Chapter 2

Science, Matter, Energy, and Systems

Summary and Objectives

2-1 What do scientists do?
Science is an endeavor to discover how nature works and to use that learned knowledge to make predictions about future events. The natural world follows orderly patterns, which, through observation and experimentation, can be understood. **CONCEPT 2-1** Scientists collect data and develop theories, models, and laws about how nature works.

1. Describe the steps involved in the scientific process. Distinguish among scientific hypothesis, scientific theory, and scientific (natural) law.
2. Distinguish between tentative or frontier science, reliable science and unreliable science. Explain the importance of peer review. Explain why people often use the term *theory* incorrectly.
3. What are some limitations of science? Describe statistics and probability, and describe how they are used in science.

2-2 What is matter and what happens when it undergoes change?
The building blocks of matter are atoms, ions, and molecules, which form elements and compounds. These different aspects of matter have mass and take up space; they may be living or non-living. **CONCEPT 2-2A** Matter consists of elements and compounds that are in turn made up of atoms, ions, or molecules. **CONCEPT 2-2B** When matter undergoes a physical or chemical change, no atoms are created or destroyed (the law of conservation of matter).

4. Define *matter*. Distinguish between forms of matter. Compare and contrast high-quality matter with low-quality matter and give an example of each.
5. Distinguish among a proton (p), neutron (n), and electron (e). What is the difference between the atomic number and the mass number? What is an isotope?
6. Distinguish between organic compounds and inorganic compounds.
7. What is the difference between a physical change and a chemical change?
8. What is the law of conservation of matter?

2-3 What is energy and what happens when it undergoes change?
Energy is the capacity to do work and transfer heat; it moves matter. Thermodynamics is the study of energy transformation. **CONCEPT 2-3A** Whenever energy is converted from one form to another in a physical or chemical change, no energy is created or destroyed (first law of thermodynamics). **CONCEPT 2-3B** Whenever energy is converted from one form to another in a physical or chemical change, we end up with lower-quality or less usable energy than we started with (second law of thermodynamics).

9. Define *energy*. Distinguish between forms of energy and quality of energy. Distinguish between high-quality energy and low-quality energy and give an example of each.
10. Describe how the law of conservation of matter and the law of conservation of energy govern normal physical and chemical changes. Briefly describe the second law of thermodynamics. Explain why this law means we can never recycle or reuse high-quality energy.

2-4 What keeps us and other organisms alive?
Ecology is the study of connections in the natural world among organisms, populations, communities, ecosystems, and the biosphere. The earth's life-support system consists of the geosphere, biosphere, hydrosphere, and atmosphere. **CONCEPT 2-4** Life is sustained by the flow of energy from the sun through the biosphere, the cycling of nutrients within the biosphere, and gravity.

11. Distinguish between organism, species, population, community, ecosystem, and biosphere.
12. Explain genetic diversity and how it contributes to biological communities.
13. Distinguish between the atmosphere, troposphere, and stratosphere. Define greenhouse gases and give two examples. What is the natural greenhouse effect?
14. List four spheres that interact to sustain life on Earth. Compare the flow of matter and the flow of energy through the biosphere.

Visit TestBankDeal.com to get complete for all chapters

2-5 What are the major components of an ecosystem?

Ecosystems are made up of abiotic (nonliving) components: water, air, nutrients, and solar energy, as well as biotic (living) components: plants, animals, and microbes. Producers, consumers, and decomposers cycle matter, energy, and nutrients in an ecosystem. **CONCEPT 2-5** Ecosystems contain nonliving and living components, including organisms that produce the nutrients they need, organisms that get the nutrients they need by consuming other organisms, and organisms that recycle nutrients by decomposing the wastes and remains of other organisms.

15. Distinguish between biotic and abiotic components of the biosphere and give two examples of each.
16. Define range of tolerance and the limiting factor principle. Give one example of a limiting factor in an ecosystem.
17. Distinguish between producers, consumers, and decomposers. List and distinguish between two types of producers and four types of consumers. Describe the concept of trophic levels.

2-6 What happens to energy in an ecosystem?

Ecological interdependence can be described in food chains and webs, energy flow, ecological efficiency, and the production of biomass. **CONCEPT 2-6** As energy flows through ecosystems in food chains and webs, the amount of chemical energy available to organisms at each succeeding feeding level decreases.

18. Apply the second law of energy to food chains and pyramids of energy flow. Explain ecological efficiency.
19. Discuss the difference between *gross primary productivity* and *net primary productivity.*

2-7 What happens to matter in an ecosystem?

Major cycles in ecosystems are the nutrient cycle, the hydrologic cycle, the carbon cycle, the nitrogen cycle, the phosphorus cycle, and the rock cycle. The carbon cycle produces carbon dioxide, and with more of it being released into the atmosphere, the world is now being affected by global warming. **CONCEPT 2-7** Matter, in the form of nutrients, cycles within and among ecosystems throughout the biosphere, and human activities are altering these chemical cycles.

20. Describe the hydrologic (water), carbon, nitrogen, or phosphorus cycle and describe how human activities are affecting each cycle.
21. List three types of rock and describe their interactions through the rock cycle.

Key Terms

science
data
experiments
scientific hypothesis
model
scientific theory
peer review
scientific law (law of nature)
tentative or frontier science
reliable science
unreliable science
probability
matter
element
compounds
atom
atomic theory
neutrons
protons
electrons
nucleus
atomic number
mass number
isotopes
molecule
chemical formula
ion
acidity
pH
organic compounds
inorganic compounds
genes
trait
chromosome
cell
matter quality
high-quality matter
low-quality matter

physical changechemical change or reaction
law of conservation of matter
energy kinetic (moving) energy
heat
electromagnetic radiation
potential (stored) energy
principle of sustainability
energy quality
high-quality energy
low-quality energy
first law of thermodynamics
law of conservation of energy
second law of thermodynamics
ecology
organism
species
population genetic diversity
habitat
community
biological community
ecosystem
biosphere
atmosphere troposphere
greenhouse gases
stratosphere
hydrosphere
geosphere
biomes
aquatic life zones
nutrients
natural greenhouse effect
biotic
abiotic
range of tolerance
limiting factors
limiting factor principle
trophic level

producers
autotrophs
photosynthesis
consumers
heterotrophs
primary consumers
herbivores
carnivores
secondary consumers
tertiary consumers
omnivores
decomposers
detritus feeders
detritivores
aerobic respiration
ecological tipping point
food chain
food web
biomass
ecological efficiency
pyramid of energy flow
gross primary productivity (GPP)
net primary productivity (NPP)
biogeochemical cycles
nutrient cycles
hydrologic (water) cycle
evaporation
precipitation
transpiration carbon cycle
nitrogen cycle
phosphorus cycle
rock
igneous rock
sedimentary rock
metamorphic rock
rock cycle

Outline

2-1 What Do Scientists Do?

A. Science assumes that events in the natural world follow orderly patterns and that, through observation and experimentation, these patterns can be understood. Scientists collect data, form hypotheses, and develop theories, models, and laws to explain how nature works.
   1. Scientists identify a problem, find out what is known about the problem, ask a question to investigate, and conduct experiments to collect data in order to answer the question.
   2. Based on observations of phenomenon, scientists form a scientific hypothesis—a possible explanation of the observed phenomenon that can be tested.
   3. Using the hypothesis, scientists make testable projections and perform further experiments (or observations) in order to accept or reject the hypothesis. (See Science Focus: Statistics and Probability)
   4. Important features of the scientific process are curiosity, skepticism, reproducibility, and peer review.

B. A scientific theory is a verified, believable, widely accepted scientific hypothesis or a related group of scientific hypotheses.
   1. Theories are explanations that are likely true, supported by evidence.
   2. Theories are the most reliable knowledge we have about how nature works.

C. A scientific/natural law describes events/actions of nature that reoccur in the same way, over and over again (such as effects of gravity on falling objects).

D. The reliability of scientific results relies on the reliability of how the experiments are conducted and interpreted.
   1. Preliminary scientific results can be described as tentative science (or frontier science). These results have not yet been widely tested or accepted by peer review, yet they are often featured in news headlines. These results are not reliable, as they have not been extensively tested. Scientists may disagree over the interpretation and accuracy of the data and conclusions.
   2. Reliable science, or scientific consensus, is hypotheses, models, theories, and laws that are widely accepted by most scientists that are experts in that field of study. These results have been peer reviewed and are reproducible.
   3. Unreliable science is that which has not undergone peer review or has been discarded as a result of peer review.

E. Limitations of Science
   1. There is always some degree of uncertainty in scientific measurements, models, observations.
   2. Scientists are human and may be biased. Peer review greatly reduces this.
   3. Many systems in science (especially environmental science) are very complex, making it difficult to test each variable. Mathematical models help simply complex analyses and modeling.
   4. Statistical tools such as sampling and estimation are important aspects of models.
   5. The scientific process can tell us about the natural world, not about the moral or ethical questions related to the topic being examined.

2-2 What Is Matter and What Happens When It Undergoes Change?

A. Matter is anything that has mass and takes up space, living or not.
   1. An element is the distinctive building block that makes up every substance.
   2. A compound is two or more different elements held together in fixed proportions by chemical bonds.

B. The building blocks of matter are atoms, ions, and molecules.
   1. An atom is the smallest unit of matter that exhibits the characteristics of an element.
   2. An ion is an electrically charged atom or combination of atoms.
   3. A compound is a combination of two or more atoms/ions of elements held together by chemical bonds.

C. An atom contains a nucleus with protons, usually neutrons, and one or more electrons moving outside the nucleus; it has no electrical charge.
   1. Subatomic particles in an atom are of three types:
      a. Protons have a positive electrical charge.
      b. Neutrons have no electrical charge.
      c. Electrons have a negative electrical charge.
   2. The nucleus is the very, very small center of the atom.

3. Each element has its own atomic number that equals the number of protons in the nucleus of each atom. [H has 1 proton and, therefore, the atomic number of 1; uranium has 92 protons and an atomic number of 92.]
4. Most of an atom's mass is found in the nucleus. The mass number is the total number of neutrons and protons in its nucleus.

D. All atoms of an element have the same number of nuclei protons; but they may have different numbers of uncharged neutrons in their nuclei. As a result, atoms may have different mass numbers. These are called isotopes.

E. Molecules are combinations of atoms held together by chemical bonds. Chemical formulas show the number and type of atoms or ions in the compound.
1. Each of the elements in the unit is represented by symbols: H=water, N=nitrogen.
2. Subscripts show the number of atoms/ions in the unit.

F. Ions are atoms with a net positive or negative electrical charge, resulting from the gain or loss of electrons (respectively). Ions are important for measuring a substance's acidity in water.

G. Organic compounds contain combinations of carbon atoms and atoms of other elements. Only methane (CH_4) has only one carbon atom.
1. Hydrocarbons: compounds of carbon and hydrogen atoms. Examples include methane (component of natural gas) and octane (component of gasoline)
2. Chlorinated hydrocarbons: compounds of carbon, hydrogen, and chlorine atoms. Examples include the pesticide DDT.
3. Simple carbohydrates (simple sugars): specific types of compounds of carbon, hydrogen, and oxygen atoms. Example: glucose
4. Macromolecules are larger, more complex organic compounds, many of which are essential to life. These include complex carbohydrates (cellulose, starch), proteins, and nucleic acids (DNA, RNA).
5. DNA contains genes, specific sequences that code for traits that can be passed to offspring. These genes make up chromosomes, DNA that is highly organized and tightly wrapped around proteins. These building blocks come together to form cells, the fundamental unit of living things.

H. According to the usefulness of matter as a resource, it is classified as having high or low quality.
1. High-quality matter is highly concentrated, often found near the earth's surface.
2. Low-quality matter is dilute, may be found deep underground and/or dispersed in air or water.

I. Although matter can change forms or re-combine into new substances, it cannot be created or destroyed.
1. Physical change: no change in the chemical composition of the matter.
2. Chemical change: chemical compositions do change; new compounds are formed. Chemical equations show how atoms and ions are rearranged to form new products.
3. Law of conservation of mater: atoms are not created or destroyed during physical or chemical changes.
4. This law means there is no “away” when we “throw something away”. We will always have to address the pollutants and wastes that we produce.

2-3 What Is Energy and What Happens When It Undergoes Change?

A. Energy is the capacity to do work and transfer heat; it moves matter.
1. Kinetic energy has mass and speed; wind, electricity, and heat are examples.
2. Electromagnetic radiation is a form of kinetic energy in which energy travels in the form of a wave. These waves have many forms as described by their differing energy contents: X rays, UV radiation, and visible light are examples.
3. Potential energy is stored energy, ready to be used; an unlit match, for example.
4. Potential energy can be changed into kinetic energy. The direct input of solar energy to the earth produces other indirect forms of renewable energy, including wind, hydropower, and biomass.
5. Energy quality is measured by its usefulness; high energy is concentrated and has high usefulness. Low energy is dispersed and can do little work.

B. The Laws of Thermodynamics govern energy changes
1. The First Law of Thermodynamics states that energy can neither be created nor destroyed.
2. The Second Law of Thermodynamics states that when energy is changed from one form to another, there is always less usable energy; energy quality is depleted. In energy changes, the resulting low-quality energy is often heat which dissipates into the air.

3. In living systems, solar energy is changed to chemical energy (food) and then in to mechanical energy (moving, thinking, living). During each conversion, high-quality energy is degraded and flows into the environment as low-quality heat.
4. The Second Law of Thermodynamics also means we can never recycle high-quality energy to perform useful work. Once the concentrated energy is used, it is degraded to low-quality heat that dissipates into the atmosphere.

2-4 What Keeps Us and Other Organisms Alive?

A. Ecology is the study of connections in the natural world. An ecologist's goal is to try to understand interactions among organisms, populations, communities, ecosystems, and the biosphere.
   1. An organism is any form of life. The cell is the basic unit of life in organisms.
   2. Organisms are classified into species, which groups organisms similar to each other together.

B. A population consists of a group of interacting individuals of the same species occupying a specific area.
   1. Genetic diversity explains that these individuals may have different genetic makeup and, thus, do not behave or look exactly alike.
   2. The habitat is the place where a population or an individual usually lives.

C. A community represents populations of different species living and interacting in a specific area – the network of plants, animals, and microorganisms. (See Science Focus: Have You Thanked the Insects Today?)

D. An ecosystem is a community of different species interacting with each other and with their nonliving environment of matter and energy. All of the earth's diverse ecosystems comprise the biosphere.

E. Various interconnected spherical layers make up the earth's life support system.
   1. The atmosphere is the thin membrane of air around the planet. The troposphere (up to 17 km above sea level) contains air we breathe, our weather, and greenhouse gases, while the stratosphere (17-50 km above earth) holds the UV-protective ozone layer.
   2. The hydrosphere consists of the Earth's water (liquid, ice, and vapor)
   3. The geosphere is made of rock mostly inside the earth: crust, mantle, and core.
   4. The biosphere contains all life on earth, including parts of the atmosphere, hydrosphere, and geosphere. Land regions are classified into biomes (forests, deserts, grasslands) with distinct climates and animals/vegetation specifically adapted to them. Biosphere extends from ocean floor to 9 km above the earth's surface.

F. High-quality energy from the sun, nutrient cycles, and gravity sustain life on Earth.

G. Solar energy reaches the earth in the form of visible light, infrared radiation (heat), and ultraviolet radiation.
   1. Much of this energy is absorbed or reflected back into space by the atmosphere.
   2. Greenhouse gases trap the heat and warm the troposphere. This natural greenhouse effect makes the planet warm enough to support life.

2-5 What Are the Major Components of an Ecosystem?

A. The major components of ecosystems are abiotic (nonliving) water, air, nutrients, and solar energy; and biotic (living) plants, animals, and microbes.

B. Each population in an ecosystem has a range of tolerance to variations in its physical and chemical environments.
   1. The limiting factor principle states that too much or too little of any abiotic factor can limit or prevent growth of a population, even if all other factors are at or near the optimum range of tolerance.
   2. Water or nutrients can be limiting factors on land, while dissolved oxygen, nutrients, and temperature can be limiting factors in aquatic systems.

C. Every organism in an ecosystem can be classified according to its trophic level (feeding level), as defined by its source of nutrients.
   1. Producers: autotrophs make their own food/nutrients (plants). All consumers rely on producers for their nutrients.
   2. Consumers: heterotrophs may feed on both producers (plants) and other consumers (animals), or may feed on plants alone (herbivores).
   3. Decomposers: detritivores feed on wastes and dead organisms and recycle the nutrients back to the ecosystem – key role in nutrient cycling. (See Science Focus: Many of the World's Most Important Species Are Invisible to Us)

2-6 What Happens to Energy in an Ecosystem?

A. Food chains and food webs help us understand how producers, consumers, and decomposers are connected to one another as energy flows through trophic levels in an ecosystem.
B. The chemical energy stored in biomass is transferred from one trophic level to another, but some energy is degraded and lost to the environment as low-quality heat. As you go "up" the food chain, there is a decrease in the amount of high-quality energy available to each organism at succeeding feeding levels.
    1. The percentage of usable chemical energy transferred as biomass from one trophic level to the next is called ecological efficiency.
    2. Typically, 10% of usable chemical energy is transferred to the next level in the food chain.
    3. Energy flow pyramids illustrate how the earth could support more people if they eat at a lower trophic level. Food webs and food chains rarely have more than 4 or 5 trophic levels due to the significant loss of energy at each level.
C. Production of biomass takes place at different rates among different ecosystems.
    1. The rate of an ecosystem's producers converting energy as biomass is the gross primary productivity (GPP).
    2. Some of the biomass must be used for the producer's own respiration. Net primary productivity (NPP) is the rate at which producers use photosynthesis to store biomass minus the rate at which they use energy for aerobic respiration. NPP measures how fast producers can provide biomass needed by consumers in an ecosystem.
    3. The planet's NPP limits the number of consumers who can survive (including humans!).
    4. Ecologists estimate that humans now use, waste, or destroy 10-55% of the earth's entire potential NPP.

2-7 What Happens to Matter in an Ecosystem?

A. Nutrient cycles (biogeochemical cycles) are global recycling systems that interconnect all organisms.
    1. Nutrient atoms, ions, and molecules continuously cycle between air, water, rock, soil, and living organisms.
    2. These cycles include the carbon, oxygen, nitrogen, phosphorus, and water cycles. They are connected to chemical cycles of the past and the future.
B. The water/hydrologic cycle collects, purifies, and distributes the earth's water in a vast global cycle.
    1. Solar energy evaporates water, the water returns as rain/snow, goes through organisms, goes into bodies of water, and evaporates again.
    2. Some water becomes surface runoff; returning to streams/rivers, causing soil erosion, and also being purified itself.
    3. Water is a major medium for transporting nutrients within and between ecosystems.
    4. About 0.024% of the earth's water supply is available as liquid fresh water in accessible groundwater deposits, lakes, rivers, and streams.
C. The water cycle is altered by man's activities.
    1. We withdraw large quantities of fresh water, often at a rate at is faster than nature can replace it.
    2. We clear vegetation, which increases runoff, reduces filtering, and increases flooding.
    3. We increase flooding when we drain wetlands for farming or development.
D. The carbon cycle circulates through the biosphere. Carbon moves through water and land systems, using processes that change carbon from one form to another.
    1. CO_2 gas is an important temperature regulator on Earth.
    2. Photosynthesis in producers and aerobic respiration in consumers, producers, and decomposers circulates carbon in the biosphere.
    3. Fossil fuels contain carbon; in a few hundred years we have almost depleted these fuels that have taken millions of years to form.
E. Addition of excess carbon dioxide to the atmosphere through our use of fossil fuels and our destruction of the world's photosynthesizing vegetation has contributed to changes in global climate
F. Bacteria are critical to the nitrogen cycle, converting nitrogen compounds into those that can be used by plants and animals as nutrients.
    1. In nitrogen fixation, gaseous N_2 is converted to ammonia, which is converted to ammonium ions that are useful to plants.
    2. Ammonia not used by plants may undergo nitrification, a conversion process that uses bacteria to convert the nitrogen to nitrite ions (toxic to plants) and nitrate ions (easily taken up by plants).
    3. Decomposer bacteria convert detritus into ammonia and ammonium ion salts in ammonification.

4. In denitrification, nitrogen is returned to a gaseous form and released into the atmosphere.

G. Human activities affect the nitrogen cycle.
   1. In burning fuel, we add nitric oxide into the atmosphere; it can return to the earth’s surface as acid rain.
   2. Nitrous oxide that comes from livestock, wastes, and inorganic fertilizers we use on the soil can warm the atmosphere and deplete the ozone layer.
   3. We destroy forest, grasslands, and wetland, thus releasing large amounts of nitrogen into the atmosphere.
   4. We pollute aquatic ecosystems with agricultural runoff and human sewage.
   5. We remove nitrogen from topsoil with our harvesting, irrigating, and land-clearing practices.

H. The phosphorous cycle circulates through the water, the earth's crust, and living organisms.
   1. Phosphate ions transferred throughout the food chain, from producers to consumers to decomposers.
   2. Phosphates that end up in the ocean can remain trapped in sediment for millions of years
   3. Phosphates are often limiting factors for plant growth on land as well as producer populations in aquatic environments.
   4. an interferes with the phosphorous cycle in harmful ways such as mining phosphate rock to produce fertilizers and detergents, cutting down tropical forests, and increasing phosphates in aquatic environments with animal waste runoff and human sewage.

I. The planet’s slowest cyclical process is the rock cycle.
   1. Igneous rock forms when magma (volcanic rock material) comes from the earth’s crust, cools, and hardens.
   2. Sedimentary rock is formed when sediment is weathered and eroded, moved from its source, and deposited in a body of water. The layers weather, erode, and become buried and compacted. This process binds the particles together and forms sedimentary rock, rocks such as sandstone and shale.
   3. When rock is exposed to high temperatures, high pressures, chemically active fluids, or a combination of these things, metamorphic rock is formed.
   4. The rock cycle concentrates the earth's nonrenewable mineral resources (on which we depend).

Teaching Tips

1. Remember when planning for the lesson, take a moment to go back and review the performance objectives listed under each key concept. Build these performance objectives into the lesson, using them as checkpoints for student understanding as the lesson unfolds. Also, take these performance objectives into consideration when incorporating outside material(s) into the lesson.

2. Recall that using informal questioning methods each session can be highly effective in helping assess what the students already know about a topic(s) before a lesson begins, and will also reveal the general knowledge base of the class. When using this method, be aware that sometimes you may expose a topic that students have little prior knowledge of or misconceptions about. If this occurs, focus attention on preparing the students for the information to come. Try to make a relevant connection between something the students are already familiar with and what they are about to learn.

3. Critical thinking activities are an excellent element to incorporate into each class meeting. The following is a possible warm-up activity for Chapter Two that can also be found under the Activities and Projects section.

   How do you feel when your home is air conditioned? Heated? How do you feel when you turn on a light? The television? Your CD player? What rights do you have to Earth’s energy resources? Are there any limits to your rights? What are they?

4. Have the students come back and revise their answers after the completion of the lesson**.** Depending on the class size, you may want to have the students share what they have learned with one another in small groups or as a class.

Topics for Term Papers and Discussion

Conceptual Topics

1. Low-energy lifestyles. Individual case studies such as Amory Lovins and national case studies such as Sweden. Many local, regional, and national organizations are providing information for decreasing individual's energy use.

2. Nature's cycles and economics. Recycling attempts in the United States; bottlenecks that inhibit recycling; strategies that enhance recycling efforts. What types of recycling programs are available in your area?

3. Cycles of matter. Particular cycles of matter, clarifying chemical changes throughout the cycle; the processes of photosynthesis and respiration, and how they connect autotrophic and heterotrophic organisms.

4. Energy flow. Energy flow in a particular ecosystem; relationships between species in a particular ecosystem; comparison of the life of a specialist with that of a generalist.

5. Humans trying to work with ecosystems. Composting; organic gardening; land reclamation; rebuilding degraded lands; tree-planting projects; landscaping with native plants.

Attitudes & Values

1. How much are you willing to pay in the short run to receive economic and environmental benefits in the long run? Explore costs and payback times of energy-efficient appliances, energy-saving light bulbs, or hybrid vehicles.

2. Can we get something for nothing? Explore the attempts of advertising to convince the public that we can indeed get something for nothing. What does it mean when people say "there's no such thing as a free lunch"? How do these factors impact our perceived wants and needs?

3. Is convenience more important than sustainability? Explore the influence of U.S. frontier origins on the throwaway mentality.

4. Do you hold any particular feelings for producers? Consumers? Decomposers? How do you feel when you think of a coyote eating a rabbit? How do you feel when you think of humans eating hamburgers? Should we eat lower on the food chain?

5. Should we rely more on perpetual sources of energy? What kinds of changes in our energy sources do you expect to see in the coming 10-20 years?

6. What lessons for human societies can be drawn from a study of species interaction in ecosystems?

7. To what extent should we disrupt and simplify natural ecosystems for our food, clothing, shelter, and energy needs and wants? To what extent do we actually disrupt these systems? What can individuals do to change this?

8. What do nature's cycles of matter suggest about landfills, incinerators, reducing consumption, and recycling?

9. How do you feel when your home is air conditioned? Heated? How do you feel when you turn on a light? The television? Your CD player? What rights do you have to Earth's energy resources? Are there any limits to your rights? What are they?

10. Based on your current understanding of energy flow and cycles of matter, evaluate the emphasis in the United States on fossil fuels and nuclear power for energy production.

Action-Oriented Topics

1. Individual. Actions that improve energy efficiency and reduce consumption of materials. Field and laboratory methods used in ecological research. Measuring net primary productivity and respiration rates; analyzing for particular chemicals in the air, water, and soil.

2. Community. Enhance recycling efforts: curbside pickup versus recycling center dropoffs; high-tech versus low-tech sorting of materials; Osage, Iowa, a case study in community energy efficiency.

3. Regional. Restoration of degraded ecosystems such as Lake Erie; coastal zone management.

4. National energy policy. Evaluation of the current national energy policy proposals in light of the laws of energy and long-term economic, environmental, and national-security interests.

Activities and Projects

1. A human body at rest yields heat at about the same rate as a 100-watt incandescent light bulb. As a class exercise, calculate the heat production of the student body of your school, the U.S. population, and the global population. Where does the heat come from? Where does it go?

2. As a class exercise, conduct a survey of the students at your school to determine their degree of awareness and understanding of the three matter and energy laws. Discuss the results in the context of the need for sustainable-earth societies.

3. As a class exercise, have each student list the kinds and amounts of food he or she has consumed in the past 24 hours. Aggregate the results and compare them on a per capita basis with similar statistics derived from studies of dietary composition and adequacy in food-deficient nations. How many people with a vegetarian diet could subsist on the equivalent food value of the meat consumed by your class?

4. Have the students debate the argument that eating lower on the food chain is socially and ecologically more responsible, cheaper, and healthier. (It is helpful to do this around a time when fasting is common.) Also, look at the long-term picture: Will eating low on the food chain sustain an exponentially growing human population indefinitely? What kinds of changes would this mean to your diet? How willing are you to change?
5. Define an ecosystem to study on campus. As a class project, analyze the nonliving and living components of the ecosystem. Draw webs and construct pyramids to show the relationships between species in the ecosystem. Project what might happen if pesticides were used in the ecosystem, if parts of the ecosystem were cleared for development, or if a coal-burning power plant were located upwind.

6. Ask a physics professor or physics lab instructor to visit your class and, by using simple experiments, demonstrate the matter and energy laws.

7. Organize a class trip to a natural area such as a forest, grassland, or estuary to observe the elements of ecosystem structure and function. Arrange for an ecologist or naturalist to provide interpretive services.

8. Bring a self-sustaining terrarium or aquarium to class and explain the structure and function of this conceptually tidy ecosystem. Discuss the various things that can upset the balance of the ecosystem and describe what would happen if light, food, oxygen, or space were manipulated experimentally.

BBC News Videos

The Brooks/Cole Environmental Science Video Library with Workbook, featuring BBC Motion Gallery Video Clips, 2011. ISBN: 978-0-538-73355-7 (Prepared by David Perault)
Who Pays The Price for Technology?

Suggested Answers for Critical Thinking Questions

1. Student answers will vary. They should emphasize the process of observation, creating hypothesis to explain or predict future behavior, testing the hypothesis, and then revising the hypothesis.

2. (a) Scientists can disprove things but they cannot prove anything absolutely because there is always some inherent uncertainty in making measurement, observations, and using models. Yet, the process of science means that many different experiments will be conducted from many different perspectives to try and understand if there is a connection between smoking and death. Scientific consensus develops over time, and new ideas are continually evaluated to see if a more accurate explanation can be developed.

   (b) This statement misinterprets the meaning of a scientific theory. The natural greenhouse theory is reliable because a scientific theory is related to a body of observations or measurements that have been well-tested and widely-accepted by the scientific community.

3. This phenomenon is not in violation of the law of conservation of matter because, while the tree is growing, it is doing so through physical and chemical changes without creating or destroying atoms. The tree is deriving matter in the form of nutrients from the earth, water, and the atmosphere, and when it dies this matter will be returned to their cycles.

4. The second law of thermodynamics states that energy always goes from a more-useful to a less-useful form when it is changed from one form to another. When a barrel of oil is used for energy, most of the energy is given off as heat, a lower-quality energy. You are unable to recycle or reuse the high-quality energy because once it has been converted into low-quality energy, or heat, it is lost to the environment.

5. (a) Energy from the sun flows through living organisms in their feeding relationships and out into the environment mainly as heat lost. The flow of energy through the biosphere depends on the cycling of nutrients because producers convert energy from the sun to nutrients for consumers and detritivores, which recycle nutrients back to producers.

   (b) The cycling of nutrients depends on gravity because it allows the planet to maintain its atmosphere. Gravity enables the movement and cycling of chemicals through the air, water, soil, and organisms.

5. Student answers will vary. Students should be able to trace their foods back to a producer species – but it might take some research for them to figure out what some of those intermediary organisms eat. As the course progresses, students may return to this thinking about their feeding level and the impact it has on the environment.

7. (a) If all the decomposers and detritus feeders were eliminated from an ecosystem, waste and dead organisms would build up and there would be no cycling of nutrients, as the detritivores aid in the breakdown of waste products into basic nutrients needed to support life.

   (b) If all the producers were eliminated from an ecosystem, consumers or heterotrophs would suffer as they have no way of producing their own energy. All higher trophic levels would also suffer and would most likely result in the halt of energy transfer through the ecosystem.

(c) If all insects were eliminated from an ecosystem, energy transfer and matter cycling through the ecosystem would be greatly altered. Insects fill important rolls such as detritivores and primary consumers; they also make up a major food/energy source to other organisms. Insects are also needed as pollinators for sexual reproduction in plants.

A balanced ecosystem cannot exist with only producers and decomposers. A healthy ecosystem depends on species diversity. Consumers maximize the rate of flow of energy and cycling of matter through ecosystems. All trophic levels are necessary for balanced nutrient cycling and energy flow.

8. Often, farmers need to add fertilizer containing nitrogen and phosphorous to their crops, without having to add carbon. The reason for this is because carbon is far more abundant than nitrogen and phosphorous. Nitrogen or phosphorus is often the limiting factor. They are essential nutrients for growing crops.

Visit TestBankDeal.com to get complete for all chapters