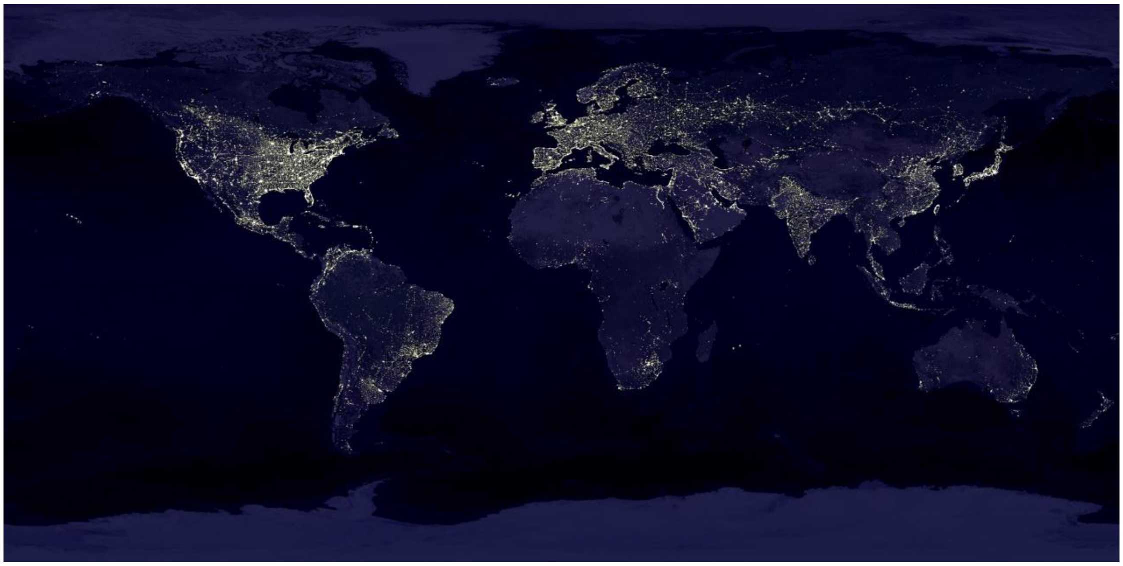
Lesson 14: Ecosystems and Human Populations



A lot of information is shown in this image of Earth's city lights. Although there is a map underlying the lights, why is it possible to see the outlines of the continents in many locations anyway? What does this tell about where cities are located? What geographical features can you locate? Can you find the Nile River? The Himalaya Mountains? The Sahara Desert?

What characteristics do the regions with the brightest lights share? What is different about them? How do they differ from the regions that are dark? What characteristics do those dark regions share and what is different about them?

The regions with the brightest lights are the most urbanized. Do they have the largest populations? Do they have the largest population densities? The brightest lights are found in the eastern half of the United States, Europe, and Japan. But the nations with the highest populations are China and India and the highest population densities are in some tiny countries such as Bangladesh, Taiwan, South Korea, and parts of Africa.

Can you locate your town?

Ecosystems

Section Objectives

- Discuss the importance of chemical and physical factors to living organisms.
- Describe the role of different species in an ecosystem.
- Describe the function of an ecosystem, and how different species fill different roles in different ecosystems.
- Describe energy transfer from the lowest to the highest trophic level in a chain, including energy loss at every trophic level.
- Discuss how materials are cycled between trophic levels and how they can enter or leave a food web at any time.

Introduction

An **ecosystem** is made up of the living creatures and the nonliving things that those creatures need within an area. Energy moves through an ecosystem in one direction. Nutrients cycle through different parts of the ecosystem and can enter or leave the ecosystem at many points.

Biological Communities

A **population** consists of all individuals of a single **species** that occur together at a given place and time. A species is a single type of organism that can interbreed and produce fertile offspring. All of the populations living together in the same area make up a community. An ecosystem is all of the living things in a community and the physical and chemical factors that they interact with.

In an Ecosystem

The living organisms within an ecosystem are its biotic factors (**Image below**). Living things include bacteria, algae, fungi, plants , and animals, including invertebrates, animals without backbones, and vertebrates, animals with backbones.

(a) The horsetail Equisetum is a primitive plant. (b) Insects are among the many different types of invertebrates. (c) A giraffe is an example of a vertebrate.

Physical and chemical features are **abiotic** factors. Abiotic factors include resources living organisms need such as light, oxygen, water, carbon dioxide, good soil, and nitrogen, phosphorous, and other nutrients. Abiotic factors also include environmental features that are not materials or living things, such as living space and the right temperature range.

Niches

Organisms must make a living, just like a lawyer or a ballet dancer. This means that each individual organism must acquire enough food energy to live and reproduce. A species' way of making a living is called its **niche**. An example of a niche is making a living as a top carnivore, an animal that eats other animals, but is not eaten by any other animals (**Image below**). Every species fills a niche, and niches are almost always filled in an ecosystem.

The top carnivore niche is filled by lions on the savanna, wolves in the tundra, and tuna in the oceans.

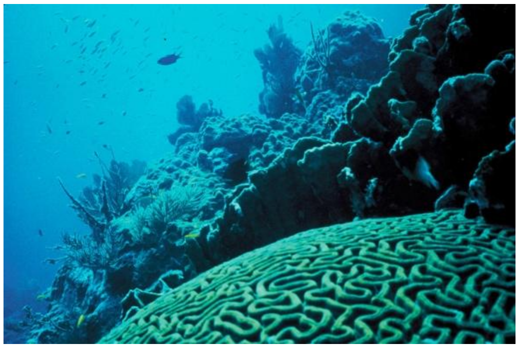
Habitat

An organism’s **habitat** is where it lives (**Image below**). The important characteristics of a habitat include climate, the availability of food, water, and other resources, as well as other factors, such as weather.

Birds living in a saguaro cactus. A habitat may be a hole in a cactus or the underside of a fern in a rainforest. It may be rocks and the nearby sea.

Roles in Ecosystems

There are many different types of ecosystems, some of which were described in the biomes discussion in the Climate chapter (**Image below**). As with biomes, climate conditions determine which ecosystems are found in which location. A particular biome encompasses all of the ecosystems that have similar climate and organisms.



Coral reefs are complex and beautiful ecosystems.

Different organisms live in each different type of ecosystems. Lizards thrive in deserts, but no reptiles can survive at all in polar ecosystems. Large animals generally do better in cold climates than in hot climates.

Despite this, every ecosystem has the same general roles that living creatures fill. It's just the organisms that fill those niches that are different. For example, every ecosystem must have some organisms that produce food in the form of chemical energy. These organisms are primarily algae in the oceans, plants on land, and bacteria at hydrothermal vents.

Producers and Consumers

The organisms that produce food are extremely important in every ecosystem. Organisms that produce their own food are called **producers**. There are two ways of producing food energy:

- Photosynthesis: plants on land, phytoplankton in the surface ocean, and some other organisms, described in the Earth's Atmosphere chapter and elsewhere.
- Chemosynthesis: bacteria at hydrothermal vents as discussed in the Earth's Oceans chapter.

Organisms that use the food energy that was created by producers are named **consumers**. There are many types of consumers.

- **Herbivores** eat producers directly (**Image below**). These animals break down the plant structures to get the materials and energy they need.
- **Carnivores** eat animals; they can eat herbivores or other carnivores.
- **Omnivores** eat plants and animals as well as fungi, bacteria, and organisms from the other kingdoms.

Deer are herbivores.

Feeding Relationships

There are many types of **feeding relationships** (**Image below**) between organisms: predators , scavengers, and decomposers.

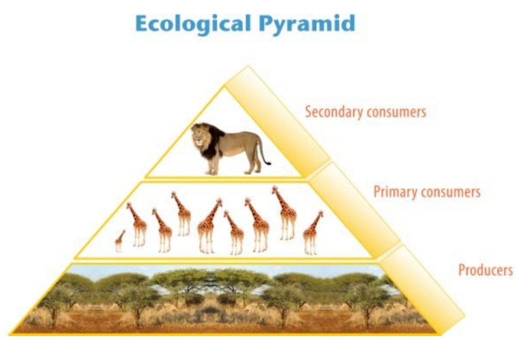
(a) A predator is an animal that kills and eats another animal, known as its prey. (b) Scavengers are animals, such as vultures and hyenas, that eat organisms that are already dead. (c) Decomposers break apart dead organisms or the waste material of living organisms, returning the nutrients to the ecosystem. Bacteria, and fungi in this photo, are decomposers.

Flow of Energy in Ecosystems

Remember from the Earth's Atmosphere chapter that plants create chemical energy from abiotic factors that include solar energy. Chemosynthesizing bacteria create usable chemical energy from unusable chemical energy. The food energy created by producers is passed to consumers, scavengers, and decomposers.

Trophic Levels

Energy flows through an ecosystem in only one direction. Energy is passed from organisms at one **trophic level** or energy level, to organisms in the next trophic level. Which organisms do you think are at the first trophic level (**Image below**)?

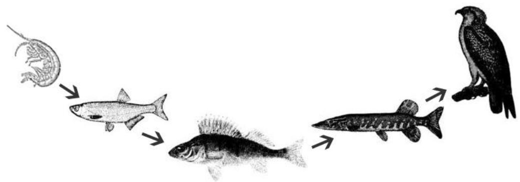


Producers are always the first trophic level, herbivores the second, the carnivores that eat herbivores the third, and so on.

Most of the energy – about 90% – at a trophic level is used at that trophic level. Organisms need it for locomotion, heating themselves, and reproduction. So animals at the second trophic level have only about 10% as much energy available to them as do organisms at the first trophic level. Animals at the third level have only 10% as much available to them as those at the second level.

Food Chains

The set of organisms that pass energy from one trophic level to the next is described as the **food chain** (**Image below**). In this simple depiction, all organisms eat at only one trophic level (**Image below**).



A simple food chain in a lake. The producers, algae, are not shown. For the predatory bird at the top, how much of the original energy is left?

What are the consequences of the loss of energy at each trophic level? Each trophic level can support fewer organisms. How many osprey are there relative to the number of shrimp?

What does this mean for the range of the osprey (or lion, or other top predator)? A top predator must have a very large range in which to hunt so that it can get enough energy to live.

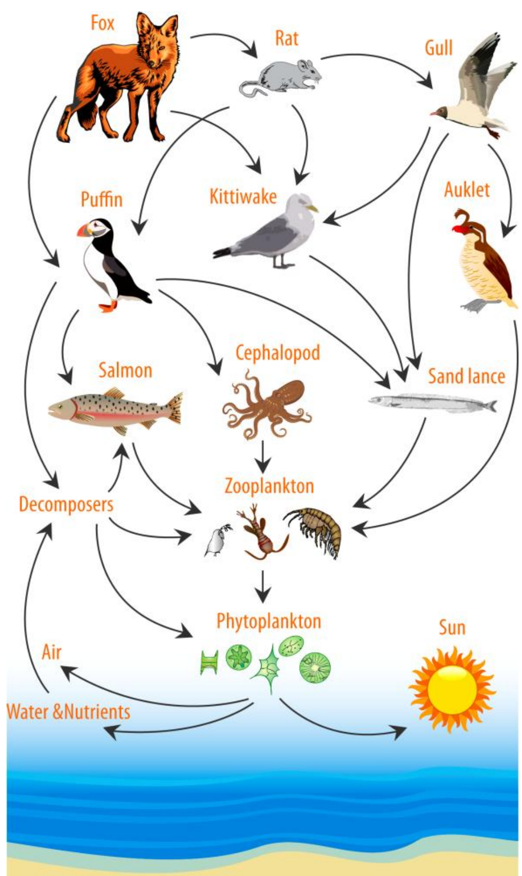
Why do most food chains have only four or five trophic levels? There is not enough energy to support organisms in a sixth trophic level. Food chains of ocean animals are longer than those of land-based animals because ocean conditions are more stable.

Why do organisms at higher trophic levels tend to be larger than those at lower levels? The reason for this is simple: a large fish must be able to eat a small fish, but the small fish does not have to be able to eat the large fish (**Image below**).

In this image the predators (wolves) are smaller than the prey (bison), which goes against the rule placed above. How does this relationship work? Many wolves are acting together to take down the bison.

Food Webs

What is a more accurate way to depict the passage of energy in an ecosystem? A **food web** (**Image below**) recognizes that many organisms eat at multiple trophic levels.



A food web includes the relationships between producers, consumers, and decomposers.

Even food webs are interconnected. All organisms depend on two global food webs. The base of one is phytoplankton and the other is land plants. How are these two webs interconnected? Birds or bears that live on land may eat fish, which connects the two food webs.

Where do humans fit into these food webs? Humans are an important part of both of these food webs; we are at the top of a food web since nothing eats us. That means that we are top predators.

Flow of Matter in Ecosystems

Nutrients are ions that are crucial to the growth of living organisms. Nutrients - such as nitrogen and phosphorous - are important for plant cell growth. Animals use silica and calcium to build shells and skeletons. Cells need nitrates and phosphates to create proteins and other biochemicals. From nutrients, organisms make tissues and complex molecules such as carbohydrates, lipids, proteins, and nucleic acids.

The flow of matter in an ecosystem is not like energy flow. Matter enters an ecosystem at any level and leaves at any level. Matter cycles freely between trophic levels and between the ecosystem and the physical environment (**Image below**).

What are the sources of nutrients in an ecosystem? Rocks and minerals break down to release nutrients. Some enter the soil and are taken up by plants. Nutrients can be brought in from other regions, carried by wind or water. When one organism eats another organism, it receives all of its nutrients. Nutrients can also cycle out of an ecosystem. Decaying leaves may be transported out of an ecosystem by a stream. Wind or water carries nutrients out of an ecosystem.

Decomposers play a key role in making nutrients available to organisms. Decomposers break down dead organisms into nutrients and carbon dioxide, which they respire into the air. If dead tissue would remain as it is, eventually nutrients would run out. Without decomposers, life on earth would have died out long ago.

Relationships Between Species

Species have different types of relationships with each other. **Competition** occurs between species that try to use the same resources. When there is too much competition, one species may move or adapt so that it uses slightly different resources. It may live at the tops of trees and eat leaves that are somewhat higher on bushes, for example. If the competition does not end, one species will die out. Each niche can only be inhabited by one species. Some relationships between species are beneficial to at least one of the two interacting species. These relationships are known as **symbiosis** and there are three types:

- In **mutualism**, the relationship benefits both species. Most plant-pollinator relationships are mutually beneficial. What does each get from the relationship?
- In **commensalism**, one organism benefits and the other is not harmed.
- In **parasitism**, the parasite species benefits and the host is harmed. Parasites do not usually kill their hosts because a dead host is no longer useful to the parasite. Humans host parasites, such as the flatworms that cause schistosomiasis.

Choose which type of relationship is described by each of the images and captions below (**Image below**).

(a) The pollinator gets food; the plant

Section Summary Part One

- Each species fills a niche within an ecosystem. Each ecosystem has the same niches, although the same species don't always fill them.
- Each ecosystem has producers, consumers, and decomposers. Decomposers break down dead tissue to make nutrients available for living organisms.
- Energy is lost at each trophic level, so top predators are scarce.
- Feeding relationships are much more complicated than a food chain, since some organisms eat from multiple trophic levels.
- Food webs are needed to show all the predator/prey interactions in an ecosystem.

Further Reading / Supplemental Links

Additional information about ecosystems: http://www.environment.sa.gov.au/education/pages/modules/biodiversity/eco_01.html

Vocabulary

trophic level
: Energy levels within a food chain or food web.

symbiosis
: Relationships between two species in which at least one species benefits.

species
: A classification of organisms that can or do interbreed and produce fertile offspring.

scavenger
: Animals that eat animals that are already dead.

producer
: An organism that converts energy into chemical energy that it can use for food. Most producers use photosynthesis but a very small number use chemosynthesis.

prey
: An animal that could be killed and eaten by a predator.

predator
: An animal that kills and eats other animals.

population
: All the individuals of a species that occur together in a given place and time.

parasitism
: A symbiotic relationship between two species in which one species benefits and one species is harmed.

omnivore
: An organism that consumes both producers and other consumers for food.

nutrients
: Ions that organisms need to live and grow.

niche
: An organism's "job" within its community.

mutualism
: A symbiotic relationship between two species in which both species benefit.

herbivore
: An animal that only eats producers.

habitat
: Where an organism lives, with distinctive features such as climate or resource availability.

food web

Interwoven food chains that show each organism eating from different trophic levels.

food chain
: An energy pathway that includes all organisms that are linked as they pass along food energy, beginning with a producer and moving on to consumers.

ecosystem
: All of the living things in a region and the physical and chemical factors that they need.

decomposer
: An organism that breaks down the tissues of a dead organism into its various components, including nutrients, that can be used by other organisms.

consumer
: An organism that uses other organisms for food energy.

competition
: A rivalry between two species, or individuals of the same species, for the same resources.

community
: All of the populations of organisms in an ecosystem.

commensalism
: A relationship in which one species benefits and the other species is not harmed.

carnivore
: Animals that only eat other animals for food.

biotic
: Living features of an ecosystem include viruses, plants, animals, and bacteria.

abiotic
: Non-living features of an ecosystem include space, nutrients, air, and water.

Points to Consider

- What happens if two species attempt to fill the same niche?
- There is at least one exception to the rule that each ecosystem has producers, consumers, and decomposers. Excluding hydrothermal vents, what does the deep sea ecosystem lack?
- Where do humans fit into a food web?
- Most humans are omnivores, but a lot of what we eat is at a high trophic level. Since ecosystems typically can support only a few top predators relative to the number of lower organisms, why are there so many people?

The Carbon Cycle and the Nitrogen Cycle

Section Objectives

- Describe the short term cycling of carbon through the processes of photosynthesis and respiration.
- Identify carbon sinks and carbon sources.
- Describe short term and long term storage of carbon.
- Describe how human actions interfere with the natural carbon cycle.
- Describe the nitrogen cycle.

Introduction

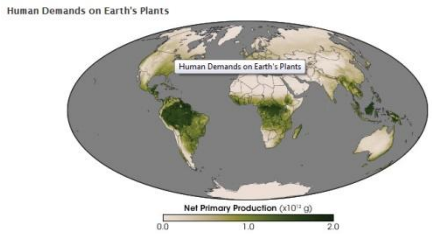
Carbon is a very important element to living things. As the second most common element in the human body, we know that human life without carbon would not be possible. Protein, **carbohydrates**, and fats are all part of the body and all contain carbon. When your body breaks down food to produce energy, you break down protein, carbohydrates, and fat, and you breathe out carbon dioxide.

Carbon occurs in many forms on Earth and is found throughout the environment (**Image below**). The element moves through organisms and then returns to the environment. When all this happens in balance, the ecosystem remains in balance too. In this section, let’s follow the path of a carbon atom over many years and see what happens.

Nitrogen is also a very important element, used as a nutrient for plant and animal growth. First, the nitrogen must be converted to a useful form. Without "fixed" nitrogen, plants, and therefore animals, could not exist as we know them.

Short Term Cycling of Carbon

The short term cycling of carbon begins with carbon dioxide (CO_2) in the atmosphere.



The production of food energy by land plants.

Through **photosynthesis**, the inorganic carbon in carbon dioxide plus water and energy from sunlight is transformed into organic carbon (food) (**Figure** above) with oxygen given off as a waste product. The chemical equation for photosynthesis is below (**Image below**):

$$\underset{\text{carbon dioxide}}{6\ CO_2} + \underset{\text{water}}{6\ H_2O} + \text{Energy from sunlight} \rightarrow \underset{\text{glucose (sugar)}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\ O_2}$$

Equation for photosynthesis.

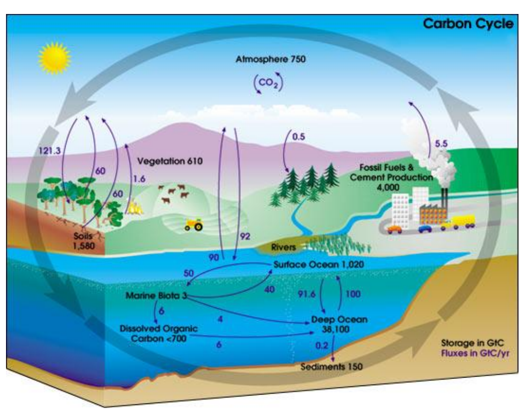
Plants and animals engage in the reverse of photosynthesis, which is **respiration**. In respiration, animals use oxygen to convert the organic carbon in sugar into food energy they can use. Plants also go through respiration and consume some of the sugars they produce.

The chemical reaction for respiration is:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + useable energy

Photosynthesis and respiration are a gas exchange process. In photosynthesis, CO_2 is converted to O_2 and in respiration, O_2 is converted to CO_2.

Do plants create energy? It is important to remember that plants do not create energy. They change the energy from sunlight into chemical energy that plants and animals can use as food (**Image below**).



The carbon cycle shows where a carbon atom might be found. The black numbers indicate how much carbon is stored in various reservoirs, in billions of tons (GtC; stands for gigatons of carbon). The purple numbers indicate how much carbon *moves between reservoirs each year. The sediments, as defined in this diagram, do not include the ~70 million GtC of carbonate rock and kerogen.*

Carbon Can Also Cycle in the Long Term

The carbon cycle has been discussed in other chapters. Using what you know, try to answer the following questions.

- How can a carbon atom cycle very quickly? One way would be if a plant takes in CO_2 to make food and then is eaten by an animal, which in turn breathes out CO_2.
- How can carbon be stored for a short period of time? Carbon that is stored as chemical energy in the cells of a plant or animal may remain until the organism dies. At that time, when the organism decomposes its carbon is released back into the environment.
- How can carbon be stored for a long period of time? If the organism is rapidly buried it may be transformed over millions of years into coal, oil, or natural gas. The carbon may be stored for millions of years.
- How can carbon be stored for long periods of time in the oceans? Many ocean creatures use calcium carbonate ($CaCO_3$) to make their shells. When these organisms die, their organic material becomes part of the ocean sediments, which may stay at the bottom of the ocean for thousands or millions of years. Eventually, these sediments may be subducted into the mantle. The carbon could cycle back up into the atmosphere: The ocean sediments melt and form magma, and the CO_2 is released when volcanoes erupt.

Carbon Sinks and Carbon Sources

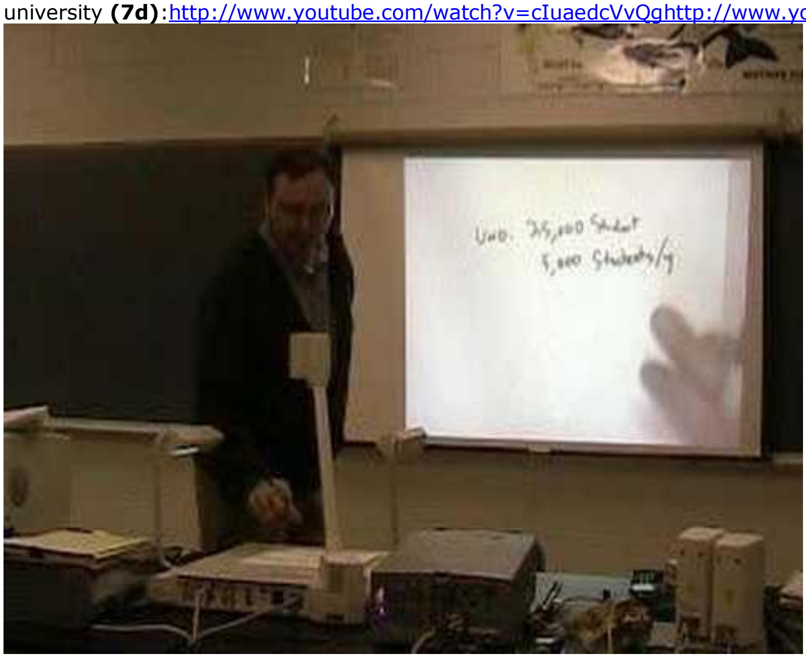
Places in the ecosystem that store carbon are **reservoirs**. Places that supply and remove carbon are **carbon sources** and **carbon sinks**. If more carbon is provided than stored, the place is a carbon source. If more carbon dioxide is absorbed than is emitted, the reservoir is a carbon sink. What are some examples of carbon sources and sinks?

- Carbon sinks are reservoirs where carbon is stored. Healthy living forests and the oceans act as carbon sinks.
- Carbon sources are reservoirs from which carbon can enter the environment. The mantle is a source of carbon from volcanic gases.

A reservoir can change from a sink to a source and vice-versa. A forest is a sink, but when the forest burns it becomes a source.

The amount of time that carbon stays, on average, in a reservoir is the **resident time** of carbon in that reservoir.

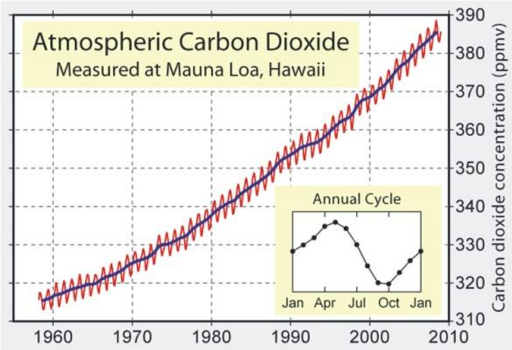
The concept of residence times is explored using the undergraduate population at UGA as an example. In this example the reservoir is the university **(7d)**:http://www.youtube.com/watch?v=cIuaedcVvQghttp://www.youtube.com/watch?v=cIuaedcVvQg (2:44).



Remember that the amount of CO_2 in the atmosphere is very low. This means that a small increase or decrease in the atmospheric CO_2 can have a large effect.

Scientists have a number of ways to see what atmospheric CO_2 levels were in the past. One is to measure the composition of air bubbles trapped in glacial ice. The amount of CO_2 in gas bubbles that date from before the Industrial Revolution, when society began to use fossil fuels, is thought to be the natural content of CO_2 for this time period; that number was 280 parts per million (ppm).

By 1958, when scientists began to directly measure CO_2 content from the atmosphere at Mauna Loa volcano in the Pacific Ocean, the amount was 316 ppm (**Image below**). In 2009, the atmospheric CO_2 content had risen to 387 ppm.



The amount of CO

Human Actions Impact the Carbon Cycle

Humans have changed the natural balance of the carbon cycle because we use coal, oil, and natural gas to supply our energy demands. Fossil fuels are a sink for CO_2 when they form but they are a source for CO_2 when they are burned. The equation for combustion of propane, which is a simple hydrocarbon looks like this (**Image below**):

$$\underset{\text{propane}}{C_3H_8} + \underset{\text{oxygen}}{5\,O_2} \rightarrow \underset{\text{carbon dioxide}}{3\,CO_2} + \underset{\text{water}}{4\,H_2O}$$

Propane combustion formula

The equation shows that when propane burns, it uses oxygen and produces carbon dioxide and water. So when a car burns a tank of gas, the amount of CO_2 in the atmosphere increases just a little. Added over millions of tanks of gas and coal burned for electricity in power plants and all of the other sources of CO_2, the result is the increase in atmospheric CO_2 seen in the graph above.

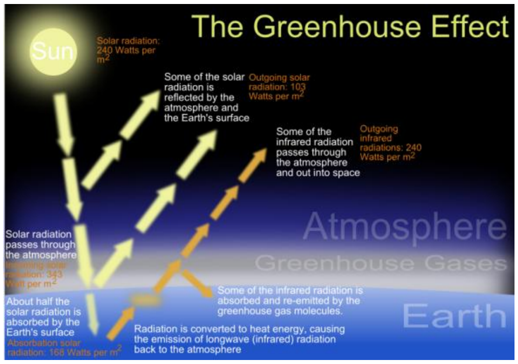
The second largest source of atmospheric CO_2 is **deforestation** (**Image below**). Trees naturally absorb CO_2 while they are alive. Trees that are cut down lose their ability to absorb CO_2. If the tree is burned or decomposes, it becomes a source of CO_2. A forest can go from being a carbon sink to being a carbon source.

This forest in Mexico has been cut down and burned to clear forested land for agriculture.

Coal, oil, and natural gas as well as calcium carbonate rocks and ocean sediments are long term carbon sinks for the natural cycling of carbon. When humans extract and use these resources, combustion makes them into carbon sources.

Why the Carbon Cycle is Important

Why is such a small amounts of carbon dioxide in the atmosphere even important? Carbon dioxide is a **greenhouse gas** (**Image below**) so it absorbs infrared energy, the longer wavelengths of the Sun’s reflected rays. Greenhouse gases trap heat energy that would otherwise radiate out into space and warms Earth. This is like what happens in a greenhouse. The glass that makes up the greenhouse holds in heat that would otherwise radiate out.



This diagram explains the role of greenhouse gases in our atmosphere.

When greenhouse gas levels in the atmosphere increase, the atmosphere holds onto more heat than it normally would. This increase in global temperatures is called **global warming**. Global warming and the effects of rising temperatures were described in the Climate chapter.

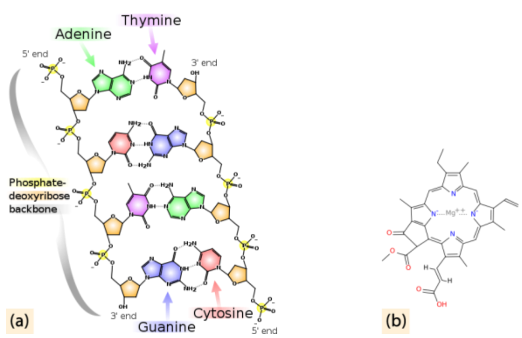
This video *Keeping up with Carbon* from NASA, focuses on the oceans. Topics include what will happen as temperature warms and the oceans can hold less carbon, and ocean acidification **(7a)**: http://www.youtube.com/watch?v=HrIr3xDhQ0Ehttp://www.youtube.com/watch?v=HrIr3xDhQ0E (5:3

9).

A very thorough but basic summary of the carbon cycle, including the effect of carbon dioxide in the atmosphere, is found in this video **(7b)**: http://www.youtube.com/watch?v=U3SZKJVKRxQhttp://www.youtube.com/watch?v=U3SZKJVKRxQ (4:37).

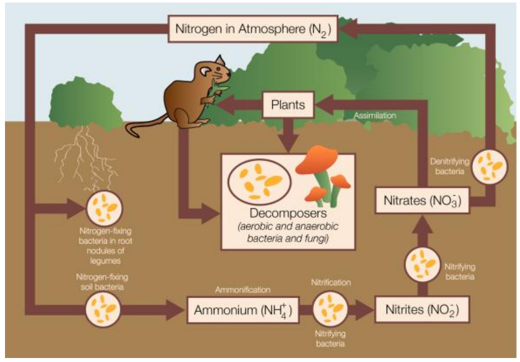
The Nitrogen Cycle

Nitrogen (N_2) is also vital for life on Earth as an essential component of organic materials, such as amino acids, nucleic acids, and chlorophyll (**Image below**).



(a) Nitrogen is found in all amino acids, proteins, and nucleic acids such as DNA and RNA. (b) hlorophyll molecules, essential for photosynthesis, contain nitrogen.

Although nitrogen is the most abundant gas in the atmosphere, it is not in a form that plants can use. To be useful, nitrogen must be “fixed,” or converted into a more useful form. Although some nitrogen is fixed by lightning or blue-green algae, much is modified by bacteria in the soil. These bacteria combine the nitrogen with oxygen or hydrogen to create nitrates or ammonia (**Image below**).



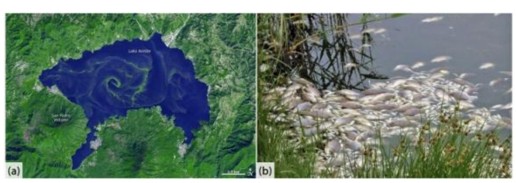
The nitrogen cycle.

Nitrogen fixing bacteria either live free or in a symbiotic relationship with leguminous plants (peas, beans, peanuts). The symbiotic bacteria use carbohydrates from the plant to produce ammonia that is useful to the plant. Plants use this fixed nitrogen to build amino acids, nucleic acids (DNA, RNA), and chlorophyll. When these legumes die, the fixed nitrogen they contain fertilizes the soil.

Animals eat plant tissue and create animal tissue. After a plant or animal dies or an animal excretes waste, bacteria and some fungi in the soil fix the organic nitrogen and return it to the soil as ammonia. Nitrifying bacteria oxidize the ammonia to nitrites, other bacteria oxide the nitrites to nitrates, which can be used by the next generation of plants. In this way, nitrogen does not need to return to a gas. Under conditions when there is no oxygen, some bacteria can reduce nitrates to molecular nitrogen.

Usable nitrogen is sometimes the factor that limits how many organisms can grow in an ecosystem. Modern agricultural practices increase plant productivity by adding nitrogen fertilizers to the soil. This can have unintended consequences:

- Nitrogen from fertilizers may return to the atmosphere as nitrous oxide or ammonia, both of which have deleterious effects. Nitrous oxide contributes to the breakdown of the ozone layer, and ammonia contributes to smog and acid rain.
- Excess fertilizers run off the land, end up in water, and then cause nitrification of ponds, lakes, and nearshore oceanic areas. The nitrogen “fertilizes” the pond, causing bacteria to grow. When these enormous amounts of bacteria die, their decomposition uses up all the available oxygen (**Image below**). Without oxygen, fish and other larger organisms die. This is called a dead zone when it happens on a large scale.



(a) Nitrogen runoff into Lake Atitl

This very thorough video on the nitrogen cycle with an aquatic perspective was created by high school students **(7a)**: http://www.youtube.com/watch?v=pdY4I-

EaqJA&feature=relatedhttp://www.youtube.com/watch?v=pdY4I-

EaqJA&feature=related (5:08).

Section Summary Part Two

- Photosynthesis, which transforms inorganic carbon into organic carbon, is an extremely important part of the carbon cycle.
- Forests and oceans are carbon sinks. When carbon is trapped in ocean sediments or fossil fuels, it is stored for millions of years.
- Humans have changed the natural carbon cycle by burning fossil fuels, which releases carbon dioxide into the atmosphere. Fossil fuels burning and deforestation are carbon sources.
- Global warming is a consequence of increased carbon dioxide and other greenhouse gases in the atmosphere.
- The nitrogen cycle begins with nitrogen gas in the atmosphere then goes through nitrogen-fixing microorganisms to plants, animals, decomposers, and into the soil.

Vocabulary

respiration
: The process in which animals use oxygen to convert sugar into food energy.

residence time
: The amount of time, on average, a substance remains in a reservoir.

reservoir
: A location where a substance is stored. The atmosphere is a reservoir for carbon dioxide.

photosynthesis
: The process using carbon dioxide, water, and energy from sunlight by which plants and algae produce their own food.

hydrocarbon
: An organic compound that contains only hydrogen and carbon.

greenhouse gas
: Gases such as carbon dioxide that absorb and hold heat from the sun’s infrared radiation.

global warming
: Warming of Earth’s atmosphere because of the addition of greenhouse gases.

deforestation
: Cutting down and/or burning trees in a forested area.

carbon source
: An area of an ecosystem that emits more carbon dioxide than it absorbs.

carbon sink
: A reservoir for carbon that absorbs more carbon dioxide than it produces.

carbohydrate
: Organic compound that supplies energy to the body; includes sugars, starches and cellulose.

Human Populations

Section Objectives

- Describe how changes in a limiting factor can alter the carrying capacity of a habitat.
- Discuss how humans have increased the carrying capacity of Earth for our species and how we may have exceeded it.
- Discuss how human activities such as agriculture and urbanization have impacted the planet.
- Describe sustainable development.

Introduction

Improvements in agriculture, sanitation, and medical care have enabled the human population to grow enormously in the last few hundred years. As the population grows, consumption, waste, and the overuse of resources also grows. People are beginning to discuss and carry out sustainable development that decreases the impact humans have on the planet.

Populations

Biotic and abiotic factors determine the population size of a species in an ecosystem. What are some important biotic factors? Biotic factors include the amount of food that is available to that species and the number of organisms that also use that food source. What are some important abiotic factors? Space, water, and climate all help determine a species population.

When does a population grow? A population grows when the number of births is greater than the number of deaths. When does a population shrink? When deaths exceed births.

What causes a population to grow? For a population to grow there must be ample resources and no major problems. What causes a population to shrink? A population can shrink either because of biotic or abiotic limits. An increase in predators, the emergence of a new disease, or the loss of habitat are just three possible problems that will decrease a population. A population may also shrink if it grows too large for the resources required to support it.

Carrying Capacity

When the number of births equals the number of deaths, the population is at its **carrying capacity** for that habitat. In a population at its carrying capacity, there are as many organisms of that species as the habitat can support. The carrying capacity depends on biotic and abiotic factors. If these factors improve, the carrying capacity increases. If the factors become less plentiful, the carrying capacity drops. If resources are being used faster than they are being replenished, then the species has exceeded its carrying capacity. If this occurs, the population will then decrease in size.

Limiting Factors

Every stable population has one or more factors that limit its growth. A **limiting factor** determines the carrying capacity for a species. A limiting factor can be any biotic or abiotic factor: nutrient, space, and water availability are examples (**Image below**). The size of a population is tied to its limiting factor.

What happens if a limiting factor increases a lot? Is it still a limiting factor? If a limiting factor increases a lot, another factor will most likely become the new limiting factor.

This may be a bit confusing so let's look at an example of limiting factors. Say you want to make as many chocolate chip cookies as you can with the ingredients you have on hand. It turns out that you have plenty of flour and other ingredients, but only two eggs. You can make only one batch of cookies, because eggs are the limiting factor. But then your neighbor comes over with a dozen eggs. Now you have enough eggs for seven batches of cookies, and enough other ingredients but only two pounds of butter. You can make four batches of cookies, with butter as the limiting factor. If you get more butter, some other ingredient will be limiting.

Species ordinarily produce more offspring than their habitat can support (**Image below**). If conditions improve, more young survive and the population grows. If conditions worsen, or if too many young are born, there is competition between individuals. As in any competition, there are some winners and some losers. Those individuals that survive to fill the available spots in the niche are those that are the most fit for their habitat.

A frog in frog spawn. An animal produces many more offspring than will survive.

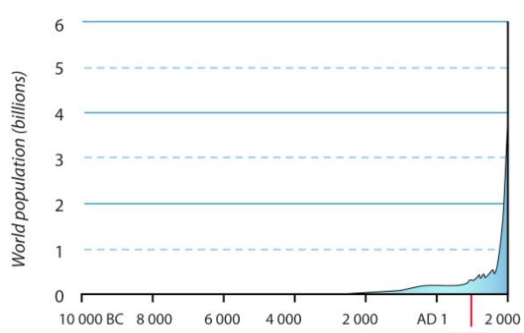
Human Population Growth

Human Population Numbers

Human population growth over the past 10,000 years has been tremendous (**Image below**). The entire human population was estimated to be

- 5 million in 8000 B.C.
- 300 million in A.D. 1
- 1 billion in 1802
- 3 billion in 1961
- 6.8 billion in 2010

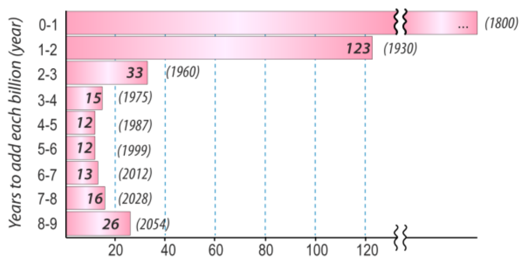
As the human population continues to grow, different factors limit population in different parts of the world. What might be a limiting factor for human population in a particular location? Space, clean air, clean water, and food to feed everyone are limiting in some locations.



Human population from 10,000 BC through 2000 AD showing the exponential increase in human population that has occurred in the last few centuries.

An interactive map of where human population growth has been over time: http://www.pbs.org/wgbh/nova/worldbalance/numbers.html

Not only has the population increased, but the rate of population growth has increased (**Image below**). Estimates are that the population will reach 7 billion in 2012, 13 years after reaching 6 billion.



The amount of time between the addition of each one billion people to the planet

Although population continues to grow rapidly, the rate that the growth rate is increasing has declined. Still, it is likely that there will be between 9 and 10 billion people sharing this planet by the middle of the century. The total added will be about 2.5 billion people, which is more than were even in existence as recently as 1950.

Earth's Carrying Capacity for Humans

What is Earth's carrying capacity for humans? Are humans now exceeding Earth's carrying capacity for our species? Many anthropologists say that the carrying capacity of humans on the planet without agriculture is about 10 million (**Image below**). This population was reached about 10,000 years ago. At the time, people lived together in small bands of hunters and gatherers. Typically men hunted and fished; women gathered nuts and vegetables.

In a hunter-gatherer society, people relied on the resources they could find where they lived.

Obviously, human populations have blown past this hypothetical carrying capacity. By using our brains, our erect posture, and our hands, we have been able to manipulate our environment in ways that no other species has ever done. What have been the important developments that have allowed population to grow?

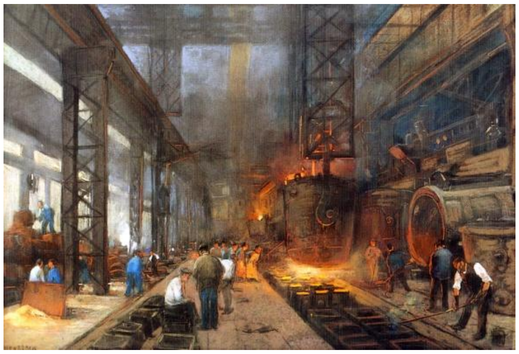
About 10,000 years ago, we developed the ability to grow our own food. Farming increased the yield of food plants and allowed people to have food available year round. Animals were domesticated to provide meat. With agriculture, people could settle down, so that they no longer needed to carry all their possessions (**Image below**). They could develop better farming practices and store food for when it was difficult to grow. Agriculture allowed people to settle in towns and cities.

(a) Like early farmers, subsistence farmers today grow only enough food for their families, with perhaps a bit extra to sell, barter, or trade. (b) More advanced farming practices allowed a single farmer to grow food for many more people.

When advanced farming practices allowed farmers to grow more food than they needed for their families (**Image below**), some people were then able to do other types of work, such as crafts or shop keeping.

Farming increasingly depended on machines. Rows of a single crop and heavy machinery are normal sights on modern-day farms.

The next major stage in the growth of the human population was the **Industrial Revolution**, which started in the late 1700's (**Image below**). This major historical event marks when products were first mass produced and when fossil fuels were first widely used for power.



Early in the Industrial Revolution, large numbers of people who had been freed from food production were available to work in factories.

Every major advance in agriculture has allowed global population to increase. Irrigation, the ability to clear large swaths of land for farming efficiently, and the development of farm machines powered by fossil fuels allowed people to grow more food and transport it to where it was needed.

The **Green Revolution** has allowed the addition of billions of people to the population in the past few decades. The Green Revolution has improved agricultural productivity by:

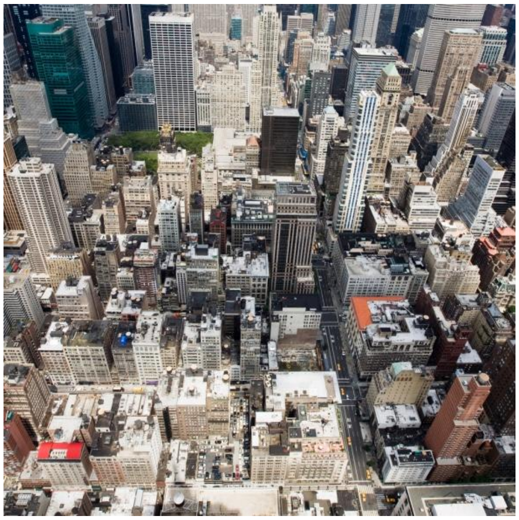
- Improving crops by selecting for traits that promote productivity; recently genetically engineered crops have been introduced.
- Increasing the use of artificial fertilizers and chemical **pesticides**. About 23 times more fertilizer and 50 times more pesticides are used around the world than were used just 50 years ago (**Image below**).
- Agricultural machinery: plowing, tilling, fertilizing, picking, and transporting are all done by machines. About 17% of the energy used each year in the United States is for agriculture.
- Increasing access to water. Many farming regions depend on groundwater, which is not a renewable resource. Some regions will eventually run out of this water source. Currently about 70% of the world's fresh water is used for agriculture.

Rows of a single crop and heavy machinery are normal sights for modern day farms.

The Green Revolution has increased the productivity of farms immensely. A century ago, a single farmer produced enough food for 2.5 people, but now a farmer can feed more than 130 people. The Green Revolution is credited for feeding 1 billion people that would not otherwise have been able to live.

What is the flip side of this? The flip side is that for the population to continue to grow, more advances in agriculture and an ever increasing supply of water will be needed. We've increased the carrying capacity for humans by our genius: growing crops, trading for needed materials, and designing ways to exploit resources that are difficult to get at, such as groundwater.

The question is, even though we have increased the carrying capacity of the planet, have we now exceeded it (**Image below**)? Are humans on Earth experiencing **overpopulation**?

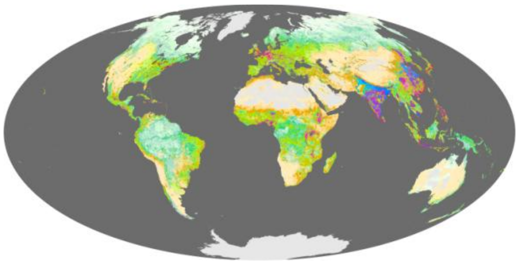


Manhattan is one of the most heavily populated regions in the world.

There is not yet an answer to that question, but there are many different opinions. In the eighteenth century, Thomas Malthus predicted that human population would continue to grow until we had exhausted our resources. At that point, humans would become victims of famine, disease, or war. This has not happened, at least not yet. Some scientists think that the carrying capacity of the planet is about 1 billion people, not the almost 7 billion people we have today. The limiting factors have changed as our intelligence has allowed us to expand our population. Can we continue to do this indefinitely into the future?

Humans and the Environment

The Green Revolution has brought enormous impacts to the planet. Natural landscapes have been altered to create farmland and cities. Already, half of the ice-free lands have been converted to human uses (**Image below**). Estimates are that by 2030, that number will be more than 70%. Forests and other landscapes have been cleared for farming or urban areas. Rivers have been dammed and the water is transported by canals for irrigation and domestic uses. Ecologically sensitive areas have been altered: wetlands are now drained and coastlines are developed.

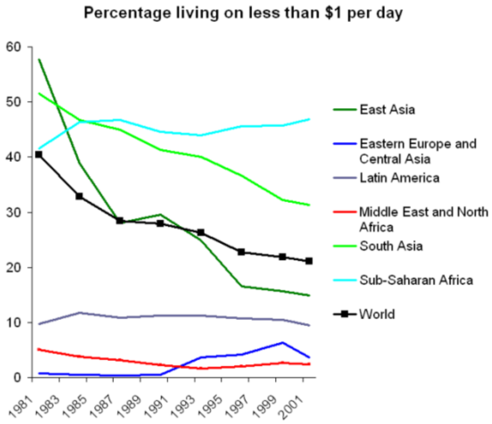


Similar to the biomes map in the Climate chapter, this map shows human ecosystems. Much of the planet

Modern agricultural practices produce a lot of pollution (**Image below**). Some pesticides are toxic. Dead zones grow as fertilizers drain off farmland and introduce nutrients into lakes and coastal areas. Farm machines and vehicles used to transport crops produce air pollutants. Pollutants enter the air, water, or are spilled onto the land. Moreover, many types of pollution easily move between air, water, and land. As a result, no location or organism — not even polar bears in the remote Arctic — is free from pollution.

Pesticides are hazardous in large quantities and some are toxic in small quantities.

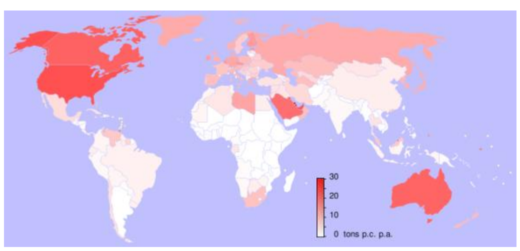
The increased numbers of people have other impacts on the planet. Humans do not just need food. They also need clean water, secure shelter, and a safe place for their wastes. These needs are met to different degrees in different nations and among different socioeconomic classes of people. For example, about 1.2 billion of the world's people do not have enough clean water for drinking and washing each day (**Image below**).



The percentage of people in the world that live in abject poverty is decreasing somewhat globally, but increasing in some regions, such as Sub-Saharan Africa.

A large percentage of people expect much more than to have their basic needs met. For about one-quarter of people there is an abundance of food, plenty of water, and a secure home. Comfortable temperatures are made possible by heating and cooling systems, rapid transportation is available by motor vehicles or a well-developed public transportation system, instant communication takes place by phones and email, and many other luxuries are available that were not even dreamed of only a few decades ago. All of these need resources to produce, and fossil fuels to power (**Image below**). Their production, use, and disposal all produce wastes.

Many people refer to the abundance of luxury items in these people's lives as **over-consumption**. People in developed nations use 32 times more resources than people in the developing countries of the world.



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Many problems worldwide result from overpopulation and over-consumption. One such problem is the advance of farms and cities into wild lands, which diminishes the habitat of many organisms. In addition, water also must be transported for irrigation and domestic uses. This means building dams on rivers or drilling wells to pump groundwater. Large numbers of people living together need effective sanitation systems. Many developing countries do not have the resources to provide all of their citizens with clean water. It is not uncommon for some of these children to die of diseases related to poor sanitation. Improving sanitation in many different areas — sewers, landfills, and safe food handling — are important to prevent disease from spreading.

Wildlife is threatened by fishing, hunting, and trading as population increases. Besides losing their habitat as land is transformed, organisms are threatened by hunting and fishing as human population grows. Hunting is highly regulated in developed nations, but many developing nations are losing many native animals because of hunting. Wild fish are being caught at too high a rate and many ocean-fish stocks are in peril.

Humans also cause problems with ecosystems when they introduce species that do not belong in a habitat. **Invasive species** are sometimes introduced purposefully, but often they arrive by accident, like rats on a ship. Invasive species often have major impacts in their new environments. A sad example is the Australian Brown Tree Snake that has wiped out 9 of the 13 native bird species on the island of Guam (**Image below**).

An Australian Brown Tree Snake perched on a post in Guam. This species wiped out 9 of the 13 native bird species on the island of Guam

A dynamic map of the spread of invasive zebra mussels is found here: http://www.nationalatlas.gov/dynamic/dyn_zm.html#

Pollution is a by-product of agriculture, urbanization, and the production and consumption of goods. Global warming is the result of fossil fuel burning.

Back to the question: Have humans have exceeded Earth's carrying capacity for our species? Carrying capacity is exceeded if:

- resources are being used faster than they are being replenished.
- the environment is being damaged.

Seen this way: The answer appears to be yes.

- Many resources are being used far in excess of the rate at which they are being replaced.
- The best farmland is already in use and more marginal lands are being developed.
- Many rivers are already dammed as much as they can be.
- Groundwater is being used far more rapidly than it is being replaced.
- Fossil fuels and mineral resources are being used faster than they are being replaced.
- Forests are being chopped down in developed and developing nations.
- Wild fish are being overharvested.
- The environment is certainly being damaged
- Pollution is discussed in the coming chapters.
- Temperatures are rising and the effects are being seen worldwide.
- Humans have caused the rate of extinction of wild species to increase to about at least 100 times the normal extinction rate.

Although many more people are alive in the world than ever before, many of these people do not have secure lives. Many people in the world live in poverty, with barely enough to eat. They often do not have safe water for drinking and bathing (**Image below**). Diseases kill many of the world's children before they reach five years of age.

Nearly half of the people living in Africa do not have access to clean water.

What if humans suddenly disappeared? Here is a very interesting view of Earth recovering from our presence: http://news.nationalgeographic.com/news/2008/11/081103-ozone-video-vin.html

Sustainable Development

A topic generating a great deal of discussion these days is sustainable development. The goals of sustainable development are to:

- help people out of poverty.
- protect the environment.
- use resources no faster than the rate at which they are regenerated.

One of the most important steps to achieving a more sustainable future is to reduce human population growth. This has been happening in recent years. Studies have shown that the birth rate decreases as women become educated, because educated women tend to have fewer, and healthier, children.

Science can be an important part of sustainable development. When scientists understand how Earth's natural systems work, they can recognize how people are impacting them. Scientists can work to develop technologies that can be used to solve problems wisely. An example of a practice that can aid sustainable development is fish farming, as long as it is done in environmentally sound ways. Engineers can develop cleaner energy sources to reduce pollution and greenhouse gas emissions.

Citizens can change their behavior to reduce the impact they have on the planet by demanding products that are produced sustainably. When forests are logged, new trees should be planted. Mining should be done so that the landscape is not destroyed. People can consume less and think more about the impacts of what they do consume.

And what of the waste products of society? Will producing all that we need to keep the population growing result in a planet so polluted that the quality of life will be greatly diminished (**Image below**)? Will warming temperatures cause problems for human populations? The only answer to all of these questions is, time will tell.

As China industrializes, its cities have become among the most polluted in the world.

Lesson Summary Part Four

- Populations of organisms are kept to a habitat's carrying capacity by factors that limit their growth.
- By developing agriculture and other technologies, the human population has grown well past any natural population limits.
- Many people on Earth live in poverty, without enough food, clean water, or shelter.
- Overpopulation and over-consumption are causing resources to be overused and much pollution to be generated.
- Society must choose development that is more sustainable to secure a long-term future for our species and the other species we share the planet with.

Further Reading / Supplemental Links

A good explanation of exponential growth and how small differences in growth rate can bring big differences in numbers: http://zebu.uoregon.edu/2003/es202/lec06.html

Vocabulary

sustainable development
: Economic development that helps people out of poverty, use resources at a rate at which they can be replaced, and protects the environment.

pesticide
: A chemical that kills a certain pest that would otherwise eat or harm plants that humans want to grow.

overpopulation
: When the population of an area exceeds its carrying capacity or when long-term harm is done to resource availability or the environment.

over-consumption
: Resource use that is unsustainable in the long term; obtaining many more products than people need.

limiting factor
: The one factor that limits the population of a region. The limiting factor can be a nutrient, water, space, or any other biotic or abiotic factor that the species need.

invasive species
: A species of organism that spreads in an area where it is not native. People often introduce invasive species either purposefully or by accident.

Industrial Revolution
: A time when mass production and fossil fuel use started to grow explosively.

Green Revolution
: Changes in the way food is produced since World War II that have resulted in enormous increases in production.

carrying capacity
: The number of individuals of a given species a particular environment can support.

Points to Consider

- How much impact on the planet does an infant born in the United States have during its lifetime, compared with one born in Senegal?
- How does consuming less impact global warming?
- Can ordinary people really make a difference in changing society toward more sustainable living?

Lesson 14 Review Questions

1. What is the difference between a population, a community, and an ecosystem?

2. What is the difference between a niche and a habitat?

3. Why are the roles in different ecosystems the same but the species that fill them often different?

4. How much energy is available to organisms on the 5th trophic level compared with those on the 1st? How does this determine how long a food chain can be?

5. Why is a food web a better representation of the feeding relationships of organisms than a food chain?

6. Why does a predator kill its prey but a parasite rarely kills its host?

7. How can carbon cycle very quickly from the atmosphere and then back into the atmosphere?

8. Describe one way that carbon can be stored for a short time in the natural cycle.

9. Describe two ways that carbon can be stored for a very long time in the natural cycle.

10. Describe two ways that humans interfere with the natural carbon cycle.

11. Describe two important functions for carbon dioxide in the atmosphere.