

Benchmarks for Science Literacy

Levels 6

	Level 6 Scientific Theories	Level 6 Ecosystems
Chapter 1: The Nature of Science		
<i>The Scientific World View</i>		
When similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, and it often takes further studies to decide. Even with similar results, scientists may wait until an investigation has been repeated many times before accepting the results as correct.	◆	◆
Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.	◆	◆
Some scientific knowledge is very old and yet is still applicable today.	◆	◆
Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested objectively and those that are essentially matters of morality. Science can sometimes be used to inform ethical decisions by identifying the likely consequences of particular actions but cannot be used to establish that some action is either moral or immoral.	◆	◆
<i>Scientific Inquiry</i>		
Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.	◆	◆T
If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations.	◆	◆T
What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results. Scientists know about this danger to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions.	◆	◆
<i>The Scientific Enterprise</i>		
Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.	◆L	
Until recently, women and racial minorities, because of restrictions on their education and employment opportunities, were essentially left out of much of the formal work of the science establishment; the remarkable few who overcame those obstacles were even then likely to have their work disregarded by the science establishment.		◆
No matter who does science and mathematics or invents things, or when or where they do it, the knowledge and technology that result can eventually become available to everyone in the world.	◆	◆
Scientists are employed by colleges and universities, business and industry, hospitals, and many government agencies. Their places of work include offices, classrooms, laboratories, farms, factories, and natural field settings ranging from space to the ocean floor.	◆	◆
In research involving human subjects, the ethics of science require that potential subjects be fully informed about the risks and benefits associated with the research and of their right to refuse to participate. Science ethics also demand that scientists must not knowingly subject coworkers, students, the neighborhood, or the community to health or property risks without their prior knowledge and consent. Because animals cannot make informed choices, special care must be taken in using them in scientific research.		

T See Technology Correlation
L See Literature Correlation

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Computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile, and analyze data, prepare research reports, and share data and ideas with investigators all over the world.		T
Accurate record-keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.	◆	◆
Chapter 2: The Nature of Mathematics		
<i>Patterns and Relationships</i>		
Usually there is no one right way to solve a mathematical problem; different methods have different advantages and disadvantages.	◆	◆
Logical connections can be found between different parts of mathematics.		
<i>Mathematics, Science and Technology</i>		
Mathematics is helpful in almost every kind of human endeavor--from laying bricks to prescribing medicine or drawing a face. In particular, mathematics has contributed to progress in science and technology for thousands of years and still continues to do so.		◆
<i>Mathematical Inquiry</i>		
Mathematicians often represent things with abstract ideas, such as numbers or perfectly straight lines, and then work with those ideas alone. The "things" from which they abstract can be ideas themselves (for example, a proposition about "all equal-sided triangles" or "all odd numbers").	◆	
When mathematicians use logical rules to work with representations of things, the results may or may not be valid for the things themselves. Using mathematics to solve a problem requires choosing what mathematics to use; probably making some simplifying assumptions, estimates, or approximations; doing computations; and then checking to see whether the answer makes sense. If an answer does not seem to make enough sense for its intended purpose, then any of these steps might have been inappropriate.	◆	◆
Chapter 3: The Nature of Technology		
<i>Technology and Science</i>		
In earlier times, the accumulated information and techniques of each generation of workers were taught on the job directly to the next generation of workers. Today, the knowledge base for technology can be found as well in libraries of print and electronic resources and is often taught in the classroom.	◆	
Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.	◆T	◆T
Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems. But they usually have to take human values and limitations into account as well.	◆	◆
<i>Design and Systems</i>		
Design usually requires taking constraints into account. Some constraints, such as gravity or the properties of the materials to be used, are unavoidable. Other constraints, including economic, political, social, ethical, and aesthetic ones, limit choices.	◆	◆T
All technologies have effects other than those intended by the design, some of which may have been predictable, and some not. In either case, these side effects may turn out to be unacceptable to some of the population and therefore lead to conflict between groups.	L	◆

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Almost all control systems have inputs, outputs, and feedback. The essence of control is comparing information about what is happening to what people want to happen and then making appropriate adjustments. This procedure requires sensing information, processing it, and making changes. In almost all modern machines, microprocessors serve as centers of performance control.

Systems fail because they have faulty or poorly matched parts, are used in ways that exceed what was intended by the design, or were poorly designed to begin with. The most common ways to prevent failure are pretesting parts and procedures, overdesign, and redundancy.

Issues in Technology

The human ability to shape the future comes from a capacity for generating knowledge and developing new technologies--and for communicating ideas to others.

Technology cannot always provide successful solutions for problems or fulfill every human need.

Throughout history, people have carried out impressive technological feats, some of which would be hard to duplicate today even with modern tools. The purposes served by these achievements have sometimes been practical, sometimes ceremonial.

Technology has strongly influenced the course of history and continues to do so. It is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live.

New technologies increase some risks and decrease others. Some of the same technologies that have improved the length and quality of life for many people have also brought new risks.

Rarely are technology issues simple and one-sided. Relevant facts alone, even when known and available, usually do not settle matters entirely in favor of one side or another. That is because the contending groups may have different values and priorities. They may stand to gain or lose in different degrees, or may make very different predictions about what the future consequences of the proposed action will be.

Societies influence what aspects of technology are developed and how these are used. People control technology (as well as science) and are responsible for its effects.

Chapter 4: The Physical Setting

The Universe

The sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night. The universe contains many billions of galaxies, and each galaxy contains many billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot.

The sun is many thousands of times closer to the earth than any other star. Light from the sun takes a few minutes to reach the earth, but light from the nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of year. Some distant galaxies are so far away that their light takes several billion years to reach earth. People on earth, therefore, see them as they were that long ago in the past.

Nine planets of very different size, composition, and surface features move around the sun in nearly circular orbits. Some planets have a great variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The earth is orbited by one moon, many artificial satellites, and debris.

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Large numbers of chunks of rock orbit the sun. Some of those that the earth meets in its yearly orbit around the sun glow and disintegrate from friction as they plunge through the atmosphere and sometimes impact the ground. Other chunks of rocks mixed with ice have long, off-center orbits that carry them close to the sun, where the sun's radiation (of light and particles) boils off frozen material from their surfaces and pushes it into a long, illuminated tail.		
<i>The Earth</i>		
We live on a relatively small planet, the third from the sun in the only system of planets definitely known to exist (although other, similar systems may be discovered in the universe).	T	
The earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the earth's.		◆
Everything on or anywhere near the earth is pulled toward the earth's center by gravitational force.		
Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns.		
The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth--the phases of the moon.		
Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space. Even relatively small changes in atmospheric or ocean content can have widespread effects on climate if the change lasts long enough.		
The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean.		◆L
Fresh water, limited in supply, is essential for life and also for most industrial processes. Rivers, lakes, and groundwater can be depleted or polluted, becoming unavailable or unsuitable for life.		◆
Heat energy carried by ocean currents has a strong influence on climate around the world.		◆
Some minerals are very rare and some exist in great quantities, but for practical purposes the ability to recover them is just as important as their abundance. As minerals are depleted, obtaining them becomes more difficult. Recycling and the development of substitutes can reduce the rate of depletion but may also be costly.		◆
The benefits of the earth's resources--such as fresh water, air, soil, and trees--can be reduced by using them wastefully or by deliberately or inadvertently destroying them. The atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally. Cleaning up polluted air, water, or soil or restoring depleted soil, forests, or fishing grounds can be very difficult and costly.		◆
<i>Processes That Shape the Earth</i>		
The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere.		
Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). The earth's surface is shaped in part by the motion of water and wind over very long times, which act to level mountain ranges.		

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Sediments of sand and smaller particles (sometimes containing the remains of organisms) are gradually buried and are cemented together by dissolved minerals to form solid rock again.

Thousands of layers of sedimentary rock confirm the long history of the changing surface of the earth and the changing life forms whose remains are found in successive layers. The youngest layers are not always found on top, because of folding, breaking, and uplift of layers.

Although weathered rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion are greatly influenced by plant roots and debris, bacteria, fungi, worms, insects, rodents, and other organisms.

Human activities, such as reducing the amount of forest cover, increasing the amount of variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of the changes have decreased the capacity of the environment to support some life forms.

Structure of Matter

All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

Equal volumes of different substances usually have different weights.

Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

The temperature and acidity of a solution influence reaction rates. Many substances dissolve in water, which may greatly facilitate reactions between them.

Scientific ideas about elements were borrowed from some Greek philosophers of 2,000 years earlier, who believed that everything was made from four basic substances: air, earth, fire, and water. It was the combinations of these "elements" in different proportions that gave other substances their observable properties. The Greeks were wrong about those four, but now over 100 different elements have been identified, some rare and some plentiful, out of which everything is made. Because most elements tend to combine with others, few elements are found in their pure form.

There are groups of elements that have similar properties, including highly reactive metals, less-reactive metals, highly reactive nonmetals (such as chlorine, fluorine, and oxygen), and some almost completely nonreactive gases (such as helium and neon). An especially important kind of reaction between substances involves combination of oxygen with something else--as in burning or rusting. Some elements don't fit into any of the categories; among them are carbon and hydrogen, essential elements of living matter.

No matter how substances within a closed system interact with one another, or how they combine or break apart, the total weight of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same.

Energy Transformation

Energy cannot be created or destroyed, but only changed from one form into another.

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Most of what goes on in the universe--from exploding stars and biological growth to the operation of machines and the motion of people--involves some form of energy being transformed into another. Energy in the form of heat is almost always one of the products of energy transformation.	◆	◆
Heat can be transferred through materials by the collisions of atoms or across space by radiation. If the material is fluid, currents will be set up in it that aid the transfer of heat.	◆	
Energy appears in different forms. Heat energy is in the disorderly motion of molecules; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elastically distorted shapes; gravitational energy is in the separation of mutually attracting masses.	◆	
<i>Motion</i>		
Light from the sun is made up of a mixture of many different colors of light, even though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.	◆T	
Something can be "seen" when light beams emitted or reflected by it enter the eye--just as something can be "heard" when sound waves from it enter the ear.	◆	
An unbalanced force acting on an object changes its speed or path of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.	◆	
Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples. These and other waves move at different speeds in different materials.	◆	
Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation--visible light. Differences of wavelength within that range are perceived as differences in color.	◆	
<i>Forces of Nature</i>		
Every object exerts gravitational force on every other object. The force depends on how much mass the objects have and on how far apart they are. The force is hard to detect unless at least one of the objects has a lot of mass.		
The sun's gravitational pull holds the earth and other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.		
Electric currents and magnets can exert a force on each other.	◆	
Chapter 5: The Living Environment		
<i>Diversity of Life</i>		
One of the most general distinctions among organisms is between plants, which use sunlight to make their own food, and animals, which consume energy-rich foods. Some kinds of organisms, many of them microscopic, cannot be neatly classified as either plants or animals.		◆
Animals and plants have a great variety of body plans and internal structures that contribute to their being able to make or find food and reproduce.		◆
Similarities among organisms are found in internal anatomical features, which can be used to infer the degree of relatedness among organisms. In classifying organisms, biologists consider details of internal and external structures to be more important than behavior or general appearance.		◆
For sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring.		◆
All organisms, including the human species, are part of and depend on two main interconnected global food webs. One includes microscopic ocean plants, the animals that feed on them, and finally the animals that feed on those animals. The other web includes land plants, the animals that feed on them, and so forth. The cycles continue indefinitely because organisms decompose after death to return food material to the environment.		◆

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Heredity		
In some kinds of organisms, all the genes come from a single parent, whereas in organisms that have sexes, typically half of the genes come from each parent.		
In sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male. As the fertilized egg, carrying genetic information from each parent, multiplies to form the complete organism with about a trillion cells, the same genetic information is copied in each cell. New varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.		
Cells		
All living things are composed of cells, from just one to many millions, whose details usually are visible only through a microscope. Different body tissues and organs are made up of different kinds of cells. The cells in similar tissues and organs in other animals are similar to those in human beings but differ somewhat from cells found in plants.		
Cells continually divide to make more cells for growth and repair. Various organs and tissues function to serve the needs of cells for food, air, and waste removal.		
Within cells, many of the basic functions of organisms--such as extracting energy from food and getting rid of waste--are carried out. The way in which cells function is similar in all living organisms. About two-thirds of the weight of cells is accounted for by water, which gives cells many of their properties.		
Interdependence of Life		
In all environments--freshwater, marine, forest, desert, grassland, mountain, and others--organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. In any particular environment, the growth and survival of organisms depend on the physical conditions.		
Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. Relationships may be competitive or mutually beneficial. Some species have become so adapted to each other that neither could survive without the other.		◆
Flow of Matter and Energy		
Food provides the fuel and the building material for all organisms. Plants use the energy from light to make sugars from carbon dioxide and water. This food can be used immediately or stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.		◆
Over a long time, matter is transferred from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change.		◆
Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat. Almost all food energy comes originally from sunlight.		◆
Evolution of Life		
Small differences between parents and offspring can accumulate (through selective breeding) in successive generations so that descendants are very different from their ancestors.		
Individual organisms with certain traits are more likely than others to survive and have offspring. Changes in environmental conditions can affect the survival of individual organisms and entire species.		◆

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Many thousands of layers of sedimentary rock provide evidence for the long history of the earth and for the long history of changing life forms whose remains are found in the rocks. More recently deposited rock layers are more likely to contain fossils resembling existing species.

Chapter 6: The Human Organism

Human Identity

Like other animals, human beings have body systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions.

Human beings have many similarities and differences. The similarities make it possible for human beings to reproduce and to donate blood and organs to one another throughout the world. Their differences enable them to create diverse social and cultural arrangements and to solve problems in a variety of ways.

Fossil evidence is consistent with the idea that human beings evolved from earlier species.

Specialized roles of individuals within other species are genetically programmed, whereas human beings are able to invent and modify a wider range of social behavior.

Human beings use technology to match or excel many of the abilities of other species. Technology has helped people with disabilities survive and live more conventional lives.

Technologies having to do with food production, sanitation, and disease prevention have dramatically changed how people live and work and have resulted in rapid increases in the human population.

Human Development

Fertilization occurs when sperm cells from a male's testes are deposited near an egg cell from the female ovary, and one of the sperm cells enters the egg cell. Most of the time, by chance or design, a sperm never arrives or an egg isn't available.

Contraception measures may incapacitate sperm, block their way to the egg, prevent the release of eggs, or prevent fertilized egg from implanting successfully.

Following fertilization, cell division produces a small cluster of cells that then differentiate by appearance and function for form the basic tissues of an embryo. During the first three months of pregnancy, organs begin to form. During the second three months, all organs and body features develop. During the last three months, the organs and features mature enough to function well after birth. Patterns of human development are similar to those of other vertebrates.

The developing embryo--and later the newborn infant--encounters many risks from faults in its genes, its mother's inadequate diet, her cigarette smoking or use of alcohol or other drugs, or from infection. Inadequate child care may lead to lower physical and mental ability.

Various body changes occur as adults age. Muscles and joints become less flexible, bones and muscles lose mass, energy levels diminish, and the sense become less acute. Women stop releasing eggs and hence can no longer reproduce. The length and quality of human life are influenced by many factors, including sanitation, diet, medical care, sex, genes, environmental conditions, and personal health behaviors.

Basic Functions

Organs and organ systems are composed of cells and help to provide all cells with basic needs.

For the body to use food for energy and building materials, the food must first be digested into molecules that are absorbed and transported to cells.

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To burn food for the release of energy stored in it, oxygen must be supplied to cells, and carbon dioxide removed. Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced. The urinary system disposed of dissolved waste molecules, the intestinal tract removes solid wastes, and the skin and lungs rid the body of heat energy. The circulatory system moves all these substances to or from cells where they are needed or produced, responding to changing demands.

Specialized cells and the molecules they produce identify and destroy microbes that get inside the body.

Hormones are chemicals from glands that affect other body parts. They are involved in helping the body respond to danger and in regulating human growth, development, and reproduction.

Interactions among the senses, nerves, and brain make possible the learning that enables human beings to cope with changes in their environment.

Learning

Some animal species are limited to a repertoire of genetically determined behaviors; others have more complex brains and can learn a wide variety of behaviors. All behavior is affected by both inheritance and experience.

The level of skill a person can reach in any particular activity depends on innate abilities, the amount of practice, and the use of appropriate learning technologies.

Human beings can detect a tremendous range of visual and olfactory stimuli. The strongest stimulus they can tolerate may be more than a trillion times as intense as the weakest they can detect. Still, there are many kinds of signals in the world that people cannot detect directly.

Attending closely to any one input of information usually reduces the ability to attend to others at the same time.

Learning often results from two perceptions or actions occurring at about the same time. The more often the same combination occurs, the stronger the mental connection between them is likely to be. Occasionally a single vivid experience will connect two things permanently in people's minds.

Language and told enable human beings to learn complicated and varied things from others.

Physical Health

The amount of food energy (calories) a person requires varies with body weight, age, sex, activity level, and natural body efficiency. Regular exercise is important to maintain a healthy heart/lung system, good muscle tone, and bone strength.

Toxic substances, some dietary habits, and some personal behaviors may be bad for one's health. Some effects show up right away, others may not show up for many years. Avoiding toxic substances, such as tobacco, and changing dietary habits to reduce the intake of such things as animal fat increase the chances of living longer.

Viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. A person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms.

White blood cells engulf invaders or produce antibodies that attack them or make them for killing by other white cells. The antibodies produced will remain and can fight off subsequent invaders of the same kind.

The environment may contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air, and water and taking steps to keep them safe.

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Mental Health		
Individuals differ greatly in their ability to cope with stressful situations. Both external and internal conditions (chemistry, personal history, values) influence how people behave.		
Often people react to mental distress by denying that they have any problem. Sometimes they don't know why they feel the way they do, but with help they can sometimes uncover the reasons.		
Chapter 7: Human Society		
Cultural Effects on Behavior		
Each culture has distinctive patterns of behavior, usually practiced by most of the people who grow up in it.	◆	◆
Within a large society, there may be many groups, with distinctly different subcultures associated with region, ethnic origin, or social class.		
Although within any society, there is usually a broad general agreement on what behavior is unacceptable, the standards used to judge behavior vary for different settings and different subgroups, and they may change with time and different political and economic conditions. Moreover, the punishments vary widely among, and even within, different societies.		
Technology, especially in transportation and communication, is increasingly important in spreading ideas, values, and behavior patterns within a society and among different societies. New technology can change cultural and social behavior.	◆	
Group Behavior		
Affiliation with a group can increase the power of members through pooled resources and concerted action. Joining a group often has personal advantages, such as companionship, a sense of identity, and recognition by others inside and outside the group. Group identity may create a feeling of superiority, which increases group cohesion but may also entail hostility toward other groups.	◆	
People sometimes react to all members of a group as though they were the same and perceive in their behavior only those qualities that fit preconceptions of the group. Such stereotyping leads to uncritical judgments, such as showing blind respect for members of some groups and equally blind disrespect for members of others groups.		
Social Change		
Some aspects of family and community life are the same now as they were a generations ago, but some aspects are very different. What is taught in school and school policies toward student behavior have changed over the years in response to family and community pressures.		
By the way they depict the ideas and customs of one culture, communications media may stimulate changes in others.		
Migration, conquest, and natural disasters have been major factors in causing social and cultural change.	◆	
Social Trade-Offs		
There are trade-offs that each person must consider in making choices--about personal popularity, health, family relations, and education, for example--that often have life-long consequences.		◆
One common aspect of all social trade-offs pits personal benefit and the rights of the individual, on one side, against the social good and the rights of society, on the other.		◆
Trade-offs are not always between desirable possibilities. Sometimes social and personal trade-offs require accepting an unwanted outcome to avoid some other unwanted one.		◆

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Political and Economic Systems		
Government provides some goods and services through its own agencies and some through contracts with private individuals or businesses. To pay for the goods and services, government must obtain money by taxing people or by borrowing the money.		◆
Government leaders come into power by election, appointment, or force.		
However they are formed, governments usually have most of the power to make, interpret, and enforce the rules and decisions that determine how a community, state, or nation will be run. Many of the rules established by governments are designed to reduce social conflict. The rules affect a wide range of human affairs, from marriage and education to scientific research and commerce.	◆	
In a central-planning model, a single authority, usually a national government, decides what to produce, how to produce it, and for whom. In a free-market model, consumers and producers (individually or in organizations) make these decisions based on what they believe will benefit themselves. No real-world economy is a pure example of either model; all economies have some features of each kind.		
Social Conflict		
Being a member of a group can increase an individual's social power or hostile actions against other groups or individuals. It may also subject that person to the hostility of people who are outside the group.		
Most groups have formal or informal procedures for arbitrating disputes among their members.		
Global Interdependence		
Trade between nations occurs when natural resources are unevenly distributed and the costs of production are very different in different countries. A nation has a trade opportunity whenever it can create more of a product or service at a lower cost than another.		
The major ways to promote economic health are to encourage technological development, to increase the quantity or quality of a nation's productive resources--more or better-trained workers, better equipment and methods--and to engage in trade with other nations.		
The purpose of treaties being negotiated directly between individual countries or by international organizations is to bring about cooperation among countries.		
Scientists are linked to other scientists worldwide both personally and through international scientific organizations.		
The global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population.		◆
Chapter 8: The Designed World		
Agriculture		
Early in human history, there was an agricultural revolution in which people changed from hunting and gathering to farming. This allowed changes in the division of labor between men and women and between children and adults, and the development of new patterns of government.		
People control the characteristics of plant and animals they raise by selective breeding and by preserving varieties of seeds (old and new) to use if growing conditions change.		
In agriculture, as in all technologies, there are always trade-offs to be made. Getting food from many different places makes people less dependent on weather in any one place, yet more dependent on transportation and communication among far-flung markets. Specializing in one crop may risk disaster if changes in weather or increases in pest populations wipe out that crop. Also, the soil may be exhausted of some nutrients, which can be replenished by rotating the right crops.		◆

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Many people work to bring food, fiber, and fuel to U.S. Markets. With improved technology, only a small fraction of workers in the United States actually plant and harvest the products that people use. Most workers are engaged in processing, packaging, transporting, and selling what is produced.		◆
Materials and Manufacturing		
The choice of materials for a job depends on their properties and on how they interact with other materials. Similarly, the usefulness of some manufactured parts of an object depends on how well they fit together with other parts.	◆	
Manufacturing usually involves a series of steps, such as designing a product, obtaining and preparing raw materials, processing the materials mechanically or chemically, and assembling, testing, inspecting, and packaging. The sequence of these steps is also often important.		
Modern technology reduces manufacturing costs, produces more uniform products, and creates new synthetic materials that can help reduce the depletion of some natural resources.		
Automation, including the use of robots, has changed the nature of work in most fields, including manufacturing. As a result, high-skill, high-knowledge jobs in engineering, computer programming, quality control, supervision, and maintenance are replacing many routine, manual labor jobs. Workers therefore need better learning skills and flexibility to take on new and rapidly changing jobs.		
Energy Sources and Use		
Energy can change from one form to another, although in the process some energy is always converted to heat. Some systems transform energy with less loss of heat than others.		
Different ways of obtaining, transforming, and distributing energy have different environmental consequences.		◆
In many instances, manufacturing and other technological activities are performed at a site close to an energy source. Some forms of energy are transported easily, others are not.		
Electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy. Moreover, electricity is used to distribute energy quickly and conveniently to distant locations.		
Energy from the sun (and the wind and water energy derived from it) is available indefinitely. Because the flow of energy weak and variable, very large collection systems are needed. Other sources don't renew or renew only slowly.		
Different parts of the world have different amounts and kinds of energy resources to use and use them for different purposes.		◆
Communication		
Errors can occur in coding, transmitting, or decoding information, and some means of checking for accuracy is needed. Repeating the message is a frequently used method.		
Information can be carried by many media, including sound, light, and objects. In this century, the ability to code information as electric currents in wires, electromagnetic waves in space, and light in glass fibers has made communication millions of times faster than is possible by mail or sound.		
Information Processing		
Most computers use digital codes containing only two symbols, 0 and 1, to perform all operations. Continuous signals (analog) must be transformed into digital codes before they can be processed by a computer.		
What use can be made of a large collection of information depends upon how it is organized. One of the values of computers is that they are able, on command, to reorganize information in a variety of ways, thereby enabling people to make more and better uses of the collection.		

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Computer control of mechanical systems can be much quicker than human control. In situations where events happen faster than people can react, there is little choice but to rely on computers. Most complex systems still require human oversight, however, to make certain kinds of judgments about the readiness of the parts of the system (including the computers) and the system as a whole to operate properly, to react to unexpected failures, and to evaluate how well the system is serving its intended purpose.

An increasing number of people work at jobs that involve processing or distributing information. Because computers can do these tasks faster and more reliably, they have become standard tools both in the workplace and at home.

Health Technology

Sanitation measures such as the use of sewers, landfills, quarantines, and safe food handling, are important in controlling the spread of organisms that cause disease. Improving sanitation to prevent disease has contributed more to saving human life than any advance in medical treatment.

The ability to measure the level of substances in body fluids has made it possible for physicians to make comparisons with normal levels, make very sophisticated diagnoses, and monitor the effects of the treatments they prescribe.

It is becoming increasingly possible to manufacture chemical substances such as insulin and hormones that are normally found in the body. They can be used by individuals whose own bodies cannot produce the amounts required for good health.

Chapter 9: The Mathematical World

Numbers

There have been systems for writing numbers other than the Arabic system of place values based on tens. The very old Roman numerals are now used only for dates, clock faces, or ordering chapters in a book. Numbers based on 60 are still used for describing time and angles.

A number line can be extended on the other side of zero to represent negative numbers. Negative numbers allow subtraction of a bigger number from a smaller number to make sense, and are often used when something can be measured on either side of some reference point (time, ground level, temperature, budget).

Numbers can be written in different forms, depending on how they are being used. How fractions or decimals based on measured quantities should be written depends on how precise the measurements are and how precise an answer is needed.

The operations + and - are inverses of each other--one undoes what the other does; likewise x and /. The expression a/b can mean different things: a parts of size $1/b$ each, a divided by b , or a compared to b .

Numbers can be represented by using sequences of only two symbols (such as 1 and 0, on and off); computers work this way.

Computations (as on calculators) can give more digits than make sense or are useful.

Symbolic Relationships

An equation containing a variable may be true for just one value of the variable.

Mathematical statements can be used to describe how one quantity changes when another changes. Rates of change can be computed from differences in magnitudes and vice versa.

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		◆
	◆	◆
		◆
	◆	◆

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Graphs can show a variety of possible relationships between two variables. As one variable increases uniformly, the other may do one of the following: increase or decrease steadily, increase or decrease faster and faster, get closer and closer to some limiting value, reach some intermediate maximum or minimum, alternately increase and decrease indefinitely, increase or decrease in steps, or do something different from any of these.

Shapes

Some shapes have special properties: Triangular shapes tend to make structures rigid, and round shapes give the least possible boundary for a given amount of interior area. Shapes can match exactly or have the same shape in different sizes.

Lines can be parallel, perpendicular, or oblique.

Shapes on a sphere like the earth cannot be depicted on a flat surface without some distortion.

The graphic display of numbers may help to show patterns such as trends, varying rates or change, gaps, or clusters. Such patterns sometimes can be used to make predictions about the phenomena being graphed.

It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point.

The scale chosen for a graph or drawing makes a big difference in how useful it is.

Uncertainty

How probability is estimated depends on what is known about the situation. Estimates can be based on data from similar conditions in the past or on the assumption that all the possibilities are known.

Probabilities are ratios, and can be expressed as fractions, percentages, or odds.

The mean, median, and mode tell different things about the middle of a data set.

Comparison of data from two groups should involve comparing both their middles and the spreads around them.

The larger a well-chosen sample is, the more accurately it is likely to represent the whole. But there are many ways of choosing a sample that can make it unrepresentative of the whole.

Events can be described in terms of being more or less likely, impossible, or certain.

Reasoning

Some aspects of reasoning have fairly rigid rules for what makes sense; other aspects don't. If people have rules that always hold and good information about a particular situation, then logic can help them to figure out what is true about it. This kind of reasoning requires care in the use of key words such as if, and, not, or, all, and some. Reasoning by similarities can suggest ideas but can't prove them one way or the other.

Practical reasoning, such as diagnosing or troubleshooting almost anything, may require many-step, branching logic. Because computers can keep track of complicated logic, as well as a lot of information, they are useful in a lot of problem-solving situations.

Sometimes people invent a general rule to explain how something works by summarizing observations. But people tend to overgeneralize, imagining general rules on the basis of only a few observations.

People are using incorrect logic when they make a statement such as "If A is true, then B is true; but A isn't true, therefore B isn't true either."

A single example can never prove that something is always true, but sometimes a single example can prove that something is not always true.

An analogy has some likenesses to but also some differences from the real thing.

	Level 6 Scientific Theories	Level 6 Ecosystems
Graphs can show a variety of possible relationships between two variables. As one variable increases uniformly, the other may do one of the following: increase or decrease steadily, increase or decrease faster and faster, get closer and closer to some limiting value, reach some intermediate maximum or minimum, alternately increase and decrease indefinitely, increase or decrease in steps, or do something different from any of these.	◆	◆
Shapes		
Some shapes have special properties: Triangular shapes tend to make structures rigid, and round shapes give the least possible boundary for a given amount of interior area. Shapes can match exactly or have the same shape in different sizes.		
Lines can be parallel, perpendicular, or oblique.		
Shapes on a sphere like the earth cannot be depicted on a flat surface without some distortion.	◆	◆
The graphic display of numbers may help to show patterns such as trends, varying rates or change, gaps, or clusters. Such patterns sometimes can be used to make predictions about the phenomena being graphed.		◆
It takes two numbers to locate a point on a map or any other flat surface. The numbers may be two perpendicular distances from a point, or an angle and a distance from a point.		
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Practical reasoning, such as diagnosing or troubleshooting almost anything, may require many-step, branching logic. Because computers can keep track of complicated logic, as well as a lot of information, they are useful in a lot of problem-solving situations.	◆	◆
Sometimes people invent a general rule to explain how something works by summarizing observations. But people tend to overgeneralize, imagining general rules on the basis of only a few observations.	◆	◆
People are using incorrect logic when they make a statement such as "If A is true, then B is true; but A isn't true, therefore B isn't true either."	◆	◆
A single example can never prove that something is always true, but sometimes a single example can prove that something is not always true.	◆	◆
An analogy has some likenesses to but also some differences from the real thing.	◆	◆

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Chapter 10: Historical Perspectives		
<i>Displacing the Earth from the Center of the Universe</i>		
The motion of an object is always judged with respect to some other object or point and so the idea of absolute motion or rest is misleading.	◆	
Telescopes reveal that there are many more stars in the night sky than are evident to the unaided eye, the surface of the moon has many craters and mountains, the sun has dark spots, and Jupiter and some other planets have their own moons.		
<i>Understanding Fire</i>		
From the earliest times until now, people have believed that even though millions of different kinds of material seem to exist in the world, most things must be made up of combinations of just a few basic kinds of things. There has not always been agreement, however, on what those basic kinds of things are. One theory long ago was that the basic substances were earth, water, air, and fire. Scientists now know that these are not the basic substances. But the old theory seemed to explain many observations about the world.		
Today, scientists are still working out the details of what the basic kinds of matter are and how they combine, or can be made to combine, to make other substances.		
Experimental and theoretical work done by French scientist Antoine Lavoisier in the decade between the American and French revolutions led to the modern science of chemistry.		
Lavoisier's work was based on the idea that when materials react with each other many changes can take place but that in every case the total amount of matter afterward is the same as before. He successfully tested the concept of conservation of matter by conducting a series of experiments in which he carefully measured all the substances involved in burning, including the gases used and those given off.		
Alchemy was chiefly an effort to change base metals like lead into gold and to produce an elixir that would enable people to live forever. It failed to do that or to create much knowledge of how substances react with each other. The more scientific study of chemistry that began in Lavoisier's time has gone far beyond alchemy in understanding reactions and producing new materials.		
<i>Splitting the Atom</i>		
The accidental discovery that minerals containing uranium darken photographic film, as light does, led to the idea of radioactivity.		
In their laboratory in France, Marie Curie and her husband, Pierre Curie, isolated two new elements that caused most of the radioactivity of the uranium mineral. They named one radium because it gave off powerful, invisible rays, and the other polonium in honor of Madam Curie's country of birth. Marie Curie was the first scientist ever to win the Nobel prize in two different fields--in physics, shared with her husband, and later in chemistry.		
<i>Discovering Germs</i>		
Throughout history, people have created explanations for disease. Some have held that disease has spiritual causes, but the most persistent biological theory over the centuries was that illness resulted from an imbalance in the body fluids. The introduction of germ theory by Louis Pasteur and others in the 19th century led to the modern belief that many diseases are caused by microorganisms--bacteria, viruses, yeasts, and parasites.		
Pasteur wanted to find out what causes milk and wine to spoil. He demonstrated that spoilage and fermentation occur when microorganisms enter from the air, multiply rapidly, and produce waste products. After showing that spoilage could be avoided by keeping germs out of by destroying them with heat, he investigated animal diseases and showed that microorganisms were involved. Other investigators later showed that specific kinds of germs caused specific diseases.		

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Pasteur found that infection by disease organisms--germs--caused the body to build up an immunity against subsequent infection by the same organisms. He then demonstrated that it was possible to produce vaccines that would induce the body to build immunity to a disease without actually causing the disease itself.

Changes in health practices have resulted from the acceptance of the germ theory of disease. Before germ theory, illness was treated by appeals to supernatural powers or by trying to adjust body fluids through induced vomiting, bleeding, or purging. The modern approach emphasizes sanitation, the safe handling of food and water, the pasteurization of milk, quarantine, and aseptic surgical techniques to keep germs out of the body; vaccinations to strengthen the body's immune system against subsequent infection by the same kind of microorganisms; and antibiotics and other chemicals and processes to destroy microorganisms.

In medicine, as in other fields of science, discoveries are sometimes made unexpectedly, even by accident. But knowledge and creative insight are usually required to recognize the meaning of the unexpected.

Harnessing Power

Until the 1800's, most manufacturing was done in homes, using small, handmade machines that were powered by muscle, wind, or running water. New machinery and steam engines to drive them made it possible to replace craftsmanship with factories, using fuels as a source of energy. In the factory system, workers, materials, and energy could be brought together efficiently.

The invention of the steam engine was at the center of the Industrial Revolution. It converted the chemical energy stored in wood and coal, which were plentiful, into mechanical work. The steam engine was invented to solve the urgent problem of pumping water out of coal mines. As improved by James Watt, it was soon used to move coal, drive manufacturing machinery, and power locomotives, ships, and even the first automobiles.

Chapter 11: Common Themes

Systems

A system can include processes as well as things.

Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes in the system as a whole.

Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem or a larger system.

Models

Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous.

Mathematical models can be displayed on a computer and then modified to see what happens.

Different models can be used to represent the same thing. What kind of model to use and how complex it should be depends on its purpose. The usefulness of a model is one of the instances in which intuition and creativity come into play in science, mathematics, and engineering.

Constancy and Change

Physical and biological systems tend to change until they become stable and then remain that way unless their surroundings change.

A system may stay the same because nothing is happening or because things are happening but exactly counterbalance one another.

Many systems contain feedback mechanisms that serve to keep changes within specified limits.

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	Level 6 Scientific Theories	Level 6 Ecosystems
Symbolic equations can be used to summarize how the quantity of something changes over time or in response to other changes.	◆	◆
Symmetry (or lack of it) may determine properties of many objects, from molecules and crystals to organisms and designed structures.		
Things that change in cycles, such as the seasons or body temperature, can be described by their cycle length or frequency, what the highest and lowest values are, and when they occur. Different cycles range from many thousands of years down to less than a billionth of a second.		◆
Scale		
Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes.	◆	
As the complexity of any system increases, gaining an understanding of it depends increasingly on summaries, such as averages and ranges, and on descriptions of typical examples of that system.	◆	◆
Chapter 12: Habits of Mind		
Values and Attitudes		
Know why it is important in science to keep honest, clear, and accurate records.	◆	◆
Know that hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations.	◆	◆
Know that often different explanations can be given for the same evidence, and it is not always possible to tell which one is correct.	◆	◆
Computation and Estimation		
Find what percentage one number is of another and figure any percentage of any number.	◆	
Use, interpret, and compare numbers in several equivalent forms such integers, fractions, decimals, and percents.		
Calculate the circumferences and areas rectangles, triangles, and circles, and the volumes of rectangular solids.		
Find the mean and median of a set of data.		
Estimate distances and travel times from maps and the actual size of objects from scale drawings.		
Insert instructions into computer spreadsheet cells to program arithmetic calculations.		
Determine what unit (such as seconds, square inches, or dollars per tankful) an answer should be expressed in from the units of the inputs to the calculation, and be able to convert compound units (such as a yen per dollar into dollar per yen, or miles per hour into feet per second).		
Decide what degree of precision is adequate and round off the result of calculator operations to enough significant figures to reasonably reflect those of the inputs.		
Express numbers like 100, 1,000, and 1,000,000 as powers of 10.		
Estimate probabilities of outcomes in familiar situations, on the basis of history or the number of possible outcomes.		
Manipulation and Observation		
Use calculators to compare amounts proportionally.		
Use computers to store and retrieve information in topical, alphabetical, numerical, and key-word files, and create simple files of their own devising.		
Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, and temperature, and choose appropriate units for reporting various magnitudes.		
Use camera and tape recorders for capturing information.		

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Inspect, disassemble, and reassemble simple mechanical devices and describe what various parts are for; estimate what effect making a change in one part of a system is likely to have on the system as a whole.

Communication Skills

Organize information in simple tables and graphs and identify relationships they reveal.

Read simple tables and graphs produced by others and describe in words what they show.

Locate information in reference books, back issues of newspapers and magazines, compact disks, and computer databases.

Understand writing that incorporates circle charts, bar and line graphs, two-way data tables, diagrams, and symbols.

Find and describe locations on maps with rectangular and polar coordinates.

Critical-Response Skills

Question claims based on vague attributions (such as "Leading doctors say...") or on statements made by celebrities or others outside the area of their particular expertise.

Compare consumer products and consider reasonable personal trade-offs among them on the basis of features, performance, durability, and cost.

Be skeptical of arguments based on very small samples of data, biased samples, or samples, or samples for which there was no control sample.

Be aware that there may be more than one good way to interpret a given set of findings.

Notice and criticize the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, (2) an analogy is not apt, (3) no mention is made of whether the control groups are very much like the experimental group, or (4) all members of a group (such as teenagers or chemists) are implied to have nearly identical characteristics that differ from those of other groups.

	Level 6 Scientific Theories	Level 6 Ecosystems
Communication Skills		
Organize information in simple tables and graphs and identify relationships they reveal.	◆T	◆T
Read simple tables and graphs produced by others and describe in words what they show.	◆T	◆T
Locate information in reference books, back issues of newspapers and magazines, compact disks, and computer databases.	◆	◆
Understand writing that incorporates circle charts, bar and line graphs, two-way data tables, diagrams, and symbols.	◆	◆
Find and describe locations on maps with rectangular and polar coordinates.		
Critical-Response Skills		
Question claims based on vague attributions (such as "Leading doctors say...") or on statements made by celebrities or others outside the area of their particular expertise.		
Compare consumer products and consider reasonable personal trade-offs among them on the basis of features, performance, durability, and cost.		◆
Be skeptical of arguments based on very small samples of data, biased samples, or samples, or samples for which there was no control sample.	◆	◆
Be aware that there may be more than one good way to interpret a given set of findings.	◆	◆
Notice and criticize the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, (2) an analogy is not apt, (3) no mention is made of whether the control groups are very much like the experimental group, or (4) all members of a group (such as teenagers or chemists) are implied to have nearly identical characteristics that differ from those of other groups.	◆	◆