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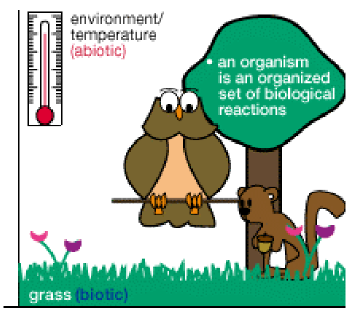
Biology Lecture Notes

Ecological Organization: The Functional Divisions of the Ecologist

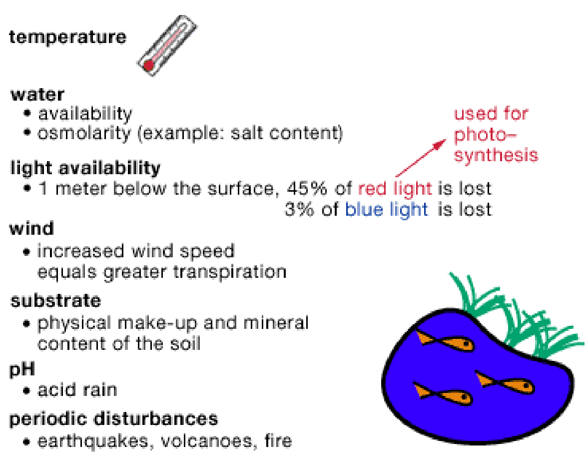
>> Key Concepts:

- **Ecology** is the study of organisms and how they interact with their environment (including **biotic** and **abiotic** factors.)
- Ecology can be divided into six levels of greater inclusiveness:
    1. organism
    2. population
    3. community
    4. ecosystem
    5. biome
    6. biosphere
- The abiotic component of the environment consists of nonliving physical and chemical factors including:
    - temperature
    - water
    - light availability
    - wind
    - substrate
    - pH
    - periodic disturbances



Review: Science is a systematic process that involves collecting information by performing experiments. The narrower the focus of study, the easier it is to run a controlled experiment and gain information about the subject at hand.

Ecologists have a challenging task since they focus on the interactions between organisms and their environment. It is difficult to design experiments when so many variables are present.



Aspects of an organism's environment include both **biotic** and **abiotic** factors. Biotic factors pertain to the living organisms in the environment. Abiotic factors are physical factors like temperature and light availability.

Since organisms are constantly exchanging materials with their environment, the environment can influence the state of an organism. For example, water is a limited resource in desert settings that influences the distribution of plants and animals.

Biology Lecture Notes

organismal
behavior, physiology, and appearance of organisms in their environment

population
all members of one species in a given area

community
the interaction of different species in a given area

these are **biotic** levels of ecological organization

ecosystem
community plus abiotic factors (temperature, humidity, light, etc.)

biomes
major ecosystems classified according to prevalent vegetation (rainforest, savannah, etc.)

biosphere
the sum of the planet's communities and ecosystems

To study different levels of interaction between organisms and their environment, ecologists look at different levels of complexity. The list on the left shows the six basic levels of organization that ecologists use for making and testing predictions.

Biology Lecture Notes

Population Ecology: Populations with Unlimited Resources

>> Key Concepts:

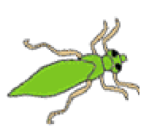
- **Population ecology** encompasses the behaviors of individuals and entire populations.
- **Birth** and **life-history strategies** have evolved low **cost/benefit ratios**.
- Hypothetical populations with unlimited resources display **exponential population growth**.

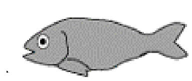
A **population** is all of the members of the same species in a given area.

Populations of Emperor penguins (*Aptenodytes forsteri*) live in Antarctica and the Antarctic Islands.

Review: **Ecology** is the study of the way organisms interact with their environment (living and nonliving.)

Population ecology encompasses both population and individual behaviors. Because populations are groups of individuals, population ecology encompasses organismal ecology, such as the study of competitive behaviors. Population ecologists also study the **birth strategies** of individual organisms that lead to the growth of populations. A related aspect of the field involves analyzing **life-history strategies**. Life-history strategies are characteristics of an organism that pertain to its schedule of growth, reproduction, and death.

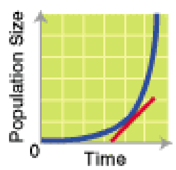




There are costs and benefits associated with different strategies.

Annual plants grow to maturity, produce many seeds, and then die within one growing season. **Dragonflies** take two-to-three years to reach maturity while living underwater, then emerge as adults, reproduce, and die within a couple of months. **Salmon** migrate from stream to ocean where they spend about seven years reaching maturity, then return upstream where their bodies change for maximum reproductive output. Then they reproduce and die.

Biology Lecture Notes



• slope = $\frac{\Delta y}{\Delta x}$

When allowed to reproduce under ideal conditions, a bacteria population would grow to an enormous size. The curve depicts a population undergoing **exponential growth**, the growth trajectory of a population with unlimited resources.

The slope (change in the y axis divided by the change in the x axis) represents the rate of change in population size. As time increases, so does the slope of the tangent at the given point in time; this increase means the rate of change in the population is increasing.

Biology Lecture Notes

Population Ecology: The Reality of Limited Resources

>> Key Concepts:

- The **exponential growth model** charts a population undergoing unlimited size increase.
- Under real conditions resources limit the growth of populations.
- The **logistic growth model** charts a population undergoing limited size increase. Logistic growth is characterized by an initial increase in the rate of growth. After the point of inflection, this rate of increase decreases until it reaches zero at the population's **carrying capacity**.
- Carrying capacity is the maximum size of a population that can be maintained by the resources of the area it occupies.

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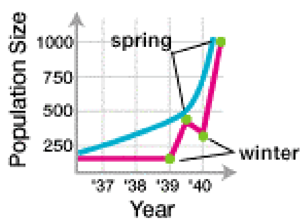

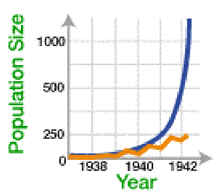

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In 1937, a small group of ring-necked pheasants was introduced to Protection Island, off of the coast of Washington state. By 1940, the population had exploded to 1,000 birds.
The first graph compares growth of the pheasant population (the jagged pink line) to an exponential growth model (the smooth blue line). In 1941 and 1942, the population continued to grow, but at a slower rate. The second graph illustrates the slower rate of growth that occurred after 1940.
At first, the population seemed to be experiencing exponential growth. Eventually, however, limited resources (such as food or nesting sites) limited the population's growth.
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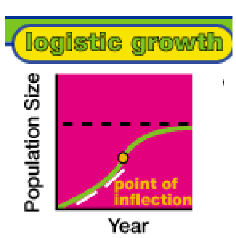

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The graph on the left illustrates the logistic growth model. The first part of the curve shows the population experiencing increasing growth rates over time. After the point of inflection, the population is still increasing in size but the rate of increase in growth is decreasing. When the population reaches carrying capacity (represented by the horizontal broken line), the change in the population equals zero, and there is no further increase in the population.
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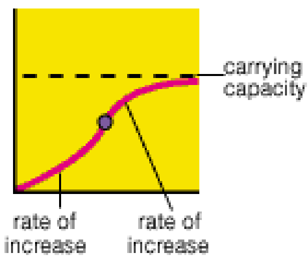
Biology Lecture Notes

Population Ecology: Population Strategy: *r* vs *K*

>> Key Concepts:

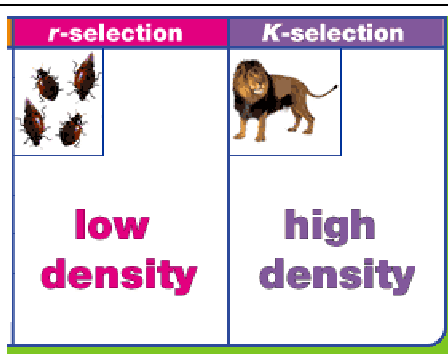
- The **logistic population growth model** predicts that a population's growth rate changes as it approaches carrying capacity.
- The model predicts that populations with either low or high densities relative to carrying capacity will have different life-history strategies.
- High-density populations are called ***K*-selected** and have adaptations that enable them to survive and reproduce with few resources.
- Low-density populations are called ***r*-selected** and have adaptations for allowing rapid reproduction.



Review: The graph on the left depicts the logistic growth of a population. The population initially increases until it reaches the **inflection point**. At that point, the rate of increase slows until it reaches carrying capacity.

The **logistic population growth model** shows that population growth varies with population density. In real-life situations, scarce resources—such as food, mates, or shelter—limit population growth.

One limitation of the model is that all individuals are considered equal regardless of their age. Adults have a greater impact on a population than young.



The logistic population growth model predicts that populations with either low or high densities relative to carrying capacity will have different life-history strategies.

Low-density populations are called *r*-selected and have adaptations that lead to rapid reproduction, like early maturation. Populations remain under the carrying capacity. Many insect species are considered to be *r*-selected.

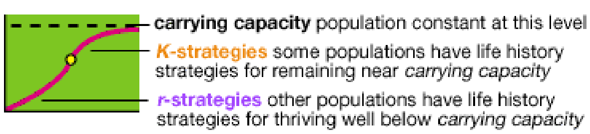
High-density populations are called *K*-selected. They have adaptations—like slow growth rate—that enable them to survive and reproduce with few resources. Populations increase and remain at carrying capacity. Many large mammals, like lions, are *K*-selected.

Biology Lecture Notes

Population Ecology: Intraspecific Competition

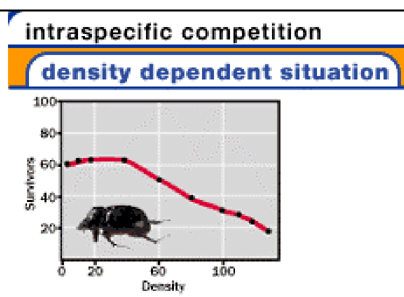
>> Key Concepts:

- **Review**: K-selection and r-selection are two different population strategies found in high-density and low-density situations, respectively.
- **Density-dependent** factors include resources such as food or nesting sites. The magnitude of the effects of these factors depends on the population size.
- **Intraspecific competition** can lead to density-dependent growth in populations.
- **Density-independent** factors (such as weather) influence a population regardless of its size.
- A mix of density-dependent and -independent factors affects most populations.
- **Interspecific interactions** are interactions between two or more species.



Review: The logistic model of population growth shows a population whose growth rate is dependent on population size. Limited resources affect the population's growth rate. The population growth rate increases until reaching the inflection point. It then decreases until the population reaches carrying capacity.

The r-selected populations have life-history strategies for thriving well below carrying capacity. K-selected populations have life history strategies for remaining near carrying capacity.



The graph on the left plots density versus survivorship in a population of rhinoceros beetles (*Strategus* sp.). As density increases, population survivorship goes down. The phenomenon occurs because of **intraspecific competition** between members of the population. As the population increases, many individuals receive an insufficient amount of a particular resource and do not survive to reproduce.

The graph illustrates an example of density-dependent factors influencing population changes.

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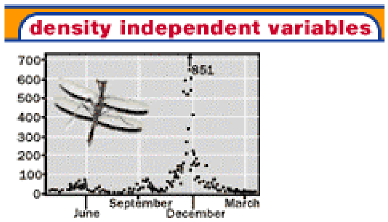
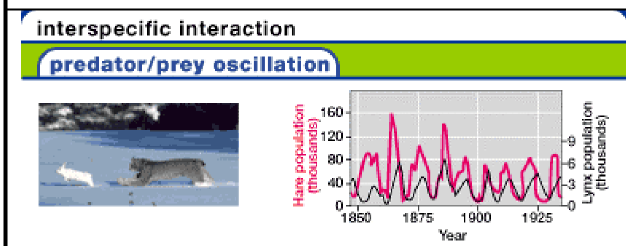


The graph on the left illustrates seasonal fluctuations in a population of Australian *Thrips* sp. Populations increase in the spring (December in Australia), but drought decimates them in the summer. The drought affects individuals regardless of population size.



A classic example of interspecific interaction involves the snowshoe hare and the lynx. Populations have been tracked in the Hudson Bay area since 1850.

Fluctuations in the hare population are followed by fluctuations in the lynx population. Some scientists interpret the oscillations in the hare population as evidence of a density-independent factor. Hare availability is most likely a limited resource, and therefore it is a density-dependent influence for the lynxes.

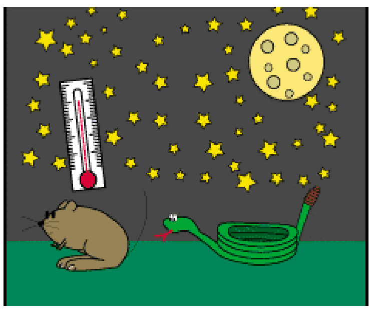
Although these explanations seem likely, the cause of the fluctuations is still a matter of debate.

Biology Lecture Notes

Community Ecology: Interspecific Interaction: Predation

>> Key Concepts:

- **Community ecology** examines interactions between populations and their environments.
- **Predation** is one form of interspecific interaction.
- Predators include **parasites** and **parasitoids**.
- Species use a variety of adaptations as protection from predation. These adaptations include:
  - **camouflage**
  - **aposematic coloration**
  - **mimicry**



The study of ecology analyzes relationships between organisms and their environment.

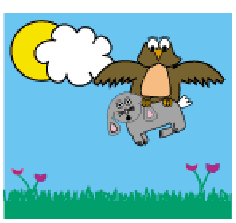
For example, in the depiction on the left, the rattlesnake has developed heat-sensing abilities that help it "see" its prey (the mouse) in the dark. The mouse comes out at night to feed, and anything that preys on it must have adaptations for hunting in the dark.

Three different levels of focus are (1) individual, (2) population, and (3) community.

One aspect of community ecology involves studying **interspecific competition** (competition between different species).

Community ecology looks for evidence of coevolution, the reciprocal evolution of two or more species.

(Remember: Evolution is a population-level phenomenon.)



Two examples of coevolution:

1. **Small mammals/birds (left)**: If a small mammal evolves behavior to avoid flying predators, it will escape predation until the predator, in this case a bird, also evolves a mechanism for identifying the prey.
2. **Edible fruit of plants/mammals**: Why is fruit so tasty? It is a successful strategy of the plant to promote seed dispersal.

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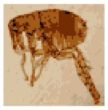
predators
actively pursue prey to obtain food



parasites
specialized predators that live in or on host

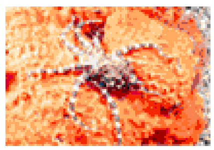
parasitoids
generally insects that lay eggs on living hosts; larvae feed on and kill host

You can analyze interspecific interactions by their effects on the populations involved.

Predators kill and eat other organisms (prey).

Parasites are specialized predators that live in or on a host.

Parasitoids (generally insects) lay eggs on living hosts; the larvae feed on and kill the host.



Organisms have evolved many defenses against predation. **Camouflage**, or cryptic coloration, enables prey to hide from predators and avoid being eaten. The frog in the illustration on the left blends in well with its environment. **Aposematic** (warning) coloration provides an advertisement that the prey item is poisonous or otherwise unpalatable. For the strategy to be successful, the prey population must be large enough for the predator to learn about—and subsequently avoid—noxious individuals.

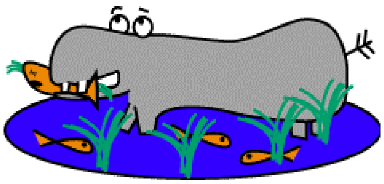
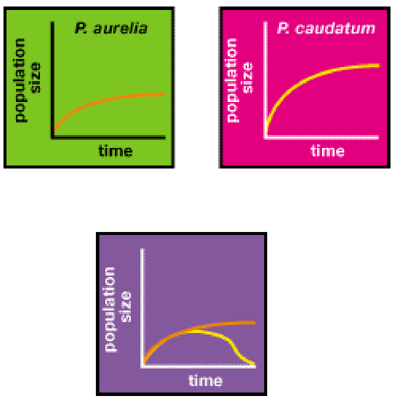
In **mimicry**, species imitate other, more-dangerous species. An example is the hawkmoth larva (not shown), which has a snake-like face on its posterior end. In Batesian mimicry, a harmless species mimics a harmful one. In Mullerian mimicry, two unpalatable species resemble each other. Both species are similarly marked with aposematic colorings/markings.

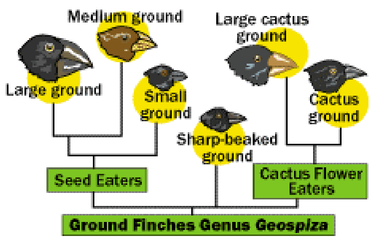
Biology Lecture Notes

Interspecific Competition: Ecological Niches

>> Key Concepts:

- Interactions between species can be described in terms of the impact they have on each other.
- **Predation** can be described as a **+ / - interaction** because one individual benefits and the other is harmed.
- By performing a series of experiments on *Paramecium sp.*, **G. F. Gause** demonstrated that **competitive exclusion** could occur.
- Competitive exclusion is considered a **- / - interaction** because the species are negatively affected.
- Evidence of competitive exclusion in nature includes **character displacement** in finches that coexist with closely related species.

	In **predation**, an organism obtains most of its food by eating other animals. This term is also applied to herbivores, which "prey" on plants. Predation can be described as a **+ / - interaction** because the predator benefits and the prey does not.
	In 1934, G. F. Gause tested the hypothesis that two species vying for the same resources could not coexist. When each of the two species *Paramecium aurelia* and *Paramecium caudatum* are grown separately, each population reaches its respective carrying capacity. When they are grown together, *P. caudatum* is driven to extinction and *P. aurelia* approaches but does not reach carrying capacity. The term **competitive exclusion** describes the elimination of one species by another. Competitive exclusion is difficult to determine in nature because of the variables that must be accounted for. One alternative is controlled experiments involving competitive species, but these experiments are sometimes logistically difficult. **J.H. Connell** coined the phrase, "ghost of competition past", which describes the difficulty of providing scientific explanations for events that have already occurred.



Character displacement is the occurrence of characteristics that are more divergent in co-occurring populations than in geographically separated populations.

Character displacement provides evidence that competitive exclusion has occurred.

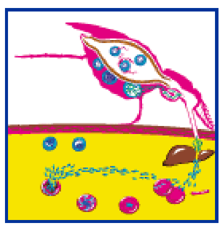
For example, two species of finches have greater similarity in beak length and depth when living in geographically separated areas than when they occur together. When the species coexist, their beaks are more morphologically distinct, most likely because of natural selection favoring less competition between the species.

Interspecific Associations: Symbiosis

>> Key Concepts:

- Four types of **interspecific interaction**:
  - **predation**
  - **competitive exclusion**
  - **mutualism**
  - **commensalism**
- Three examples of symbiosis:
  - **parasitism**
  - **mutualism**
  - **commensalism**
- Because actual interspecific interactions in nature are complex, they are often difficult to categorize.

interspecific interactions	
predation	+/–
competitive exclusion	–/–



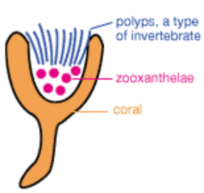
The table on the far left categorizes two different types of **interspecific interactions**.

Review: In **predation**, an organism (usually an animal) obtains most of its food by eating other animals. Predation is classified as a **+ / - interaction** because the predator benefits and the prey is harmed (eaten).

In **parasitism**, a form of predation, one organism (the parasite) feeds on another (the host) without killing it immediately (if ever). Parasites are generally specific to particular host species.

Acting as a parasite, the female mosquito sucks blood to nourish eggs in her abdomen.

interspecific interactions	
predation	+/–
competitive exclusion	–/–
mutualism	+/+

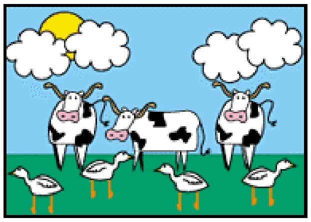


Mutualism is an association between two or more species that benefits the organisms involved.

Invertebrate animals called polyps live symbiotically with zooxanthelae. The skeletons of the polyp form what is known as "coral." If the water temperature is high (global warming), the polyp will release the zooxanthelae, thereby disturbing the vitality of the coral reef ecosystem.

Biology Lecture Notes

interspecific interactions	
predation	+/–
competitive exclusion	–/–
mutualism	+/+
commensalism	+/o



In **commensalism**, one species benefits and the other is apparently not affected. Whether or not one of the species is completely unaffected is still debated.

While the herd of cattle grazes, they inadvertently flush insects from the vegetation, and the cattle egrets eat these insects.

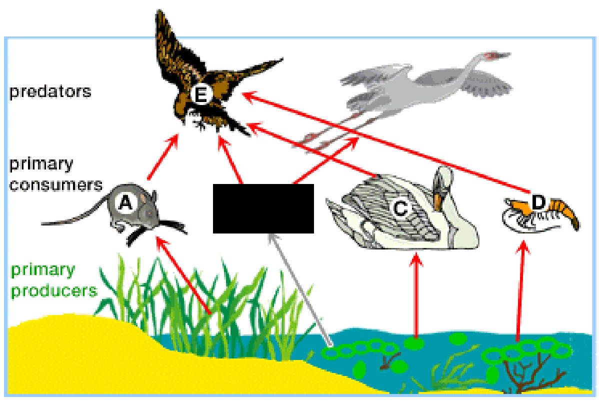
Question: Is this truly a commensalistic relationship? Community ecology seeks information about these and other interspecific interactions.

Biology Lecture Notes

The Decline in Species Diversity and the Current Mass Extinction

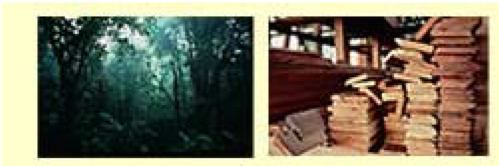
>> Key Concepts:

- **Species diversity** is the number of species in a community
- The species in a community are interdependent on one another. The extinction of a particular species will affect the other species that rely on it as a prey item.
- The Earth is currently undergoing a **mass extinction**, as a result of human activity and over-consumption. Two species-rich ecosystems that are particularly affected are the **tropical rainforests** and the **coral reefs**.
- The tropical rainforests contain the highest species diversity of any ecosystem on Earth.
- About 25% of all marine species live on coral reefs.



A loss in **species diversity**, the number of species in a community, can affect the stability of a community. The food web shown on the left shows that, with the exception of **autotrophs**, organisms rely on other organisms to obtain food. If species B becomes extinct (as portrayed by the black box), predators such as species E are affected, and will have to compensate by feeding more intensely on A, C, and D. The populations of A, C, and D may be detrimentally affected, as well as the autotrophic plants that they consume. The example shows that the loss of one species can affect the entire food web of producers, consumers, and predators.

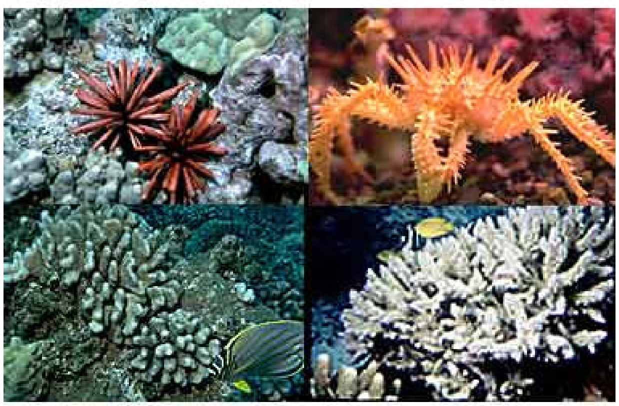
Biology Lecture Notes



The Earth is currently undergoing a **mass extinction**, which is caused by humans and our role as consumers. Two ecosystems that are particularly affected are tropical rainforests and coral reefs.

The **tropical rainforests** contain the highest species diversity of any ecosystem on Earth. Two primary causes of destruction are the use of tropical wood for construction and eating South American beef from cattle raised in the tropics.

Decisions about ending tropical rainforest destruction should protect the indigenous people's right to a fair standard of living.



Approximately 24% of all marine species live on coral reefs. 27% of the reefs have been effectively lost. Five main causes of destruction are: global warming, runoff, sedimentation, collection of coral, and cyanide fishing.

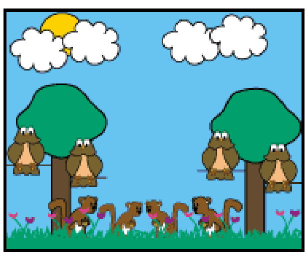
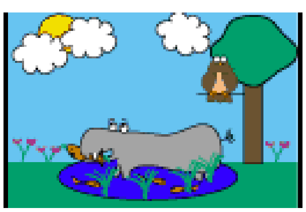
Zooxanthellae are mutualistic symbionts in the dermal tissue of many corals. An increase in water temperature of only one or two degrees causes coral bleaching, an event where the coral expels its zooxanthellae. Global warming may be raising the ocean temperature and contributing to coral bleaching.

Biology Lecture Notes

Ecosystems: A Flow of Energy

>> Key Concepts:

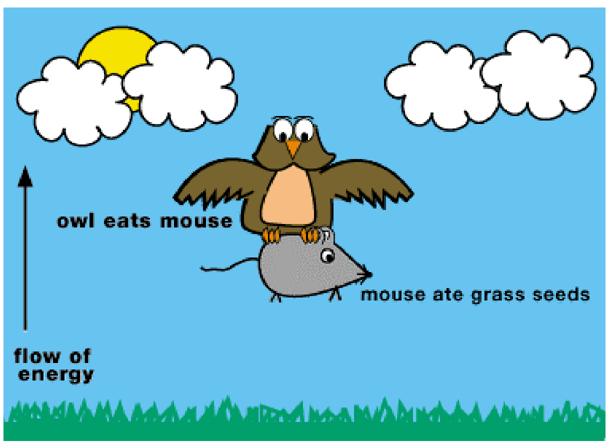
- The **ecosystem** is the most comprehensive level of organization an ecologist can study.
- Two processes that emerge at the ecosystem level are:
  - **flow of energy**
  - **cycle of materials**
- **Primary producers** form the base of the **trophic** (feeding) structure of organisms. **Consumers** feed on producers or other consumers.
- A **food chain** is a feeding sequence that is used to describe the flow of energy and materials in an ecosystem.
- In general, food energy and nutrients are transferred up a series of trophic levels:
  - **primary producer**—forms the base of the food pyramid
  - **primary consumer**—feeds on primary producers
  - **secondary consumer**—feeds on primary consumers
  - **tertiary consumer**—feeds on secondary consumers
  - **quaternary consumer**—feeds on tertiary consumers
- The **food web** presents a more accurate representation of trophic interaction than the food chain.

	**Review**: A population is a collection of organisms of the same species. A community is all of the populations that live in a given area. An **ecosystem** is the biological community in an area and the physical environment with which it interacts.
	Two major ecosystem-level processes: 1. **flow of energy—**Some living things (**primary producers**) have organized systems that harness light energy from the sun. Other living things (**consumers**) feed on these organisms or other consumers. Because of **entropy**, energy transfer through the food chain is inefficient. In ecological systems, energy does not cycle; it is constantly dissipated and lost as heat energy. 2. **cycle of materials—**In contrast to the one-way flow of energy, the amount of materials on the planet is finite. These materials are constantly being recycled by organisms.

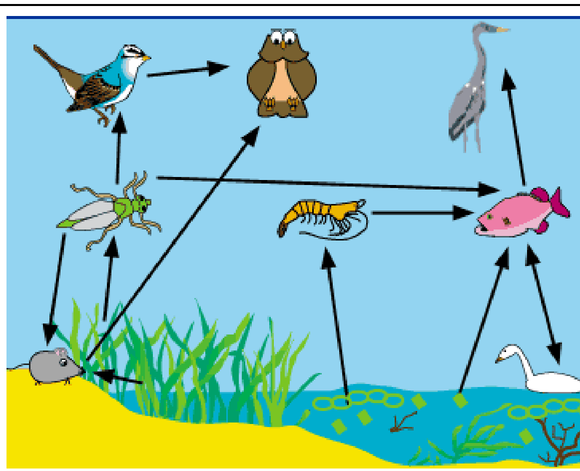
Biology Lecture Notes

trophic level	example	characteristic
quarternary consumers	hawk (carnivore)	eats tertiary consumers
tertiary consumers	snake (carnivore)	eats secondary consumers
secondary consumers	mouse (generalist)	eats primary consumers
primary consumers	beetle (herbivore)	consume primary producers
primary producers	plants	produce own food by photosynthesis

The chart on the left shows the basic trophic levels and their typical characteristics. **Primary producers** are autotrophs, capable of obtaining organic food molecules without eating other organisms. Plants use the energy from the sun to convert carbon dioxide to sugars. **Primary consumers** feed on primary producers. **Secondary consumers** feed on primary consumers. Tertiary consumers feed on secondary consumers. **Quaternary consumers** feed on tertiary consumers.



The diagram on the left illustrates a simple **food chain**. The grass species are the primary producers that use solar energy to synthesize sugar. The mouse is the primary consumer that feeds on grass seeds. The owl is the secondary consumer, feeding on the mouse.



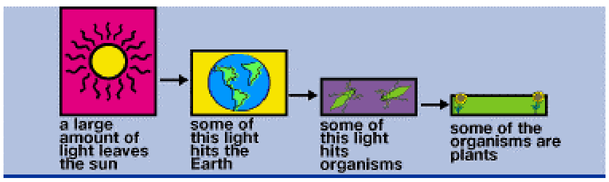
In actual communities, the feeding relationships among trophic levels are rarely linear. The complex **food web** on the left shows how energy may be transferred amongst the trophic levels.

Biology Lecture Notes

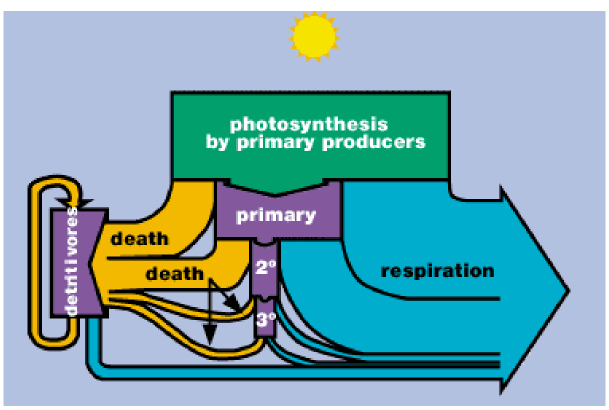
Ecosystems: Productivity and Energy Flow

>> Key Concepts:

- **Detritivores** obtain their energy from nonliving things.
- **Primary productivity** is a measure of the incorporation of energy (usually solar) into bodies of organisms.
- The transfer of energy from trophic level to trophic level is 10% on average. Most of the remaining energy is expended on respiration and growth.
- "Warm-blooded" organisms expend more energy on respiration than "cold-blooded" organisms.



Only a fraction of the energy that leaves the sun hits the earth; plants intercept only a fraction of that energy. It is estimated that about 1% of the energy in sunlight is available for primary producers. From this small amount, plants produce 170 billion tons of biomass.

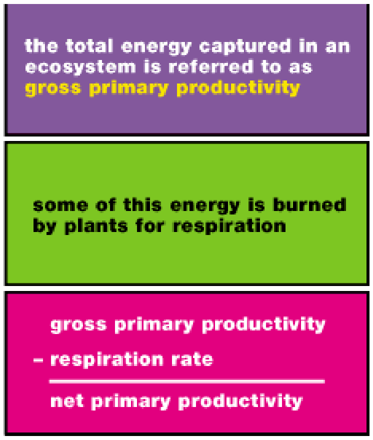


The illustration on the left shows the flow of energy through trophic levels. The relative amount of energy obtained by each trophic level is reflected in the graphic.

Primary producers are green plants and other organisms that can bind energy from inorganic sources into the chemical bonds of organic compounds. Plants convert solar energy into chemical energy in the form of carbohydrates. Plants produce a relatively large amount of chemical energy. Overall, the transfer of energy from trophic level to trophic level is 10% on average. Energy that is consumed on respiration, growth, and waste matter at any previous trophic level is no longer available to the subsequent trophic levels.

Detritivores consume the energy available from all of the other trophic levels after organisms in those levels die.

Biology Lecture Notes



Because plants are the primary producers in many communities, it is of great interest to measure the amount of chemical energy they produce and how much of that is available to higher trophic levels.

Gross primary productivity is a measure of the energy that is bound (and organic matter created) per unit area by the photosynthesis of green plants. As discussed earlier, not all of the energy obtained by the plants is available for the other trophic levels. The plants use some of the energy for respiration.

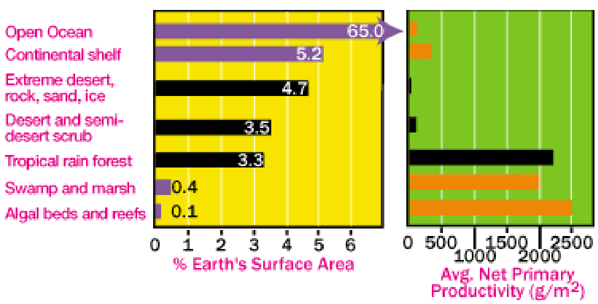
Net primary productivity is gross primary productivity minus plant respiration. The more efficient a plant is at conserving energy, the greater its net primary productivity.

Biology Lecture Notes

Productivity Pyramids: Visualizing Energy Flows

>> Key Concepts:

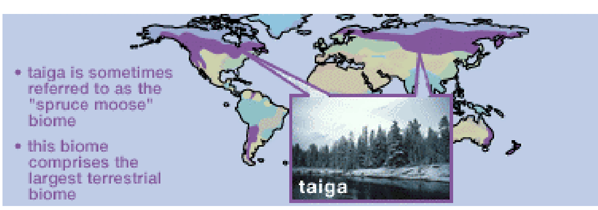
- Ecosystems can be analyzed on the basis of **primary productivity-to-area ratios** and **total productivity**.
- The **open ocean** has the greatest total productivity. The rain forests have the highest productivity-to-area ratio.
- The energy and biomass pyramids of different ecosystems have different appearances.
- Deciduous forests have a large proportion of biomass tied up in primary producers.



Question: Where do you think the highest rates of photosynthesis occur on our planet?

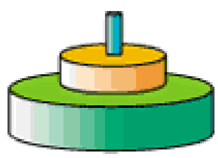
Review: A **biome** is a major ecological community type, such as desert or tropical rain forest.

Comparing productivity across seven biomes yields interesting results. The **open ocean** accounts for an estimated 65% of the earth's surface (see yellow graph) and contains photosynthetic algae and other primary producers. The ocean, however, accounts for a relatively small proportion of the earth's productivity. **Tropical rain forests** comprise less than 0.5% of the earth's surface, yet they account for much of the earth's productivity. The rain forests are home to nearly half of the earth's biological species, many of which are primary producers.



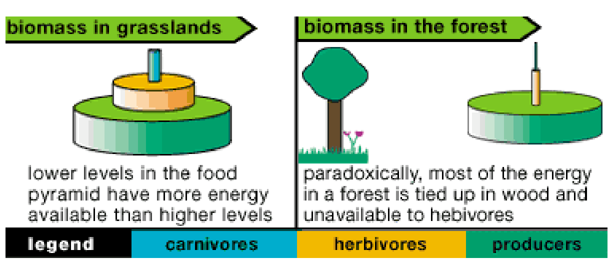
Review: A **food chain** portrays a feeding sequence from producers to consumers. A **biome** is a geographical region characterized by a distinctive landscape and community.

Different biomes have different food chains, depending on the predominant vegetation and organisms of the region. Coniferous trees characterize taiga, the largest terrestrial biome. Herbivores such as deer and moose feed on vegetation. Carnivores such as lynxes prey on herbivores.

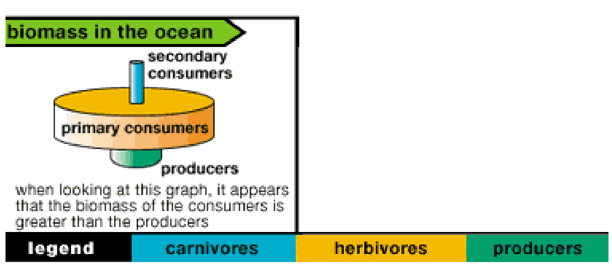


One way to look for patterns and distinctions between different food chains is to organize them by “stacking” the trophic levels on top of each other. Because primary producers form the base of the food chain, they are placed at the foundation (bottom) of the stack. Organizing trophic levels in this manner provides information about the efficiency of energy transfer through trophic levels.

Biomass is the aggregate dry weight of all organisms in a community or ecosystem. In the graphic on the left, the biomass present in each trophic level is represented. Many food chains that are organized in this manner look like a pyramid. Note that primary producers (the dark green area) account for the greatest proportion of biomass present. Energy transfer along trophic levels is, on average, 10% efficient. This rate of efficiency means that only 10% of the energy available in a given trophic level is transferred to the next trophic level.



The graphic on the left compares a food pyramid of grassland versus forest biome. Primary producers in grasslands are mainly herbaceous grasses. In the forest, primary producers are mainly hardwood trees. Because much of the biomass of trees is in the form of wood, little of it is available to primary consumers. Energy in the animal tissues of herbivores (primary consumers) is more efficiently assimilated. Consequently, the transfer of energy from primary to secondary consumers is more efficient.



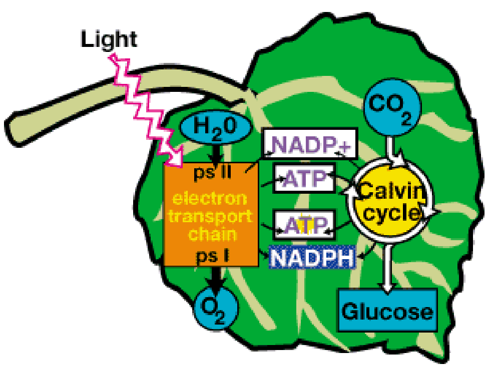
A food pyramid of an ocean food chain appears very different from terrestrial food chains. In the illustration to the left, the biomass of the primary producers appears to be less than that of the primary consumers. There is a greater biomass of primary producers, but because turnover rate is so high, the biomass of the primary producers is represented as a smaller section.

Biology Lecture Notes

Productivity Pyramids: Pyramid of Numbers

>> Key Concepts:

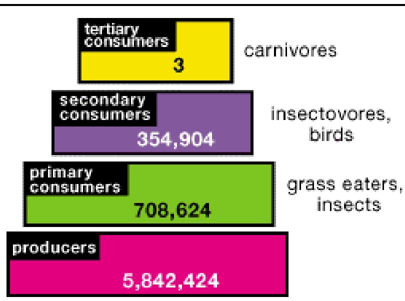
- Analyzing various **productivity** (**food**) **pyramids** reveals that approximately 10% of the energy present in a **trophic level** is incorporated into **biomass** in the next trophic level.
- The number of **primary producers** in an ecosystem is a limiting factor for the number of organisms in higher trophic levels.
- A census taken of a Michigan bluegrass field indicated that approximately 6 million primary producers supported only three tertiary consumers.



Review: The **primary producers** are green plants and other organisms than can bind energy from inorganic sources into the chemical bonds of organic compounds. Using the sun's energy, plants convert carbon dioxide into carbohydrates.

Primary producers supply food either directly or indirectly for all of the other organisms on the planet.

Trophic levels are feeding levels used to categorize organisms according to their source of nutrition.



Question: Which trophic level has the greatest number of organisms?

The producers make up the largest trophic level. A census taken of a Michigan bluegrass field (results shown on the left) indicated that close to 6 million primary producers supported only three tertiary consumers.

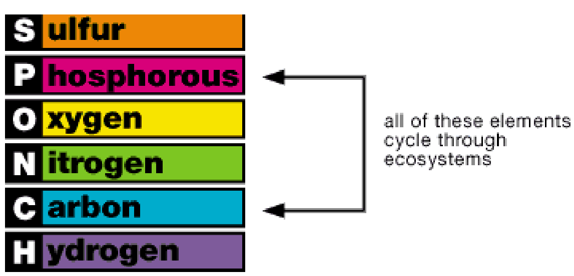
Because primary producers make energy available to all of the other levels of the food chain, the number of primary producers in an ecosystem limits the number of organisms in the other trophic levels.

Biology Lecture Notes

Ecosystems and Material Cycles: Water, Carbon, and Sulfur

>> Key Concepts:

- All ecosystems need a **flow of energy** and a **cycle of materials**
- In the **carbon cycle**, carbon dioxide (CO_2) is converted to glucose by photosynthesis, and glucose is converted to CO_2 by respiration.
- In the **hydrologic cycle**, the sun's energy drives water evaporation. The water then condenses to form precipitation.
- In the sulfur cycle, volcanoes and factories emit sulfur oxides. These sulfur oxides are incorporated into vegetation, which decomposes, thereby completing the cycle.

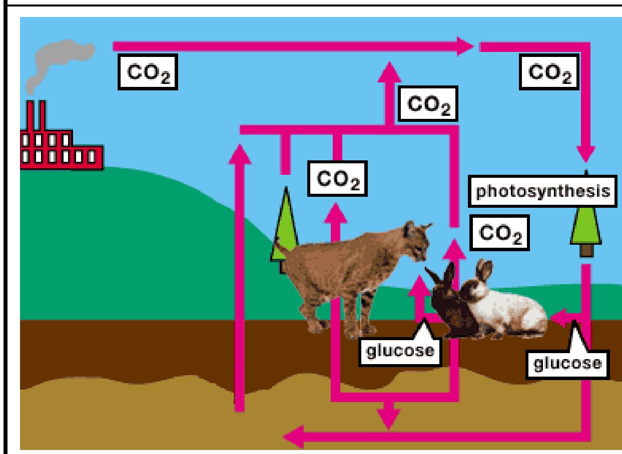


All ecosystems need two basic things:

1. **flow of energy**
2. **cycle of materials**

Review: Energy flows through ecosystems in one direction and cannot be recycled.

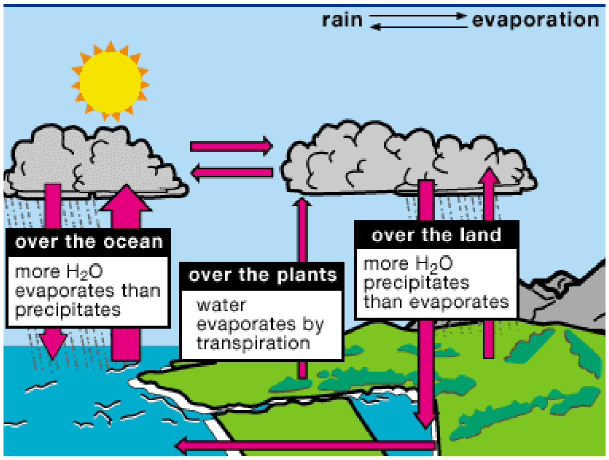
Materials like elements are recycled by ecosystems. The chart on the left shows six fundamental elements used by living organisms. The mnemonic to remember them is the nonsense word "SPONCH." They are sulfur, phosphorous, oxygen, nitrogen, carbon, and hydrogen.



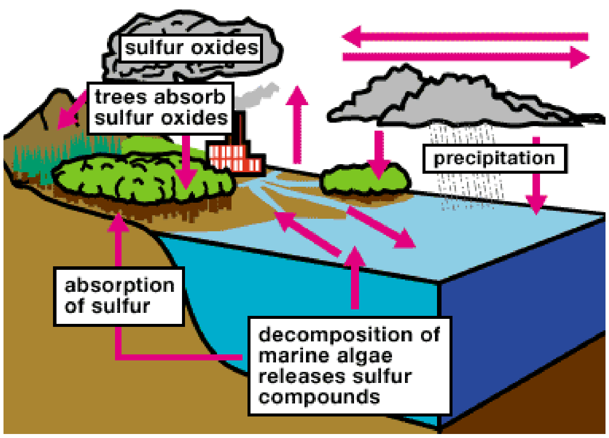
In the **carbon cycle**, carbon dioxide (CO_2) is converted to glucose by photosynthesis; glucose is converted to CO_2 during respiration. The image on the left illustrates the cycling of CO_2 in an ecosystem.

A surplus of CO_2 exists in the atmosphere because of industry and large-scale deforestation.

Biology Lecture Notes



In the **hydrologic cycle**, the sun's energy drives water evaporation, which then condenses to form precipitation. Over the open ocean, more water evaporates than precipitates. Also, over large tracts of forested area, a large amount of water evaporates because of plant transpiration (the evaporation of water by plants through the leaves.) Over most land areas, more water precipitates than evaporates.



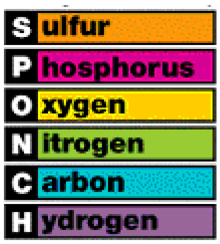
The sulfur cycle is fairly complex. On land, trees and other photosynthetic organisms absorb sulfur oxides and incorporate them into organic matter. Dead organic matter may be converted to sulfates by bacteria. The burning of fossil fuel releases large amounts of sulfur oxides into the atmosphere, resulting in acid rain. In the ocean, certain kinds of algae contain large concentrations of sulfur compounds. When the algae decompose, they release sulfur compounds that may be available for absorption by terrestrial plants.

Biology Lecture Notes

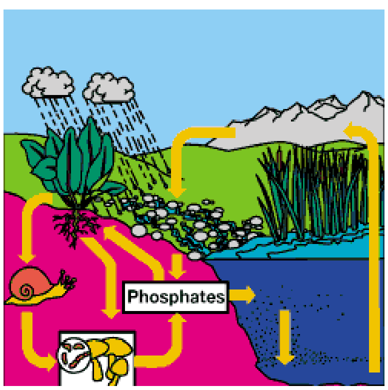
Ecosystems and Material Cycles: Nitrogen and Phosphorus Cycles

>> Key Concepts:

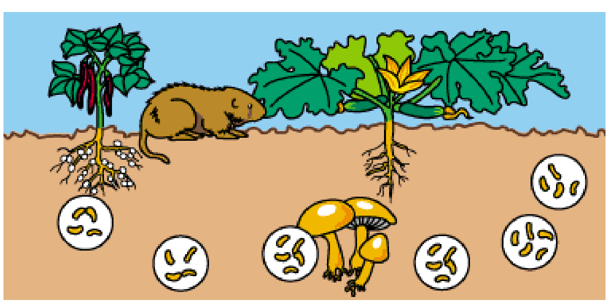
- **Review**: Six major elements cycled through organisms are sulfur, phosphorus, oxygen, nitrogen, carbon, and hydrogen.
- In the **phosphorus cycle**, inorganic phosphorus enters ecosystems from the weathering of rocks. Plants take it up and convert it to an organic form.
- In the **nitrogen cycle**, nitrogen-fixing bacteria convert N_2 into ammonium (NH_4^+), which plants use.



Review: The mnemonic "SPONCH" refers to six major elements that cycle through living organisms. The elements are sulfur, phosphorus, oxygen, nitrogen, carbon, and hydrogen.



In living organisms, phosphorus is an essential component of ATP, DNA, and phosphorylated intermediates. Phosphorus enters ecosystems from the weathering of rocks in soil and water. Phosphorus is taken up by plants, and thereby enters the food chain. The processes of detritivores recycle the phosphates.



The nitrogen cycle

Seventy-five percent of the earth's atmosphere is gaseous nitrogen (N_2). Though the majority of our atmosphere is nitrogen, our bodies cannot absorb nitrogen gas.

Nitrogen-fixing bacteria convert atmospheric nitrogen (N_2) into ammonium (NH_4^+), a compound that is usable by plants. Nitrogen-fixing bacteria of the genus *Rhizobium* live as symbionts in nodules on the roots of legumes.

Nitrifying bacteria convert NH_4^+ to nitrites (NO_2^-) and nitrates (NO_3^-), which are forms of nitrogen that are usable by plants.

Denitrifying bacteria convert nitrates into atmospheric N_2.

Biology Lecture Notes

The Effects of Human Population Growth: Lake Eutrophication

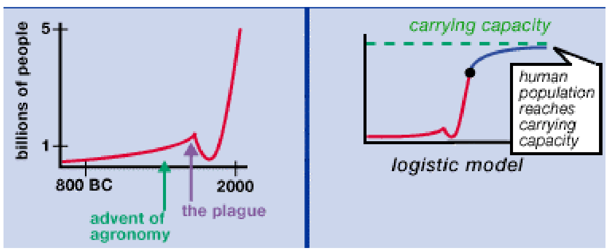
>> Key Concepts:

- Human populations may affect ecosystem level processes, such as chemical cycling.
- The human population is currently undergoing an exponential growth phase with a population exceeding 6 billion.
- One effect of human population growth is lake **eutrophication**.
- By studying ecology, humans can learn to lessen their impact on ecosystems.

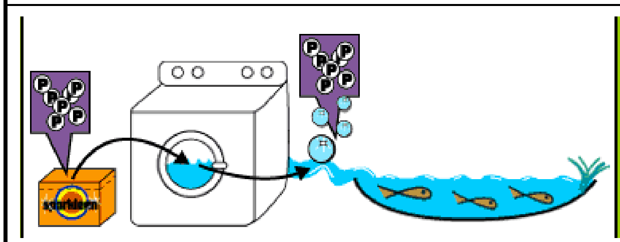
Question: How do humans affect the Earth's ecosystems?

Human population growth limits the resources available to other organisms and affects ecosystem level processes such as chemical cycling.

Review: Exponential growth is the geometric increase of a population that has access to unlimited resources.



The graph on the far left charts human population growth over time. Currently in many countries, the human population growth approaches an exponential curve. Eventually, human population change will be affected by limited resources and approach **carrying capacity** (graph on immediate left).



Review: **eutrophication** is the nutrient enrichment of a lake or a stream that causes a change in the lake's community. It sometimes occurs during the process of ecological succession.

Eutrophication can also result from the runoff of fertilizer or the addition of sewage. An increased residential use of phosphate enriched detergents resulted in the eutrophication of Lake Erie. The nutrients upset the existing community balance, causing algae blooms. Algae use large quantities of oxygen vital to other organisms. When the algae die, the action of detritivores depletes the oxygen supply further. Eventually, Lake Erie was declared dead.

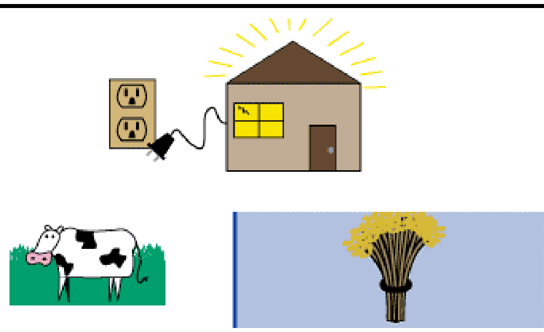
When phosphate-free detergent was used instead, the lake began to improve. Certain native fish and invertebrates still have not repopulated the lake.

Biology Lecture Notes

Toxic Accumulation and Ozone Depletion

>> Key Concepts:

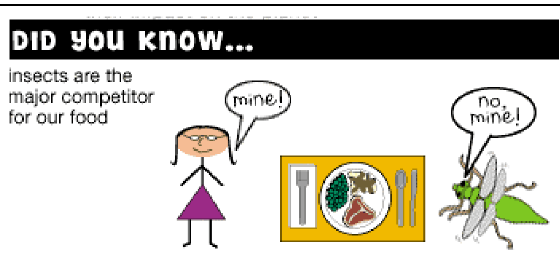
- Humans have a tremendous impact (mostly negative) on the **biosphere**.
- One example of negative impact involves the contamination of food chains by the chemical **DDT**.
- The accumulation of DDT in the food chain is an example of **biological magnification**. In one study, DDT concentration was 10 million times greater in the topmost predator than in the primary producer's water supply.
- Other examples of negative human impact include:
  - ozone depletion
  - acid rain
  - greenhouse effect



Humans should use technology to lessen their impact on the planet.

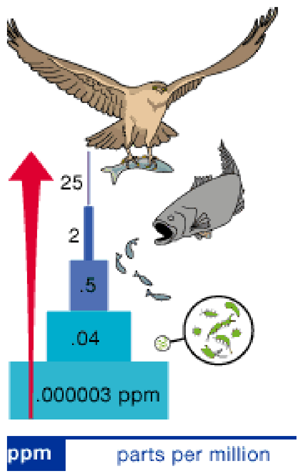
The advent of agronomy (the science of farming) solved the problem of finding enough food, which increased the amount of time available for other tasks.

As human populations grow exponentially, the need for raw materials also grows exponentially.



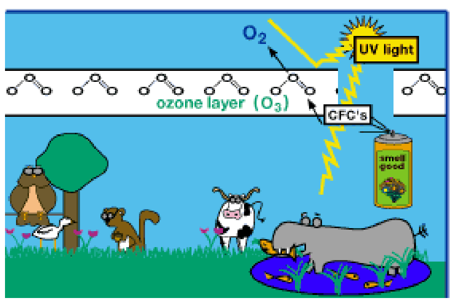
Many insects benefit human food production. Without pollinating insects, we would have few vegetables, fruits, clover, and many other important crops. A few insects, however, are competitors with humans for food crops and are considered pests. Before we fully understood the complexity of ecosystems, the approach to eradicating these pests was a widespread use of pesticides.

After World War II, many people began using the fat-soluble pesticide **DDT** for controlling insect populations. The pesticide has a low rate of biological breakdown and can remain in the environment long after it is sprayed. Because it is fat-soluble, it accumulates in the fatty tissues of organisms.



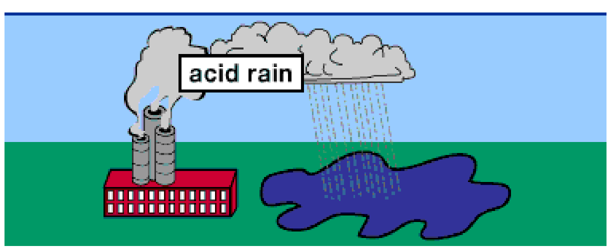
People began to suspect an environmental problem when populations of fish-eating birds began to decline drastically. The levels of pesticides found in the birds' tissues were in much greater concentration than were present in the environment.

The phenomenon of **biological magnification** describes the process in which substances become concentrated with each higher trophic level. In one study, the DDT concentration was 10 million times greater in the topmost predator than in the primary producer's water supply (see the illustration on the left).

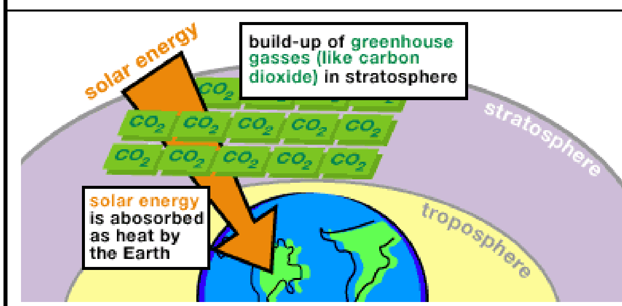


The **ozone layer** is an atmospheric layer within the stratosphere. It contains **ozone** (O_3), an unstable form of oxygen. The ozone layer filters out harmful UV radiation.

Chlorofluorocarbons (CFCs) present in aerosol deodorant and other substances release chlorine ions that react with O_3, breaking it down to O_2. In 1985, scientists found holes in the ozone layer over the North and South poles that appeared to be growing larger. Evidence links the ozone holes to CFC use, but the debate continues.



Acid rain occurs when sulfur oxides and nitrogen oxides react with water in the air to form strong acids. Acid rain has dramatic effects on aquatic ecosystems. For example, a lake in the Adirondacks has the same pH as vinegar and is totally devoid of life.



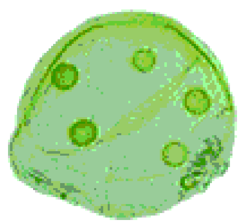
Increased carbon dioxide emissions have resulted in the **greenhouse effect**. Solar energy passes through the atmosphere to the earth where it is absorbed and radiated as heat. An accumulation of carbon dioxide acts like glass in a greenhouse and reflects the heat back to the earth. It is estimated that a two degree rise in global temperature could cause the polar ice caps to melt.

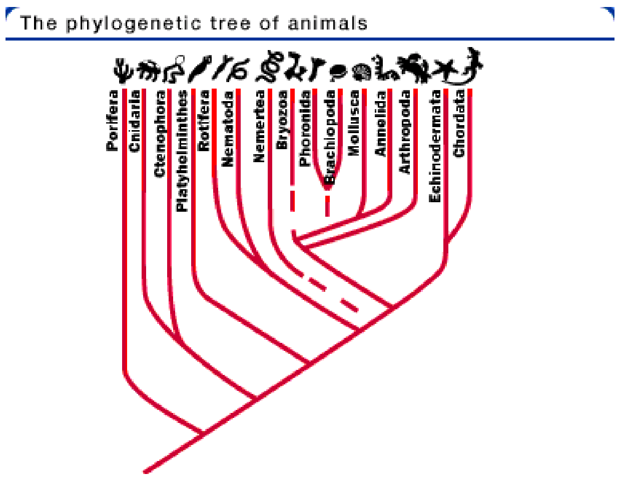
Biology Lecture Notes

Constructing a Phylogenetic Tree of Animals: Animal Development

>> Key Concepts:

- The entire animal kingdom may have descended from a single common ancestor, probably a colonial flagellated protist.
- Four key characteristics of an animal are:
  1. ingestion of food
  2. structural proteins for support
  3. presence of nerves and muscles
  4. unique embryological development
- The second major branching point of the phylogenetic tree of animals involves **radial** versus **bilateral symmetry** (no sides versus two-sided body plan.)

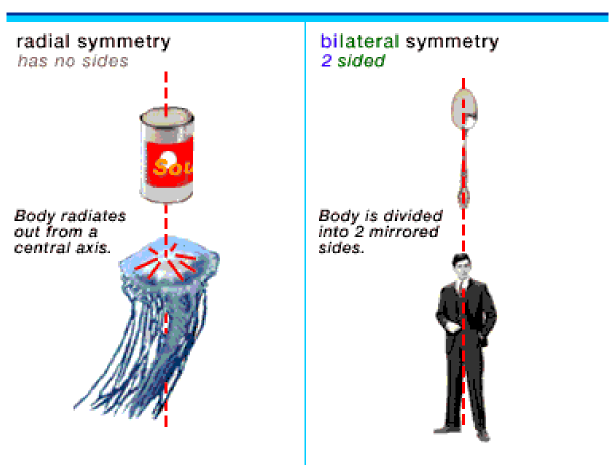
	To construct a phylogenetic tree of animals, first determine the possible common ancestor. It is believed that the common ancestor was a multicellular colonial flagellated protist that lived more than 700 million years ago. The term **colonial** describes a group of cells that are physically adjoining, but not dependent on each other. The common ancestor may have looked something like the green algae *Volvox*, a modern colonial organism.
	General homologies among animals include: 1. ingestion of food 2. use of protein for structural support versus cell walls 3. presence of nerves and muscles 4. unique embryological development **Review**: The **outgroup** is a species or group of species that are more closely related to each other than to other species in their clade. Multicellularity is one of the few shared characteristics among sponges (the outgroup) and the rest of the animal kingdom.



Review: The Linnaean system of taxonomy, shown below and left, uses a hierarchical system of classification with the following groupings of greater specificity. A mnemonic that is useful for remembering the order and name of the groupings is seen below and right:

Kingdom	**K**
Phylum	**P**
Class	**C**
Order	**O**
Family	**F**
Genus	**G**
Species	**S**

Looking at the phylogenetic tree of animals, you can see that sponges diverged from the rest of the animal kingdom at an early point. Taxonomic classification reflects the sponge's early divergence. Sponges, which lack true tissues, are grouped as parazoa ("besides the animals"). The rest of the animal kingdom is collectively called the eumetazoa ("true animals").



The eumetazoa are divided into two major branches based on differences in body symmetry:

Members of the phyla Cnidaria (hydras and jellyfish) and Ctenophora (comb jellies) have **radial symmetry**. The term radial means branching out in all directions from a common center. Animals with radial symmetry have a top and a bottom, but no sides.

Animals of the other major branch include many different phyla and are characterized by **bilateral symmetry**. Animals that are bilateral (two-sided) have a dorsal (top) and ventral side (underneath) side, but also have a head and a tail end.

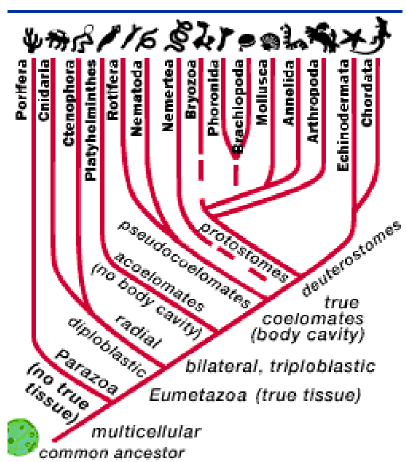
The term **cephalization** describes an evolutionary trend toward the concentration of sensory equipment at the anterior end of the body.

Biology Lecture Notes

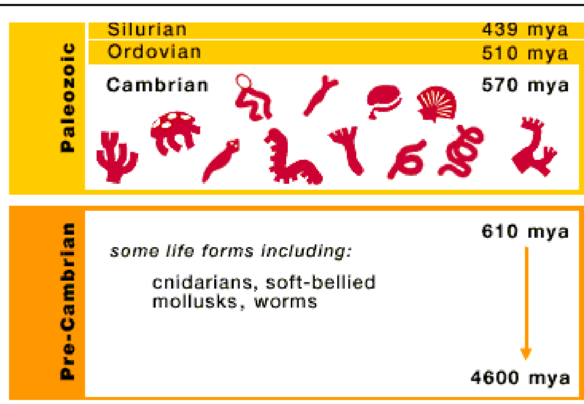
Animal Diversity: The Cambrian Explosion and the Move to Land

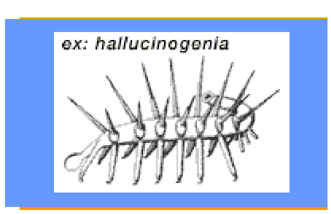
>> Key Concepts:

- Using anatomical and embryological evidence, we can group the animal kingdom into 35 phyla.
- It is believed that most of these phyla evolved during the **Cambrian explosion**.
- Key adaptations by terrestrial organisms include a means of preventing desiccation of the:
  - body
  - gametes
  - embryo



The illustration shows the evolutionary relationships among some of the major extant animal phyla. The animal kingdom is grouped into 35 phyla, and it is believed that most of the phyla evolved during the **Cambrian explosion**.



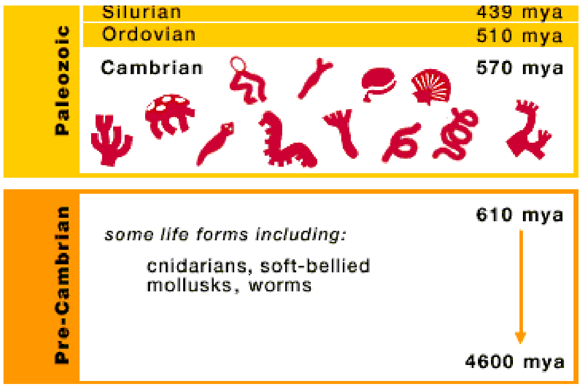


The Cambrian period marks the beginning of the Paleozoic era, which began about 570 million years ago and lasted 222 million years. The era includes five other periods: Ordovician, Silurian, Devonian, Carboniferous, and Permian.

Fossils from the **Burgess Shale** (a fossil bed in British Columbia) of the Cambrian period reveal such a rich diversity of life that the period is called the **Cambrian explosion**. All of the modern animal phyla and some extinct groups were formed during this time.

During the Cambrian, the ocean floor was covered with corals, sea lilies, sponges, snails, squidlike cephalopods, trilobites, at least one kind of chordate, and other marine animals. Members of the genus *Hallucinogenia*, odd-looking marine animals, are now extinct.

Biology Lecture Notes



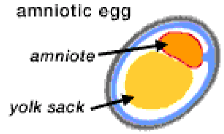
Scientists still debate possible causes of the **Cambrian explosion**. Oxygen concentrations probably played a key role, increasing over a critical biological threshold (10% of present-day oxygen, or higher) in the late in the Precambrian era.

Geologists believe that the continents were gradually flooded during the Cambrian period. Adaptations of animals pertained to survival in aquatic environments. The sea continued to cover the continents through the Silurian and receded somewhat over subsequent periods.

Members of the phyla Chordata and Arthropoda were among the first animals to adapt to terrestrial conditions that began to emerge in the Silurian period.

obstacle: dessication

	amphibians	reptiles
body	still need moisture	scales protect against water loss
gametes	amplexus allows for a more controlled external fertilization, but it still takes place in water	internal fertilization provides an aquatic medium internally
development	zygote develops in water	amniotic egg



Survival on land versus water requires adaptations that prevent water loss from gametes (sex cells), the developing embryo, and the adult body. The chart on the left shows some key adaptations of amphibians and reptiles.

The Carboniferous period is also called the age of **amphibians**, because they were the only vertebrates on land during this time. They thrived in swampy conditions, the prevalent terrestrial habitat during this period. Modern amphibians still have a close association with water. Their skin requires moisture for respiration. Fertilization is external and must take place in an aqueous medium. The zygote must develop in water.

Reptiles evolved from an amphibian ancestor. The reptilian body plan is adapted for terrestrial conditions. Scales provide protection from desiccation. Fertilization is internal, providing the aquatic medium necessary and decreasing the animals' dependence on water. Development of the embryo takes place in the amniotic egg, which is adapted to dry conditions.