LESSON 1

Ecological Footprints

READING TOOL **Cause and Effect** Review Figure 7-1 and the lesson text to determine what makes up an individual's ecological footprint. For each of the items listed, identify two ways you can reduce the impact you make on the planet by reducing your ecological footprint.

Carbon Footprint Producers	Ways to Reduce
Energy use needed to create your home	
Energy use needed to sustain your home	
Agricultural processes used to create your food	
Processes used to get fresh water for you	
Processes used to take care of your waste products (trash, sewage)	
Processes used to create products you use	
Processes used to sustain your entertainment	
Fossil fuels used to power your vehicles	

Lesson Summary

Our Changing Ecological Footprints

KEY QUESTION *How do ecological footprints of typical Americans compare to the global average?*

Human population is climbing towards 9 billion. Because of this, changes we have made to Earth—so that we could feed, clothe, house, and entertain ourselves—are negatively affecting its atmosphere, climate, and oceans. This is why understanding, controlling, and adapting to human-caused global change are the greatest scientific challenges of this century. The view of global systems and model of global change we are developing will help us understand what humans are doing to Earth—and how we can slow down these changes.

Ecological Footprints Each person has an **ecological footprint**, which is the total area of healthy land and water ecosystems needed to provide the resources each person uses. This includes resources like energy, food, water, and shelter, as well as the production of wastes like sewage trash and greenhouse gases.

National and Global Ecological Footprints There is no universally-standard formula for calculating ecological footprints. To calculate a country's ecological footprint, scientists determine an average citizen's footprint, then multiply that by the country's population. We can learn a lot about how many resources a country uses by studying their ecological footprint. We can also learn about how many resources we use ourselves. According to some calculations, the average American has an ecological footprint over four times the global average. This ecological footprint is more than twice the size of an average person living in England or Japan, and more than six times the size of the average person in China. That incredible amount of human activity drives changes in global systems that affect environments worldwide. Learning how to reduce our ecological footprint is one of our greatest challenges.

The Age of Humans

KEY QUESTION *What is the Anthropocene?*

Humans' status on "spaceship Earth" has drastically changed since the Industrial Revolution of the 1800s, when we began harnessing the power of fossil fuels to run machinery.

As you read, circle the answers to each Key Question. Underline any words you do not understand.

BUILD Vocabulary

ecological footprint total amount of functioning ecosystem needed to both provide the resources a human population uses, and to absorb the wastes that population generates

anthromes globally significant ecological patterns created by long-term interactions between humans and ecosystems

Related Words Ecology is the scientific study of interactions among organisms and between organisms and their environment.

☑ **Why would a scientist studying ecological footprints be called an "ecologist"?**

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READING TOOL

Connect to Visuals

Examine Figure 7-4 in your textbook to learn about the different anthromes that make up the continental United States.

☑ **Find your state on the map and list the different anthromes that exist there.**

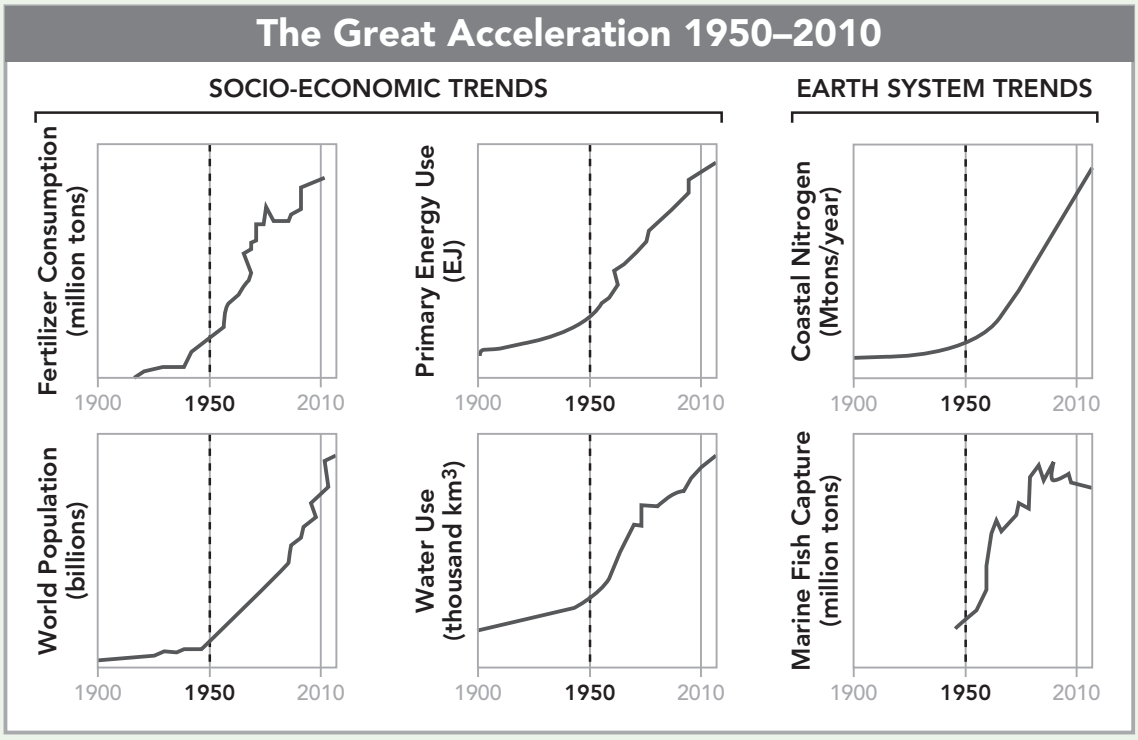
_____

The Great Acceleration The 1950s was a period called "The Great Acceleration," when humans impact on planet Earth began greatly accelerating. Fewer people died and more people were born thanks to scientific advancements.

The Anthropocene Also called "the age of humans", the Anthropocene is the period during which human activity has become the major cause of global change.

Anthromes: Human-Altered Biomes Anthropogenic biomes, or **anthromes**, are globally significant ecological patterns created by long-term interactions between humans and ecosystems. These have replaced traditional biomes over much of the Earth.

Visual Reading Tool: The Impact of Humans



Sources: (1) Olivier Rousseau, IFA; IFA database. (2) A Grubler, International Institute for Applied Systems Analysis (IIASA); Grubler et al. (2012). (3) M Flörke, Centre for Environmental Systems Research, University of Kassel; Flörke et al. (2013); aus der Beek et al. (2010); Alcamo et al. (2003). (4) HYDE database; Klein Goldewijk et al. (2010). (5) Mackenzie et al. (2002). (6) Data are from the FAO Fisheries and Aquaculture Department online database (Food and Agriculture Organization-FIGIS (FAO-FIGIS), 2013).

Review the charts and answer the following questions.

1. Describe the trends for world population and water use and compare them. Why do you think these trends are similar or different?

_____

_____

2. What other resources would also increase because of the increase in world population? Use the graph to justify your answer.

_____

_____

CHAPTER 7

LESSON 2

Causes and Effects of Global Change

READING TOOL **Main Idea and Details** For each heading in this lesson, explain the main idea in the table below. Then, list details that support and explain the main idea.

Heading	Main Idea	Details
Human Causes of Global Change		
Changing Atmosphere and Climate		
Changes in Land Use		
Pollution		

Lesson Summary

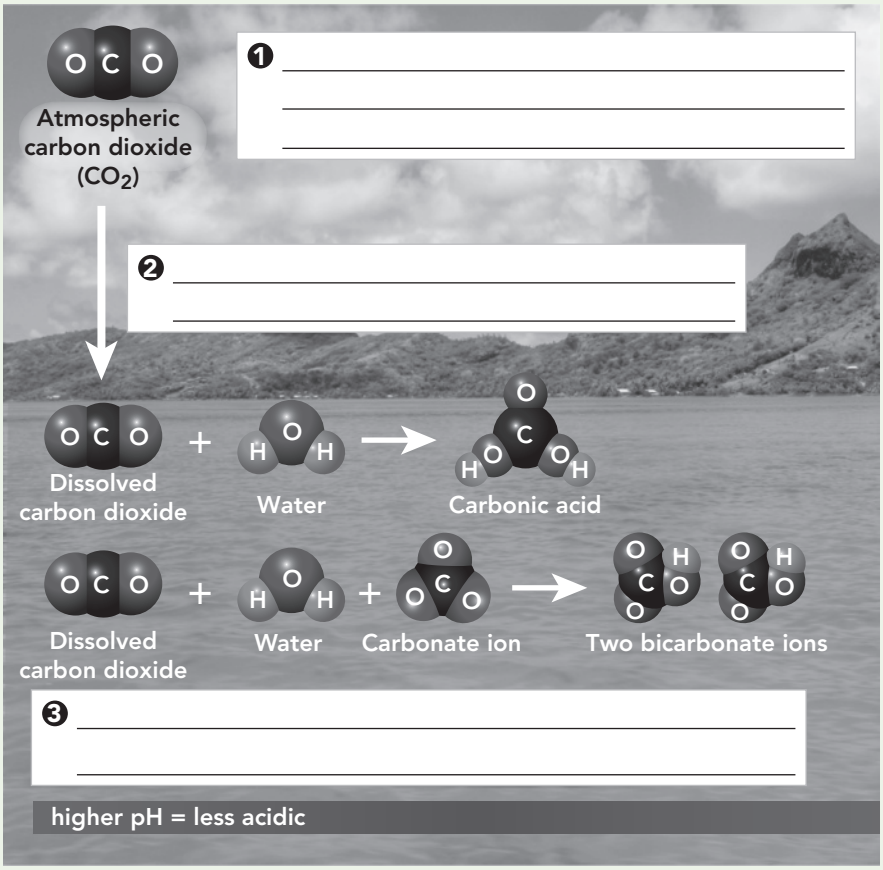
Human Causes of Global Change

KEY QUESTION *How do human activities change the atmosphere and climate?*

As you read, circle the answers to each Key Question. Underline any words you do not understand.

The Understanding Global Change (UGC) model begins with global systems as they exist on Earth. Then, we add in human causes of global change and ecological interactions and processes in the biosphere (or non-human causes) of global change. Current human activities, like over-harvesting some species or changing the way we use land, stress ecosystems and the organisms living in them in ways that threaten biodiversity and ecosystem services. Often, single activities affect several global systems, rather than just one.

Visual Reading Tool: Ocean Acidification



1. Describe how the diagram shows the ocean acidification process.
2. How do carbon dioxide levels change ocean chemistry?

BUILD Vocabulary

climate change measurable long-term changes in averages of temperature, clouds, winds, precipitation, and the frequency of extreme weather events

global warming increase in the average temperatures on Earth

Make Connections

You have learned that the environmental conditions on our planet usually remain stable, but have been changing since humans have begun to flourish and change our planet. One of the first noticeable changes on our planet was global warming. ☑ **What is the connection between global warming and climate change?**

Changing Atmosphere and Climate

KEY QUESTION *How do changes in the atmosphere drive climate change and other changes in global systems?*

Human activities that affect global systems are changing Earth's atmosphere faster than it has changed historically.

Fossil Fuels and the Atmosphere Scientists have confirmed that atmospheric carbon dioxide levels have been increasing since the Industrial Revolution.

Climate Change Ocean Acidification, Nitrogen Enrichment From Fossil Fuels **Climate change** is defined as measurable long-term changes in averages of temperature, clouds, winds, precipitation, and the frequency of extreme weather events. **Global warming**, or the increases in average global temperatures, is caused by climate change. Acid rain damages plant leaves and root systems by releasing metals from some soils. Ocean acidification is caused when carbon dioxide released from fossil-fuel burning dissolves in seawater and turns into acid. Nitrogen released from burning fossil fuels travels through the air and water falling far from its source and causing algal blooms.

Agriculture and the Atmosphere Methane is produced and released through cattle farming and the cultivation of rice in flooded paddies. Methane is a more powerful greenhouse gas than carbon dioxide.

Changes in Land Use

KEY QUESTION *How do the ways we use land drive change in global systems?*

Human activity has transformed about three-quarters of Earth's surface to provide food, housing, and energy.

Deforestation/Reforestation Healthy forests hold soil in place, protect freshwater quality, absorb carbon dioxide, and moderate local climates. When forests are lost, those ecosystems services disappear.

Deforestation **Deforestation** can affect water quality in streams and rivers. In mountainous areas, deforestation increases soil erosion, which can cause landslides.

Natural Regrowth Through Succession Many forests east of the Mississippi River are secondary forests that grew back after primary forests were cut. This is called secondary succession.

Reforestation Scientifically-guided reforestation, or replanting of forests, can replace areas that have been cleared of trees. Reforestation contributes to dependable, clean drinking water availability.

Agriculture Today, agricultural activities cover more of Earth's land surface than any other human activity.

Monoculture **Monoculture** involves planting large areas with a single highly-productive crop year after year. It requires large amounts of fertilizer and pesticide. When large areas are used for grazing, or to grow monocultures for long periods, fertilizers and pesticides can change soil structure and microbiomes in ways that degrade soil and prevent secondary succession.

Nitrogen Enrichment From Agriculture Today's fertilizer manufacturing and application has more than doubled the amount of biologically active nitrogen cycling through the biosphere, dramatically changing the natural nitrogen cycle.

Development/Urbanization Large amounts of sewage caused by urbanization can disrupt nutrient cycles and stimulate growth of toxic or ecologically damaging blooms of bacteria and algae.

Habitat Loss, Fragmentation, and Restoration
Human-caused changes in natural habitats occur through habitat loss and fragmentation, or through restoration.

BUILD Vocabulary

deforestation destruction of forests

monoculture farming strategy of planting a single, highly productive crop year after year

Prefixes The prefix *de-* indicates removal, separation, or reversal. In the case of deforestation, the *de-* indicates the removal of trees.

☑ **What other words with the prefix *de* can you think of that indicate the removal of something helpful to humans?**

READING TOOL

Make Connections

For many years, farmers only planted one crop type in the same field year after year. This monoculture has been shown to be harmful to the environment.

☑ **How should farmers change the agricultural production methods to avoid these dangers?**

BUILD Vocabulary

invasive species any non-native species whose introduction causes, or is likely to cause, economic harm, environmental harm, or harm to human health

pollutant harmful material that can enter the biosphere through the land, air, or water

ozone layer atmospheric layer in which ozone gas is relatively concentrated; protects life on Earth from harmful ultraviolet rays in sunlight

smog gray-brown haze formed by a mixture of chemicals

biological magnification the increasing concentration of a harmful substance in organisms at higher trophic levels in a food chain or food web

Using Prior Knowledge Pollutants are harmful materials that can enter our ecosystem through a variety of ways. ☑ **Name three substances or products you use regularly that could be considered pollutants if they got into our air, water, or soil.**

_____

_____

_____

_____

Habitat Loss Habitats can be lost to urban, suburban, or industrial development, and to logging or agriculture. Species living there will move away or die off.

Habitat Fragmentation Habitat fragmentation causes biodiversity loss and makes ecosystems vulnerable to disturbances.

Habitat Restoration The right conditions and a lot of work are needed to restore damaged habitats, but it can be done. Ecological restoration aims to re-create conditions closely resembling the original ecosystem.

Hunting and Fishing Humans have hunted species to extinction and overfishing has caused significant declines in worldwide fish populations.

Invasive Species An **invasive species** is any non-native species whose introduction causes, or is likely to cause, economic harm, environmental harm, or harm to human health.

Pollution

KEY QUESTION *What kinds of pollutants are drivers of global change?*

A **pollutant** is any harmful material created as a result of human activity and released into the environment.

CFCs and Stratospheric Ozone (CFCs) are industrially-produced gases causing the destruction of the stratosphere, or upper section of our atmosphere. This layer, called the **ozone layer**, absorbs ultraviolet light and acts like global sunscreen.

Ground-Level Ozone **Smog** is a haze formed by chemical reactions among pollutants released by industrial processes and automobile exhaust.

Industrial and Agricultural Pollution Wastes from manufacturing and energy productions are discarded into air, water and soil. These chemicals enter the water supply as runoff.

Biological Magnification The process in which pollutants are concentrated as they pass through trophic levels of the food chain is called **biological magnification**.

DDT DDT was a widely-used pesticide that caused disastrous effects in organisms after entering the water supply, including reduction in fish-eating bird populations.

PCBs PCBs are toxic chemicals causing water pollution. Banned in the 1970s, they are still causing issues in our environment today.

Heavy Metals Heavy metals accumulate in food webs and pose health threats.

CHAPTER 7

LESSON 3

Measuring and Responding to Change

READING TOOL **Cause and Effect** Complete the graphic organizer with the possible effects and possible solutions of each identified climate change. Several answers are filled in for you.

Identified Climate Changes		Possible Effects	Possible Solutions
Data shows that global temperatures are rising.	Species are forced to move to different areas to survive or face extinction.	Some species may not survive or may become extinct; species will need to adapt for survival.	Reduce rising global temperatures by reducing carbon emissions.
	Extreme weather events will occur more often.		
Data shows that global sea levels are rising.	Coastlines are receding.		
Data shows that global sea temperatures are rising.	Marine life is being negatively affected.		

Lesson Summary

As you read, circle the answers to each Key Question. Underline any words you do not understand.

READING TOOL

Active Reading

The IPCC has concluded that the atmosphere and the oceans are warming based upon climate data that has been collected over many years. **Based upon previous data, what are scientists predicting for the future regarding the average temperature on our planet?**

Climate Change: The Data

KEY QUESTION *What evidence supports the claims that the climate is changing?*

When a 5300-year-old ancient human emerged from melting glacial ice, the Worldwatch Institute noted to the world that our ancestors were telling us the Earth is getting warmer. Although it was a dramatic announcement, scientists needed data to back up that claim.

IPCC Climate Data The Intergovernmental Panel on Climate Change (IPCC) provides the world with the most reliable climate data available. This international organization was established to provide the best possible scientific information on climate change. Their reports contain data with analyses that are agreed upon and accepted by over 2500 international climate scientists and all governments participating in the research. They released their most recent report in 2014, which made a strong case that our global climate is undergoing change—and that human activity influences climate.

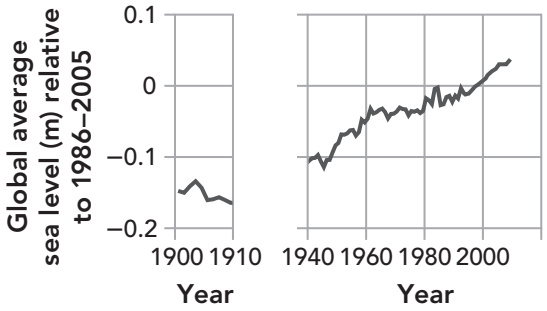
Climate Changes Through data collection and analyses, scientists have found that both the atmosphere and the oceans have been warming; that sea levels are rising; and that arctic sea ice, glaciers, and snow cover are all decreasing.

Human Activity Influences Change The latest IPCC report (from 2014) states firmly that "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history." This states, in no uncertain terms, that humans are partly responsible for changes in our climate.

Modeling With Data Scientific researchers use data to construct computer-based models that help predict future climate trends. The most widely-accepted of these models predict that average global temperatures will rise somewhere between 0.3 and 1.7 degrees Celsius (or up to 3 degrees Fahrenheit) by the end of the twenty-first century if all the world's countries agree on very strong measures to curb greenhouse gas emissions. If countries continue to produce greenhouse gases at the rates they have been in recent years, global temperatures could rise somewhere between 2.6 and 4.8 degrees Celsius (or up to 4 degrees Fahrenheit) by the year 2100. Although seemingly small, these changes represent major consequences for the Earth and its inhabitants.

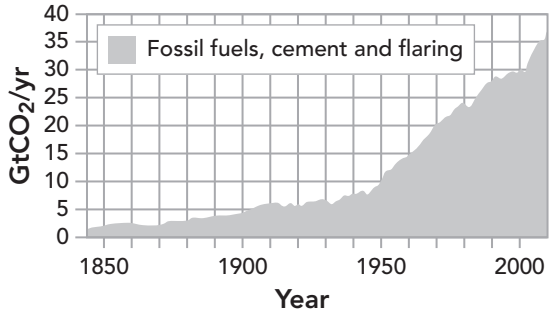
Visual Reading Tool: Sea Level Changes & CO_2 Emissions

Globally Averaged Sea Level Change 1900–2010



Source: Based on data from the Intergovernmental Panel on Climate Change. Only one data set is shown.

Global Anthropogenic CO_2 Emissions



Quantitative information of CH_4 and N_2O emission time series from 1850 to 1970 is limited.
Source: Adapted from Intergovernmental Panel on Climate Change.

1. On each chart, circle the date when the measured data steeply increased. How do these two dates relate to each other?

2. What caused the sudden increase in CO_2 emissions?

3. What causes sea levels to rise?

4. How are CO_2 emissions and sea level rise related?

Climate Change Impacts

KEY QUESTION *What are some impacts of climate change?*

The 2014 IPCC report concludes that "changes in climate have caused impacts on natural and human systems on all continents and across oceans." Climate change includes much more than just the direct effects of global warming. Total rainfall and seasonal distribution of rainfall are changing. Heat waves are expected to become longer and more intense. Many areas will experience more episodes of extreme heat and storms. The temperatures are rising fastest in the Arctic Circle.

Ecological Impacts Small changes in climate or temperature can significantly affect organisms and ecosystems. Organisms each have a range of tolerance for temperature, humidity, and rainfall. If conditions move outside those tolerance zones, the organism must move to a more suitable location, or face extinction. Life cycles in many plants and animals are triggered by seasonal temperature changes, and data confirms that over 1700 species are experiencing shifts in these life cycles due to global temperature increases.

READING TOOL

Connect to Visuals

In 7.1, we saw a chart showing that America has one of the highest ecological footprints in the world. Compare that with Figure 7-19.

☑ What connection could there be with increased temperatures in the Arctic Circle and the relative closeness of America?

READING TOOL

Sequence of Events

There have been many examples of environmental successes in the past. This usually involves the IPCC or governments creating plans to curb emissions based upon environmental data. Over time, a measurable improvement is seen.

☑ **Describe the sequence of events that led to phasing out CFCs, which has helped stratospheric ozone to begin recovering.**

Impacts on Human Systems Changes in temperature and rainfall have begun to negatively affect crop cycles, like corn and wheat. Water availability is also changing and is expected to continue to become less available, directly affecting farming practices further. Areas are experiencing earlier or smaller snow run-offs as well as summer droughts.

Sea Level Rise Global warming is affecting sea levels. These levels have risen, on average, at a rate of 1.8 millimeters every year since 1961, or almost four inches over the 55-year period from 1961 to 2016. Melting ice from glaciers and polar caps add water to the oceans. Extra heat retained in the atmosphere is absorbed by the oceans, making them warmer and adding to rising sea levels through expansion.

Designing Solutions

KEY QUESTION *What is the role of science in responding to climate change?*

One of the goals of science is to help us understand our natural world and to apply that knowledge to improve the human condition. When scientific data is properly collected, analyzed, and applied, it helps us make important decisions that could positively affect the future of humanity. It also makes sense to note that when it is not collected, analyzed, or applied properly, it could negatively impact the future of our planet. Scientific research can have a positive impact on the global environment by (1) recognizing a problem in the environment, whether from human or other causes, (2) gathering data to document and analyze that problem and identify its cause, and then (3) guiding changes in our behavior based on scientific understanding.

Environmental Successes Research is vital for guiding us toward positive results on climate change. Several successes we've seen through science-applied changes include removing lead from gasoline, which has helped reduce water pollution, and the banning of CFCs, which has helped to repair the depleted ozone.

Climate Change Challenge Of all the ecological challenges humanity has faced, climate change is the most complicated and difficult to fix. Since the world still depends heavily on the burning of fossil fuels and methane-producing agriculture, efforts to address climate change will require major changes in the systems supporting human life. It is up to government policy-makers around the world to use science to inform their decisions on this vital issue.

CHAPTER 7

LESSON 4

Sustainability

READING TOOL Active Reading For each section of this lesson, take notes on how sustainable development can be achieved.

Lesson Section	Connection to Sustainable Development
United Nations Sustainable Development Goals	
Renewable Resources	
Nonrenewable Resources	
Innovation	
Resilience	

Lesson Summary

Sustainable Development

KEY QUESTION *What criteria can be used to evaluate whether development is sustainable?*

Ecological science can help guide us in providing for human needs without causing long-term environmental harm, but science alone is not enough. Global planning requires input from economics, sociology, and other disciplines to affect the most positive change. Using resources in ways that preserve ecosystem services is called **sustainable development**.

As you read, circle the answers to each Key Question. Underline any words you do not understand.

BUILD Vocabulary

sustainable development strategy for using natural resources without depleting them and for providing human needs without causing long-term environmental harm

Sustainable development recognizes links between ecology, or the natural world, and economics, or the costs of processes. Sustainable development includes three nested spheres: Earth's life support system, society, and the economy. Our economy operates within our society, and our practices must be affordable for those operating those practices, as well as for those benefitting from them. For development to be sustainable, it needs to be cost-effective and non-harmful to our natural world.

United Nations Sustainable Development Goals

The United Nations has set and promoted 17 Sustainable Development Goals. Sustainable development should provide for human needs while preserving ecosystem services. It should cause no long-term harm to soil, water, and climate. It should consume as little energy and material as possible. Finally, sustainable development must take into account human needs and economic systems. It must do more than simply allow humans to survive; it should help them improve their situation.

Visual Reading Tool: Explaining Sustainable Development

Identify each link in the chain of sustainable development.

1. _____ **2.** _____ **3.** _____

Explain why each link is equally important to sustainable development.

_____

_____

_____

Renewable Resources Sustainable development focuses on careful use of renewable ecosystem services. A **renewable resource** can be produced or replaced by a healthy ecosystem. Drinkable water provided by the Earth and filtered by wetlands is an example. If human-caused environmental changes impact ecosystems, water quality may fail. When this happens, mechanical or chemical treatment must occur to provide safe drinking water.

Nonrenewable Resources If natural processes cannot replenish resources within a reasonable time, they are considered **nonrenewable resources**.

Innovation Human intelligence and scientific creativity have improved our lives in many dramatic ways. Technology won't automatically solve our problems, unless it is guided by sustainable goals and practices. To evolve successfully, we need to be constantly innovating – new ideas and new engineering solutions that provide necessary services at reasonable costs. Solar panels are one example of human innovation that solves a problem (burning fossil fuels for energy). Although they've been on the market for over twenty years, before now, they were too expensive for most people to purchase. Engineering and manufacturing innovations of solar panels have dramatically lowered the price, and they are just now becoming affordable for the average consumer. Another example of an innovation is wind turbines that generate energy from wind, a renewable resource. Technological improvements in wind turbines have created smaller units that harness greater levels of energy.

Resilience Ecological scientists and many government agencies, like the US Military for example, recognize that life in the Anthropocene, or "age of humans", involves a high level of unpredictability. Some of that unpredictability involves loss of ecosystem services from biodiversity loss. More unpredictability will come from potential extreme weather events in the future. This is why sustainable development must include the element of **resilience**, which is the ability to deal with change and move on. Sustainable development practices must be flexible enough to deal with unknown environmental stresses and events, like cold snaps, droughts, floods, heat waves, and intense storms. Examples of solid resilience are US cities that are hit by strong hurricanes. These areas see loss of human life and major property damage, but are resilient enough (so far) to recover afterwards, even if it takes several years. Examples of areas with less resilience to hurricane damage are Haiti and Honduras. They have experienced a much greater loss of human life and more widespread destruction of property due to hurricanes. Often, this destruction is beyond their ability to handle on their own, and they must call for global assistance to recover.

BUILD Vocabulary

renewable resource resource that can be produced or replaced by healthy ecosystem functions

nonrenewable resource resource that cannot be replenished by a natural process within a reasonable amount of time

resilience the ability to deal with change and move on

Related Words A resource is anything that is necessary for life.

☑ **Name three items that are necessary to your life that are considered renewable resources.**

_____

_____

7 Chapter Review

Review Vocabulary

Match the vocabulary term to its definition.

1.	anthromes	a. farming strategy of planting a single productive crop in the same field year after year
2.	monoculture	b. an organism or community's ability to deal with change and successfully move on
3.	biological magnification	c. ecological patterns created by human interactions with ecosystems
4.	resilience	d. increasing concentration of harmful substances progressing through food chains

Fill in the blanks with the correct terms.

5. _____ are resources that can be reproduced or replaced by natural processes, while _____ cannot be reproduced or replaced by natural processes in a reasonable amount of time.

Review Key Questions

Provide evidence and details to support your answers.

6. Explain how the average Americans' ecological footprint compares to the average ecological footprint of people in other countries.

7. Identify two unsustainable agricultural practices currently in use in the United States.

8. Identify three ways unsustainable development practices have contributed to climate change.

9. Explain how the element of resilience affects two of the key factors needed for sustainable development: environment and society.