Living in the Environment 20th edition Miller Solutions Manual

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Chapter 1

The Environment and Sustainability

Chapter Outline

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TYING IT ALL TOGETHER Learning from the Earth and Sustainability

CORE CASE STUDY

Learning from the Earth

LO 1.1 Define sustainability.
LO 1.2 State the definition of the term biomimicry as coined by Janine Benyus.

Sustainability is the capacity of the earth's natural systems that support life and human social systems to survive or adapt to changing environmental conditions indefinitely. Many scientists are calling upon us to focus on learning from the earth about how to live more sustainably, a concept known as **biomimicry**.

1.1 Principles of Sustainability
LO 1.1A Outline the three scientific principles of sustainability.
LO 1.1B Explain how biomimicry can be used to learn from the earth about how to live more sustainably.
LO 1.1C Explain how our lives and economies depend on the sun and on natural capital.
LO 1.1D List five key components of sustainability.
LO 1.1E Identify six principles of sustainability.

Section Outlines

A. Three goals of environmental science are:
   1. to learn how nature works
   2. to understand how humans interact with the environment
   3. to learn how we can live more sustainably.
B. Three scientific principles of sustainability:
   1. Reliance on solar energy
   2. Biodiversity
   3. Chemical or nutrient cycling
C. Key components of sustainability:

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1. Natural capital comprises natural resources and ecosystem services.
2. Renewable resources can be replenished in the foreseeable future (forests, fertile topsoil).
3. Nonrenewable resources are found in fixed quantities and are not renewable on a human time scale.
4. Ecosystem services are natural services provided by healthy ecosystems that support life and human economies at no monetary cost to us.

D. Three additional principles of sustainability:
1. Full-cost pricing
2. Win-win solutions
3. Responsibility to future generations

INDIVIDUALS MATTER 1.1

Janine Benyus: Using Nature to Inspire Sustainable Design and Living

Janine Benyus has had a lifelong interest in learning how nature works and how to live more sustainably. Benyus says that when we need to solve a problem or design a product, we should ask: Has nature done this, and how did it do it? Benyus has set up the nonprofit Biomimicry Institute that has developed a curriculum for K–12 and university students and has a 2-year program to train biomimicry professionals.

E. Countries differ in their resource use:
1. More-developed countries have greater use of earth's resources.
2. Less-developed countries use fewer resources although they have greater population.

1.2 Human Impacts on the Earth

LO 1.2A Explain the tragedy of the commons in terms of open-access and shared resources.
LO 1.2B Define ecological footprint and per capita ecological footprint.
LO 1.2C Explain how a country's ecological deficit is related to its biocapacity.
LO 1.2D List the three major cultural changes that have influenced the human ecological footprint.

A. The process of depleting resources is known as environmental degradation or natural capital degradation.
B. Tragedy of the commons is the degrading of mutually shared resources, such as the atmosphere.
C. Harmful environmental impact is called an ecological footprint—the amount of biologically productive land and water needed to supply a population in an area with renewable resources.
D. Biocapacity is the ability of ecosystems to regenerate the renewable resources used by a population, city, region, country, or the world, and to absorb the resulting wastes and pollution indefinitely.
E. We would need 1.7 planet Earths to sustain the world's 2012 rate of resource use far into the future.
F. Impact, population size, affluence, and technologies (IPAT) is another environmental impact model.
1. Impact (I) of human activities is the product of three factors: population size (P), affluence (A) or resource consumption per person, and the beneficial and harmful environmental effects of technologies (T).
a. Impact (I) = Population (P) × Affluence (A) × Technology (T)
G. China has a growing number of affluent consumers.
1. China has the world's largest population and second-largest economy.
H. Cultural changes can increase or shrink our ecological footprint.
1. Three major cultural changes have occurred in human history:
a. Agricultural revolution

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b. Industrial–medical revolution
c. Information–globalization revolution
d. And now a fourth, called the sustainability revolution

1.3 Causes of Environmental Problems
LO 1.3A Describe exponential growth in terms of human population growth.
LO 1.3B Explain how affluence can cause environmental problems.
LO 1.3C Give three examples of hidden harmful environmental and health costs.
LO 1.3D List three effects of the nature deficit disorder.
LO 1.3E List the three major categories of environmental worldviews.
LO 1.3F List six biomimicry principles identified by people working in the field of biomimicry.

A. Major causes of environmental problems are:
   1. population growth
   2. wasteful and unsustainable resource use
   3. omission of the harmful environmental and health costs of goods and services from market prices
   4. increasing isolation from nature
   5. competing environmental worldviews.
B. Exponential growth occurs when a population increases by a fixed percentage per unit of time.
C. Affluence results in high levels of consumption:
   1. Affluence can lead to an unsustainable addiction to acquiring material things.
   2. Affluence can also lead to better education, improved health, and more resources to address environmental issues.
D. Prices of goods and services rarely include their harmful environmental and health costs.
E. People are increasingly becoming isolated from nature.
   1. nature deficit disorder
F. Environmental worldviews and ethics determine the way people view the seriousness of environmental problems.
   1. Human-centered environmental worldview sees the natural world as a support system for human life. Two variations in this worldview are:
      a. planetary management worldview
      b. stewardship worldview.
   2. Life-centered environmental worldview considers all species as having value in fulfilling their particular role within the biosphere, regardless of their use to humans.
   3. The Earth-centered environmental worldview expresses that we are part of, and dependent on, nature, and the Earth's natural capital exists for all species and not just for humans.

CASE STUDY
The Rise of Environmental Conservation and Protection in the United States
In the 19th century, some thinkers questioned the idea that America's resources were inexhaustible, which had the impetus of starting the conservation movement.
By the early 20th century, the preservationist movement, led by John Muir and the conservationists, led by Teddy Roosevelt and Gifford Pinchot, worked to bring about 36 national wildlife reserves and more than tripled the size of the national forests. Aldo Leopold's writings laid the groundwork for the field of environmental ethics. In 1962, Rachel Carson alerted us to the harmful effects of the widespread use of pesticides. Many environmental historians mark Carson's wake-up call as the beginning of the modern environmental movement in the United States.

SCIENCE FOCUS 1.1
Some Biomimicry Principles

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Janine Benyus calls upon us to evaluate each of the goods and services we produce and use by asking, is it something nature would do? Does it help sustain life? Will it last? By learning from nature and using such principles, innovative scientists, engineers, and business people are leading a biomimicry revolution by creating life-friendly goods and services and profitable businesses that could enrich and sustain life far into the future.

1.4 Environmentally Sustainable Societies
LO 1.4A Explain why an environmentally sustainable society protects natural capital.
LO 1.4B List six requirements for living more sustainably.

A. An environmentally sustainable society meets the current and future basic resource needs of its people in a just and equitable manner by protecting natural capital and living off its income.
   1. Natural capital is a global trust fund of natural resources and ecosystem services available to people now and in the future and to the earth's other species.
   2. Living sustainably means living on natural income, which are the renewable resources such as plants, animals, soil, clean air, and clean water, provided by the earth's natural capital.

INDIVIDUALS MATTER 1.2
Tuy Sereivathana: Elephant Protector
Since 1970, Cambodia's rain forest cover has dropped from over 70% of the country's land area to 3%, primarily because of population growth, rapid development, illegal logging, and civil war. This severe forest loss forced elephants to search for food and water on farmlands, setting set up a conflict between elephants and poor farmers, who killed the elephants to protect their food supply. Since 1995, Tuy Sereivathana has been on a mission to accomplish two goals: (1) to double the population of Cambodia's endangered Asian elephants by 2030 and (2) to show poor farmers that protecting elephants and other forms of wildlife can help them escape poverty.

Teaching Tips

Large Lecture Courses

What are the greatest environmental problems facing the world today? List student responses on the board and ask them to suggest what the consequences of these problems might be for them and their families. Then, perform the same brainstorming activity by focusing on the local region only. Ask the students to suggest reasons for any discrepancies between the two lists, such as local industries or activities. Use this exercise as an opportunity to highlight the main themes that will be touched on during the rest of the course and textbook, and to show the students the ways in which environmental issues permeate their own lives.

Small Lecture Courses

Ask students to get in small groups of three to six students each. Have each group rank what they perceive to be the three greatest environmental crises facing their generation. For each, they should list the reasons why that issue is so important. Then, have the groups place their original list on the board, and facilitate a debate between groups over which issue is most pressing and why. Use this exercise to illustrate the complexity of environmental issues, insofar as the public is generally not in agreement as to the cause, severity, or potential solutions.

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Key Terms

biocapacity
biodiversity
chemical cycling
ecology
ecosystem
ecosystem services
environment
environmental degradation
environmental activism
earth-centered environmental worldview
environmentalism
environmentally sustainable society
exhaustible resource
exponential growth
full-cost pricing
human-centered environmental worldview
inexhaustible resource
less-developed countries
life-centered environmental worldview
more-developed countries
natural capital
natural capital degradation
natural income
natural resources
nonrenewable resources
nutrient cycling
per capita ecological footprint
renewable resource resource
scientific principles of sustainability
solar thermal system
sustainability
sustainability revolution
species

Term Paper Research Topics

1. How do nations with large ecological footprints due to resource consumption compare with nations with low resource consumption but high population? How could each lower their ecological footprints?

2. Poverty: definition and roots. How are poverty and environmental degradation related?

3. What is biomimicry? Investigate how an existing technology could be modeled on a natural system.

4. Examine an instance of ecosystem services in detail and show how an existing technology for the same purpose would be more costly.

5. Explain and compare the use of inexhaustible resources with exhaustible resources.

6. IPAT—Ecological footprint model

7. Culture as mediator of ecological footprint

8. 2005 UN Millennium Ecosystem Assessment

Activities and Projects

1. As a class project, "adopt" a developing country. Assign teams of students to investigate various aspects of the nation's physical, population, economic, social, political, and other characteristics, as well as lifestyle and quality of life. Allocate class time for periodic brief reports and discussions of research results.

2. As a class project or extra-credit exercise, contact the local Department of Transportation (DOT) and find out if they offer an Adopt-a-Highway program. Adopt a stretch of highway and have students pick up litter. Students can keep tallies of the different types of litter collected (metal cans, snack food wrappers, etc.) and prepare a pie chart and report to submit to the DOT.

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3. As a class exercise, compute the cost of a hamburger, a movie ticket, a single-family home, and/or other commodities 30 years in the future, assuming the current inflation rate.

4. As a class exercise, compile a list of resources that are considered important today but were not recognized as resources 100 years ago. What are some things that have ceased to be significant resources during the last 50 years? What resources of the present will probably be of little value 50 years from now?

5. Have the class make a list of changes in your community's environment that have occurred over the last 10 years. Have them vote on which changes they consider desirable and which ones undesirable. Discuss the changes on which there is least consensus about desirability. Clarify the differences in values that underlie differences in students' responses.

6. Have students assume roles as futurists and predict life as it will be in the year 2050.

7. Have your students write scenarios describing what everyday life would be like in the United States after a transition is made to a sustainable society. Identify areas of consensus and disagreement.

8. As a class exercise, have each student write out and hand in anonymously a list of the essential components of "the good life." Read some or all of the lists aloud to the class. Write a composite list on the blackboard and discuss each component in terms of sustainable-Earth values and guidelines.

Chapter Review

Core Case Study

1. Summarize the authors' vision of a more sustainable world by using concepts of biomimicry.
    - Life on earth has existed for around 3.8 billion years by adaptations that have allowed organisms to survive several catastrophic environmental changes. Scientists call upon us to focus on learning from the earth about how to live more sustainably.
    - In recent years, there have been efforts to make people more aware of such earth wisdom. Biologist Janine Benyus is a pioneer in this area. In 1997, she coined the term "biomimicry" to describe the rapidly growing scientific effort to understand, mimic, and catalog the ingenious ways in which nature has sustained life on the earth for 3.8 billion years.

Section 1.1

2. What are the key concepts for this section? Define environment. Distinguish among environmental science, ecology, and environmentalism. What is an ecosystem? What are the three scientific principles of sustainability derived from how the natural world works? What is solar energy, and why is it important to life on the earth? Define solar energy, biodiversity, and chemical (or nutrient) cycling, and explain why it is important to life on the earth.
    - Key concepts: Nature has been sustained for billions of years by relying on solar energy, biodiversity, and chemical cycling. Our lives and economies depend on energy from the sun and on natural resources and ecosystem services (natural capital) provided by the earth. We could live more sustainably by following the six principles of sustainability.
    - The environment is everything around us.
    - Environmental science is an interdisciplinary study of how humans interact with living and nonliving parts of their environment.

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- Ecology is the biological science that studies how organisms, or living things, interact with one another and with their environment.
- Environmentalism is a social movement dedicated to protecting the earth's life-support systems for all forms of life.
- An ecosystem is a set of organisms within a defined area or volume interacting with one another and with their environment of nonliving matter and energy.
- The three scientific principles of sustainability are (1) dependence on solar energy, (2) biodiversity, and (3) chemical cycling.
- Solar energy is the energy imparted to the earth system by the sun. The sun warms the planet and provides energy that plants use to produce nutrients. The sun also powers indirect forms of solar energy, such as wind and flowing water.
- Biodiversity is the variety of genes, organisms, species, and ecosystems in which organisms exist and interact. The interactions among species provide vital ecosystem services and keep populations from growing too large.
- Chemical cycling is the circulation of chemicals necessary for life from the environment, through organisms, and back to the environment. Organisms must recycle chemicals continuously in order to survive.

3. Define natural capital. Define natural resources and ecosystem services and give two examples of each. Give three examples of how we are degrading natural capital. Explain how finding solutions to environmental problems involves making trade-offs. Explain why individuals matter in dealing with the environmental problems we face. What are three economic, political, and ethical principles of sustainability? What is full-cost pricing, and why is it important? Describe the role of Janine Benyus in promoting the important and growing field of biomimicry.
    - Natural capital is the sum of natural resources and natural services that keep us and other species alive and support human economies.
    - Natural resources are materials and energy in nature that are essential or useful to humans. Examples of natural resources include water and oil.
    - Ecosystem services are processes provided by healthy ecosystems. Examples of ecosystem services include renewal of topsoil and pollination.
    - We degrade natural capital by cutting down trees faster than they can grow back, replacing diverse and sustainable forests with croplands, and adding harmful chemicals and wastes into streams and oceans faster than they can cleanse themselves.
    - The search for environmental solutions often involves conflicts. In these cases, it is important to make trade-offs, where both sides get something out of the deal.
    - History has shown that almost all the significant changes in human systems have come from the bottom up, through the collective actions of individuals and from individuals inventing more sustainable ways of doing things. Thus, sustainability begins with actions at personal and local levels.
    - The three economic, political, and ethical principles of sustainability are (1) full-cost pricing, (2) win-win solutions, and (3) a responsibility to future generations.
    - Full-cost pricing involves adding detrimental costs related to the environment and human health to the prices of goods and services. Full-cost pricing would give consumers better information about the environmental impacts of their lifestyles, and it would allow them to make more informed choices about the goods and services they use.
    - Janine Benyus has had a lifelong interest in learning how nature works and how to live more sustainably. She realized that 99% of the species that have lived on the earth

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became extinct because they could not adapt to changing environmental conditions. She set up the nonprofit Biomimicry Institute that has developed a curriculum for K–12 and university students, and also has a two-year program to train biomimicry professionals.

4. What is a resource? Distinguish between an inexhaustible resource and a renewable resource, and give an example of each. What is the sustainable yield of a renewable resource? Define and give two examples of a nonrenewable or exhaustible resource. Distinguish between more-developed countries and less-developed countries, and give an example of a high-income, a middle-income, and a low-income country.
   - A resource is anything we can obtain from the environment to meet our needs and wants.
   - Inexhaustible resources have continual supplies, and renewable resources will be replenished as long as we do not use them too rapidly. Solar energy is perpetual, and wood resources are renewable.
   - Sustainable yield is the highest rate at which a resource can be used without indefinitely reducing its available supply.
   - Nonrenewable resources are resources that exist in a fixed quantity, such as copper or oil.
   - The United Nations classifies countries as economically developed or developing based primarily on their degree of industrialization and their per capita gross domestic product at purchasing power parity (GDP-PPP). Most developed countries are highly industrialized and have a high per capita GDP-PPP. Some developing countries are middle-income and moderately developed, whereas others are low-income and least developed. The United States is a high-income country, Brazil is a middle-income country, and Haiti is a low-income country.

Section 1.2

5. What is the key concept for this section? How have humans improved the quality of life for many people? How are humans living unsustainably? Define and give three examples of environmental degradation (natural capital degradation). About what percentage of the earth's natural or ecosystem services has been degraded by human activities? What is the tragedy of the commons? What are two ways to deal with this effect?
   - Key concept: Humans dominate the earth with the power to sustain, add to, or degrade the natural capital that supports all life and human economies. As our ecological footprints grow, we are depleting and degrading more of the earth's natural capital.
   - Humans have developed an astounding array of useful materials and products. Life spans are increasing, infant mortality is decreasing, education is on the rise, some diseases are being conquered, and the population growth rate has slowed. Poverty has been reduced. The food supply is generally more abundant and safer, air and water are getting cleaner in many parts of the world, and exposure to toxic chemicals is more avoidable. We have protected some endangered species and ecosystems and restored some grasslands and wetlands, and forests are growing back in some areas that we cleared.
   - Humans are living unsustainably by wasting, depleting, and degrading much of the earth's life-sustaining natural capital.
   - Natural capital degradation involves using resources at an unsustainable rate. Examples include forests shrinking, topsoil eroding, and deserts expanding.
   - About 60% of the earth's natural or ecosystem services have been degraded by human activities.

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- The tragedy of the commons is the process of environmentally degrading many openly shared renewable resources.
- One way to deal with the degradation of shared resources is to use a shared or open-access renewable resource at a rate well below its estimated sustainable yield by using less of the resource, regulating access to the resource, or doing both. Another is to convert shared renewable resources to private ownership. Some resources, however, cannot be converted to private ownership.

6. What is affluence? What is an ecological footprint? What is a per capita ecological footprint? Define biocapacity. Use the ecological footprint concept to explain how we are living unsustainably in terms of the estimated number of planet earths that we need to sustain ourselves now and in the future. What is the IPAT model for estimating our environmental impact? Explain how three major cultural changes that have taken place over the last 10,000 years have increased our overall environmental impact. What would a sustainability revolution involve?
   - Affluence is wealth.
   - Ecological footprint refers to the amount of biologically productive land and water needed to provide the people in a particular country or area with an indefinite supply of renewable resources and to absorb and recycle the wastes and pollution produced by such resource use.
   - The per capita ecological footprint is the average ecological footprint of an individual in a given country or area.
   - Biocapacity is the ability of the earth's productive ecosystems to regenerate the renewable resources used by a population, city, region, country, or the world, and to absorb the resulting wastes and pollution indefinitely.
   - We are living unsustainably by overextracting resources and not allowing adequate time for the processes of recycling and regeneration. Today we are using one and one-half of the earth's supply of resources.
   - The IPAT model shows that the environmental impact (I) of human activities is the product of three factors: population size (P), affluence (A) or resource consumption per person, and the beneficial and harmful environmental effects of technologies (T). The following equation summarizes this IPAT model:
     Impact (I) = Population (P) × Affluence (A) × Technology (T)
     The IPAT model includes the environmental impact of using both renewable and nonrenewable resources.
   - Each of the three cultural changes (the agricultural revolution, the industrial–medical revolution, and the information–globalization revolution) gave us more energy and new technologies with which to alter and control more of the planet's resources to meet our basic needs and increasing wants. They also allowed expansion of the human population, mostly because of larger food supplies and longer life spans. In addition, these cultural changes resulted in greater resource use, pollution, and environmental degradation and allowed us to dominate the planet and expand our ecological footprints.
   - A sustainability revolution would involve avoiding degradation and depletion of the natural capital that supports all life and our economies and restoring natural capital that we have degraded.

Section 1.3

7. What are the two key concepts for this section? Identify six basic causes of the environmental problems that we face. What is exponential growth? What is the rule of 70? What is the current

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size of the human population? About how many people are added each year? How large is the world's population projected to be in 2050? How do Americans, Indians, and the average people in the poorest countries compare in terms of average resource consumption per person? Summarize the potentially harmful and beneficial environmental effects of affluence.

- Key concepts: Basic causes of environmental problems are population growth, wasteful and unsustainable resource use, poverty, avoidance of full-cost pricing, increasing isolation from nature, and different environmental worldviews. Our environmental worldviews play a key role in determining whether we live unsustainably or more sustainably.
- Some basic causes of environmental problems are:
    - population growth
    - wasteful and unsustainable resource use
    - poverty
    - omission of the harmful environmental and health costs of goods and services from market prices
    - increasing isolation from nature
    -
    - competing environmental worldviews.
- Exponential growth occurs when a quantity, such as the human population, increases at a fixed percentage per unit of time, such as 1% or 2% per year.
- The rule of 70 is doubling time (years) = 70/annual growth rate (%).
- There are now about 7.7 billion people on the earth. About 89 million are added each year.
- By 2050, the population could reach 9.8 billion.
- The exponential rate of global population growth has declined since 1963.Nevertheless, unless death rates rise sharply, there will probably be 9.8 billion of us by 2050 (up from 6.9 in 2010).
- The average American consumes about 30 times as much as the average Indian and 100 times as much as the average person in the world's poorest countries.
- Growing affluence results in high levels of consumption and unnecessary waste of resources. It can allow for better education, which can lead people to become more concerned about environmental quality. It also provides money for developing technologies to reduce pollution, environmental degradation, and resource waste.

8. Explain how excluding the harmful environmental and health costs from the prices of goods and services affects the environmental problems we face. What is the connection between government subsidies, resource use, and environmental degradation? What are two ways to include the harmful environmental and health costs of the goods and services that we use in their market prices? Explain how lack of knowledge of nature and importance of natural capital and our increasing isolation from nature can intensify the environmental problems that we face. What is an environmental worldview? What are environmental ethics? What are five important ethical questions relating to the environment? Distinguish between the human-centered, life-centered, and earth-centered environmental worldviews. What are three levels of biomimicry? List eight key biomimicry principles.
    - Excluding the harmful environmental costs in the prices of goods and services can hurt the environment because the consumer does not realize the value being lost.
    - Environmentally harmful subsidies encourage the depletion and degradation of natural capital.

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- Two ways to include harmful environmental and health costs in market prices over the next two decades would be to shift from environmentally harmful government subsidies to environmentally beneficial subsidies and to tax pollution and wastage heavily while reducing taxes on income and wealth.
- Lack of knowledge of natural capital prevents us from understanding the importance of reducing our ecological footprints.
- Environmental worldview is a set of assumptions and values reflecting how you think the world works and what you think your role in the world should be.
- Environmental ethics are beliefs about what is right and wrong with how we treat the environment.
- Five important ethical questions relating to the environment:
    - Why should we care about the environment?
    - Are we the most important species on the planet, or are we just another one of the earth's millions of life forms?
    - Do we have an obligation to see that our activities do not cause the extinction of other species? If so, should we try to protect all species or only some? How do we decide which ones to protect?
    - Do we have an ethical obligation to pass the natural world on to future generations in a condition that is as good as or better than what we inherited?
    - Should every person be entitled to equal protection from environmental hazards regardless of race, gender, age, national origin, income, social class, or any other factor?
    - Should we seek to live more sustainably, and if so, how?
- A human-centered environmental worldview sees the natural world as a support system for human life. According to the life-centered environmental worldview, all species have value in fulfilling their particular role within the biosphere, regardless of their potential or actual use to humans. According to the earth-centered environmental worldview, we are part of, and dependent on, nature, and the earth's natural capital exists for all species, not just for humans.
- Three levels of biomimicry are as follows:
    - The first level involves mimicking the characteristics of species, such as bumps on a whale's fins or the wing and feather designs of birds, that are believed to have enhanced the long-term survival of such species.
    - The second and deeper level involves mimicking the processes that species use to make shells, feathers, and other parts that benefit their long-term survival without using or producing toxins and without using the high-temperature or high-pressure processes we use in manufacturing.
    - The third and deepest level involves mimicking the long-term survival strategies and beneficial environmental effects of natural ecosystems such as forests and coral reefs.
- Eight key biomimicry principles are:
    - Runs on sunlight, not fossil fuels
    - Does not waste energy
    - Uses only what it needs
    - Adapts to changing environmental conditions
    - Depends on biodiversity for population control and adaptation
    - Creates no waste because the matter outputs of one organism are resources for other organisms
    - Does not pollute its own environment
    - Does not produce chemicals that cannot be recycled by the earth's chemical cycles

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Section 1.4

9. What is the key concept for this section? What is an environmentally sustainable society? What is natural income and how is it related to sustainability? Describe Tuy Sereivathana's efforts to prevent extinction of elephants in Cambodia and to reduce the country's poverty. List nine principles for living more sustainably. What are two pieces of good news about making the transition to a more sustainable society? What are this chapter's three big ideas?
    - Key concept: Living sustainably means living off the earth's natural income without depleting or degrading the natural capital that supplies it.
    - An environmentally sustainable society is one that meets the current and future basic resource needs of its people in a just and equitable manner without compromising the ability of future generations to meet their basic needs.
    - Natural income is the renewable resources such as plants, animals, and soil provided by the earth's natural capital. Living sustainably means not depleting or degrading the earth's natural capital.
    - Tuy Sereivathana directs the Cambodian Elephant Conservation Group, devoted to reducing poaching and helping farmers work together to use low-cost and innovative ways to protect their crops without having to kill elephants. He has helped farmers set up nighttime lookouts for elephants.
      He taught villagers to scare raiding elephants away by using foghorns and fireworks and using solar-powered electric fences to mildly shock them. He also encouraged farmers to stop growing watermelons and bananas, which elephants love, and to grow crops such as eggplant and chili peppers that elephants shun.
    - Nine principles to live more sustainably means:
        - Learning from nature
        - Protecting natural capital
        - Not wasting resources (there is no waste in nature)
        - Recycling and reusing nonrenewable resources
        - Using renewable resources no faster than nature can replenish them
        - Incorporating the harmful health and environmental impacts of producing and using goods and services into their market prices
        - Preventing future ecological damage and repairing past damage
        - Cooperating with one another to find win-win solutions to the environmental problems we face
        - Accepting the ethical responsibility to pass the earth that sustains us on to future generations in a condition as good as or better than what we inherited.
    - The first piece of good news is that research by social scientists suggests that it takes only 5%–10% of the population of a community, a country, or the world to bring about major social change. Second, such research also shows that significant social change can occur in a much shorter time than most people think.
    - This chapter's three big ideas are as follows:
        - We can ensure a more sustainable future by relying more on energy from the sun and other renewable energy sources, protecting biodiversity through the preservation of natural capital, and avoiding the disruption of the earth's vital chemical cycles.
        - A major goal for achieving a more sustainable future is full-cost pricing—the inclusion of harmful environmental and health costs in the market prices of goods and services.

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- We will benefit ourselves and future generations if we commit ourselves to finding win-win solutions to environmental problems and to leaving the planet's life-support system in a condition as good as or better than what we now enjoy.

Suggested Answers to End-of-Chapter Questions

Critical Thinking

The following are examples of the material that should be contained in possible student answers to the end-of-chapter Critical Thinking questions. They represent only a summary overview and serve to highlight the core concepts that are addressed in the text. It should be anticipated that the students will provide more in-depth and detailed responses to the questions depending on an individual instructor's stated expectations.

1. Why is biomimicry so important? Find an example of something in nature that you think could be mimicked for some beneficial purpose. Explain that purpose and how biomimicry could apply.

   Answers may vary. Biomimicry is important because nature has sustained life on the earth for 3.8 billion years, and following nature's plan to solve technological problems is a sustainable plan. The textbook uses the example of a gecko's ability to adhere to surfaces as a model for toxin-free "gecko tape."

2. What are the three most environmentally unsustainable components of your lifestyle? List two ways in which you could apply each of the six **principles of sustainability** (Figures 1.2 and 1.7) to make your lifestyle more environmentally sustainable.

   Answers may vary. Environmentally unsustainable components of lifestyle might be excessive energy use, and not recycling. Some examples of applying the principles of sustainability include reducing energy consumption and relying more heavily on solar energy, reducing resource use and recycling when possible, and advocating a reduction in population growth. Other answers might include supporting full-cost pricing, responsibility to future generations, and striving for win-win results.

3. For each of the following actions, state one or more of the three scientific principles of sustainability that are involved: (a) recycling aluminum cans, (b) using a rake instead of a leaf blower, (c) walking or bicycling to class instead of driving, (d) taking your own reusable bags to the grocery store to carry your purchases home, and (e) volunteering to help restore a prairie or other degraded ecosystem.

   (a) Chemical Cycling: In nature there is no waste, so recycling the aluminum soda can mimic nutrient recycling. As less energy is used in the aluminum recycling process than starting from raw materials such as bauxite, we are less dependent on nonrenewable energy sources.

   (b) Dependence on Solar Energy: As no electrical or gasoline energy is expended by using the rake, we are less dependent on nonrenewable energy sources such as coal to generate the electricity to power the leaf blower.

   (c) Dependence on Solar Energy: By not using gasoline to drive the car, we rely more on renewable rather than nonrenewable energy and positively impact biodiversity in areas where oil drilling is having harmful ecological effects.

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(d) Dependence on Solar Energy: If we use a reusable grocery bag made from organically grown cotton, we rely on solar energy rather than nonrenewable energy sources that may have been used to make a plastic bag, which may or may not be recyclable; using paper bags can have an effect on the biodiversity of forest lands.

(e) Biodiversity: By restoring habitat, you will be enhancing biodiversity and also helping the future recycling of nutrients from the plantings.

4. Explain why you agree or disagree with the following propositions: (**a**) Stabilizing population is not desirable because without more consumers, economic growth would stop. (**b**) The world will never run out of resources because we can use technology to find substitutes and to help us reduce resource waste.

   Student answers will vary depending on their viewpoint but could include the following:

   a. Disagree: The earth has a finite amount of resources. With ever-increasing numbers of consumers, the economy may eventually max out as these resources are diminished and the costs skyrocket. This would lead to greater disparity between rich and poor people and end up promoting increased poverty rather than increased wealth.

   b. Agree: Companies like 3M have reduced their waste by selling their generated waste products to other companies that need the materials in the manufacturing processes for goods that they produce. With an increase in such technology in the future, more materials have the potential to be reused and recycled indefinitely.

5. Should nations with large ecological footprints reduce their footprints to decrease their harmful environmental impact and leave more resources for nations with smaller footprints and for future generations? Explain.

   Student answers will vary depending on their viewpoint but could include the following:

   More-developed countries, such as the United States, Japan, Canada, Australia, and Germany and most other European countries, have 17% of the world's population and use about 70% of the earth's natural resources, whereas less-developed countries, with 83% of the world's population, use about 30% of the world's natural resources. An ethical consideration might consider that affluent countries have a responsibility to reduce their environmental impact whether less-developed nations use those resources or not. At present, we are living unsustainably.

6. When you read that at least 19,000 children age 5 and younger die each day (13 per minute) from preventable malnutrition and infectious disease, what is your response? How would you address this problem?

   Student answers will vary. The instructor could lead a discussion in which each student is asked to explain their answer. Through this discussion, students will be spurred into action.

7. Explain why you agree or disagree with each of the following statements: **(a)** humans are superior to other forms of life, **(b)** humans are in charge of the earth, **(c)** the value of other forms of life depends only on whether they are useful to humans, **(d)** all forms of life have a right to exist, **(e)** all economic

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growth is good, **(f)** nature has an almost unlimited storehouse of resources for human use, **(g)** technology can solve our environmental problems, **(h)** I don't have any obligation to future generations, and **(i)** I don't have any obligation to other forms of life.

Student answers will vary. The instructor can take the opportunity to lead a discussion in which some students elaborate on their own particular viewpoint.

8. What are the basic beliefs of your environmental worldview? Record your answers. Then at the end of this course, return to your answer to see if your environmental worldview has changed. Are the beliefs included in your environmental worldview consistent with the answers you gave to Question 7 above? Are your actions that affect the environment consistent with your environmental worldview? Explain.

   Student answers will vary. This question provides the instructor with the basis for a discussion on individual worldviews and allows for each student to consider their own current beliefs. It is hoped that by the end of the course, everyone in the class has gained a greater understanding of the environment and increased their environmental literacy. It also provides the instructor the chance to discuss specific *actions* individual members of the class can take to make sure that if they "talk the talk" they also "walk the walk" from an environmental perspective. This will help students to minimize their ecological footprint individually, as well as the class on the whole.

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Doing Environmental Science

Estimate your own ecological footprint by using one of the many estimator tools available on the internet. Is your ecological footprint larger or smaller than you thought it would be, according to this estimate? Why do you think this is so? List three ways in which you could reduce your ecological footprint. Try one of them for a week and write a report on this change. List three ways you could increase your beneficial environmental impact.

Ecological Footprint Analysis

If the *ecological footprint per person* of a country or of the world is larger than its *biological capacity per person* to replenish its renewable resources and absorb the resulting waste products and pollution, the country or the world is said to have an *ecological deficit*. If the reverse is true, the country or the world has an *ecological credit* or *reserve.* See Figure 1.11 for a map of the world's ecological debtor and creditor countries. Use the data in the accompanying table to calculate the ecological deficit or credit for the countries listed. (As an example, this value has been calculated and filled in for World.)

Place	**Per Capita** Ecological Footprint (Hectares per person)	**Per Capita** Biocapacity (Hectares per person)	**Ecological** Credit (+) or Debit (–) (Hectares per person)
World	2.8	1.8	–1.0
United States	8.4	3.6	
Canada	8.0	15.0	
Mexico	2.5	1.2	
Brazil	3.1	8.9	
South Africa	3.4	1.1	
United Arab Emirates	9.8	0.6	
Israel	4.7	0.3	
Germany	5.0	1.8	
Russian Federation	5.6	6.9	
India	1.1	0.5	
China	3.7	1.0	
Australia	6.9	13.3	
Bangladesh	0.8	0.4	
Denmark	7.1	4.0	
Japan	4.7	0.6	
United Kingdom	4.8	1.2	

Compiled by the authors using data from World Wide Fund for Nature: Living Planet Report 2017 and the Global Footprint Network 2018.

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Place	**Per Capita** Ecological Footprint (Hectares per person)	**Per Capita** Biocapacity (Hectares per person)	**Ecological** Credit (+) or Debit (–) (Hectares per person)
World	2.8	1.8	−1.0
United States	8.4	3.6	−4.8
Canada	8.0	15.0	+7.0
Mexico	2.5	1.2	−1.3
Brazil	3.1	8.9	+5.8
South Africa	3.4	1.1	−2.3
United Arab Emirates	9.8	0.6	−9.2
Israel	4.7	0.3	−4.4
Germany	5.0	1.8	−3.2
Russian Federation	5.6	6.9	+1.3
India	1.1	0.5	−0.6
China	3.7	1.0	−2.7
Australia	6.9	13.3	+6.4
Bangladesh	0.8	0.4	−0.4
Denmark	7.1	4.0	−3.1
Japan	4.7	0.6	−0.1
United Kingdom	4.8	1.2	−3.6

Compiled by the authors using data from World Wide Fund for Nature: Living Planet Report 2017 and the Global Footprint Network 2018.

1. Which three countries have the largest ecological deficits? Why do you think they have such large deficits?

    - The United Arab Emirates has an ecological deficit of 9.2 hectares per person, the United States has an ecological deficit of 4.8 hectares per person, and Israel has an ecological deficit of 4.4 hectares per person. The United States' deficit is likely due to affluence and overconsumption. The United Arab Emirates and Israel most likely have a high population relative to available resources.

2. Which three countries have the largest ecological credit? Why do you think each of these countries has an ecological credit?

    - Brazil has an ecological credit of 5.8 hectares per person, Australia has an ecological credit of 6.4 hectares per person, and Canada has an ecological credit of 7.0 hectares per person. These may be due to low population sizes relative to available resources.

3. Rank the countries in order from the largest to the smallest per capita ecological footprint.

    - United Arab Emirates
      United States
      Canada
      Denmark
      Australia
      Russian Federation
      Germany

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United Kingdom
Japan
Israel
China
South Africa
Brazil
World
Mexico
India
Bangladesh

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