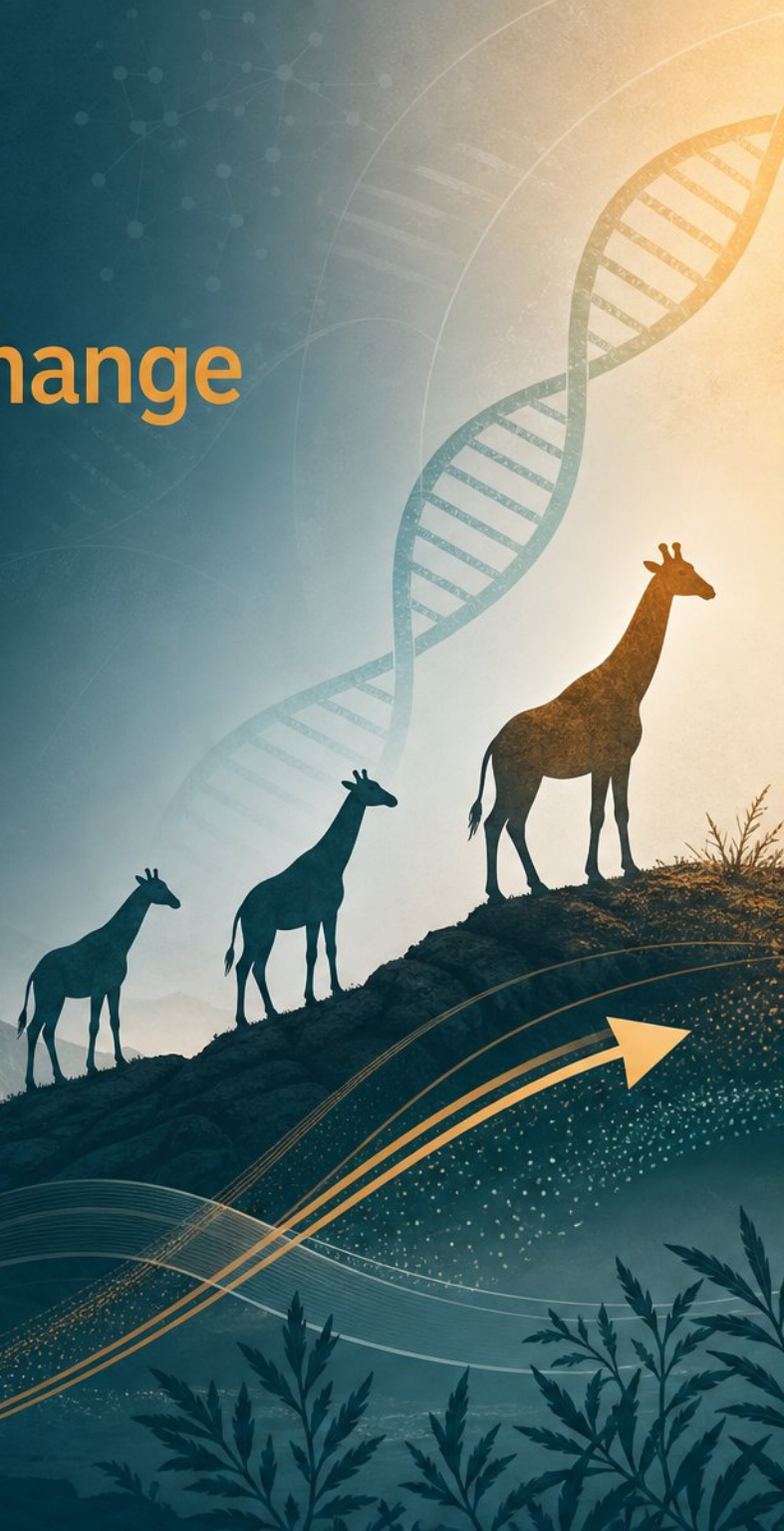
Natural Selection:
Variation, Survival, and Change

- **Define** the full training scope: heritable variation, differential survival, reproduction drive population change over generations.
- **Preview** the structure: foundations, sources of variation, selection pressures, adaptation, population genetics, evidence, misconceptions, applications.
- **Distinguish** natural selection as a mechanism from evolution as broader change in allele frequencies over time.



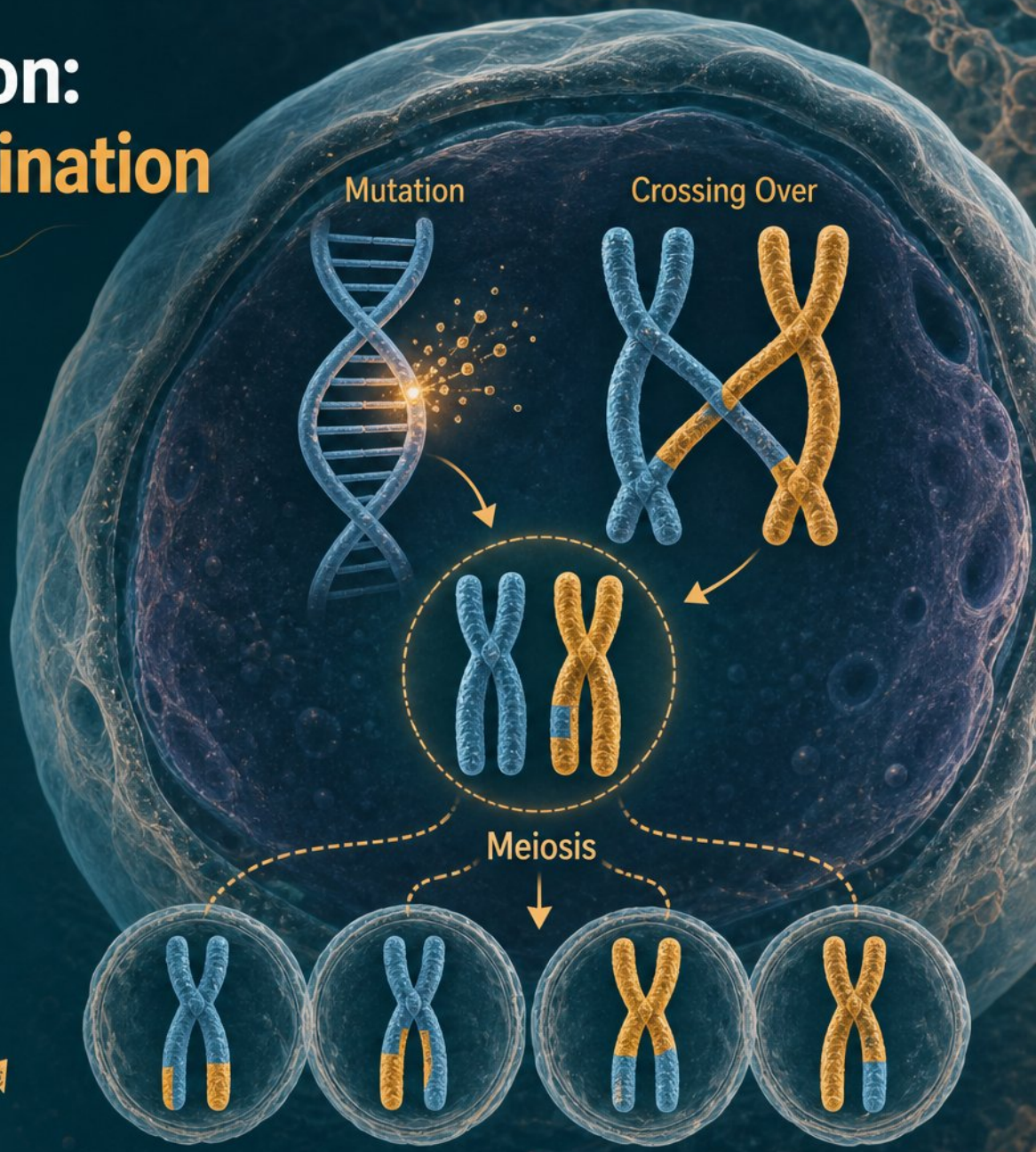
Foundations: Darwin, Wallace, and the Core Logic

- Darwin and Wallace independently formulated natural selection in the mid-19th century
- Malthusian population pressure inspired the struggle for existence concept
- Three necessary conditions: variation, inheritance, differential reproductive success
- Overproduction leads to competition; favorable traits become more common over generations

The Source of Variation: Mutation and Recombination

- Mutation is the ultimate source of new alleles; recombination shuffles existing variation
- Genetic variation arises randomly, not directed by an organism's need or fitness
- Independent assortment and crossing over during meiosis create new gene combinations
- Genotype is the genetic makeup; phenotype is the observable trait, often polygenic
- Only germline mutations in reproductive cells are heritable and relevant to evolution

The Genetic Dice Roll



Selection Pressures:

How the Environment Filters Variation

- **Biotic and abiotic pressures:** predation, climate, competition, disease, human activity
- **Stabilizing selection:** favors the average phenotype, reduces extremes
- **Directional selection:** shifts the population toward one extreme phenotype
- **Disruptive selection:** favors both extremes, selects against the intermediate
- **Relative fitness depends on** the specific environment, not absolute strength

Adaptation:
Traits Shaped by Differential Survival

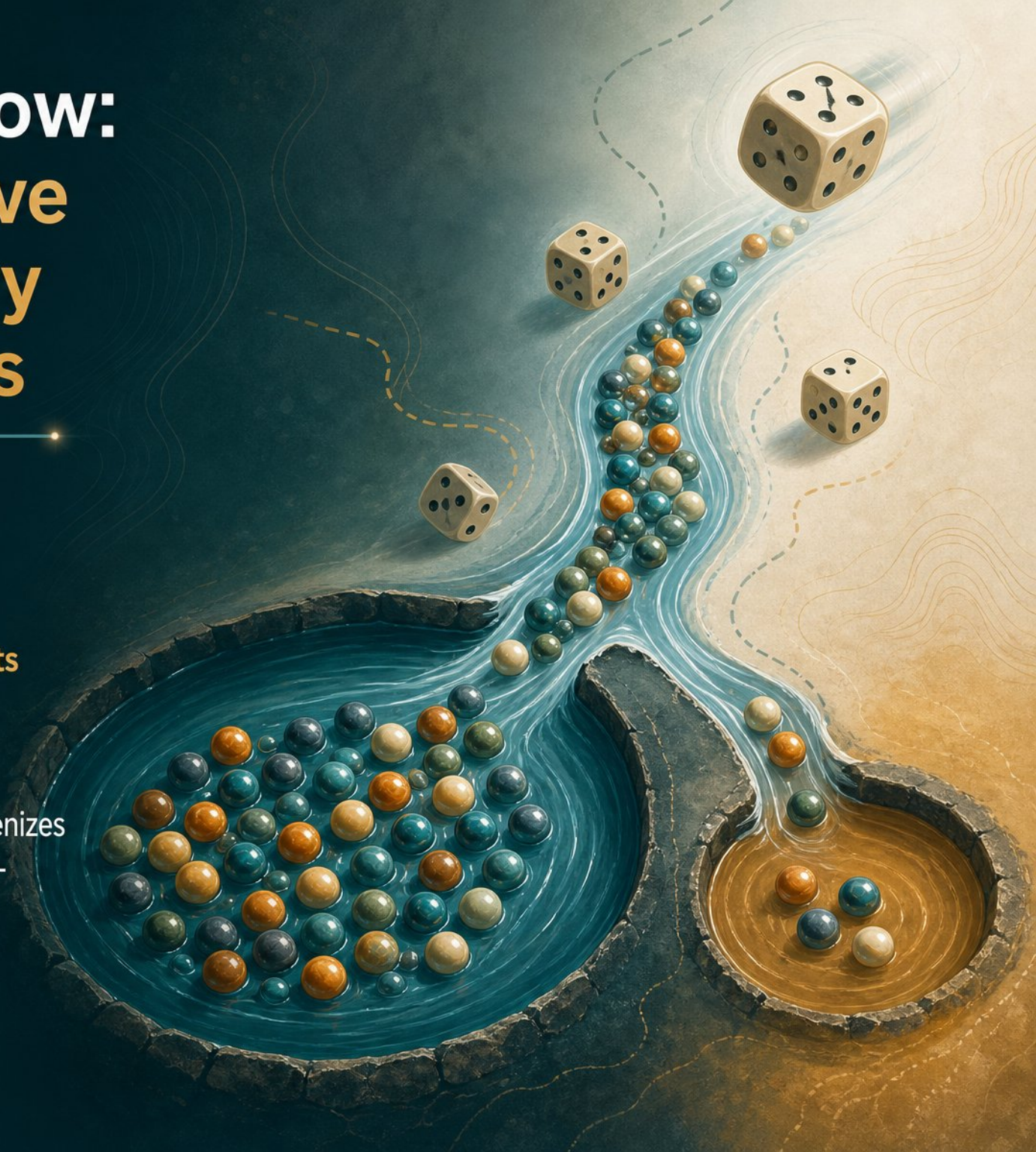
- Adaptation: heritable trait boosting fitness in a given environment
- Structural (camouflage), physiological (lactose tolerance), behavioral (migration)
- Natural selection cannot produce perfection—constraints and trade-offs limit outcomes
- Not all traits are adaptations; some are byproducts or results of genetic drift

The Population View: Allele Frequencies and Microevolution

- Evolution = change in allele frequencies over generations
- Hardy-Weinberg equilibrium: null model with no change
- $p^2 + 2pq + q^2$ predicts genotype frequencies
- Conditions: no selection, no mutation, no migration, random mating, large size
- Deviation signals selection, drift, gene flow, or mutation

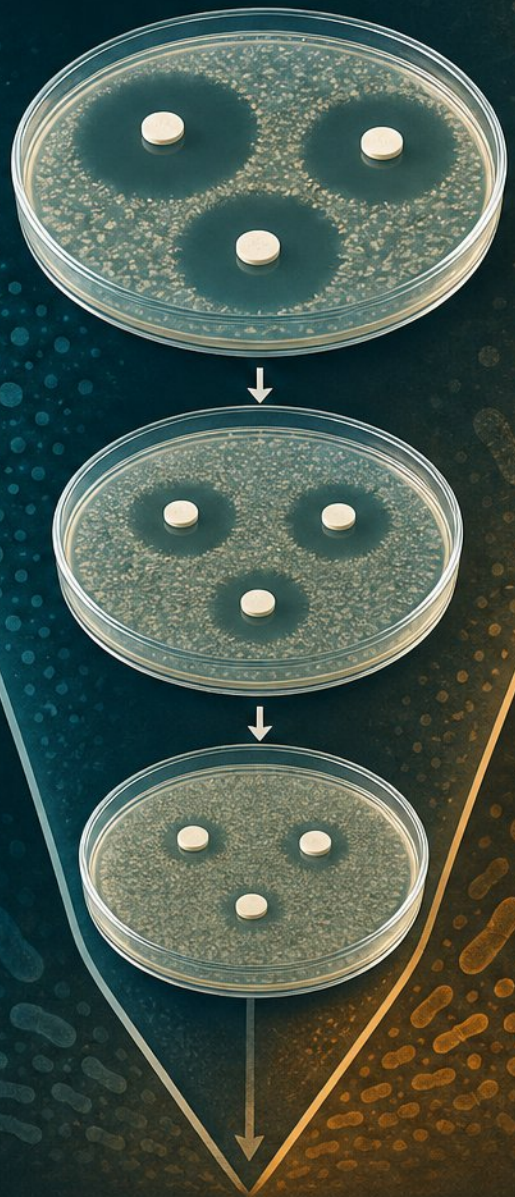
Drift and Flow: Non-Adaptive Evolutionary Mechanisms

- **Genetic drift:** random allele frequency changes, strongest in small populations
- **Bottlenecks & founder effects** slash diversity, enabling rapid divergence
- **Gene flow (migration)** homogenizes populations, increasing within-group diversity
- Drift and flow can reinforce or counteract natural selection



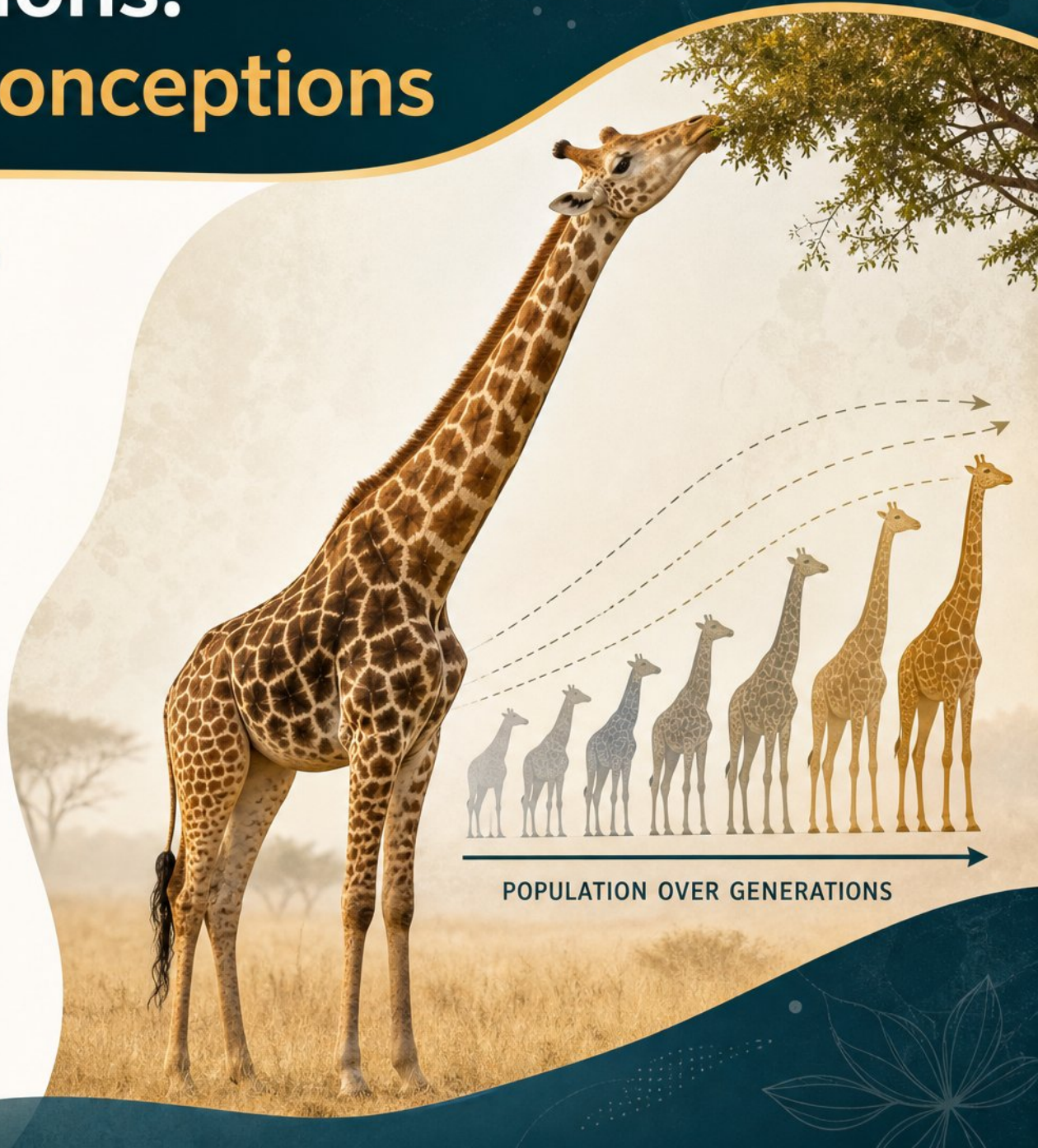
Observable Evidence:
Natural Selection in Action

- Antibiotic resistance in bacteria is a direct, observable case of natural selection.
- Pesticide and herbicide resistance demonstrate rapid agricultural selection.
- Climate warming increases antibiotic resistance genes in environmental bacteria.
- Fossil records and comparative anatomy support descent with modification over deep time.
- Climate-driven selection shifts seasonal traits and resistance in pathogens.



Clear Separations: Common Misconceptions

- Natural selection acts on individuals; populations evolve over generations.
- "Fittest" means reproductive success, not strength or speed.
- Natural selection has no foresight, goal, or direction.
- Humans share a common ancestor with apes, not modern apes.
- Organisms do not try to adapt; mutations are not need-driven.



More Misconceptions:
Randomness, Progress, and Perfection

- Evolution is not random chance; mutation is random, selection is not

- Evolution has no goal; complexity can decrease when advantageous

- Traits are compromises, limited by trade-offs and historical legacies

- Natural selection is one mechanism; drift, gene flow, and mutation also drive change

Implications: Medicine, Agriculture, and Conservation

- Antibiotic stewardship slows evolution of resistant superbugs in medicine.
- Crop refuges and rotation manage pest and pathogen resistance.
- Genetic rescue and connectivity preserve adaptive potential for threatened species.
- Evolutionary rescue links extinction avoidance to resistance management across fields.

Connecting Microevolution to Biodiversity

- Microevolutionary change accumulates over generations, producing macroevolutionary patterns and speciation
- Variation, selection, drift, and isolation drive diversification at all biological scales
- Evolutionary principles guide crop breeding, wildlife corridors, and genetic rescue in conservation
- Applied evolutionary biology integrates genetics, ecology, and policy to address global challenges

Synthesis and Reflection: Connecting Variation, Survival, and Change

- **Recap:** Random variation → differential survival → population change

- **Reflect:** Identify a selection pressure in a familiar context and predict the evolutionary response

Variation, Survival, Change

- Natural selection is one mechanism; drift, flow, and mutation also shape diversity

- **Further learning:** Explore resources in evolutionary biology, population genetics, and applied evolution

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