Chapter 4

Evolution, Biodiversity, and Population Ecology

PowerPoint® Slides prepared by
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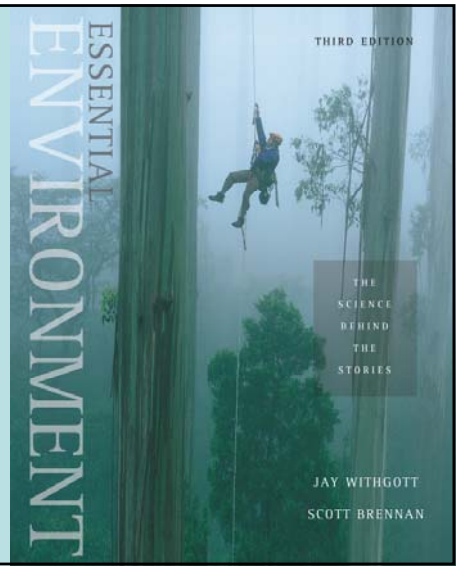


This lecture will help you understand:

- Natural selection
- How evolution influences biodiversity
- Reasons for species extinction
- Ecological organization
- Population characteristics
- Population ecology

Striking gold in Costa Rica

- Golden toads were discovered in 1964, in Monteverde, Costa Rica.
  - The mountainous cloud forest has a perfect climate for amphibians.
  - 200 golden toads were found in one area, 5 m (16.4 ft) in diameter.
  - The area was protected as the Monteverde Cloud Forest Preserve.
- Unfortunately, the toads became extinct within 25 years.
  - Due to global warming's drying effect on the forest

Evolution: the source of Earth's biodiversity

- **Biological evolution**: genetic change in populations of organisms across generations
  - Has resulted in a lush world of millions of species
- May be random, or directed by natural selection
  - **Natural selection**: the process by which traits that enhance survival and reproduction are passed on more frequently to future generations than those that do not

(a) Resplendent quetzal

(c) Harlequin frog

(d) Scutellerid bug

(b) Puffball mushroom

Understanding evolution is vital

- We need to understand how organisms adapt to their environment and change over time.
- It is needed for ecology, a central component of environmental science.
  - •Relevant for agricultural, medicine, pesticide resistance, environmental health

Natural selection shapes organisms

- In 1858, Darwin and Wallace both proposed natural selection as the mechanism of evolution.
  - Organisms face a constant struggle to survive and reproduce.
  - Organisms tend to produce more offspring than can survive.
  - Individuals of a species vary in their characteristics.
  - Some individuals are better suited to their environment and will survive and pass their genes on to their offspring.

Genetic variation

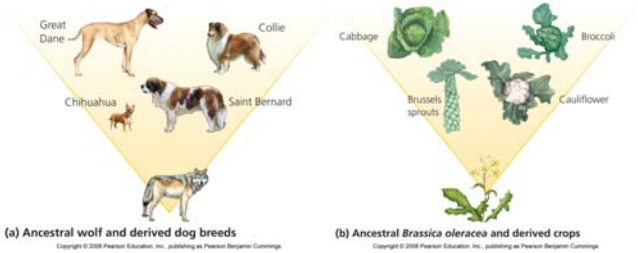
- Genes of better-adapted individuals will be more prevalent than those of less well-adapted individuals in future generations.
- **Adaptive trait (adaptation)**: a trait (characteristic) that promotes reproductive success
- **Mutations**: accidental changes in DNA that may be passed on to the next generation
  - Non-lethal mutations provide the genetic variation on which natural selection acts.
- Sexual reproduction, which involves recombination (the mixing of parental genes), also leads to variation.

Evidence of natural selection is everywhere

- The results of natural selection are evident in every adaptation of every organism.
- Evident in experiments with bacteria and fruit flies
- Selective breeding of animals that exaggerates preferred traits

Artificial selection

- **Artificial selection**: the process of selection conducted under human direction
  - For example, by allowing only like individuals to breed, breeders have created the great variety of dog breeds and crop plants.

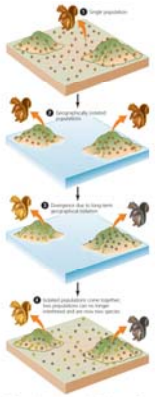


Evolution generates biodiversity

- **Biological diversity** (**biodiversity**): an area's sum total of all organisms
  - The diversity of species
  - Their genes
  - Their populations
  - Their communities
- **Population**: a group of individuals of a species that live in the same area
- **Species**: a population or group of populations whose members share characteristics and can freely breed with one another and produce fertile offspring

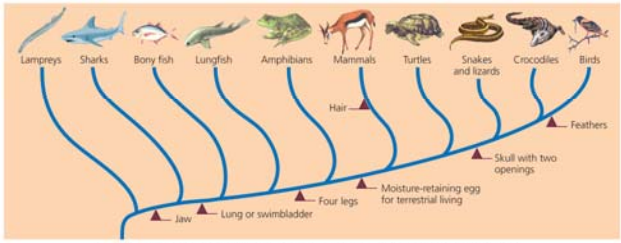
Speciation produces new types of organisms

- **Speciation**: the process of generating new species
  - A single species can generate multiple species
- **Allopatric speciation**: species formation due to physical separation of populations
  - Can be separated by glaciers, rivers, mountains, etc.
  - Over time, each population accumulates different mutations
  - Populations can no longer interbreed
  - The main mode of species creation



Speciation results in diverse life forms

- Speciation generates complex patterns of diversity above the species level.
- **Phylogenetic trees**: represents the history of species divergence
  - Scientists can trace when certain traits evolved.
  - Show relationships between species, populations, or genes



Fossils help decipher life's history

- Dead organisms are often buried by sediment, which can preserve the organism's bones, shells, and teeth.
- **Fossil**: an imprint in stone of a dead organism
- **Fossil record**: cumulative body of fossils worldwide
  - Geologic processes over millions of years created assemblages of fossilized organisms.

Extinction

- Species generally evolve from simple to complex and small to big, but the opposite can occur.
  - Species survival depends on which species are favored by natural selection.
- Speciation is only part of the story; species also disappear.
- **Extinction**: the disappearance of a species from Earth
  - Average time a species spends on earth: 1–10 million years

The number of species in existence = speciation - extinction

Some species are more vulnerable to extinction

- Extinction occurs when the environment changes too rapidly for natural selection to work.
- Many factors can cause extinction:
  - Climate change
  - Changing sea levels
  - Arrival of new, harmful species
  - Severe weather (i.e., droughts)
  - Specialized species and small populations
- **Endemic species**: a species only exists in a certain area
  - Very susceptible to extinction
  - Usually have small populations (i.e., golden toad)

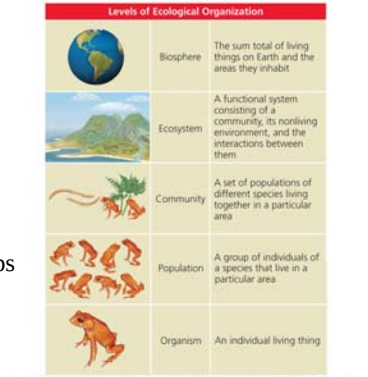
Earth has had several mass extinctions

- **Background extinction rate**: extinction usually occurs one species at a time
  - Most historical extinctions
- **Mass extinction events**: 5 events in Earth's history that killed off massive numbers of species at once
  - 50-95% of all species went extinct at one time
- Humans are causing the sixth mass extinction event.
  - Population growth
  - Development
  - Resource depletion

Species extinction due to human activities may be the single biggest environmental problem we face, because extinction is irreversible.

Ecology is studied at several levels

- **Ecology**: the study of interactions among organisms and their environment
  - Ecology and evolution are tightly intertwined.
- **Biosphere**: all living things on Earth and the areas they inhabit
  - Ecologists study relationships on many levels.



Levels of ecological organization

- **Population ecology**: investigates the quantitative dynamics of how individuals within a species interact
- **Community ecology**: focuses on interactions among species
- **Ecosystem ecology**: studies living and non-living components of systems to reveal patterns
  - Nutrient and energy flows

Organismal ecology: habitat

- **Habitat:** the specific environment in which an organism lives
  - Includes living and non-living elements
  - Scale-dependent: from square meters to miles
- **Habitat use**: each organism thrives in certain habitats, but not in others
- **Habitat selection**: the process by which organisms actively select habitats in which to live
  - Availability and quality of habitat are crucial to an organism's well-being
  - Human developments conflict with this process

Organismal ecology: niche

- **Niche**: an organism's use of resources and its functional role in a community
  - Habitat use, food selection, role in energy, and nutrient flow
  - Interactions with other individuals
- **Specialists**: species with narrow niches and very specific requirements
  - Extremely good at what they do, but vulnerable to change
- **Generalists**: species with broad niches that can use a wide array of habitats and resources
  - Able to live in many different places

Population characteristics

- All populations show characteristics that help scientists predict their future dynamics.
- **Population size**: the number of individual organisms present at a given time
  - Numbers can increase, decrease, cycle, or remain the same

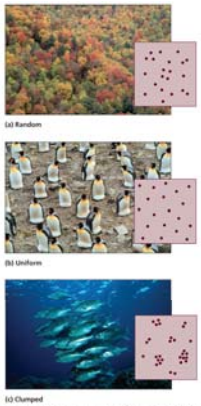
In 100 years, passenger pigeons — billions of birds — were driven to extinction.

Population characteristics

- **Population density**: the number of individuals within a population per unit area
  - Generally, larger organisms have lower population densities because they need more resources.
  - High densities make it easier to find mates, but increase competition and vulnerability to predation.
  - Low densities make it harder to find mates, but individuals enjoy plentiful resources and space.
  - Reduced resources can lead to overcrowding, disease, predators, parasites, and extinction.

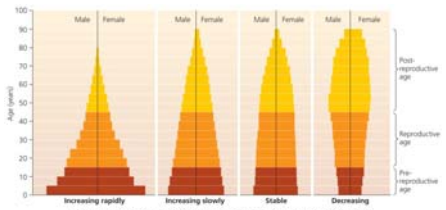
Population characteristics

- **Population distribution (dispersion)**: spatial arrangement of organisms within an area
  - *Random* — haphazardly located individuals, with no pattern
  - *Uniform* — individuals are evenly spaced due to territoriality or competition
  - *Clumped* — arranged according to availability of resources
    - Most common in nature



Population characteristics

- **Sex ratio**: proportion of males to females
  - In monogamous species, a 50/50 sex ratio maximizes population growth.
- **Age structure (age distribution)**: the relative numbers of organisms of each age within a population
  - **Age structure diagrams (pyramids)**: show the age structure of populations



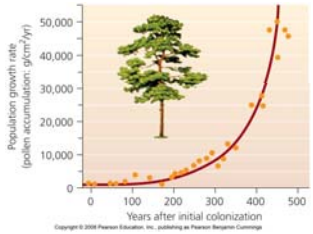
Four factors of population change

- Population growth or decline is due to:
  - **Natality**: births within the population
  - **Mortality**: deaths within the population
  - **Immigration**: arrival of individuals from outside the population
  - **Emigration**: departure of individuals from the population

Growth rate = (birth rate + immigration rate) - (death rate + emigration rate)

Exponential population growth

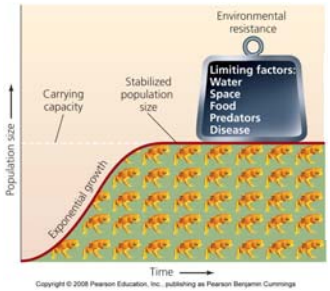
- **Exponential growth**: a population increases by a fixed percent
  - A fixed percent of a large number produces a large increase.
  - Graphed as a J-shaped curve
- Exponential growth cannot be sustained indefinitely.
  - It occurs in nature with a small population and ideal conditions.



Limiting factors restrain growth

- Exponential growth rarely lasts for long.
- **Limiting factors**: physical, chemical, and biological characteristics that restrain population growth
  - Water, space, food, predators, and disease
- **Environmental resistance**: all limiting factors taken together that stop exponential growth
  - Stabilizes the population size

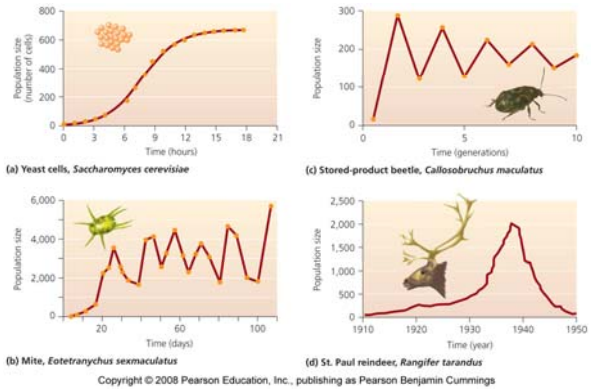
Carrying capacity



- **Carrying capacity**: the maximum population size of a species that its environment can sustain
  - An S-shaped **logistic growth curve**
  - Limiting factors slow and stop exponential growth.
- Carrying capacities change

Humans have raised their carrying capacity by decreasing the carrying capacities for other .

Perfect logistic curves aren't often found



Population density affects limiting factors

- A population's density can increase or decrease the impact of certain factors.
- **Density-dependent factors**: limiting factors whose influence is affected by population density
  - Increased risk of predation and competition for mates occurs with increased density.
  - The logistic growth curve represents the effects of density dependence.
- **Density-independent factors**: limiting factors whose influence is not affected by population density
  - Events such as floods, fires, and landslides

Biotic potential and reproductive strategies vary

- Population regulation is not only due to environmental limiting factors, but to attributes of the organism itself.
- **Biotic potential**: an organism's ability to produce offspring
- **K-selected species**: animals with long gestation periods and few offspring ("quality, not quantity")
  - Have a *low* biotic potential
  - Must compete for resources
  - Stabilize at or near carrying capacity
- **r-selected species**: animals which reproduce quickly ("quantity, not quality")
  - Have a *high* biotic potential

K-selected vs. r-selected species

TABLE 5.4 Traits of r-selected and K-selected species

r-selected species	K-selected species
Small size	Large size
Fast development	Slow development
Short-lived	Long-lived
Reproduction early in life	Reproduction later in life
Many small offspring	Few large offspring
Fast population growth rate	Slow population growth rate
No parental care	Parental care
Weak competitive ability	Strong competitive ability
Variable population size, often well below carrying capacity	Constant population size, close to carrying capacity
Variable and unpredictable mortality	More constant and mortality predictable

Population changes affect communities

- As environmental conditions change, many species are affected.
  - Multiple species can go extinct.
    - i.e., As the Costa Rican cloud forest dried up, many amphibian, reptile, and bird species also disappeared.
    - Species from lower, drier habitats appeared.
  - The composition of entire communities changes.

Conservation can address biodiversity loss

- Human development, resource extraction, and population growth are speeding the rate and degree of change in populations and communities.
- Today, millions of people are taking action to safeguard biodiversity.
  - Establishing national parks
  - Safeguarding endangered species
  - Recovering species' populations

Conclusion

- Natural selection, speciation, and extinction help determine Earth's biodiversity.
- Understanding how ecological processes work at the population level is critical to protecting biodiversity.
- Population ecology also informs the study of human populations, another key endeavor in environmental science.