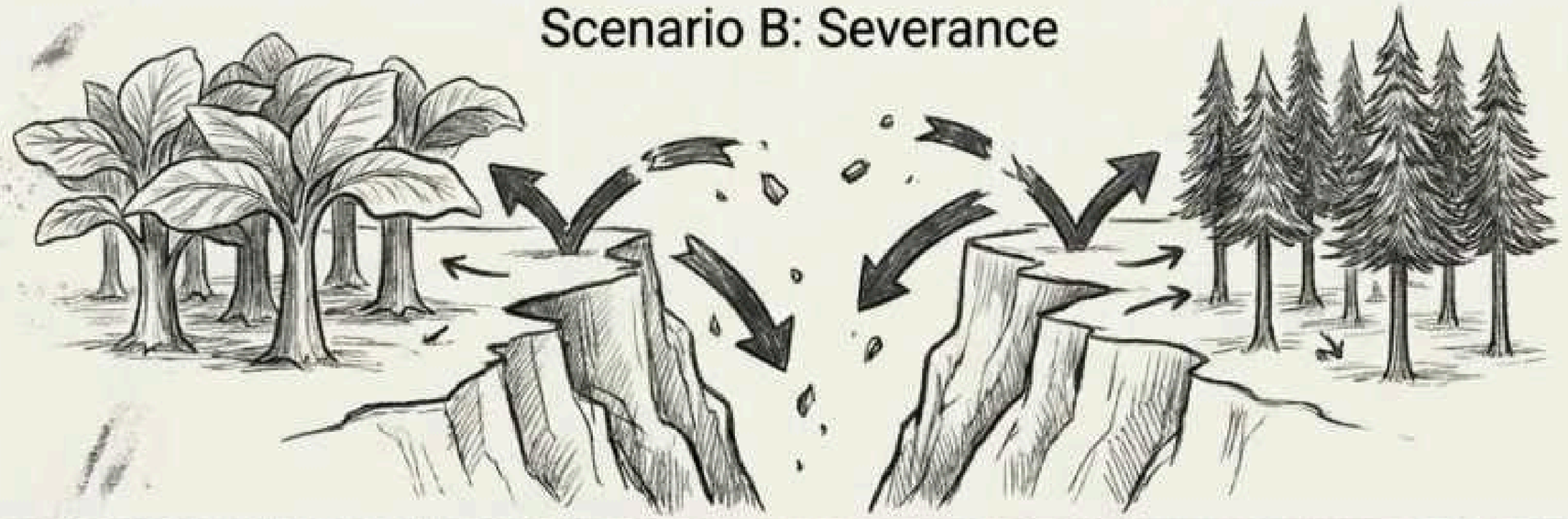
¶ 2.9

Scenario A: Connection



Gene Flow: Movement of genes through migration and interbreeding makes populations more similar.

Scenario B: Severance



The Break: Cutting off gene flow allows populations to drift apart and adapt to local conditions—the vital first step toward forming new species.

The Hardy-Weinberg baseline of perfect stasis

¶ 2.10

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$



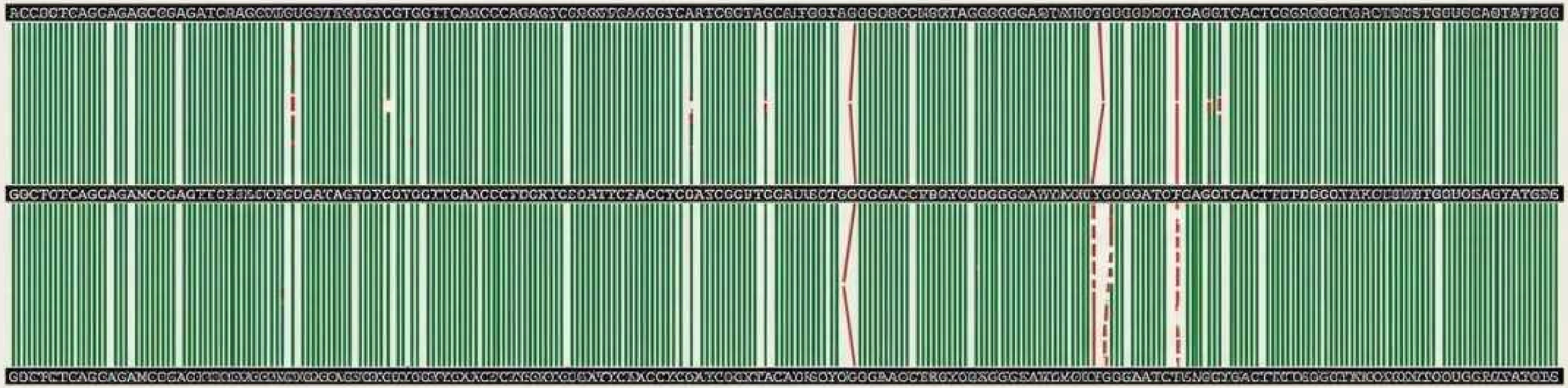
1908 Discovery: Mathematician G. H. Hardy and physician Wilhelm Weinberg independently formulated this principle.

The Null Hypothesis: Allele frequencies stay completely constant if no evolutionary forces act. When real populations depart from this math, it proves that selection or drift is actively occurring.

The universal code points to a common origin

¶ 2.11

Human

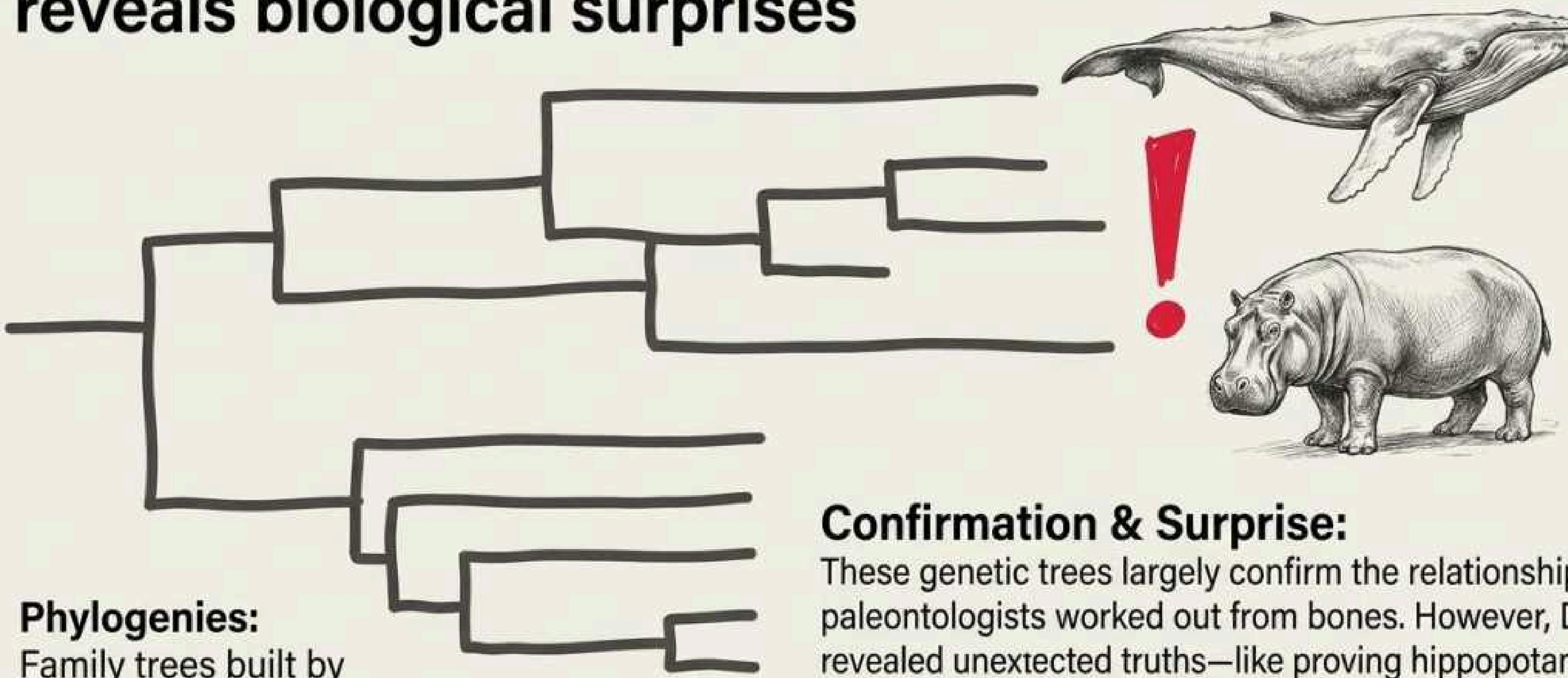


Chimpanzee

The Universal Code: All living things (with minor exceptions) run on the exact same genetic code.	**Direct Comparison:** The more closely related two species are, the more similar their DNA. Where directly compared, human and chimpanzee sequences are roughly 98% to 99% identical.

¶ 2.12

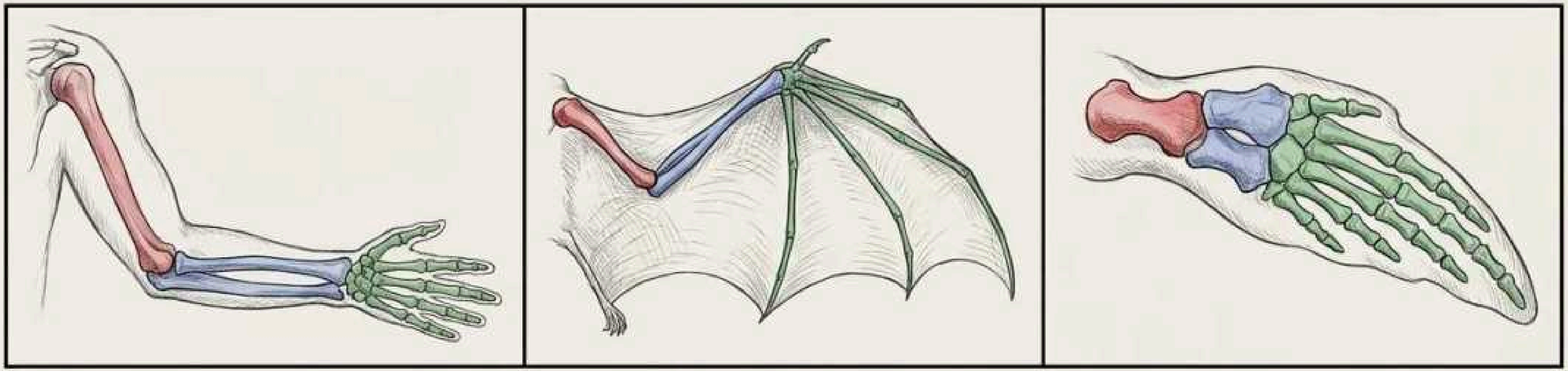
DNA builds family trees and reveals biological surprises



Phylogenies:
Family trees built by comparing DNA.

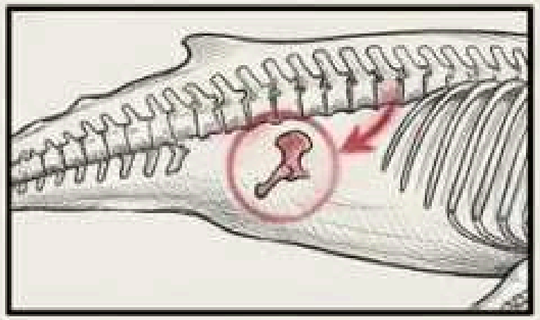
Confirmation & Surprise:
These genetic trees largely confirm the relationships paleontologists worked out from bones. However, DNA revealed unextected truths—like proving hippopotamuses are the closest living animal relatives to whales.

Homologous and vestigial structures record deep history

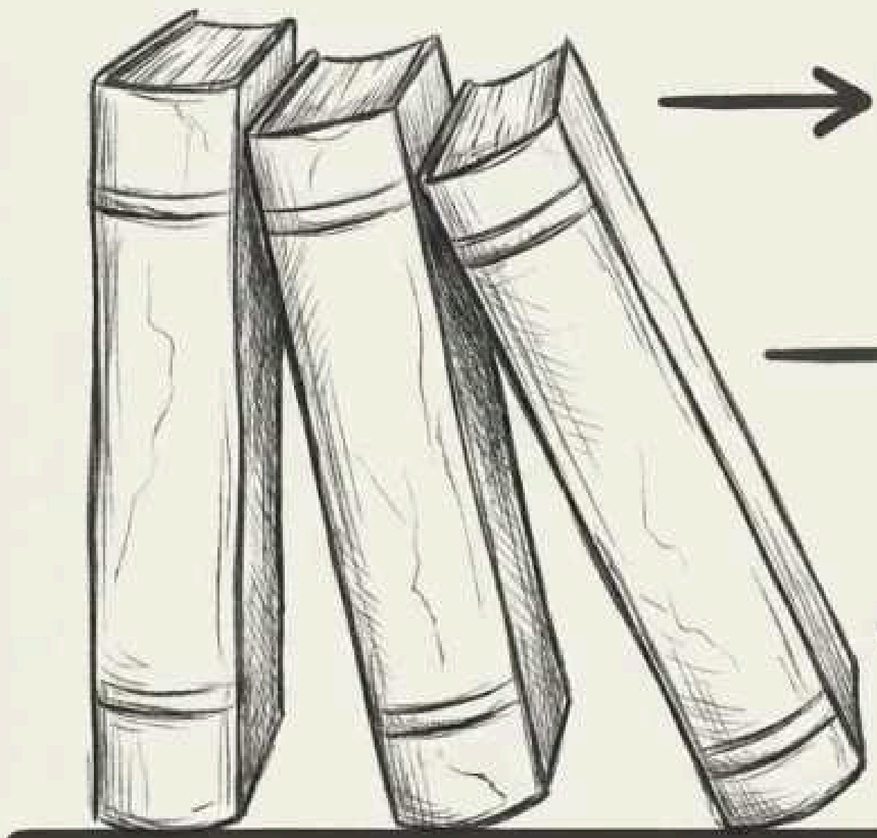


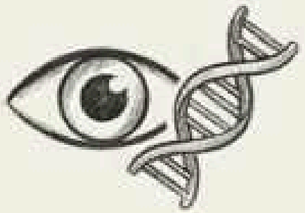
Homologous: Makes perfect sense only as an inheritance from a common ancestor.

Vestigial: Evolutionary leftovers, like the tiny hip bones of whales or the human tailbone.



Expanding the evolutionary framework

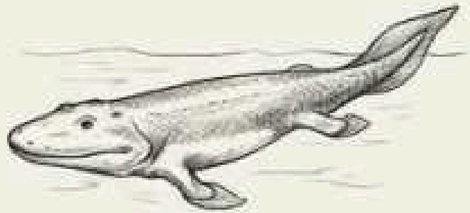




1976: Richard Dawkins's *The Selfish Gene* – Popularized the gene's-eye view of evolution.



2006: Sean B. Carroll's *The Making of the Fittest* – Explains the molecular DNA evidence.



2008: Neil Shubin's *Your Inner Fish* – Traces the deep evolutionary history of the human body.

Synthesis Exercise: Distinguishing the forces of change

Explain the difference between these two forces, and provide one real-world example where drift best explains a common trait.

Natural Selection (Adaptive)	Genetic Drift (Random)
.....	.....
.....	.....
.....	.....
.....	.....



Based on today's lecture, explain exactly why small populations are especially vulnerable to genetic forces.

Next time — Species and the History of Life. →