

Introduction to Ecology and Evolution

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Study guide – key concepts, definitions, and connections

1. What Is Ecology?

Subfield	Focus	Typical Questions
Population Ecology	Dynamics of a single species (size, age structure, birth/death rates)	How does a rabbit population fluctuate over time?
Community Ecology	Interactions among species (predation, competition, mutualism)	What roles do wolves and deer play in a forest?
Ecosystem Ecology	Flow of energy and nutrients through abiotic and biotic components	How does carbon move from plants to soil microbes?
Landscape Ecology	Spatial patterns across habitats (patches, corridors)	How does fragmentation affect pollinator movement?
Global Ecology (Biosphere)	Planet-scale processes (climate, biogeochemical cycles)	How does deforestation influence atmospheric CO ₂ ?

Core Ecological Principles

1. **Hierarchy of Organization** – individual → population → community → ecosystem → biosphere.
2. **Energy Flow** – unidirectional; governed by the **law of thermodynamics**; primary production → consumers → decomposers.
3. **Matter Cycling** – closed loops (e.g., nitrogen, phosphorus).
4. **Limiting Factors** – abiotic (temperature, water) and biotic (predation, competition) constraints on population growth.
5. **Carrying Capacity (K)** – maximum sustainable population size given resource limits.
6. **Density-Dependent vs. Density-Independent Regulation** – feedback mechanisms that depend on (or are independent of) population density.

Key Models

- **Exponential Growth:** $(N(t) = N_0 e^{rt})$ (r = intrinsic rate of increase).
- **Logistic Growth:** $(N(t) = \frac{K}{1 + \left(\frac{K-N_0}{N_0}\right)e^{-rt}})$.

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- Lotka-Volterra Predator-Prey Equations:

$$\left[\begin{aligned} \frac{dN}{dt} &= rN - aNP \\ \frac{dP}{dt} &= baNP - mP \end{aligned} \right] \quad (N = \text{prey}, P = \text{predator}; a = \text{attack rate}, b = \text{conversion efficiency}, m = \text{predator mortality}).$$

2. What Is Evolution?

Concept	Definition	Example
Variation	Heritable differences among individuals.	Beak length in finches.
Selection	Differential survival/reproduction based on traits.	Dark moths survive better in polluted forests.
Inheritance	Transmission of genetic information across generations.	DNA replication, epigenetic marks.
Time	Cumulative change over generations.	Development of antibiotic resistance.

Mechanisms of Evolutionary Change

Mechanism	How It Works	Typical Outcome
Natural Selection	Fitness differences → allele frequency shifts.	Adaptation to local environment.
Genetic Drift	Random sampling of alleles, strongest in small populations.	Loss of genetic variation, fixation of neutral alleles.
Gene Flow (Migration)	Movement of individuals/genes among populations.	Homogenization of allele frequencies.
Mutation	New genetic variants arise spontaneously.	Source of raw material for evolution.
Sexual Selection	Preference for certain traits influences reproductive success.	Elaborate plumage in birds of paradise.

Evolutionary