Populations, Communities, and Interactions

C4.1.1—Populations as interacting groups of organisms of the same species living in an area

Populations

A population is a group of organisms of the same species that live in a specific area and interact with one another. They share a gene pool and have the ability to interbreed.

Characteristics of Populations:

Size: The number of individuals in a population.
Density: The number of individuals per unit area/volume.
Birth and death rates: Determines the growth of the population.

Factors Affecting Population Size:

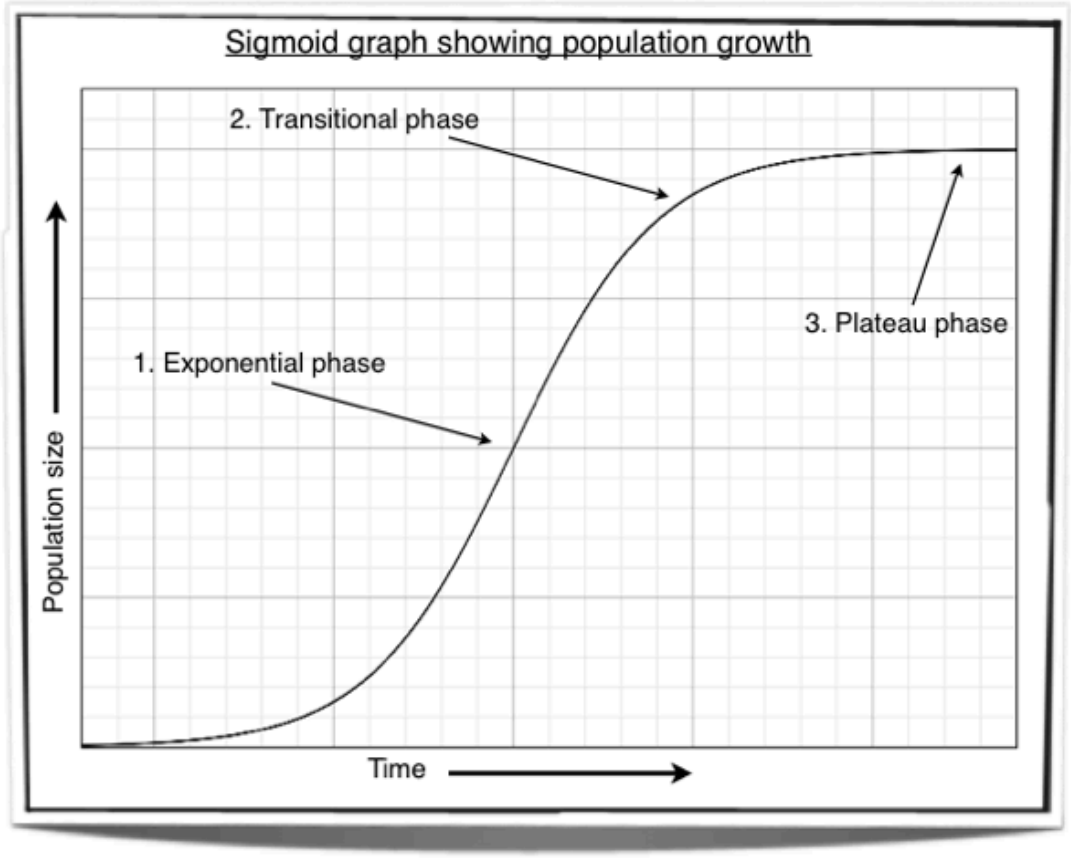
Natality (birth rate): Increase in population size.
Mortality (death rate): Decrease in population size.
Immigration: Organisms entering the population from elsewhere.
Emigration: Organisms leaving the population.

Population Interactions:

Populations don't just exist; they interact with each other and the environment. This can affect population dynamics (changes over time). These interactions can include:

Competition: Occurs when resources are limited.
Predation: One organism (predator) feeds on another (prey).
Symbiosis: Close, long-term interactions between species, including mutualism (both benefit), commensalism (one benefits, the other isn't harmed or helped), and parasitism (one benefits, the other is harmed).

C4.1.7—Population growth curves



Exponential (or J-shaped) Growth:

- Occurs under ideal conditions with unlimited resources.
- Population size increases rapidly and continuously over time.

Logistic (or S-shaped) Growth:

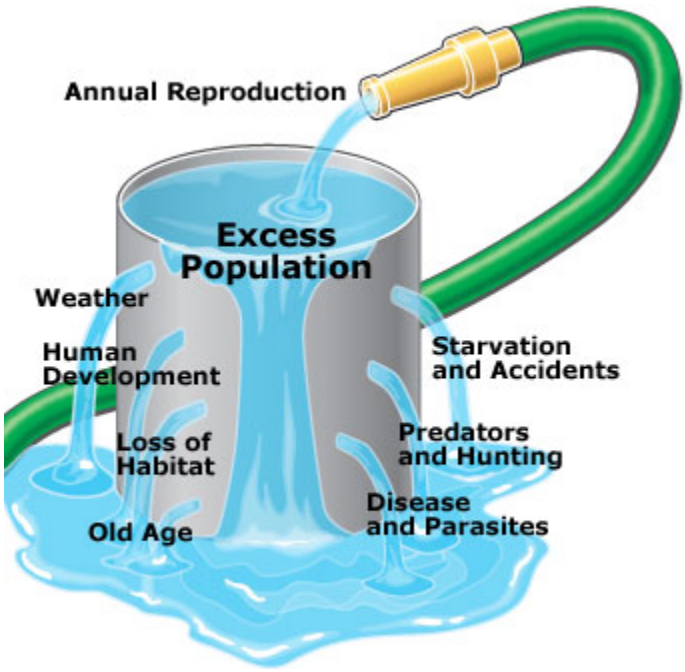
- Considers limits on population growth due to resource constraints.
- Initial exponential growth is followed by a slowdown, and eventually, the population stabilizes near the carrying capacity.

Carrying Capacity (K):

- Maximum population size that an environment can sustainably support given the available resources.
- Above this point, limiting factors (like food and space) reduce population growth.

C4.1.5—Carrying capacity and competition for limited resources

Carrying Capacity (K)



Definition: Carrying capacity refers to the maximum number of individuals of a particular species that a specific environment can support over a prolonged period without degradation of that environment.

Factors Influencing Carrying Capacity: These include food availability, water, living space, predators, disease, and the state of the environment.

Limiting Factors:

- Environmental factors that restrain population growth.
- Can be density-dependent (e.g., competition, predation) or density-independent (e.g., weather, natural disasters).

Competition for Limited Resources

Intra-specific Competition: Competition among members of the same species. As resources become scarcer, intra-specific competition intensifies. This can lead to reduced growth, survival, and reproduction rates for individuals.

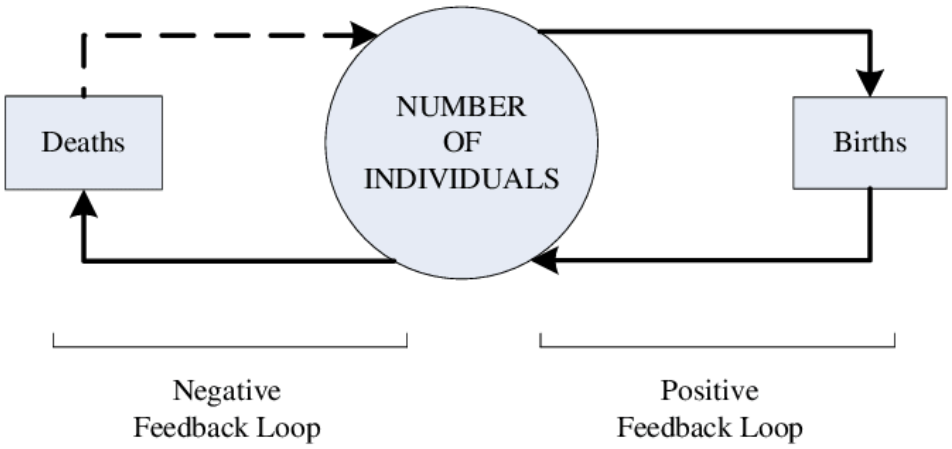
Inter-specific Competition: Competition between different species for shared resources. When two species compete for the same limited resource, one species will often be more efficient and outcompete the other, which can lead to the competitive exclusion principle.

Density-dependent Factors: Factors that have a greater impact as the population density increases. Competition for resources, predation, and disease are examples. These factors play a significant role in slowing population growth as it approaches carrying capacity.

Effects of Competition**:** Intense competition can lead to decreased population size, decreased growth rate, or migration out of an area. It can also drive evolutionary changes as species adapt to reduce competition.

C4.1.6—Negative feedback control of population size by density-dependent factors

Definition of Negative Feedback: A mechanism where a change in a given direction results in effects that counteract or oppose that change, bringing the system back toward equilibrium.



Examples of Density-dependent Factors:

Competition for Resources: As population size increases, individuals compete more intensely for limited resources such as food, water, and shelter. This increased competition can decrease birth rates or increase death rates.

Predation: In many ecosystems, as the population of a prey species increases, the population of predators may also increase because more food is available. This can then lead to a higher predation rate, acting as a check on the prey population.

Disease: Higher population densities can lead to more rapid spread of contagious diseases, which can reduce the population size.

Parasitism and Herbivory: Just like diseases, the impact of parasites and herbivores can become more pronounced as the host or plant population density increases.

Waste Accumulation: In some cases, the waste products of organisms can accumulate in an area. Higher densities can lead to more rapid accumulation of waste, which can negatively impact the environment and reduce its carrying capacity.

Negative Feedback Mechanism:

1. Population Increase: As a population grows, the density of the population also increases.
2. Density-dependent Factor Activation: As a result of increased density, density-dependent factors (like competition, predation, or disease) become more pronounced.
3. Population Decrease: These factors then serve to reduce population size by decreasing birth rates, increasing death rates, or both.
4. Restoration of Equilibrium: As the population size decreases, the effects of the density-dependent factors lessen, leading to the potential for population growth again. The system tends toward equilibrium around the carrying capacity.
5. Density-dependent Factors: Factors that have a greater impact as the population density increases. Competition for resources, predation, and disease are examples. These factors play a significant role in slowing population growth as it approaches carrying capacity.

C4.1.9—Community as All Interacting Organisms in an Ecosystem:

- A community refers to all the interacting organisms in an ecosystem.
- It encompasses various forms of life, including plants, animals, fungi, and bacteria.
- Communities are essential components of ecosystems, where organisms of different species coexist and interact within a given geographical area.

C4.1.10—Competition versus Cooperation in Intraspecific Relationships:

Intraspecific Competition (Within the Same Species):

- Occurs when individuals of the same species compete for limited resources such as food, water, and mates.

<u>Reasons for intraspecific competition include:</u>

- Limited resources: When there are not enough resources to satisfy the needs of all individuals, competition arises.
- Reproductive competition: Individuals may compete for the opportunity to mate and pass on their genes.
- Territorial disputes: Competition for territory can be fierce, especially among territorial species.

<u>Examples of Competition:</u>

- Lions in a pride competing for access to the same prey.
- Trees in a forest competing for sunlight, nutrients, and space.

Intraspecific Cooperation (Within the Same Species):

- Cooperation involves individuals of the same species working together for mutual benefit.

Reasons for cooperation include

- Enhanced survival: Group living can provide protection from predators and improve foraging efficiency.
- Reproductive benefits: Cooperative breeding can increase the chances of offspring survival.
- Resource sharing: Individuals may cooperate to share limited resources

Examples of Cooperation:

- Honeybees in a hive working together to collect nectar and care for the colony.
- Wolves in a pack hunting together to bring down larger prey.

C4.1.11—Interspecific Relationships Within Communities:

Interaction Type	Description	Example
Herbivory	Consumption of plant material by herbivores	Grazing of grass by cows, deer, or insects
Predation	One organism capturing and consuming another for sustenance	A lion preying on a wildebeest
Interspecific Competition	Different species competing for the same limited resources	Multiple bird species competing for nesting sites in a tree
Mutualism	Symbiotic relationship where both species benefit	Bees obtaining nectar and pollinating flowers
Parasitism	One organism benefiting at the expense of another	Ticks feeding on the blood of mammals
Pathogenicity	Harm caused by pathogens to their host species	Bacteria causing tuberculosis in humans

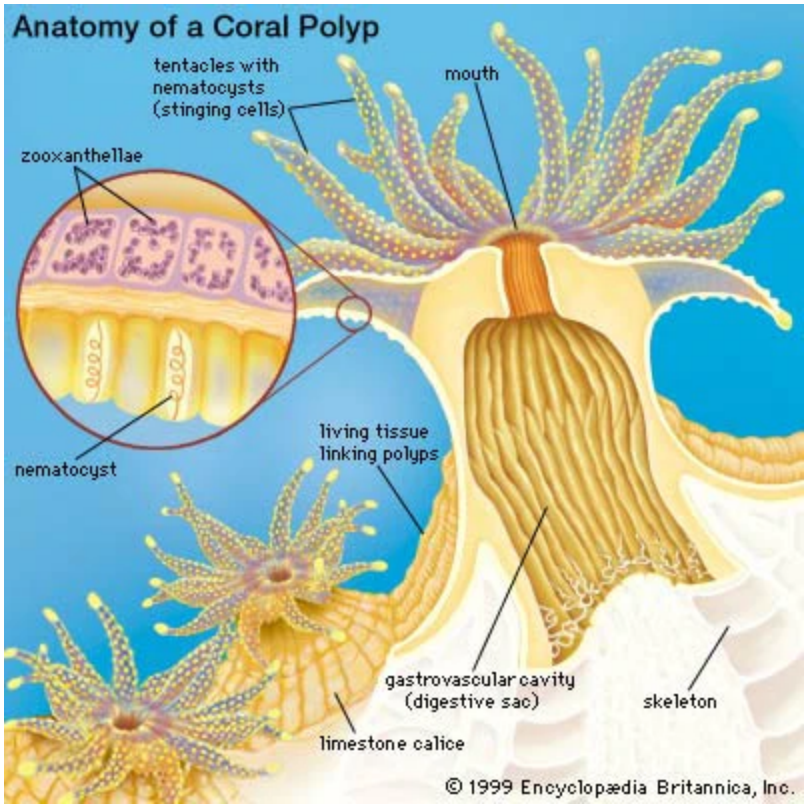
These ecological interactions play crucial roles in shaping the structure and dynamics of communities and ecosystems. Understanding these relationships is fundamental for ecology and biodiversity conservation.

Table 1: Effects of Different Biological Interactions on Involved Species

Interaction Type	Effect on Species 1	Effect on Species 2
Herbivory	+	-
Predation	+	-
Interspecific Competition	-	-
Mutualism	+	+
Parasitism	+	-
Pathogenicity	-	+

C4.1.12—Mutualism as an interspecific relationship that benefits both species:

Symbiotic Relationship	Host Organism	Symbiont	Benefits to Host	Benefits to Symbiont
Root Nodules	Fabaceae (Legumes)	Rhizobia bacteria	Fixes atmospheric nitrogen into usable form.	Receive carbohydrates and a protective environment.
Mycorrhizae	Orchidaceae (Orchids)	Mycorrhizal fungi	Provides carbon and nutrients for germination; aids in nutrient absorption.	Habitat and nutrients from the adult orchid.
Zooxanthellae	Hard corals	Photosynthetic algae (Zooxanthellae)	Receive oxygen and organic compounds from photosynthesis.	Protected environment and compounds for photosynthesis.


Anatomy of a Coral Polyp
tentacles with nematocysts (stinging cells)
mouth
zooxanthellae
nematocyst
living tissue linking polyps
gastrovascular cavity (digestive sac)
skeleton
limestone calice
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C4.1.13—Resource competition between endemic and invasive species:

Endemic Species - An endemic species is one that is found naturally in only one geographic area and nowhere else in the world.

Invasive Species - An invasive species is a non-native organism that spreads rapidly in a new area, often causing harm to the environment, economy, or human health.

European Starlings in North America

- European Starlings were introduced in the late 19th century when 100 birds were released in Central Park, New York, by a group aiming to establish all the birds mentioned in Shakespeare's works in the United States.
- The species quickly adapted to various climates across North America and their population burgeoned to millions.

Ecological Impact:

- Starlings are aggressive competitors for nesting sites. They often displace native birds such as bluebirds, martins, and woodpeckers by taking over their nesting cavities.
- They form large flocks that can disrupt ecosystems by outcompeting native bird species for food resources, including insects and fruit.

C4.1.14—Tests for interspecific competition:

Laboratory Experiments: In a controlled lab setting, researchers can grow two species of plants in the same soil medium to assess competition for nutrients. By varying the density of one species and observing the growth response of the other, they can infer competitive interactions.

Field Observations by Random Sampling: Scientists may use random quadrats in a natural meadow to record the presence and growth of two flower species that potentially compete for pollinators. By analyzing the patterns of co-occurrence and the abundance of flowers, they can suggest a competitive relationship.

Field Manipulation by Removal of One Species: Ecologists might selectively remove an invasive shrub from a forest understory to see if the native shrub species, which is currently sparse, will recover. The recovery and spread of the native shrub after the removal would indicate that interspecific competition was likely limiting its success.

C4.1.17—Top-down and bottom-up control of populations in communities:

- In top-down control, predators control the population of prey,
- In bottom-up control, the availability of resources controls the population.
- The dominant control type in a community depends on various factors, including the specific species and environmental conditions.

Factor	**Top-Down Control Likely to be Dominant**	**Bottom-Up Control Likely to be Dominant**
Resource Availability	Less significant when resources are abundant; predators control species abundance.	Most significant when resources are scarce; availability of nutrients controls.
Ecosystem Complexity	More evident in complex ecosystems with diverse interactions and multiple trophic levels.	More evident in simpler ecosystems with fewer trophic levels.
Human Impacts	Reduction in top predators due to human activity can lessen top-down control.	Human activities that alter resource availability can increase bottom-up control.
Temporal and Spatial Factors	Seasonal or spatial changes can temporarily shift dominance to predators.	Seasonal or spatial variation in resource availability can shift control.

C4.1.16—Predator–prey relationships as an example of density-dependent control of animal populations:

The reintroduction of wolves to Yellowstone serves as an example of density-dependent population control through the following points:

- **Increased Predation**: Higher elk densities make them easier prey for wolves, leading to higher predation rates.
- **Wolf Population Growth**: More elk means more food for wolves, potentially increasing the wolf population, which in turn increases predation pressure on elk.
- **Elk Behavior Changes**: As elk numbers rise, competition and vulnerability increase, leading to changes in their behavior and habitat use, which affect their survival rates.
- **Resource Competition Among Elk:** Larger elk populations face greater food competition, resulting in weaker individuals that are more prone to predation.
- **Predator-Prey Feedback Loop**: A larger elk population can support more wolves, but as wolves control elk numbers, the wolf population may also eventually decline, allowing elk numbers to recover, which illustrates a density-dependent regulation cycle.

Links to Videos:
Wolves in Yellowstone National Park
Other Effects of Wolves on the Yellowstone National Park Ecosystem

C4.1.18—Allelopathy and secretion of antibiotics:

Allelopathy in Plants:

- Biological phenomenon where plants secrete biochemicals (allelochemicals) into the environment.
- Purpose: Inhibit the growth of competing plants for resources like light, water, or nutrients.

Example:
European context: English Walnut (*Juglans regia*) in Europe produces juglone, which affects the growth of nearby plant species.

Juglone's Mechanism of Action:

- Inhibits the respiration of nearby plants by disrupting electron transport in mitochondria.
- Interferes with DNA replication and cellular metabolism.
- Affects the normal growth and development of other plants' root systems.

Effects on Plants:

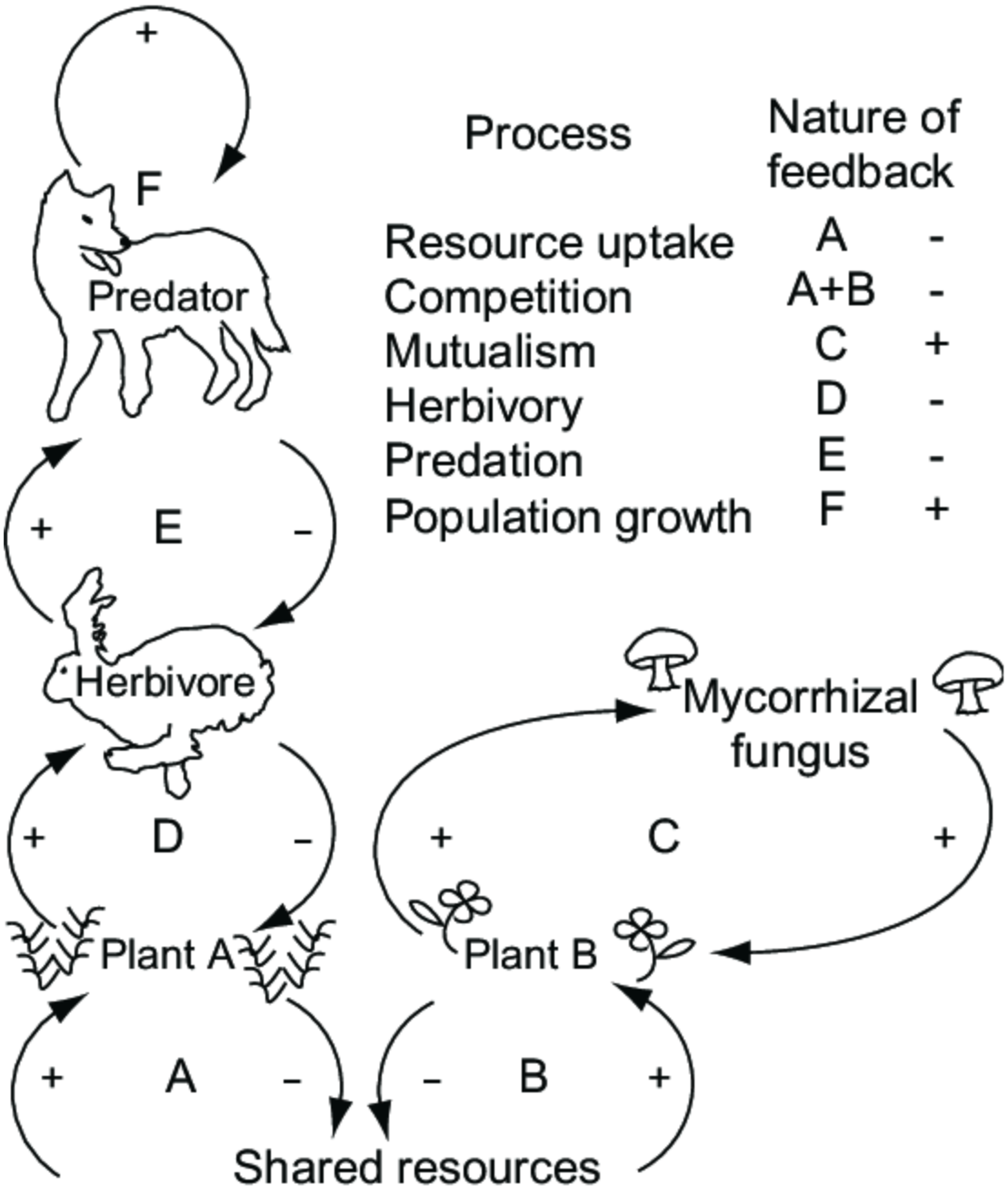
- Stunted growth, yellowing leaves (chlorosis), and eventual plant death.
- Sensitivity to juglone varies widely among plant species.

Antibiotics in Microorganisms:

Example:
Streptomyces releases antifungal and antibacterial compounds to outcompete other microorganisms in the soil.

Similarity between Antibiotics and Allelopathy:

- Both processes involve the release of chemical substances into the environment to deter potential competitors.
- Strategies used by organisms to ensure survival and maintain ecological niches by reducing competition.



Process		Nature of feedback
Resource uptake	A	-
Competition	A+B	-
Mutualism	C	+
Herbivory	D	-
Predation	E	-
Population growth	F	+