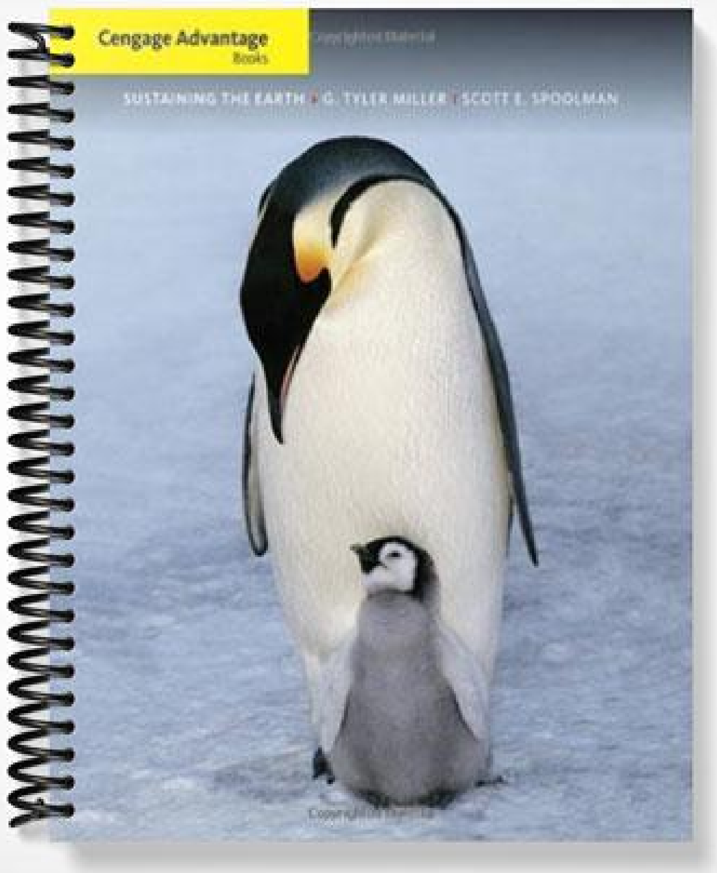
SOLUTIONS MANUAL



Chapter 2

Science, Matter, Energy, and Ecosystems

Summary and Objectives

2-1 What is science?
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 how science works. Distinguish between tentative or frontier, reliable science and unreliable science. Summarize the limits of environmental science.
2. Describe the steps involved in the scientific process. Distinguish among scientific hypothesis, scientific theory, and scientific (natural) law.

2-2 What is matter and how can matter 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, which 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).

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

2-3 What is energy and how can it be changed?
Energy is the capacity to do work and transfer heat; it moves matter. This matter is moved by kinetic or potential energy in a chemical change or a physical change. Thermodynamics is the study of energy transformation. **CONCEPT 2-3A** When 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 changed from one form to another, we end up with lower-quality or less-usable energy than we started with (second law of thermodynamics).

7. 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.
8. 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.

2-4 What keeps us and other organisms alive?
Ecology is the study of connections in the natural world and the connections—compromised or severed by this use of matter and energy—by man and other organisms. The cell is the basic unit of life in organisms. Organisms, any form of life, are classified into species; and a population is a group of interacting individuals of the same species. An ecosystem, representing communities of populations with different species, supports the living and interacting of these species within a specific area. Earth’s biosphere encompasses its air, water, solar, and soil systems. **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.

9. Distinguish between organism, species, population, community, ecosystem, and biosphere.
10. List four spheres that interact to sustain life on Earth. Compare the flow of matter and the flow of energy through the biosphere.

2-5 What are the major components of an ecosystem?
The major components of ecosystems are abiotic (nonliving) water, air, nutrients, and solar energy; and biotic (living) plants, animals, and microbes. **CONCEPT 2-5** Ecosystems contain nonliving (abiotic) and living (biotic) components, including producers, which produce the nutrients they need; consumers, which get their nutrients by consuming other organisms; and detritivores, which recycle nutrients back to producers.

11. Distinguish between biotic and abiotic components of the biosphere and give two examples of each.
12. Define *limiting factor principle*. Give one example of a limiting factor in an ecosystem.
13. Distinguish between producers and consumers. List and distinguish between two types of producers and four types of consumers.

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.

14. Apply the second law of energy to food chains and pyramids of energy flow.
15. Discuss the difference between *gross primary productivity* and *net primary productivity.* List three ecosystem types that are highly productive.

2-7 What happens to matter in an ecosystem?
Major recycles 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 and in the biosphere, and human activities are altering these chemical cycles.

16. Briefly describe the carbon, nitrogen, phosphorous, and hydrological cycles. Apply the law of conservation of matter to biogeochemical cycles (nutrient cycles).
17. Describe the hydrologic(water), carbon, nitrogen, or phosphorus cycle and describe how human activities are affecting each cycle.
18. List three types of rock and describe their interactions through the rock cycle.

Key Terms

science (p. 22)
scientific hypothesis (p. 22)
model (p. 23)
scientific theory (p. 23)
scientific methods (p. 23)
peer review (p. 23)
scientific (natural) law (p. 23)
tentative or frontier science (p. 23)
reliable science (p. 23)
unreliable science (p. 24)
matter (p. 25)
elements (p. 25)
compounds (p. 25)
atom (p. 25)
atomic theory (p. 25)
protons (p. 25)
neutrons (p. 25)
electrons (p. 25)
nucleus (p. 25)
atomic number (p. 26)
mass number (p. 26)
isotopes (p. 26)
ion (p. 26)
acidity (p. 26)
pH (p. 26)
molecule (p. 26)
chemical formula (p. 26)
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genes (p. 28)
trait (p. 28)
chromosome (p. 28)
cell (p. 28)
matter quality (p. 28)
high-quality matter (p. 28)
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chemical change or reaction (p. 29)
law of conservation of matter (p. 29)
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heat (p. 29)
electromagnetic radiation (p. 29)
potential (stored)energy (p. 30)
energy quality (p. 30)
high-quality energy (p. 30)
low-quality energy (p. 30)
law of conservation of energy (p. 30)
first law of thermodynamics (p. 30)
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energy productivity (p. 31)
ecology (p. 31)
organism (p. 31)
species (p. 31)
population (p. 32)
genetic diversity (p. 32)
habitat (p. 32)
community (p. 32)
biological community (p. 32)
ecosystem (p. 32)
biosphere (p. 32)
atmosphere (p. 32)
troposphere (p. 32)
greenhouse gases (p. 33)
stratosphere (p. 33)
hydrosphere (p. 33)
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biomes (p. 33)
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abiotic (p. 34)
biotic (p. 34)
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limiting factors (p. 35)
limiting factor principle (p. 35)
scientific principle of sustainability (p. 35)
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photosynthesis (p. 36)
consumers (p. 36)
heterotrophs (p. 36)
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carnivores (p. 36)
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omnivores (p. 36)
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detritivores (p. 36)
aerobic respiration (p. 36)
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biomass (p. 38)
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rock (p. 46)
igneous rock (p. 46)
sedimentary rock (p. 46)
metamorphic rock (p. 46)
rock cycle (p. 46)

Outline

2-1 The Nature of Science

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 collect facts or scientific data.
   2. Based on observations of phenomenon, scientists form a scientific hypothesis—an unconfirmed explanation of an observed phenomenon to be tested.
   3. Parts of the scientific process are skepticism, reproducibility, and peer review.

B. A scientific theory is a verified, believable, widely accepted scientific hypothesis or a related group of scientific hypotheses. (See Science Focus: The Scientific Consensus on Global Warming, p. 24)
   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.

D. There are many types of scientific methods used to gather data, formulate hypotheses, state theories and laws and, then, test them. Observation leads to a hypothesis, then to an experiment that produces results that lead to a conclusion. Variables/factors influence the gathering of data. In a controlled experiment, the scientist attempts to isolate and student the effect of one variable.
   1. In an experimental group, one chosen variable is changed.
   2. In a control group, the chosen variable is not changed.
   3. Multivariable analysis uses mathematical models to analyze interactions of many variables.

E. Scientists try to establish that a particular theory/law has a high probability of being true. They always include a degree of uncertainty.

F. Tentative or frontier science is scientific results that have not been confirmed; sound science or reliable science results from scientific results that have been well tested and are widely accepted.

G. Unreliable science is scientific results/hypotheses that have not been reviewed by peer scientists.

2-2 What Is Matter and How Can Matter 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 are charged positively.
      b. Neutrons are uncharged.
      c. Electrons are charged negatively.
   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. 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 and, then, are called isotopes.
E. Chemical formulas are a type of shorthand to show the type and number of atoms/ions in a 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. Most 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
   2. Chlorinated hydrocarbons: compounds of carbon, hydrogen, and chlorine atoms
   3. Simple carbohydrates: specific types of compounds of carbon, hydrogen, and oxygen atoms
   4. Polymers are larger and more complex organic compounds, which have molecular units linked by chemical bonds; the major types are complex carbohydrates, proteins, and nucleic acids.
      a. Genes: specific sequences of nucleotides in a DNA molecule
      b. Chromosomes: combinations of genes that make a single DNA molecule, plus some proteins
G. All compounds without the combination of carbon atoms and other elements' atoms are inorganic compounds.
H. According to the usefulness of matter as a resource, it is classified as having high or low quality.
   1. High-quality matter is concentrated with great potential for usefulness
   2. Low-quality matter is dilute and found deep underground and/or dispersed in air or water.
I. When matter has a physical change, its chemical composition is not changed; the molecules are organized in different patterns.
J. In a chemical change, the chemical composition of the elements/compounds changes. Shorthand chemical equations represent what happens in the reaction.
K. The Law of Conservation of Matter states that no atoms are created or destroyed during a physical or chemical change. The same is true for energy.
   1. Atoms are rearranged into different patterns/combinations.
   2. Atoms can have physical or chemical changes but they are never created or destroyed.
   3. There will always be some waste/pollutants.

2-3 What Is Energy and How Can It Change Its Form?

A. Energy is the capacity to do work and transfer heat; it moves matter.
   1. Kinetic energy has mass and speed; wind and electricity are examples.
   2. Potential energy is stored energy, ready to be used; an unlit match, for example.
B. Electromagnetic radiation is energy that travels as a wave, a result of changing electric and magnetic fields. Each form of electromagnetic radiation has a different wavelength and energy content. The electromagnetic spectrum describes the range of electromagnetic waves that have different wavelengths and energy content.
C. Energy quality is measured by its usefulness; high energy is concentrated and has high usefulness. Low energy is dispersed and can do little work.

D. The First Law of Thermodynamics states that energy can neither be created nor destroyed. And 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.
   1. In changing forms of energy, heat is often produced and lost.
   2. Changing forms of energy produces a small percentage of energy; much is lost in the process, energy not used by the application.
   3. In living systems, solar energy is changed to chemical energy to mechanical energy; much energy/heat is lost in this process.
   4. High-quality energy cannot be recycled/reused.
   5. Energy efficiency/productivity measures the amount of useful work by a specific input of energy. Overall, energy efficiency is very poor—about 16% of the energy produces useful work.

2-4 Earth's Life Support Systems, from Organisms to the Biosphere

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. Genetic diversity explains that these individuals may have different genetic makeup and, thus, do not behave or look exactly alike. 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. A biological community consists of all the populations of different species interacting and living in a specific area; this is a network of plants, animals, and microorganisms. (See Science Focus: Have You Thanked the Insects Today? on p. 33)
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.
   2. The troposphere is the air layer about 11 miles above sea level.
   3. The stratosphere lies above the troposphere between 22–30 miles; it filters out the sun's harmful radiation.
F. The hydrosphere consists of Earth's water, found in liquid water, ice, and water vapor.
G. The geosphere consists of the hot core, upper mantle, and crust.
H. Biomes are the terrestrial portions of the biosphere such as forests, deserts, and grasslands.
I. Sun, cycles, and gravity sustain life on Earth.
   1. The one-way flow of high-quality solar energy through materials and living things (as they eat) produces low-quality energy.
   2. Matter cycles through parts of the biosphere.
   3. Gravity causes the downward movement of chemicals as matter cycles through the earth.
J. Solar energy just passes through the earth as electromagnetic waves; they warm the atmosphere, evaporate, and recycle water, generate wind, and support plant growth.
K. As solar radiation interacts with the earth, infrared radiation is produced. Greenhouse gases trap the heat and warm the troposphere. This natural greenhouse effect makes the planet warm enough to support life.
L. The earth's temperature, distance from the sun, and size all produce a livable planet. Its liquid water, orbit around the sun, and gravitational mass all contribute to sustaining life as we know it.

2-5 Energy Flow in Ecosystems

A. The major components of ecosystems are abiotic (nonliving) water, air, nutrients, and solar energy; and biotic (living) plants, animals, and microbes.
B. Ecosystem characteristics include a range of tolerance to physical and chemical environments by the ecosystem's populations.
   1. Range of tolerance: The distribution of a species in an ecosystem is determined by the levels of one or more physical or chemical factors being within the range tolerated by that species.
      a. 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. An abiotic factor such as lack of water or poor soil can be understood here.

    b. Aquatic life zones can be limited by the dissolved oxygen (DO) content in the water or by the salinity.

C. Every organism in an ecosystem is either a producer/autotroph (self-feeder) or a consumer/heterotroph. Autotrophs make their own food (like green plants and algae through photosynthesis). Heterotrophs may feed on both producers (plants) and other consumers (animals), or may feed on plants alone (herbivores). (See Science Focus: Many of the World's Most Important Species Are Invisible to Us, p.37)
    1. Detritivores are detritus (dead organic matter) feeders and decomposers.
    2. Natural ecosystems produce little waste.

2-6 Energy Flow in Ecosystems

A. Food chains and food webs help us understand how eaters, the eaten, and the decomposed are interconnected in an ecosystem.

B. The sequence of organisms as they are eaten is a food chain.
    1. Trophic levels are feeding levels for organisms within an ecosystem.
        a. Producers belong to the first tropic level.
        b. Primary consumers belong to the second tropic level.
        c. Secondary consumers belong to the third tropic level.
    2. Food webs are complex networks of interconnected food chains.

C. Energy flow in a food web/chain decreases at each succeeding organism.

D. The dry weight of all organic matter within the organisms of a food chain/web is called biomass. Ecological efficiency is the term that describes the percentage of usable energy transferred as biomass from one trophic level to another.

E. The greater number of trophic levels in a food chain, the greater loss of usable energy.

F. The pyramid of energy flow visualizes the loss of usable energy through a food chain. The more simple the trophic level, the less energy used to support organisms at that level. There is a large loss of energy between successive trophic levels.

G. 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.

H. Humans are using, wasting, and destroying biomass faster than producers can make it.

2-7 Matter Cycling in Ecosystems

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.

C. The water cycle is altered by man's activities.
    1. We withdraw large quantities of fresh water and clear vegetation, which increases runoff, reduces filtering, and increases flooding.
    2. We add nutrients like fertilizers and modify the quality of the water.

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 global warming.
   1. The natural greenhouse effect is being strengthened by increasing temperatures.
   2. Various bacteria also recycle nitrogen in the earth's air, water, soil, and organisms.
      a. The nitrogen cycle converts nitrogen (N_2) into compounds that are useful nutrients for plants and animals.
      b. The nitrogen cycle includes these steps:
         1) Specialized bacteria convert gaseous nitrogen to ammonia in nitrogen fixation.
         2) Special bacteria convert ammonia in the soil to nitrite ions and nitrate ions; the latter is used by plants as a nutrient. This process is nitrification.
         3) Decomposer bacteria convert detritus into ammonia and water-soluble salts in ammonification.
         4) In denitrification, nitrogen leaves the soil. Anaerobic bacteria in soggy soil and bottom sediments of water areas convert NH3 and NH4+ back into nitrite and nitrate ions; then nitrogen gas and nitrous oxide gas are released into the atmosphere.
   3. Human activities affect the nitrogen cycle.
      a. In burning fuel, we add nitric oxide into the atmosphere; it can return to the earth's surface as acid rain.
      b. Nitrous oxide that comes from livestock, wastes, and inorganic fertilizers we use on the soil can warm the atmosphere and deplete the ozone layer.
      c. We destroy forest, grasslands, and wetland, thus releasing large amounts of nitrogen into the atmosphere.
      d. We pollute aquatic ecosystems with agricultural runoff and human sewage.
      e. We remove nitrogen from topsoil with our harvesting, irrigating, and land-clearing practices.
   4. We need to use phosphorus-based fertilizers because the phosphorus cycle is much slower in moving through the earth's water, soil, and organisms.
      a. Phosphorous washes from the land, eventually into the ocean where it may stay for millions of years. Phosphorus is used as a fertilizer to encourage plant growth.
      b. Man interferes with the phosphorous cycle in harmful ways such as mining phosphate rock to produce fertilizers and detergents, cutting down tropical forests, and with animal waste runoff and human sewage.
   5. The planet's slowest cyclical process is the rock cycle.
      a. Igneous rock forms when magma (volcanic rock material) comes from the earth's crust, cools, and hardens. Examples are lava rock and granite. This is the melting process.
      b. 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; this is the erosion process.
      c. When rock is under high temperatures, high pressures, chemically active fluids, or a combination of these things, metamorphic rock is formed. Slate and marble are examples. This is the metamorphic process.

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.

Term Paper and Discussion Topics

Conceptual Topics

1. Low-energy lifestyles. Individual case studies such as Amory Lovins and national case studies such as Sweden.

2. Nature's cycles and economics. Recycling attempts in the United States; bottlenecks that inhibit recycling; strategies that enhance recycling efforts.

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, and weather stripping.

2. Can we get something for nothing? Explore the attempts of advertising to convince the public that we can indeed get something for nothing. Explore attempts to create perpetual motion machines. Explore the history of the free lunch concept.

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?

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?

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?

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.

Video Resources

Atmosphere. (Habitable Planet Video Course viewable online for free)
The atmosphere is what makes the Earth habitable. Heat-trapping gases allow ecosystems to flourish.
http://www.learner.org/resources/series209.html

Community of Living Things. *Four modules: Change, Diversity, Interrelationships, Energy;* 60 min., 45 min., 75 min., 45 min. respectively; PBS.

Journey of the Blob. 10 min. Look Again Series. 1990 BFF.
An illustration of the water cycle in a cautionary tale about pollution.

NOVA: *Secrets of the Crocodile Caves—The Unique Animals of Madagascar.* (60 min.) 2004
Madagascar is home to a wide variety of organisms that occupy specific niches. Learn about a small segment of the complex food web of a region in Madagascar.
Related worksheet: http://www.pbs.org/wgbh/nova/teachers/activities/3102_croccave_01.html

The Water Cycle and Erosion. 15 min.; CBS.

Turning Down the Heat. 46 min., 2000. BFF.

ABC NEWS Videos
Provide your students with the latest hot topics in biology through ABC NEWS videos.

U.S. Forests; Environmental Science in the Headlines, 2006 ISBN: 049501611X

Website Resources

Interactive Rock Cycle. Annenberg Media Learner.org
Interactive rock cycle website, which provides an opportunity to view short animations of common rock-forming processes. Animations also illustrate the path of a rock moving through the rock cycle.
http://www.learner.org/interactives/rockcycle/

FT Exploring Science and Technology
Comprehensive website discussing the concept of energy, types of energy, thermodynamics, conversion of energy and flow.
http://www.ftexploring.com/energy/energy.html

Rader's CHEM4KIDS.com
Explore the basics about atoms, which are created by the matter around us. Atoms are used to create the elements. Elements are used to create molecules, and so on.
http://www.chem4kids.com/files/atom_intro.html

Suggested Answers for Critical Thinking Questions

1. Student answers will vary.

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.

   (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.

6. (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.

7. Oftentimes, 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.