District of Columbia

Science
Pre-K through Grade 12 Standards





Contents

Introduction

This document provides teachers and curriculum coordinators with a summary of what science content should be taught from grade to grade, prekindergarten through high school. Building on the highly rated Indiana Academic Standards, this document draws on the comments and suggestions of more than 30 teachers and administrators throughout the district who worked in roundtables from March through November 2005, early childhood educators whose development of prekindergarten standards has been under way for two years, and experts in the field of science education who reviewed the final draft. Focus groups involving 20 DC Public School teachers reviewed and commented on the final draft, and their feedback is reflected as well. This document represents the combined talents of each of these critical stakeholders.

Students are naturally curious about the world and their place in it. Nurturing and sustaining this curiosity and giving it a scientific foundation is a high priority in DCPS. A high level of scientific literacy has become a necessity for everyone if they are to make sound choices in daily life and engage intelligently in public discourse about many of the salient issues of our day. Increasingly, jobs demand advanced science skills and require people to reason, make decisions, and solve problems. Other countries are investing heavily to create scientifically literate work forces. To keep pace, the United States needs to have an equally capable citizenry. These learning standards are designed to meet that challenge.

Organization of the Learning Standards

The goal of science education is to teach students the fundamental concepts of the earth, life, and physical sciences and the connections across these domains. Each of the divisions of science has its particular approach and domain, and when taken together, they present a coherent view of the world. We encourage an understanding that much of the scientific work done in the world draws on multiple disciplines. Connecting the domains of natural science with one another — and with mathematical study — and then making practical applications through technology is a goal of science education in the district.

Another goal is to teach students about the active process of investigation and the critical review of evidence. Gathering and evaluating information, perceiving patterns, and then devising and testing possible explanations about the scientific content they are learning prompts students to become independent and critical thinkers. In addition to "hands-on" experiences, students require "minds-on" experiences. Rigorous science methods and thought processes have application well beyond the bounds of science to support learning goals in all subject areas and pathways in life. Thus scientific investigation in the early grades begins with simple exploration and progresses to increasingly organized and sophisticated science investigations in higher grades. Students need to draw on all of these skills, habits of mind, and subject matter knowledge to participate fully in the intellectual and civic life of American society, and to further their education in those areas if they seek it.

Given these goals, the document is organized as follows: In the elementary grades, the standards integrate all of the major domains of science every year. At the middle and high school level, the standards adopt a discipline-based approach. The high school science standards are written to allow for choice in course organization and sequence. Specifically:

- Prekindergarten through grade 5 is organized according to the domains of science: earth, life, and physical sciences, with standards for scientific thinking and inquiry listed separately.
- Grades 6 through 8 focus on one of each of the domains: grade 6 on earth sciences, grade 7 on life sciences, and grade 8 on physical sciences. Standards are listed under key areas of study, noted by topic headings (e.g., the solar system, plate tectonics).
- High school is organized by courses (e.g., Earth Science, Biology, Chemistry, Physics, and Environmental Science) and is similarly formatted around key areas of study.

Guiding Principles to Effective Science Education[1]

The guiding principles present a set of tenets about effective programs for prekindergarten through grade 12 and instruction in science. These principles articulate some ideals of teaching and learning, as well as administering effective science programs in DCPS. They show how educators may create educational environments characterized by curiosity, persistence, respect for evidence, and open-mindedness, balanced with healthy skepticism and a sense of responsibility.

Guiding Principle I: Scientific explanations are always subject to change in the face of new evidence.

Ideas with the most durable explanatory power become established theories. A key criterion of science is that it provides a clear, rational, and succinct account of patterns in nature that are based on data gathering and analysis and other evidence obtained through direct observations or experiments, and reflect inferences that are broadly shared and communicated.

Guiding Principle II: An effective program in science is integrally related to mathematics.

Mathematics is an essential tool for scientists and engineers because it specifies in precise and abstract (general) terms the many attributes of natural phenomena and manmade objects and the nature of relationships among them. Mathematics also facilitates precise analysis and prediction. Because of the central importance of mathematics to science, all teachers, curriculum coordinators, and others who help to implement these standards must be aware of the level of mathematical knowledge needed for each science course at the high school level and ensure that the appropriate mathematical knowledge has already been taught or, at the least, is being taught concurrently.

Guiding Principle III: An effective program in science addresses students' prior knowledge and misconceptions.

Teachers must be skilled at unearthing inaccuracies in students' prior knowledge and observations, and in devising experiences that will challenge those mistaken beliefs and redirect student learning along more productive routes. Children can hold onto misconceptions, even while reproducing "correct answers" to questions. For example, young children may repeat that the earth is round (as they have been told) while continuing to believe that the earth is flat, which is what they can see for themselves. The students' natural curiosity provides one entry point for learning experiences designed to remove students' misconceptions in science.

[1] *Guiding Principles II–VI were edited and adapted from the Massachusetts Science and Technology/Engineering Framework.*

Guiding Principle IV: Investigation, experimentation, and problem solving are central to effective science education. Investigations introduce students to the nature of original research, increase students' understanding of scientific and technological concepts, promote skill development, and provide entry points for all learners.

Puzzlement and uncertainty are common features in experimentation. Students need time to examine their ideas as they learn how to apply them to explaining a natural phenomenon or solving a design problem. Opportunities for students to reflect on their own ideas, collect evidence, make inferences and predictions, and discuss their findings are all crucial to growth in scientific understanding. When possible, students should also replicate in the classroom important experiments that have led to well-confirmed knowledge about the natural world. By carefully following the thinking of experts, students can learn to improve their own problem-solving efforts.

Guiding Principle V: Students need opportunities to talk about their work in focused discussions with peers and with those who have more experience and expertise. Scientists work as members of their professional communities where ideas are tested, modified, extended, and re-evaluated over time. Thus, the ability of scientists to convey their ideas to others is essential for these advances to occur. This communication can occur informally, in the context of an ongoing student collaboration or online consultation with a scientist or engineer, or more formally, when a student presents findings from an individual or group investigation. Effective communication of scientific and technological ideas requires practice in making written and oral presentations, fielding questions, responding to critiques, and developing replies.

Guiding Principle VI: Implementation of an effective science program requires districtwide planning, collaboration with experts, appropriate materials, support from parents and community, and ongoing professional development. Middle school teachers have the right to expect that students coming from different elementary schools share a common set of experiences and understandings in science, and that the students they send on to high school will be well prepared for what comes next.

Implementation also requires extensive professional development. Teachers must have the content knowledge and the pedagogical expertise to use the materials in a way that enhances student learning. A well-planned program for professional development should provide for both content learning and content-based pedagogical training. At the secondary level, each area of science study needs to be taught by teachers who are certified in that area.

Introduction of a new science program can be more effective when families and community members are brought into the selection and planning process. Parents who have a chance to examine and work with the materials in the context of family nights or science fairs or other occasions will be able to better understand and support their children's learning. The district is particularly fortunate to have much local talent from the science community willing and able to lend expertise to assist with the implementation of the new standards. Teachers and administrators should invite scientists, engineers, higher education faculty, representatives of local businesses, and museum personnel to help evaluate the planned curriculum and enrich it with community connections.

The science standards that appear on the following pages present a vision of a scientifically literate student population prepared to meet the demands of our 21st-century world. To achieve this vision will require a vast and significant process that will extend over many years and will involve hard work. By using this document to guide that work, the nation's capital has an opportunity to demonstrate that our students — America's students — can compete anywhere in the world in the all-important disciplines of science. The district is up to the challenge.

Prekindergarten	Kindergarten
SCIENTIFIC THINKING AND INQUIRY	
PK.1. Broad Concept: Children develop inquiry and process skills. Students: 1. Ask questions and make predictions. (Students ponder, "Where does the sun go at night?" Children put snow in a bucket and conclude, "If we take the bucket inside, the snow's going melt.") 2. Explore cause and effect. (Students add blocks to a tower to see how high it can rise before it falls, or they place pennies, one by one, in two floating boats to see which boat sinks first.) 3. Use tools to explore and investigate. (Students use a pair of binoculars to watch a bird building a nest, or they use a string to measure the growth of a plant.) 4. Collect, organize, and record information. (Children draw a picture of worms found outside, or they sort leaves found on the playground and line them up by shape.) 5. Discuss and draw conclusions and form generalizations. (Children notice that mixing yellow and blue paint always makes the paint turn green. A student asserts, "I can do things now that I couldn't do when I was a baby because I'm big now.") 6. Communicate observations and findings through a variety of methods. (A student explains to a friend how he turned dirt into mud. Children draw a picture of a carrot, showing the root in the soil and the leaves above the soil.)	**K.1. Broad Concept:** Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions about objects or events they can observe, and then perform simple investigations. Students: 1. Describe objects accurately by drawing pictures. 2. Raise questions about the natural world and know that scientific inquiry can be used to seek answers to questions about it. 3. Gather information about objects through the use of one or more of the senses, such as sight, smell, touch, and (under supervision) taste. 4. Use magnifiers to see small features of objects. 5. Use a thermometer to measure temperature.
EARTH SCIENCE	
PK.2. Broad Concept: Children are familiar with the Earth and the natural world. Students: 1. Observe and describe the natural world around them. (Children look at dark clouds and conclude, "It's going to rain." A student says, "I think it's spring because I saw some flowers in our garden.") 2. Explore how their actions can cause changes in the environment. (Students use the recycle bins in the classroom. Children observe aloud, "Look how the dirt gets darker when we put water on it.")	**K.2. Broad Concept:** Objects in the sky move in predictable patterns. As a basis for understanding this concept, students: 1. Recognize that day and night repeat in a predictable pattern. 2. Recognize that seasons repeat in predictable patterns over time. 3. Know the sun, moon, and stars can be observed at certain times of the day.

Grade 1

SCIENTIFIC THINKING AND INQUIRY

1.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Observe, describe, draw, and sort objects as a way of isolating and categorizing some of their properties.
2. Investigate and make observations to seek answers to questions.
3. Recognize and demonstrate what people can learn about plants and animals by observing them closely over a period of time.
4. Use tools, such as rulers and magnifiers, to investigate the world and make observations.
5. Measure the length of objects having straight edges in centimeters or nonstandard units to the nearest unit.
6. Demonstrate that magnifiers help people see small features of objects.
7. Describe and compare objects in terms of number, shape, texture, size, mass, color, and motion.
8. Write brief informational descriptions of a real object, person, place, or event using information from the observations.

EARTH SCIENCE

1.2. Broad Concept: The Earth is composed of land, air, and water. As a basis for understanding this concept, students:

1. Recognize and explain that water, rocks, soil, and living organisms are found on the Earth's surface.
2. Investigate and explain that air is a mixture of different gases that surrounds us and takes up space, and whose movement we feel as wind.
3. Observe and measure that the sun supplies heat and light to the Earth and is necessary for most life.

Prekindergarten	Kindergarten
PHYSICAL SCIENCE	
PK.3. Broad Concept: Children are familiar with the physical properties and uses of materials and objects. Students: **1.** Explore the physical properties of objects and materials. (Students can use a magnifying glass to examine sand, and they can pick up some metal objects using a magnet.) **2.** Observe, describe, compare, and categorize objects on the basis of qualities such as weight, shape, size, color, and temperature. (Children can use a balance to compare the weights of rocks in a collection, or they can use sorting trays to arrange a collection of bottle caps.) **3.** Experiment with how things move and change. (Students can create different inclines with blocks to explore the velocity of toy cars. Children can shake cream in a plastic jar until it becomes butter.)	**K.3. Broad Concept:** Objects can be described by their observable properties. As a basis for understanding this concept, students: **1.** Recognize that objects are made of materials with particular properties, such as clay, cloth, paper, metal, etc. **2.** Investigate and compare physical properties of objects (e.g., color, size, shape, weight, texture, flexibility, attraction to magnets, ability to float and sink). **K.4. Broad Concept:** The motion of objects can be observed and measured. As a basis for understanding this concept, students: **1.** Compare the position of an object in relationship to another object. **2.** Explain that things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow.
LIFE SCIENCE	
PK.4. Broad Concept: Children are familiar with living things (plants and animals) and what they need to survive. Students: **1.** Explore and observe changes in plants and animals, their life cycles, and habitats. (Children can care for a classroom pet by providing food and water as needed and by helping to clean the cage. On a nature walk, students might observe aloud, "Look, that squirrel is putting something in his mouth.") **2.** Observe, describe, compare, and categorize plants and animals. (Students might say, "Birds can fly, but cats can't." They notice differences and say, "Some of our plants are tall, and some are short.") **3.** Identify common needs of plants and animals. (Children might say, "All animals need air to breathe," or after hearing Anne Morris' *Bread, Bread, Bread* read aloud, they say, "Everyone eats bread, but there are different kinds.")	**K.5. Broad Concept:** Different types of plants and animals inhabit the Earth. As a basis for understanding this concept, students: **1.** Know there are many different kinds of plants and animals. **2.** Describe that plants and animals are alike in some ways and different in others (e.g., appearance and behavior).

Grade 1

PHYSICAL SCIENCE

1.3. Broad Concept: The motion of objects can be observed, measured, and changed. As a basis for understanding this concept, students:

1. Observe and describe that the way to make something move (faster or slower or in a different direction) is by giving it a push or a pull, which is called a *force*.
2. Explain that the greater the applied force, the greater the change in the motion of the object.
3. Demonstrate and observe that magnets supply a force that can be used to make some things move without touching them.
4. Recognize and demonstrate how things near Earth fall to the ground unless something holds them up (i.e., they are subject to the force of gravity).

LIFE SCIENCE

1.4. Broad Concept: Different types of plants and animals inhabit the Earth. As a basis for understanding this concept, students:

1. Explain that most living things need food, water, and air.
2. Observe and describe that there can be differences, such as size or markings, among the individuals within one particular plant or animal group (e.g., maple trees, zebras). Variation is a normal characteristic of many kinds of living things.
3. Observe and explain that animals eat plants and/or other animals for food.
4. Recognize that animals (including humans) and plants are living things that grow, reproduce, and need food, air, and water.
5. Identify the external features that local plants and animals have (such as those found in schoolyards or in city neighborhoods) that enable them to survive in their environment.

Grade 2	Grade 3
SCIENTIFIC THINKING AND INQUIRY	
2.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students: 1. Describe objects as accurately as possible and compare observations with those made and reported by others. 2. Make new observations when there is disagreement among observers or among successive observations. 3. Demonstrate the ability to work with a team, but still reach and communicate one's own conclusions about findings. 4. Use tools, such as thermometers, magnifiers, rulers, or balances, to investigate, observe, measure, design, and build things. 5. Measure objects in standard units and include units in reports of measurements with simple calculations (e.g., 3 cm + 3 cm = 6 cm). 6. Draw pictures and write brief, coherent descriptions that correctly portray key features of an object. 7. Recognize and explain that people are more likely to believe ideas when they are supported by observations. 8. Explain that some events can be predicted with near certainty, such as a sunrise and sunset, and some cannot, such as storms. 9. Explain that sometimes a person can make general discoveries about a group of objects or organisms, such as insects, plants, or rocks, by studying just a few of them, even though the group may vary in details. Understand that this is not inconsistent with the existence of biological variation. 10. Make simple line and bar graphs (e.g., track daily changes in outdoor air temperature).	**3.1. Broad Concept:** Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students: 1. Recognize and explain that when a scientific investigation is repeated, carefully and under the same conditions, a similar (but not necessarily identical) result is expected. 2. Participate in different types of guided scientific investigations (related to content in this grade), such as observing objects and events and collecting specimens for analysis, including longer-term investigations that take place over several days, weeks, or months. 3. Keep and report records of investigations and observations using tools, such as journals, charts, graphs, and computers. 4. Discuss the results of investigations and consider the explanations of others. 5. Demonstrate the ability to work cooperatively while respecting the ideas of others and communicating one's own conclusions about findings. 6. Measure and mix dry and liquid materials in prescribed amounts, following reasonable safety precautions. 7. Keep a notebook that describes ongoing observations and that is still understandable weeks or months later. 8. Appropriately use simple tools — such as clamps, rulers, scissors, and hand lenses, as well as other technology (e.g., such as calculators and computers) — to help solve problems. 9. Make sketches and write descriptions to aid in explaining procedures or ideas. 10. Ask, "How do you know?" in appropriate situations, and attempt reasonable answers when others ask the same question. 11. Explain that one way to make sense of something is to think of how it compares to something more familiar (e.g., vibrations of an object in air such as a tuning fork, a plucked string of a string instrument, human vocal cords).

Grade 4

SCIENTIFIC THINKING AND INQUIRY

4.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Recognize and describe how results of similar scientific investigations may turn out differently due to inconsistencies in methods, materials, or observations, or the limitations of the tools used.
2. Explain that clear communication is an essential part of the process of scientific inquiry because it enables scientists to inform others about their work, to expose their ideas to evaluation by other scientists, and to allow scientists to stay informed about scientific discoveries around the world.
3. Use numerical data to describe and compare objects and events.
4. Write descriptions of investigations by using observations as support for explanations.
5. Support statements with ideas and data found in print and electronic media, identify and evaluate the sources used, and expect others to do the same.
6. Identify better reasons for believing something rather than citing comments such as, "Everybody knows that," "I just know," or "Because they say," and discount such reasons when given by others.
7. Explain how scientific thinking can be distorted by strong feelings, and explain why and when it is appropriate or necessary to separate emotions from the reasoning process.

Grade 5

SCIENTIFIC THINKING AND INQUIRY

5.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Recognize and describe how results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations, or because of limitations of the precision of the instruments used.
2. Evaluate the validity of claims based on the amount and quality of the evidence cited.
3. Keep a notebook to record observations and be able to distinguish inferences from actual observations.
4. Write instructions that others can follow to carry out an investigation.
5. Read and follow step-by-step instructions when learning new investigations.
6. Identify the controlled variable and at least one independent variable in a scientific investigation, when appropriate.
7. Explain that predictions can be based on what is known about the past, assuming that conditions are similar.
8. Realize and explain why predictions may be more accurate if they are based on large collections of similar events for statistical accuracy.
9. Determine area and volume of rectangular shapes from linear dimensions, using the expressions $A = l \times w$ and $V = l \times w \times h$.
10. Understand how plotting data on a number line helps in seeing where the data lie, including the outliers.
11. Explain the distortion inherent in using only a portion of the data collected to describe the whole. Understand that it is sometimes acceptable to discard data.

Grade 2	Grade 3
SCIENCE AND TECHNOLOGY	
2.2. Broad Concept: Although each of the human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. As a basis for understanding this concept, students: 1. Give examples of how our lives would be different without such technologies as automobiles, computers, and electric motors.	**3.2. Broad Concept:** Although each of these human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. As a basis for understanding this concept, students: 1. Define technology as the application of human ingenuity and skill to the solution of practical problems (e.g., typewriter, computer). 2. Identify and demonstrate how an invention can be used in different ways, such as a radio or a cell phone that can be used to receive both information and entertainment. 3. Construct something to perform a task, by using commonly available materials, such as paper, cardboard, wood, plastic, or metal, or by using existing objects.

Grade 4	Grade 5
SCIENCE AND TECHNOLOGY	
4.2. Broad Concept: Although each of the human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. As a basis for understanding this concept, students: **1.** Demonstrate how scientific tools, such as microscopes, telescopes, and cameras, can be used to gather accurate information for making scientific comparisons of objects and events. **2.** Discuss and give examples of how technologies, such as computers and medical X-rays, have improved the lives of people. **3.** Describe how human beings have made tools and machines, such as X-ray cameras, microscopes, satellites, and computers, to observe and do things that they could not otherwise sense or do at all, or as quickly or efficiently. **4.** Make simple and safe electrical circuits with a battery and various plugs, sockets, and terminals.	**5.2. Broad Concept:** Although each of the human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. As a basis for understanding this concept, students: **1.** Give examples of technology, such as telescopes, microscopes, and cameras, that enable scientists and others to observe things that are too small or too far away to be seen without them and to study the motion of objects that are moving very rapidly or are hardly moving. **2.** Give examples of advances in technology that have positively and/or negatively affected society. **3.** Give examples of materials not present in nature that have become available because of science and technology, such as cloth, metal alloys, plastic, ceramics, and concrete.

Grade 2

EARTH SCIENCE

2.3. Broad Concept: Weather can be observed, measured, and described. As a basis for understanding this concept, students:

1. Explain how weather patterns occur continually on Earth.
2. Explain that air temperature, humidity, wind speed and direction, and precipitation make up the weather in a particular place and time.
3. Investigate and compare weather changes from day to day and place to place.
4. Describe and chart that the temperature and amounts of rain or snow vary in the same months in each place every year.
5. Explain the difference between weather and climate.
6. Describe the differences among the various forms of precipitation (rain, snow, sleet, and hail).
7. Cite specific examples of how human beings protect themselves from adverse weather conditions through different means.

2.4. Broad Concept: The Earth's resources can be conserved. As a basis for understanding this concept, students:

1. Recognize and explain how certain materials — such as recycled paper, cans, and certain types of plastic containers — can be used again.
2. Explain how discarded products contribute to the problem of waste disposal and how recycling and reuse can help solve this problem.

Grade 3

EARTH SCIENCE

3.3. Broad Concept: Objects in the sky move in regular and predictable patterns. As a basis for understanding this concept, students:

1. Observe and describe the apparent motion of the sun and moon over a time span of one day.
2. Using a globe, demonstrate how the Earth rotates on its axis every 24 hours, producing the night-and-day cycle.
3. Observe and describe how there are more stars in the sky than anyone can easily count, but they are not spaced or spread evenly.
4. Observe and describe that the sun can be seen only in the daytime; the moon can be seen sometimes at night and sometimes during the day.
5. Observe and describe the changes that occur in the observable shape of the moon over the course of a month (i.e., the moon looks a little different every day, but looks the same again about every four weeks).
6. Demonstrate and describe that sunlight can be blocked to create shadows, and the direction and length of shadows vary at different times of day.

Grade 4

EARTH SCIENCE

4.3. Broad Concept: Waves, wind, water, and ice shape and reshape the Earth's land surface. As a basis for understanding this concept, students:

1. Explain how waves, wind, water, and glacial ice shape and reshape Earth's land surface by eroding rock and soil in some areas and depositing them in other areas.
2. Explain how the surface of the Earth changes over various time scales due to processes, such as erosion and weathering, landslides, volcanic eruptions, earthquakes, and mountain building.

4.4. Broad Concept: The properties of rocks and minerals reflect the processes that formed them. As a basis for understanding this concept, students:

1. Define a mineral as a naturally occurring, crystalline inorganic solid substance. Recognize that each mineral has its own characteristic properties (e.g., quartz, mica).
2. Describe the physical properties of minerals, including hardness, color, luster, cleavage, and streak, and recognize that one mineral can be distinguished from another by use of a simplified key.
3. Recognize and describe that most rock is composed of different combinations of one or more minerals.
4. Explain how weathering breaks rocks up into smaller pieces. Recognize that these pieces may be many sizes and shapes, from jagged boulders to smooth grains of sand and even smaller.
5. Describe the different layers of the Earth, including the crust, mantle, and core.
6. Define the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed from older rocks.
7. Explain how soil is made partly from rock weathered by water and wind, and partly from decomposition of plant and animal remains, and that it contains many living organisms.
8. Describe the different properties of soil, including its color, texture (size of particles), and ability to retain water and support the growth of plants.

Grade 5

EARTH SCIENCE

5.3. Broad Concept: The solar system consists of planets and other bodies that orbit the sun in predictable paths. As a basis for understanding this concept, students:

1. Describe the Earth as part of a system called the *solar system,* which includes the sun (a star), planets, comets, asteroids, and many moons.
2. Recognize that the Earth is the third planet from the sun in our solar system.
3. Demonstrate how the Earth orbits the sun in a year's time, and Earth rotates on its axis about once every 24 hours.
4. Describe that, like all planets and stars, the Earth is approximately spherical in shape.
5. Explain that the alternation between day and night and the apparent movement of the sun, moon, and stars across the sky depend on the rotation of the Earth on its axis.
6. Observe how telescopes are used both to magnify images of distant objects in the sky, including the moon and the planets, and to gather enough light from very dim objects to make them visible.
7. Observe and describe that stars vary in size, but they are so far away that they look like points of light.
8. Observe stars and identify ones that are unusually bright, and others that have unusual colors, such as red or blue.

5.4. Broad Concept: Water on Earth moves from the ocean to the land through the processes of evaporation and condensation. As a basis for understanding this concept, students:

1. Investigate and describe that when liquid water evaporates, it turns into a gas (vapor) mixed into the air, and can condense and reappear as a liquid when cooled or as a solid (ice) if cooled below the freezing point of water.
2. Explain how water moves in air masses from one place to another in the form of clouds, fog, or as invisible water vapor, and falls to the Earth as rain, hail, sleet, or snow.
3. Describe that clouds are made of tiny droplets of water or ice crystals.
4. Explain that the air around us is matter and has weight (a force) and exerts pressure; explain that air pressure varies a little from place to place and from time to time.

(continued)

Grade 2	Grade 3
EARTH SCIENCE *(continued)*	
PHYSICAL SCIENCE	
2.5. Broad Concept: Materials come in different states, including solids, liquids, and gases. As a basis for understanding this concept, students: 1. Recognize that solids have a definite shape; liquids and gases take the shape of their containers. 2. Recognize that materials can be manipulated to change some of their properties (e.g., cooling or heating). 3. Investigate and explain that water, like many other substances, can be a liquid, a solid, or a gas, and it can transform from one state to another. 4. Explain how water can be transformed from one state to another by adding or taking away heat energy. 5. Describe when water is frozen into ice and the ice is allowed to melt, the amount of water is the same as it was at the beginning. 6. Investigate and explain how water left in an open container seems to disappear into the air (evaporation), but water in a small, closed container does not disappear.	**3.4. Broad Concept:** Energy takes many forms and has many sources. As a basis for understanding these concepts, students: 1. Recognize that energy is needed to carry out almost any kind of change. 2. Describe basic forms of energy, including mechanical (kinetic and potential), light, sound, heat, chemical, nuclear, and electrical. 3. Recognize that energy can be transformed from one form to another. 4. Describe how people use electricity or the chemical energy from burning fuels, such as wood, oil, coal, or natural gas, to obtain heat energy for doing tasks, such as cooking their food and warming their houses. 5. Investigate and describe how moving air and water (carriers of kinetic energy, the energy of motion) can be used to run machines like windmills and waterwheels. 6. Demonstrate that things that make sound do so by vibrating objects, such as vocal cords and musical instruments. Describe that the sound travels as a vibration through the air.

Grade 4	Grade 5
EARTH SCIENCE *(continued)*	
	5.4. Broad Concept: Water on Earth moves from the ocean to the land through the processes of evaporation and condensation. As a basis for understanding this concept, students: 5. Describe that winds blow from areas of higher pressure to areas of lower pressure. 6. Explain how global patterns, such as the jet stream and ocean currents, influence local weather and climate in ways that can be measured in terms of temperature, pressure, wind direction and speed, and amounts of precipitation. 7. Explain that water on Earth cycles through different forms and in different locations (e.g., underground water and vapor in the atmosphere). 8. Using maps and globes, recognize that the Earth's oceans are all connected as one body of water that covers about three-quarters of the Earth's surface.
PHYSICAL SCIENCE	
4.5. Broad Concept: Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept, students: 1. Explain that energy comes from the sun in the form of visible light and other radiation we cannot see without special instruments, but some of what we cannot see we can feel as heating (infrared radiation), and some can cause sunburn (ultraviolet radiation). 2. Investigate and describe how light travels through empty space or a transparent medium in a straight line until it strikes an object, and, if the object is transparent, the light will bend (refract) at the interface. 3. Explain when light strikes a surface, it can be reflected, scattered, refracted, and/or absorbed. 4. Observe and explain that when one object rubs against another (such as one's hands rubbing together) the kinetic energy (energy of motion) is transformed into heat energy. 5. Recognize that heat energy can be absorbed or given off by both living and nonliving things. 6. Explain that energy in fossil fuels comes originally from the energy of sunlight used by plants that grew a long time ago. *(continued)*	**5.5. Broad Concept:** Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept, students: 1. Recognize that all matter is made of small particles called *atoms*, which are too small to see with our eyes; describe how atoms may combine to form molecules or crystalline solids (compounds). 2. Recognize that there are more than 100 different kinds of atoms (each called an *element*), which are displayed on the periodic table of the elements. 3. Explain that all matter is made up of an element, a compound, or mixtures of elements and compounds. 4. Investigate and describe that heating and cooling cause changes in the properties of substances. For example, liquid water can turn into steam by boiling, and liquid water can turn into ice by freezing. 5. Explain that many kinds of chemical changes occur faster at higher temperatures. 6. Explain that when a warm object and a cool one are placed in contact, heat flows from the warmer object to the cooler one until they are both at the same temperature. Know that heat transfer can also occur at a distance by radiation. 7. Investigate and describe how some materials conduct heat much better than others, and poor conductors (insulators) can be used to reduce heat loss or gain. *(continued)*

Grade 2	Grade 3
PHYSICAL SCIENCE *(continued)*	

Grade 4

PHYSICAL SCIENCE *(continued)*

4.6. Broad Concept: Electricity and magnetism are related phenomena that have many useful applications in everyday life. As a basis for understanding this concept, students:

1. Recognize that some materials are electrical conductors and others are electrical insulators.
2. Demonstrate that magnets attract objects made of iron and a few other substances (called *magnetic materials*), but they do not attract objects made of most other substances.
3. Investigate and describe that a magnet does not have to touch an object made of magnetic material to exert a force on it.
4. Describe that magnets have poles; unlike poles of two magnets attract each other while like poles repel.
5. Explain how an electrically charged object does not have to touch another object to exert a force — called the *electrostatic force* — on it.
6. Recognize that there are two types of electric charge: *positive* and *negative*.
7. Explain that if two electrically charged objects are near each other, each will exert an attractive or repulsive force on the other. Describe that like charges repel each other and unlike charges attract each other.
8. In spite of some similarities, explain how the electrostatic force and the magnetic force are not the same thing.
9. Explain that electric current can flow only if there is a complete closed loop of conducting material (called a *circuit*) for it to flow through. Know that a switch is a device for opening and closing a circuit.
10. Explain how electrical energy can be used to produce light, heat energy, motion (kinetic energy), or sound energy.

Grade 5

5.6. Broad Concept: Unbalanced forces cause changes in velocity. As a basis for understanding this concept, students:

1. Explain that objects can move with a very wide range of speeds, with some moving very slowly and some moving too quickly for people to see them.
2. Demonstrate that if the forces acting on an object are balanced so that the net force is zero, the object will remain at rest if it is initially at rest or will maintain a constant speed and direction if it is initially moving.
3. Investigate and describe that unbalanced forces cause changes in the speed and/or direction of motion of an object (acceleration).
4. Describe that, for an object moving in a straight line, acceleration, a, is the change in velocity, v, divided by the time, t, that change takes $(a = v \div t)$.
5. Investigate and describe that the greater the net force, F, applied to a body, the greater its acceleration, a. Describe that the greater the mass, m, of an object, the smaller the acceleration produced by a given force.
6. Demonstrate and explain that things on or near Earth are pulled toward Earth's center by the gravitational force that Earth exerts on them.

Grade 2	Grade 3

LIFE SCIENCE

Grade 2

2.6. Broad Concept: Plants and animals have structures that serve different functions in growth, survival, and reproduction. As a basis for understanding this concept, students:

1. Observe and identify the visible, external features of plants and animals and describe how these features help them live in different environments.
2. Observe and cite examples of how some animals and plants change their appearance as the seasons change.

2.7. Broad Concept: Living things depend on one another and their environment for survival. As a basis for understanding this concept, students:

1. Observe and describe how animals may use plants, or even other animals, for shelter and nesting.
2. Explain that food for almost all kinds of animals can be traced through a food web back to green plants.
3. Observe and explain that plants and animals both need to take in water, animals need to take in food, and green plants need light.
4. Recognize and explain that materials in nature, such as grass, twigs, sticks, and leaves, can be recycled and used again, sometimes in different forms, as birds do in making their nests.
5. Observe and describe how the local environment (water, dry land) supports a wide variety of plants and animals, some unique to the Chesapeake Bay.
6. Cite examples of how animals and plants sometimes cause changes in their surroundings. While some of these changes are easy to see, some are very small and hard to recognize, even though they can be very important.
7. Recognize that there is a vast world of living things, called *microorganisms*, too small to see with the unaided eye.
8. Recognize that most microorganisms do not cause disease and many are beneficial (e.g., yeasts, bacteria of the soil).

(continued)

Grade 3

3.5. Broad Concept: Plants and animals can be classified according to the physical characteristics that they share. As a basis for understanding this concept, students:

1. Demonstrate that a great variety of living things can be sorted into groups in many ways using various properties, such as how they look, where they live, and how they act, in order to decide which things belong to which group.
2. Explain that characteristics used for classification depend on the purpose of the grouping.

3.6. Broad Concept: Plants and animals have predictable life cycles. As a basis for understanding this concept, students:

1. Recognize that plants and animals go through predictable life cycles that include birth, growth, development, reproduction, and death.
2. Describe the life cycle of some living things, such as the frog and butterfly, including how they go through striking changes of body shape and function as they go through metamorphosis.
3. Compare and contrast how life cycles vary for different living things.

3.7. Broad Concept: Humans have a variety of mechanisms to stay healthy. As a basis for understanding this concept, students:

1. Explain that people need water, food, air, waste removal, and a particular range of temperatures, just as other animals do, although different animals can tolerate very different ranges of temperature and other features of their surroundings.
2. Explain that eating a variety of healthful foods and getting enough exercise and rest help people stay healthy.
3. Explain that some things people take into their bodies from the environment can hurt them, and give examples of such things.
4. Recognize that food provides energy as well as materials for growth, maintenance, and repair of body parts.
5. Recognize that vitamins and minerals are substances required by the body in small amounts to synthesize essential substances and carry out essential processes
6. Describe how, as a person matures, the amounts and kinds of food and exercise needed by the body change.

Grade 4

LIFE SCIENCE

4.7. Broad Concept: All organisms need energy and matter to live and grow. As a basis for understanding this concept, students:

1. Explain that organisms interact with one another in various ways, such as providing food, pollination, and seed dispersal.
2. Observe and recognize that some source of energy is needed for all organisms to stay alive and grow.
3. Describe how energy derived from the sun is used by green plants to produce chemical energy in the form of sugars (photosynthesis), and this energy is transferred along a food chain from producers (plants) to consumers to decomposers.
4. Observe and explain that most plants produce far more seeds than actually grow into new plants.
5. Describe the structures in plants (leaves, roots, flowers, stem, bark, wood) that are responsible for food production, support, water transport, growth, and protection.
6. Describe the many beneficial attributes of plants, including trees, in improving and sustaining an urban environment.
7. Explain how in all environments, organisms grow, die, and decay, as new organisms are produced by the older ones.
8. Recognize that there are many kinds, and vast numbers, of living things too small to see with the naked eye called microorganisms, but they can be easily seen with the aid of various kinds of microscopes.
9. Explain how dead plants and animals are the food source for many microorganisms.
10. Investigate the Chesapeake Bay watershed and wetlands, and describe how they support a wide variety of plant and animal life that interact with other living and nonliving things.

(continued)

Grade 5

LIFE SCIENCE

5.7. Broad Concept: All living things are composed of cells, from just one to many quadrillions, whose details usually are visible only through a microscope. As a basis for understanding this concept, students:

1. Observe and describe that some organisms consist of a single cell that needs an environment that can supply food, water, sometimes oxygen, and a way to dispose of waste. (Some single-celled organisms are anaerobes.)
2. Observe and explain that some organisms are made of a collection of similar cells that benefit from cooperating.
3. Explain that in complex organisms such as humans, cells can have a very wide variety of forms and perform very different roles (e.g., nerve cells, muscle cells, and fat cells).

5.8. Broad Concept: Many characteristics of an organism are inherited from the parents, but others result from the influence of the environment. As a basis for understanding this concept, students:

1. Explain why there must be a reliable way to transfer information from one generation to the next in order for offspring to resemble their parents.
2. List some characteristics of plants and animals that are fully inherited (e.g., form of flower, shape of leaves) and others that are affected by the climate or environmental conditions (e.g., browning of leaves from too much sun, language spoken).

5.9. Broad Concept: Adaptations in physical structure or behavior may improve an organism's chance for survival. As a basis for understanding this concept, students:

1. Explain that in any particular environment, some kinds of plants and animals survive well, some do not survive as well, and some cannot survive at all.
2. Identify organisms that are not native to the Washington, DC, area and how they undergo changes to increase their chance of survival in the area.
3. Explain how organisms can cause changes in their environment to ensure survival, and these changes may affect the ecosystem (the living and nonliving components of the environment).
4. Explain that organisms fit enough to survive in a particular environment will typically produce offspring fit enough to survive and reproduce in that particular environment. Over time, these inherited characteristics are carried as the predominant forms (e.g., adaptations such as shape of beak, length of neck, shape of teeth).

(continued)

Grade 2	Grade 3
LIFE SCIENCE *(continued)*	
2.8. Broad Concept: Many different types of plants and animals inhabit the Earth. As a basis for understanding this concept, students: 1. Recognize and explain that living things are found almost everywhere in the world in habitats such as the oceans, rivers, rainforests, mountain ranges, arctic tundra, farms, cities, and other environments. Recognize that some habitats are extreme, such as the very deepest parts of the oceans or inside hot springs. 2. Recognize that the numbers and types of living things can vary greatly from place to place. 3. Give examples of the many kinds of organisms that lived in the past that are now extinct (have died out), and explain how these organisms were similar to, and others very different from, organisms that are alive today. 4. Describe that plants and animals in our city have habitats that are essential to their survival. For instance, the schoolyard is a habitat that provides the basic needs for a variety of plants and animals. **2.9. Broad Concept:** Humans have predictable life cycles. As a basis for understanding this concept, students: 1. Recognize and discuss that people are more like one another than they are like other animals. Each type of animal is more like its relatives (family) than it is like the animals of other types (or families). 2. Explain that humans, like all living things, reproduce offspring of their own kind. 3. Observe that and describe how offspring are very much, but never exactly, like their parents and like other offspring of the same parents. 4. Recognize that people have a wide but not unlimited range of external features, such as differences in their size, shape, and color of hair, skin, and eyes.	

Grade 4

LIFE SCIENCE *(continued)*

4.8. Broad Concept: Humans have a variety of mechanisms to combat disease. As a basis for understanding this concept, students:

1. Describe that human beings have body systems very similar to those of other animals, especially other mammals (warm-blooded vertebrate animals that have, in the female, milk-secreting organs for feeding the young).
2. Explain that some diseases are caused by germs (harmful microorganisms such as some bacteria and viruses) and some are not, and those caused by microorganisms may be spread to other people.
3. Explain that disease-bearing microorganisms, called *pathogens,* can enter the body and interfere with the proper function of various parts of the body.
4. Recognize that there are beneficial microorganisms, such as normal intestinal flora.
5. Explain that washing hands with soap and water reduces the number of pathogens that can get into the body or that can be passed on to other people.
6. Describe the body's defenses against pathogens, including tears, saliva, skin, some types of white blood cells, stomach secretions, and an internal system of chemical testing.
7. Explain that a healthy body can fight most invasive pathogens; however, some interfere with the body's defenses.
8. Identify diseases that human beings can usually catch only once because their bodies build up an immunity to them.
9. Recognize that vaccines can prevent some diseases so that people do not catch them at all.

Grade 5

5.9. Broad Concept: Adaptations in physical structure or behavior may improve an organism's chance for survival. As a basis for understanding this concept, students:

5. Explain how changes in an organism's habitat are sometimes beneficial and sometimes harmful, and how changes in the environment (drought, cold) have caused some plants and animals to die, migrate, or become extinct.
6. Explain that many plants and animals can survive harsh environments because of seasonal behaviors (e.g., in winter, some trees shed leaves, some animals hibernate).
7. Recognize that some animal behaviors are instinctive (e.g., turtles burying their eggs, human infants crying when hungry) and others learned (e.g., a wolf's hunting skills, humans' ability to build fires for warmth).
8. Describe well-defined plant behaviors, such as the way seedlings' stems grow toward light and their roots grow downward in response to gravity.
9. Examine the information that fossils provide us about living things that inhabited the Earth in the distant past, and describe how they can be compared both to one another and to living organisms according to their similarities and differences.
10. Recognize and describe how artifacts and preserved remains provide some evidence of the physical characteristics and possible behaviors of human beings and their ancestors who lived long ago.

Grade 6

SCIENTIFIC THINKING AND INQUIRY

6.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Give examples of different ways scientists investigate natural phenomena, and identify processes all scientists use, such as collection of relevant evidence, the use of reasoning, the development and testing of hypotheses, and the use and construction of theory to make sense of the evidence.
2. Plan and conduct simple investigations based on student-developed questions that pertain to the content under study, and write instructions others can follow in carrying out the investigations.
3. Identify dependent and independent variables in those investigations that have controls. And, if no controls are used, explain why.
4. Recognize and explain that hypotheses are valuable even if they turn out not to be true, but that many investigations are not hypothesis driven.
5. Write a report of an investigation that includes the problem to be solved, the methods employed, the tests conducted, the data collected or evidence examined, and the conclusions drawn.
6. Locate information in reference books, back issues of newspapers and magazines, CD-ROMs, and online databases.
7. Draw conclusions based on scientific evidence, and indicate whether further information is needed to support a specific conclusion or to discriminate among several possible conclusions.
8. Record and organize information in simple tables and graphs, and identify relationships they reveal. Use tables and graphs as examples of evidence for explanations when writing essays or writing about lab work, fieldwork, etc. Read simple tables and graphs produced by others, and describe in words what they show.
9. Read a topographic map and a geologic map for evidence provided on the maps.
10. Construct and interpret a simple map.

SCIENCE AND TECHNOLOGY

6.2. Broad Concept: Although each of the human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. Students:

1. Explain that computers have become valuable 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.
2. Explain that technology is essential to science for such purposes as measurement, data collection, graphing and storage, computation, communication and assessment of information, and access to outer space and other remote locations.

Grade 6

THE SOLAR SYSTEM

6.3. Broad Concept: Astronomy and planetary exploration reveal the structure and scale of the solar system. As a basis for understanding this concept, students:

1. Recognize that the solar system consists of the Earth, moon, sun, eight generally recognized other planets that orbit the sun and their satellites, and smaller objects, such as asteroids and comets.
2. Describe how the planets move around the sun in elliptical orbits, and explain how the near coplanarity of the orbits, along with the principle of conservation of momentum, is evidence essential to our understanding of how the solar system was originally formed.
3. Explain that the moon is Earth's only natural satellite, but several of the other planets have natural satellites as well. Understand Earth also has many artificial satellites and that all of these satellites, artificial and natural, are in elliptical orbits around their primaries.
4. Explain that large numbers of chunks of rock and ices (asteroids and comets), much smaller than planets, orbit the sun.
5. Describe, as seen from Earth, how planets change their position relative to the background of stars.
6. Construct models or drawings to explain that the seasons are caused by the tilt of the Earth's axis relative to the plane of its orbit and its revolution around the sun. Explain how this results in uneven heating of the various parts of Earth's surface that varies over the course of the year.
7. Describe that as spring turns to summer at a particular place on Earth, the days grow longer and the sun moves higher in the sky, resulting in more intense heating. In fall and winter, the opposite occurs. Explain how this variation in heating results in the seasons.
8. Recognize and describe the sun as a midsize star located near the edge of a disk-shaped galaxy of stars called the *Milky Way*. Recognize that the universe contains many billions of galaxies, and each galaxy contains many billions of stars.
9. Recognize that the sun-to-Earth distance is such that it takes about eight minutes for light from the sun to reach Earth. Know that the next nearest star is many thousands of times farther from Earth, and its light takes about four years to reach Earth.
10. Explain that gravity is a force of attraction that every mass in the universe exerts on every other mass, and everything on or anywhere near Earth is attracted toward and attracts Earth's center by a gravitational force.
11. Describe that the sun's gravitational attraction holds Earth and the other planets in their orbits, just as the planets' gravitational attraction keeps their moons in orbit around them.

Grade 6

HEAT (THERMAL ENERGY)

6.4. Broad Concept: The transfer of energy through radiation and convection currents affects many phenomena on the Earth's surface. As a basis for understanding this concept, students:

1. Explain the meaning of radiation, convection, and conduction (three mechanisms by which heat is transferred to, through, and out of the Earth's system).
2. Describe that the heat from the sun falls on Earth unevenly because of its spherical shape. Describe that regions close to the equator receive more concentrated solar energy than those closer to the poles.
3. Observe and explain how uneven heating sets up convective cells in the atmosphere and oceans that distribute heat away from the equator.
4. Explain that much of the heat from the sun is absorbed by the land and oceans and then is released into the atmosphere.
5. Recognize that, compared to other substances such as rock and soil, a given mass of water requires a greater input or output of heat energy to change its temperature by a given amount.
6. Describe why ocean temperatures, therefore, tend to vary seasonally less than land areas and why coastal areas tend to have cooler summers and warmer winters than inland areas at a similar distance from the poles.

WEATHER AND CLIMATE

6.5. Broad Concept: Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. As a basis for understanding this concept, students:

1. Explain how different regions receive different amounts of solar heating because of their latitude, clouds, surface water ice, and other variables. Understand that this results in large-scale convective air flow and weather patterns.
2. Recognize and describe that the currents in the air and ocean distribute heat energy.
3. Explain that a great deal of heat energy is absorbed when water evaporates and is released when it condenses. Illustrate that this cycling of water and heat in and out of the atmosphere plays a critical role in climatic patterns.
4. Explain how mountain ranges and other major geographical features affect the climate (e.g., mountains produce rain shadows, land masses interrupt ocean currents).
5. Describe how climates may have changed abruptly in the past as a result of changes in Earth's crust, such as gas and dust from volcanic eruptions or impacts of meteorites, asteroids, and comets from space.
6. Describe how the Earth's atmosphere exerts a pressure that decreases with distance above sea level and, at every point, is the same in all directions.

Grade 6

RESOURCES

6.6. Broad Concept: Sources of materials differ in amounts, distribution, usefulness, and the time required for their formation. As a basis for understanding this concept, students:

1. Explain that fresh water is limited in supply and uneven in distribution; describe why it is essential for life as we know it and also for most human activities, including industrial processes.
2. Recognize that fresh water is a resource that can be depleted or polluted, making it unavailable or unsuitable for humans.
3. Recognize that the Earth's resources for humans, such as fresh water, air, arable soil, and trees, are finite.
4. Explain that the atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally.
5. Investigate and describe how pollutants can affect weather and the atmosphere.
6. Explain that recycling, reuse, and the development of substitutes can reduce the rate of depletion of many minerals.
7. Describe that most rainwater that falls in Washington, DC, will eventually drain into the Chesapeake Bay.
8. Explain the important role of the water cycle within a watershed.

THE ROCK CYCLE

6.7. Broad Concept: Rock materials are continuously recycled in the rock cycle. As a basis for understanding this concept, students:

1. Recognize minerals are naturally occurring crystalline solids with definite chemical compositions, and identify common minerals using a key to their diagnostic properties.
2. Examine and recognize most rocks are made of one or more minerals.
3. Describe how igneous rocks are formed when older rocks are melted and then recrystallized. Understand they may be cooled deep in the Earth or at or near the surface as part of volcanic systems.
4. Explain how metamorphic rocks are formed when older rocks are heated (short of melting) and/or subjected to increased pressure.
5. Describe how sedimentary rocks are formed when older rocks are subjected to weathering into sediments, and those sediments are eroded, transported, deposited, then compacted and cemented.
6. Observe and describe common igneous, metamorphic, and sedimentary rocks, including granite, obsidian, pumice (igneous); slate, schist, marble (metamorphic); sandstone, shale, and limestone (sedimentary).

Grade 6

PLATE TECTONICS

6.8. Broad Concept: Plate tectonics explain important features of the Earth's surface and major geologic events. As the basis for understanding this concept, students:

1. Describe the solid lithosphere of Earth, including both the continents and the ocean basins, and how it is broken into several plates that ride on a denser, hot, and gradually deformable layer in the mantle called the *asthenosphere* (weak sphere).
2. Explain why the Earth has a hot interior.
3. Explain how lithosphere plates move very slowly, pressing against one another in some places, pulling apart in other places, and sliding past one another in others.
4. Compare and contrast oceanic plates and continental plates.
5. Explain the process in which plates push against one another, one of them may be dense enough to sink under the other, a process called *subduction*. Explain that oceanic lithosphere may sink under continental or oceanic lithosphere, but continental lithosphere does not subduct.
6. Describe that subducting plates may partially melt and form magma, which rises to the surface as lava to feed volcanoes and form volcanic mountain chains associated with deep-sea trenches.
7. Explain when plates push against each other and neither is dense enough to subduct (both continental), the plates will crumple and fold and form large mountain chains.
8. Explain that earthquakes are sudden motions along breaks in the crust called *faults*, and volcanoes/fissures are locations where magma reaches the surface as lava.
9. Describe how earthquakes and volcanoes often, but not always, occur along the boundaries between plates.
10. Describe that under the ocean basins, molten rock may well up between separating plates to create new ocean floor.
11. Explain how volcanic activity along the ocean floor may form undersea mountains, which can grow above the ocean's surface to become islands (e.g., the Hawaiian Islands).
12. Explain how physical evidence, such as fossils and surface features of glaciation, supports detailed explanations of how Earth's surface has evolved over geologic time.

Grade 6

EARTH AND LIFE HISTORY

6.9. Broad Concept: Evidence from rocks allows us to understand the evolution of life on Earth. As the basis for understanding this concept, students:

1. Explain how the Earth's surface is built up and broken down by natural processes, including deposition of sediments, rock formation, erosion, and weathering.
2. Describe that the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impact of asteroids.
3. Explain that 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, and other organisms.
4. Explain how thousands of layers of rock confirm the long history of the changing surface of Earth.
5. Illustrate and describe that remains of changing life forms are found in successive layers, although the youngest layers are not always found on top because of the folding, breaking, and uplifting of layers.
6. Recognize that evidence from geologic layers and radioactive dating indicates that Earth is approximately 4.6 billion years old and life on this planet has existed for more than 3 billion years.
7. Observe and explain that fossils provide evidence of how life and environmental conditions have changed.

Grade 7

SCIENTIFIC THINKING AND INQUIRY

7.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Explain that when similar investigations give different results, further studies may help to show whether the differences are significant.
2. Explain why it is important in science to keep honest, clear, and accurate records.
3. Explain why research involving human subjects requires that potential subjects be fully informed about the risks and benefits associated with the research and that they have the right to refuse to participate.
4. Recognize testable hypotheses in investigations that pertain to the content under study, and write instructions that others can follow in carrying out the investigation.
5. Communicate the steps and results from an investigation in written reports and verbal presentations.
6. Incorporate circle charts, bar and line graphs, diagrams, scatter plots, and symbols into writing, such as lab or research reports, to serve as visual displays of evidence for claims and/or conclusions.
7. Recognize whether evidence is consistent with a proposed explanation. Know that different explanations can be given for the same evidence, and that partial evidence may be exploited for reasons other than truth seeking.
8. Question claims based on vague attributes or on authority, such as "leading doctors say," or based on statements made by celebrities or others outside the area of their particular expertise.

SCIENCE AND TECHNOLOGY

7.2. Broad Concept: Although each of the human enterprises of science and technology has a character and history of its own, each is dependent on and reinforces the other. Students:

1. Explain types of technology that are developed and in use, such as in agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing, and communication.
2. Know how technologies having to do with food production, sanitation, and disease prevention have dramatically changed how people live and work, and have resulted in changes in factors that affect the growth of human population.

Grade 7

BIOLOGICAL CLASSIFICATION

7.3. Broad Concept: Similarities are used to classify organisms since they may be used to infer the degree of relatedness among organisms. As a basis for understanding this concept, students:

1. Recognize and describe that a key distinction among organisms is between autotrophs, such as green plants (which use energy from sunlight to make their own food), and heterotrophs, such as animals and fungi (which consume other organisms as food and harvest energy from them).
2. Recognize and describe that biological classifications are based on how organisms are related: Organisms are classified into a hierarchy of groups and subgroups, with species as the most fundamental unit.
3. Recognize and describe the definition of a species as a group or population of organisms closely resembling one another that can mate and breed to produce fertile offspring.
4. Describe how similarities among organisms are found in external and internal anatomical features, including specific characteristics at the cellular level, such as the number of chromosomes.

Grade 7

CELL BIOLOGY

7.4. Broad Concept: All living things are composed of cells, from just one to many quadrillions, whose details usually are visible only through a microscope. As a basis for understanding this concept, students:

1. Investigate and explain that all living things are composed of one or more cells, that cells are organisms' basic units of structure and function, and that cells come only from existing cells (Theodor Schwann's and Matthias Schleiden's cell theory).
2. Describe that the way in which cells function is similar in all living organisms.
3. Explain that in those cells that contain a nucleus (*eukaryotic* plant and animal cells), the nucleus is the main repository for genetic information.
4. Identify cells such as bacteria and blue-green algae as *prokaryotes*. Explain that *prokaryotic* cells differ from *eukaryotic* cells most prominently in that they don't have a membrane-bound nucleus. Know their genetic information is in a threadlike mass, often a very long loop of DNA.
5. Know intracellular bodies with specific functions are called *organelles*. Describe the important organelles among them, such as mitochondria, which liberate energy for the work that cells do, and chloroplasts, which capture sunlight energy for photosynthesis.
6. Describe that plant cells have chloroplasts and a cellulose cell wall and that animal cells do not.
7. Observe and explain that about two-thirds of the mass of a typical cell is accounted for by water and that water gives cells many of their properties.
8. Describe how the most basic chemical functions of organisms, such as extracting energy from food and getting rid of wastes, are started or carried out completely within the cell.
9. Explain how cells in multicellular organisms continually divide to make more cells for growth and repair, and how various organs and tissues function to serve the needs of cells for food, air, and waste removal.
10. Recognize that many organisms are single-celled (e.g., bacteria, yeasts), and explain how this one cell must carry out all of the basic functions of life.
11. Construct a chart and describe that multicellular organisms are organized hierarchically from cells to tissues to organs to organ systems to organisms.

Grade 7

GENETICS

7.5. Broad Concept: Every organism requires information in the form of a set of instructions that specifies its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept, students:

1. Describe that heredity is the passage of information for developing and maintaining the organism's body from one generation to another, and that genes are the basic units of heredity; genes are made of DNA, consisting of very long molecules located in the chromosomes of each cell.
2. Explain how, in asexual reproduction, offspring are an almost identical copy of the mother cell.
3. Explain how, in sexual reproduction, a single reproductive cell from a female (female gamete, egg, or ovum) merges with a specialized cell from a male (male gamete or spermatozoon) to make a fertilized egg (zygote). This carries genetic information from both parental gametes and multiplies to form the complete organism.
4. Recognize and describe that new varieties of cultivated plants, such as corn and apples, and domestic animals, such as dogs and horses, have resulted from selective breeding, over multiple generations, for particular traits.
5. Explain how the use of genetic-engineering techniques can speed the process of creating new varieties and introduce characteristics not easily available by selective breeding, and can make possible more precise modifications involving the manipulation of just one or a few genes.

BIOLOGICAL EVOLUTION

7.6. Broad Concept: Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept, students:

1. Describe that biological variation (phenotype variation) is the raw material on which natural selection operates.
2. Explain how Darwin's research and that of his followers supported a concept of differential survival in terms of fitness (i.e., given the potential exponential increase of offspring and the only linear potential increase of resources, favorable variations that aid individual organisms in their survival in a given environment will confer on those organisms a greater reproductive success for that variety).
3. Describe how biological evolution results primarily from the action of natural selection on the available variation in a population of organisms.
4. Explain how independent lines of evidence drawn from geology, fossils, comparative anatomy, and molecular biology provide the firm basis of evolutionary theory.
5. Using specific examples, explain that extinction of a species is a result of mismatch of adaptation and the environment.

Grade 7

THE HUMAN BODY

7.7. Broad Concept: Human beings have body systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions. As a basis for understanding this concept, students:

1. Describe the specific functions and roles of each major human body system, including the digestive, respiratory, excretory, reproductive, circulatory, nervous, endocrine, musculoskeletal, and immune systems.
2. Explain that human beings have many similarities and differences, and the similarities make it possible for human beings to donate blood and organs to one another.
3. Explain how the amount of food energy (usually measured in calories) that a person requires varies with body weight, age, sex, activity level, and metabolic rate.
4. Research and explain that regular exercise is important to maintain a healthy heart/lung (cardiovascular) system, good muscle tone, and strong bone structure.
5. Identify specific examples of how viruses, bacteria, fungi, and more complex parasites may infect the human body and interfere with normal body functions.
6. Explain how white blood cells engulf invaders or produce antibodies that attack invaders or mark the invaders for killing by other white blood cells. Know that these white cells are part of a larger system that produces "immunity" or the capacity to resist disease due to pathogens.
7. Know that antibodies produced in response to an invader can remain for long periods in the system and can fight off subsequent invaders of the same kind.
8. Recognize that 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, as well as taking steps to keep them safe.
9. Research and explain the contributions of key scientists that have studied infection by disease organisms (germs), including Anton van Leeuwenhoek, Louis Pasteur, Joseph Lister, Robert Koch, Dimitri Iwanowski, and Alexander Fleming.
10. Explain how fundamental changes in health practices have resulted from the establishment of the germ theory of disease.

Grade 7

ECOLOGY

7.8. Broad Concept: Organisms in ecosystems exchange energy and nutrients among themselves and with the physical environment. As a basis for understanding this concept, students:

1. Recognize that in all environments, such as freshwater, marine, forest, desert, grassland, mountain, farms, cities, and others, organisms with similar needs and living strategies compete with one another for resources, including food, space, water, air, and shelter.
2. Describe how two types of organisms may interact in a competitive or cooperative relationship, such as producer/consumer, predator/prey, parasite/hosts, or as symbionts.
3. Illustrate and explain how plants use the energy from light to make simple sugars, and more complex molecules, from carbon dioxide and water through a process called *photosynthesis*. Understand how this produces food that can be used immediately or stored for later use.
4. Create a food web to explain how energy and matter are transferred between producers, primary consumers, and secondary consumers.
5. Describe how organisms that eat plants break down the plant structures to produce the materials and energy that they need to survive, and in turn, other organisms consume them.
6. Explain how dead plants and animals, broken down by other living organisms (especially microorganisms and fungi), contribute to the cycling of matter through the system as a whole.
7. Describe how, as any population of organisms grows, it is held in check by one or more environmental constraints (e.g., depletion of food or nesting sites, increased numbers of predators or parasites).
8. Explain why in urban environments a species (mostly human beings) settles in dense concentrations.
9. Describe that all organisms, including the human species, are part of and depend on two main interconnected global food webs: the ocean food web and the land food web.
10. Recognize that entire species may prosper in spite of the poor survivability or bad fortune of individuals.

Grade 8

SCIENTIFIC THINKING AND INQUIRY

8.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Describe how scientific knowledge is subject to modification and refinement as new information challenges prevailing theories.
2. Test hypotheses that pertain to the content under study.
3. Describe how if more than one variable changes at the same time in an experiment, the outcome of the experiment may not be attributable to a change in any single variable.
4. Explain why accuracy and openness in record keeping and replication are essential for maintaining an investigator's credibility with other scientists and society.
5. Write clear step-by-step instructions (procedural summaries) for conducting investigations.
6. Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.
7. Use tables, charts, and graphs in making arguments and claims in presentations about lab work.
8. Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, or temperatures, and choose appropriate units. Explain how to interpolate on analog scales.
9. Explain why arguments may be invalid if based on very small samples of data, biased samples, or experiments in which there was no control sample.
10. Identify and criticize the reasoning in arguments in which fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, an analogy is not apt, no mention is made of whether the control group is very much like the experimental group, or all members of a group are implied to have nearly identical characteristics that differ from those of other groups.
11. Describe the work of pioneers of physics and cosmology, such as Nicolaus Copernicus, Galileo Galilei, Johannes Kepler, Isaac Newton, Hans Christian Oersted and Andre-Marie Ampère, Dmitry Ivanovich Mendeleyev, Albert Einstein, and Lise Meitner.
12. Apply simple mathematical models to problems (e.g., formulas such as $F = ma$).

Grade 8

STRUCTURE OF MATTER

8.2. Broad Concept: Elements have distinct macroscopic properties and atomic structures. As a basis for understanding this concept, students:

1. Explain that all matter is made up of atoms that are far too small to see directly through an optical microscope.
2. Construct a model of an atom and know the atom is composed of protons, neutrons, and electrons.
3. Using a periodic chart, explain that the atoms of any element are similar to each other, but they are different from atoms of other elements. Know that the atoms of a given isotope are identical to each other.
4. Diagram and describe how atoms may combine (bond) into molecules or into large crystalline arrays.
5. Know that there are more than 100 elements that combine in a multitude of ways to produce compounds that make up all the living and nonliving things in the universe.
6. Describe how elements can be classified, based on similar properties, into categories, including highly reactive metals, less reactive metals, highly reactive nonmetals, less reactive nonmetals, and some almost completely nonreactive (noble) gases.
7. Understand how an ion is an atom or group of atoms (molecule) that has acquired an electric charge by losing or gaining one or more electrons.
8. Describe how the atoms, molecules, or ions comprising an object are in constant individual motion, and explain how their average motional (kinetic) energy determines the temperature of the object, and how the strength of the forces between them determines the state of matter at that temperature.
9. Explain that the melting and boiling temperatures of a substance (element or compound) depend on pressure and are independent of the amount of the sample. (Some materials do not melt and others do not boil because they decompose as the temperature is raised; other materials do not have a sharp melting point because they are not homogeneous.)
10. Describe the contributions of the scientists involved with the development of current atomic theory, including John Dalton, Marie and Pierre Curie, Joseph John Thomson, Albert Einstein, Max Planck, Ernest Rutherford, Niels Bohr, and Erwin Schroedinger.

Grade 8

REACTIONS

8.3. Broad Concept: Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept, students:

1. Discover and explain how elements and compounds (reactants) react with each other to form products with different properties.
2. Describe Antoine Lavoisier's work, including 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 (Law of Conservation of Matter).
3. Explain how the idea of atoms, as proposed by John Dalton, explains the conservation of matter: In chemical reactions, the number of atoms stays the same no matter how they are arranged, and the mass of atoms does not change significantly in chemical reactions, so their total mass stays the same.
4. Investigate and explain how during endothermic chemical reactions heat energy is absorbed from the surroundings, and in exothermic reactions heat energy is released to the surroundings.
5. Investigate and explain that reactions occur at different rates, slow to fast, and that reaction rates can be changed by changing the concentration of reactants, the temperature, the surface areas of solids, and by using a catalyst.
6. Recognize that solutions can be acidic, basic, or neutral, depending on the concentration of hydrogen ions in the solution. Understand that because this concentration can vary over a very large range, the logarithmic pH scale is used to describe how acidic or basic a solution is (each increase of one in the pH scale is an increase of 10 times in concentration).
7. Recognize that indicators of chemical changes include temperature change, the production of a gas, the production of a precipitate, or a color change.

DENSITY AND BUOYANCY

8.4. Broad Concept: All objects experience a buoyant force when immersed in a fluid. As a basis for understanding this concept, students:

1. Demonstrate that the mass of an object is a measure of the quantity of matter it contains (measured in kg or g), and that its weight (measured in N) is the magnitude of the gravitational force exerted between Earth and that much mass.
2. Know that density is mass per unit volume.
3. Investigate and explain that equal volumes of different substances usually have different masses and, therefore, different densities.
4. Determine and explain that the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid the object has displaced; this principle can be used to predict whether an object will float or sink in a given fluid.
5. Determine the density of substances (regular and irregular solids, and liquids) from direct measurements of mass and volume, or of volume by water displacement.

Grade 8

CONSERVATION OF ENERGY

8.5. Broad Concept: Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept, students:

1. Explain how energy is the ability to do work and is measured in joules (J).
2. Describe kinetic energy as the energy of motion (e.g., a rolling ball), and potential energy as the energy of position or configuration (e.g., a raised object or a compressed spring).
3. Investigate and explain how kinetic energy can be transformed into potential energy, and vice versa (e.g., in a bouncing ball).
4. Recognize and describe that energy is a property of many systems and can take the forms of mechanical motion, gravitational energy, the energy of electrostatic and magnetostatic fields, sound, heat, and light (electromagnetic field energy).
5. Describe that energy may be stored as potential energy in many ways, including chemical bonds and in the nucleus of atoms.
6. Explain that the sun emits energy in the form of light and other radiation, and only a tiny fraction of that energy is intercepted by the Earth.
7. Know that the sun's radiation consists of a wide range of wavelengths, mainly visible light, infrared, and ultraviolet radiation.
8. Investigate and explain that heat energy is a common product of an energy transformation, such as in biological growth, the operation of machines, the operation of a lightbulb, and the motion of people.
9. Explain how electrical energy can be generated using a variety of energy sources and can be transformed into almost any other form of energy, such as mechanical motion, light, sound, or heat.
10. Investigate and explain that in processes at the scale of atomic size or greater, energy cannot be created or destroyed but only changed from one form into another.
11. Compare and contrast how heat energy can be transferred through radiation, convection, or conduction.

Grade 8

ELECTRICITY AND MAGNETISM

8.6. Broad Concept: Electricity and magnetism are related phenomena that have many useful applications in everyday life. As a basis for understanding this concept, students:

1. Investigate and explain that an object can be electrically charged either positively or negatively; objects with like charges repel each other, and objects with unlike charges attract each other.
2. Explain that when an electric current flows why there is always a magnetic field associated with it.
3. Describe the role that electromagnets play in electric motors, electric generators, and simple devices such as doorbells and earphones.
4. Explain how electrical circuits provide a means of transferring electrical energy from sources such as generators to devices in which heat, light, sound, and chemical changes are produced.
5. Know that power is energy per unit of time, expressed in watts, W, and 1 W = 1 J/s. Explain that devices are rated according to their power capacity or consumption.

FORCES

8.7. Broad Concept: When an object is subject to two or more forces at once, the effective force is the cumulative effect of all the forces. As a basis for understanding this concept, students:

1. Recognize that a force has both magnitude and direction.
2. Observe and explain that when the forces on an object are balanced (equal and opposite forces that add up to zero), the motion of the object does not change.
3. Explain why an unbalanced force acting on an object changes the object's speed or direction of motion or both.
4. Explain that every object exerts an attractive gravitational force on every other object.
5. Know that the greater the mass of an object, the more force is needed to change its motion.
6. Explain that if the net force acting on an object always acts toward the same center as the object moves, the object's path is a curve about the force center. (Motion in a circular orbit is the simplest example of this concept.)
7. Plot and interpret distance versus time graphs for constant speed.

Grade 8

WAVES

8.8. Broad Concept: Waves have characteristic properties that are common to all types of wave. As a basis for understanding this concept, students:

1. Observe and explain how waves carry energy from one place to another.
2. Explain how a mechanical wave is a disturbance that propagates through a medium.
3. Explain how electromagnetic waves differ from mechanical waves in that they do not need a medium for propagation; nevertheless, they can be described by many of the same quantities: amplitude, wavelength, frequency (or period), and wave speed.
4. Investigate and explain how sound in a fluid (e.g., air) is a longitudinal wave whose speed depends on the properties of the fluid in which it propagates.
5. Investigate and explain how light waves, sound waves, and other waves move at different speeds in different materials.
6. Demonstrate that vibrations in materials set up wave disturbances, such as sound and earthquake waves, which spread away from the source.
7. Recognize that human eyes respond to a narrow range of wavelengths of the electromagnetic spectrum (red through violet) called *visible light.*
8. Summarize how something can be "seen" when light waves emitted or reflected by an object enter the eye, just as something can be "heard" when sound waves from an object enter the ear.
9. Explain that waves obey the superposition principle: Many waves can pass through the same point at once, and the wave amplitude at that point is the sum of the amplitudes of the individual waves.

High School Earth Science

SCIENTIFIC INVESTIGATION AND INQUIRY

ES.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error (random and systematic error) inherent in an experiment.
9. Identify discrepant results and identify possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving proportionalities, linear relations, quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Recognize the implications of statistical variability in experiments, and explain the need for controls in experiments.
15. Observe natural phenomena, and analyze their location, sequence, or time intervals (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
16. Read a topographic map and a geologic map for information provided on the maps.
17. Construct and interpret a simple scale map and topographic cross-section.
18. Describe the contributions of key scientists throughout history, including Claudius Ptolemy, Nicholas Copernicus, Johannes Kepler, Tycho Brahe, Galileo Galilei, Nicholas Steno, Sir Charles Lyell, James Hutton, Henrietta Leavitt, Alfred Wegener, and Edwin Powell Hubble.

High School Earth Science

THE UNIVERSE

ES.2. Broad Concept: Galaxies are made of billions of stars and form most of the visible mass of the universe. As a basis for understanding this concept, students:

1. Recognize that the universe contains many billions of galaxies, and each galaxy contains many billions of stars.
2. Describe various instrumentation used to study deep space and the solar system (e.g., telescopes that record in various parts of the electromagnetic spectrum, including visible, infrared, and radio, refracting or reflecting telescopes, and spectrophotometer).
3. Describe Hubble's law, and understand the big bang theory and the evidence that supports it (microwave background radiation, relativistic Doppler effect).
4. Explain the basics of the fusion processes that are the source of energy of stars.
5. Explain that the mass of a star and the balance between collapse and fusion determine the color, brightness, lifetime, and evolution of a star.
6. Analyze the life histories of stars and different types of stars found on the Hertzsprung-Russell diagram, including the three outcomes of stellar evolution based on mass (black hole, neutron star, white dwarf).
7. Describe how elements with an atomic number greater than helium have been formed by nuclear fusion processes in stars, supernova explosions, or exposure to cosmic rays.
8. Explain that the redshift from distant galaxies and the cosmic microwave background radiation provide evidence for the big bang model that the universe has been expanding for 13 to 14 billion years.
9. Construct a model and explain the relationships among planetary systems, stars, multiple-star systems, star clusters, galaxies, and galactic groups in the universe.

THE SOLAR SYSTEM

ES.3. Broad Concept: Our solar system is composed of a star, planets, moons, asteroids, comets, and residual material left from the evolution of the solar system over time. The sun is one of billions of stars residing in one of billions of galaxies in a universe that has been changing and evolving over vast amounts of time. As a basis for understanding this concept, students:

1. Describe the location of the solar system in an outer edge of the disc-shaped Milky Way galaxy, which spans 100,000 light-years.
2. Compare and contrast the differences in size, temperature, and age of our sun and other stars.
3. Understand and describe the nebular theory concerning the formation of solar systems, including the roles of planetesimals and protoplanets.
4. Observe and describe the characteristics and motions of the various kinds of objects in our solar system, including planets, satellites, comets, and asteroids, and the influence of gravity and inertia on these motions.
5. Explain how Kepler's laws predict the orbits of the planets.

High School Earth Science

THE EARTH SYSTEM

ES.4. Broad Concept: Interactions among the solid Earth, hydrosphere, and atmosphere have resulted in ongoing evolution of the earth system over geologic time. As a basis for understanding this concept, students:

1. Examine and describe the structure, composition, and function of Earth's atmosphere, including the role of living organisms in the cycling of atmospheric gases.
2. Investigate and describe the composition of the Earth's atmosphere as it has evolved over geologic time (outgassing, origin of atmospheric oxygen, variations in carbon dioxide concentration).
3. Describe the main agents of erosion: water, waves, wind, ice, plants, and gravity.
4. Explain the effects on climate of latitude, elevation, and topography, as well as proximity to large bodies of water and cold or warm ocean currents.
5. Explain the possible mechanisms and effects of atmospheric changes brought on by things such as acid rain, smoke, volcanic dust, greenhouse gases, and ozone depletion.
6. Determine the origins, life cycles, behavior, and prediction of weather systems.
7. Investigate and identify the causes and effects of severe weather.
8. Explain special properties of water (e.g., high specific and latent heats) and the influence of large bodies of water and the water cycle on heat transport and, therefore, weather and climate.
9. Describe the development and dynamics of climatic changes over time corresponding to changes in the Earth's geography (plate tectonics/continental drift), orbital parameters (the Milankovitch cycles), and atmospheric composition.
10. Describe the nitrogen and carbon cycles and their roles in the improvement of soils for agriculture.
11. Explain that the oceans store carbon dioxide mostly as dissolved HCO_{3-} and $CaCO_3$ as precipitate or biogenic carbonate deposits.
12. Use weather maps and other tools to forecast weather conditions.
13. Use computer models to predict the effects of increasing greenhouse gases on climate for the planet as a whole and for specific regions.
14. Read and interpret space weather data (solar flares, geomagnetic storms, solar wind).

High School Earth Science

THE HYDROLOGIC CYCLE

ES.5. Broad Concept: Water is continually being recycled by the hydrologic cycle through the watersheds, oceans, and the atmosphere by processes such as evaporation, condensation, precipitation runoff, and infiltration. As a basis for understanding this concept, students:

1. Explain how water flows into and through a watershed (e.g., properly use terms precipitation, aquifers, wells, porosity, permeability, water table, capillary water, and runoff).
2. Describe the processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff, and groundwater percolation, infiltration, and transpiration.
3. Identify and explain the mechanisms that cause and modify the production of tides, such as the gravitational attraction of the moon, the sun, and coastal topography.

THE ROCK CYCLE

ES.6. Broad Concept: Rocks and minerals are continually being modified within the rock cycle. As a basis for understanding this concept, students:

1. Differentiate among the processes of weathering, erosion, transportation of materials, deposition, and soil formation.
2. Illustrate the various processes and rock types that are involved in the rock cycle, and describe how the total amount of material stays the same throughout formation, weathering, sedimentation, and reformation.
3. Explain the absolute and relative dating methods used to measure geologic time.
4. Recognize and explain geologic evidence, including fossils and radioactive dating, that indicates the age of the Earth.
5. Trace the evolution of the solid Earth in terms of the major geologic eras.

PLATE TECTONICS

ES.7. Broad Concept: Plate tectonics operating over geologic time has altered the features of land, sea, and mountains on the Earth's surface. As the basis for understanding this concept, students:

1. Explain the work of Alfred Wegener, including reintroduction of the idea of moving continents, and the skepticism with which his theories were first received and why.
2. Analyze the evidence that supports the hypothesis of movement of the plates (from paleomagnetism, paleontology, paleoclimate, and the continuity of geological structure and stratigraphy across ocean basins).
3. Trace the development of a lithospheric plate from its growing margin at a divergent boundary (mid-ocean ridge) to its destructive margin at a convergent boundary (subduction zone).
4. Explain the relationship between convection currents and the motion of the lithospheric plates.
5. Explain why, how, and where earthquakes occur, how they are located and measured, and the ways that they can cause damage (directly by shaking and secondarily by fire, tsunami, landsliding, or liquefaction).
6. Observe and explain how rivers and streams are dynamic systems that erode and transport sediment, change their course, and flood their banks in natural and recurring patterns.

High School Biology

SCIENTIFIC INVESTIGATION AND INQUIRY

B.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis, and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error (random and systematic) inherent in an experiment.
9. Identify discrepant results and possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving linear and quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of rocks and succession of species in an ecosystem).
15. Explain that science discoveries can have both positive and negative implications, involve different decisions regarding ethics and allocation of resources (e.g., organ transplants, stem cell research, forest management, and land use).
16. Recognize and deal with the implications of statistical variability in experiments, and explain the need for controls in experiments.

High School Biology

CHEMISTRY OF LIVING THINGS

B.2. Broad Concept: Living things are made of atoms bonded together to form molecules, some of the most important of which are large and contain carbon (i.e., "organic" compounds). As a basis for understanding this concept, students:

1. Describe basic atomic structure using simplified Bohr diagrams to understand the basis of chemical bonding in covalent and ionic bonds.
2. Describe the structure and unique properties of water and its importance to living things.
3. Describe the central role of carbon in the chemistry of living things because of its ability to combine in many ways with itself and other elements.
4. Know that living things are made of molecules largely consisting of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
5. Know that living things have many different kinds of molecules, including small ones such as water; midsize ones such as sugars, amino acids, and nucleotides; and large ones such as starches, proteins, and DNA.
6. Observe and explain the role of enzymatic catalysis in biochemical processes.
7. Explain the hierarchical organization of living things from least complex to most complex (subatomic, atomic, molecular, cellular, tissue, organs, organ system, organism, population, community, ecosystem, and biosphere).

CELL BIOLOGY

B.3. Broad Concept: All living things are composed of cells. All the fundamental life processes of a cell are either chemical reactions or molecular interactions. As a basis for understanding this concept, students:

1. Compare and contrast the general anatomy and constituents of prokaryotic and eukaryotic cells and their distinguishing features: Prokaryotic cells do not have a nucleus, and eukaryotic cells do. Know that prokaryotic organisms are classified in the Eubacteria and Archaebacteria Kingdoms and that organisms in the other four kingdoms have eukaryotic cells.
2. Understand the function of cellular organelles and how the organelles work together in cellular activities (e.g., enzyme secretion from the pancreas).
3. Observe and describe that within the cell are specialized parts for the transport of materials, energy capture and release, waste disposal, and motion of the whole cell or of its parts.
4. Describe the organelles that plant and animal cells have in common (e.g., ribosomes, golgi bodies, endoplasmic reticulum) and some that differ (e.g., only plant cells have chloroplasts and cell walls).
5. Demonstrate and explain that cell membranes act as highly selective permeable barriers to penetration of substances by diffusion or active transport.
6. Explain that some structures in the eukaryotic cell, such as mitochondria, and in plants, such as chloroplasts, have apparently evolved by endosymbiosis (one organism living inside another, to the advantage of both) with early prokaryotes.

(continued)

High School Biology

CELL BIOLOGY *(continued)*

B.3. Broad Concept: All living things are composed of cells. All the fundamental life processes of a cell are either chemical reactions or molecular interactions. As a basis for understanding this concept, students:

7. Describe that the work of the cell is carried out by structures made up of many different types of large (macro) molecules that it assembles, such as proteins, carbohydrates, lipids, and nucleic acids.
8. Demonstrate that most cells function best within a narrow range of temperature and pH; extreme changes usually harm cells by modifying the structure of their macromolecules and, therefore, some of their functions.
9. Explain that a complex network of proteins provides organization and shape to cells.
10. Explain that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division.
11. Describe that all growth and development of organisms is a consequence of an increase in cell number, size, and/or products.
12. Explain how cell activity in a multicellular plant or animal can be affected by molecules from other parts of the organism.
13. Explain why communication and/or interaction are required between cells to coordinate their diverse activities.
14. Recognize and describe that cellular respiration is important for the production of adenosine triphosphate (ATP), which is the basic energy source for cell metabolism.
15. Differentiate between the functions of mitosis and meiosis. Mitosis is a process by which a cell divides into each of two daughter cells, each of which has the same number of chromosomes as the original cell. Meiosis is a process of cell division in organisms that reproduce sexually, during which the nucleus divides eventually into four nuclei, each of which contains half the usual number of chromosomes.
16. Explain how zygotes are produced in the fertilization process.
17. Describe that all organisms begin their life cycles as a single cell, and in multicellular organisms the products of mitosis of the original zygote form the embryonic body.

GENETICS

B.4. Broad Concept: Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept, students:

1. Research and explain the genetic basis for Gregor Mendel's laws of segregation and independent assortment.
2. Describe how the discovery of the structure of DNA by James D. Watson and Francis Crick made it possible to interpret the genetic code on the basis of a nucleotide sequence. Know the important contribution of Rosalind Franklin's data to this discovery (i.e., the careful X-ray crystallography on DNA that provided Watson and Crick the clue they needed to build the correct structure).
3. Explain how hereditary information is passed from parents to offspring in the form of "genes," which are long stretches of DNA consisting of sequences of nucleotides. Explain that in eukaryotes, the genes are contained in chromosomes, which are bodies made up of DNA and various proteins.

(continued)

GENETICS *(continued)*

B.4. Broad Concept: Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept, students:

4. Know every species has its own characteristic DNA sequence.
5. Explain the flow of information is usually from DNA to RNA, and then to protein.
6. Explain how the genetic information in DNA molecules provides the basic form of instructions for assembling protein molecules and that this mechanism is the same for all life forms.
7. Understand and describe how inserting, deleting, or substituting short stretches of DNA alters a gene. Recognize that changes (mutations) in the DNA sequence in or near a specific gene may (or may not) affect the sequence of amino acids in the encoded protein or the expression of the gene.
8. Explain the mechanisms of genetic mutations and chromosomal recombinations, and when and how they are passed on to offspring.
9. Understand and explain that specialization of cells is almost always due to different patterns of gene expression, rather than differences in the genes themselves.
10. Explain how the sorting and recombination of genes in sexual reproduction result in a vast variety of potential allele combinations in the offspring of any two parents.
11. Explain that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.
12. Explain how the actions of genes, patterns of inheritance, and the reproduction of cells and organisms account for the continuity of life.
13. Investigate and describe how a biological classification system that implies degrees of kinship between organisms or species can be deduced from the similarity of their nucleotide (DNA) or amino acids (protein) sequences. Know that such systems often match the completely independent classification systems based on anatomical similarities.

BIOLOGICAL EVOLUTION

B.5. Broad Concept: Evolution and biodiversity are the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept, students:

1. Investigate and explain how molecular evidence reinforces and confirms the fossil, anatomical, behavioral, and embryological evidence for evolution, and provides additional detail about the sequence in which various lines of descent branched off from one another.
2. Explain how a large diversity of species increases the chance that at least some living things will survive in the face of large or even catastrophic changes in the environment.
3. Research and explain how natural selection provides a mechanism for evolution and leads to organisms that are optimally suited for survival in particular environments.
4. Explain that biological diversity, episodic speciation, and mass extinction are depicted in the fossil record, comparative anatomy, and other evidence.

(continued)

High School Biology

BIOLOGICAL EVOLUTION *(continued)*

B.5. Broad Concept: Evolution and biodiversity are the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept, students:

5. Describe how life on Earth is thought to have begun as one or a few simple one-celled organisms about 3.5 billion years ago, and that during the first 2 billion years, only single-cell microorganisms existed. Know that, once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms could evolve.
6. Explain that prior to the theory first offered by Charles Darwin and Alfred Wallace, the universal belief was that all known species had been created *de novo* at about the same time and had remained unchanged.
7. Research and explain that Darwin argued that only biologically inherited characteristics could be passed on to offspring, and that some of these characteristics would be different from the average and advantageous in surviving and reproducing; over generations, accumulation of these inherited advantages would lead to a new species.
8. Explain Gregor Mendel's identification of what we now call "genes," how they are sorted in reproduction, and how this led to an understanding of the mechanism of heredity. Understand how the integration of his concept of heredity and the concept of natural selection has led to the modern model of speciation and evolution.
9. Explain how biological evolution is also supported by the discovery that the genetic code found in DNA is the same for almost all organisms.
10. Explain that evolution builds on what already exists, so the more variety there is, the more there can be in the future.

PLANT BIOLOGY

B.6. Broad Concept: Plants are essential to animal life on Earth. As a basis for understanding this concept, students:

1. Describe the structure and function of roots, leaves, flowers, and stems of plants.
2. Identify the roles of plants in the ecosystem: Plants make food and oxygen, provide habitats for animals, make and preserve soil, and provide thousands of useful products for people (e.g., energy, medicines, paper, resins).
3. Know that about 250,000 species of flowering plants have been identified.
4. Explain the photosynthesis process: Plants make simple sugars and other molecules in their leaves, and chlorophyll found in the leaves can make the food and nutrients that the plant can use from carbon dioxide, water, nutrients, and energy from sunlight.
5. Explain that during the process of photosynthesis, plants release oxygen into the air.
6. Describe that plants have broad patterns of behavior that have evolved to ensure reproductive success, including co-evolution with animals that distribute a plant's pollen and seeds.
7. Recognize that plants have a greater problem with "unpredictable environments" because they cannot seek shelter as many animals can.

High School Biology

THE MAMMALIAN BODY

B.7. Broad Concept: As a result of the coordinated structures and functions of organ systems, the internal environment of the mammalian body remains relatively stable (homeostatic), despite changes in the outside environment. As a basis for understanding this concept, students:

1. Explain the major systems of the mammalian body (digestive, respiratory, reproductive, circulatory, excretory, nervous, endocrine, integumentary, immune, skeletal, and muscular) and how they interact with each other.
2. Analyze the complementary activity of major body systems, such as how the respiratory and circulatory systems provide cells with oxygen and nutrients, and remove toxic waste products such as carbon dioxide.
3. Explain how the nervous system mediates communication between different parts of the body and the environment.
4. Describe that the nervous and endocrine systems maintain overall regulation of optimal conditions within the body by chemical communication.
5. Investigate and cite specific examples of how the mammalian immune system is designed to protect against microscopic organisms and foreign (or nonself) substances from outside the body and against some aberrant (e.g., cancer) cells that arise within.

ECOSYSTEMS

B.8. Broad Concept: Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept, students:

1. Illustrate and describe the cycles of biotic and abiotic factors (matter, nutrients, energy) in an ecosystem.
2. Describe how factors in an ecosystem, such as the availability of energy, water, oxygen, and minerals, and the ability to recycle the residue of dead organic materials, cause fluctuations in population sizes.
3. Explore and explain how changes in population size have an impact on the ecological balance of a community and how to analyze the effects.
4. Describe how the physical or chemical environment may influence the rate, extent, and nature of the way organisms develop within ecosystems.
5. Describe how ecosystems can be reasonably stable over hundreds or thousands of years.
6. Explain that ecosystems tend to have cyclic fluctuations around a state of rough equilibrium, and change results from shifts in climate, natural causes, human activity, or when a new species or non-native species appears.
7. Explain how layers of energy-rich organic material, mostly of plant origin, have been gradually turned into great coal beds and oil pools by the pressure of the overlying Earth and its internal heat.
8. Using ecological studies, explain distinct relationships and differences between urban environments and other environmental systems.
9. Investigate and describe how point and nonpoint source pollution can affect the health of a bay's watershed and wetlands.
10. Assess the method for monitoring and safeguarding water quality, including local waterways such as the Anacostia and Potomac rivers, and know that macroinvertebrates can be early warning signs of decreasing water quality.

High School Chemistry

SCIENTIFIC INVESTIGATION AND INQUIRY

C.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis, and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error inherent in an experiment.
9. Identify discrepant results and possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving linear and quadratic equations, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Recognize and deal with the implications of statistical variability in experiments, and explain the need for controls in experiments.

High School Chemistry

PROPERTIES OF MATTER

C.2. Broad Concept: Physical and chemical properties can be used to classify and describe matter. As a basis for understanding this concept, students:

1. Investigate and classify properties of matter, including density, melting point, boiling point, and solubility.
2. Determine the definitions of and use properties such as mass, volume, temperature, density, melting point, boiling point, conductivity, solubility, and color to differentiate between types of matter.
3. Know the concept of a mole in terms of number of particles, mass, and the volume of an ideal gas at specified conditions of temperature and pressure.
4. Distinguish between the three familiar states of matter (solid, liquid, and gas) in terms of energy, particle motion, and phase transitions, and describe what a plasma is.
5. Infer and explain that physical properties of substances, such as melting points, boiling points, and solubility, are due to the strength of their various types of bonds (interatomic, intermolecular, or ionic).
6. Write equations that describe chemical changes and reactions.
7. Classify substances as metal or nonmetal, ionic or molecular, acid or base, and organic or inorganic, using formulas and laboratory investigations.

ACIDS AND BASES

C.3. Broad Concept: Acids, bases, and salts are three classes of compounds that form ions in water solutions. As a basis for understanding this concept, students:

1. Explain that strong acids (and bases) fully dissociate and that weak acids (and bases) partially dissociate.
2. Define pH as the negative of the logarithm of the hydrogen (hydronium) ion concentration, and calculate pH from concentration data.
3. Illustrate and explain the pH scale to characterize acid and base solutions: Neutral solutions have pH 7, acids are less than 7, and bases are greater than 7.
4. Describe the observable properties of acids, bases, and salt solutions.
5. Explain the Arrhenius theory of acids and bases: An acid donates hydrogen ions (hydronium) and a base donates hydroxide ions to a water solution.
6. Explain the Brønsted-Lowry theory of acids and bases: An acid is a hydrogen ion (proton) donor, and a base is a hydrogen ion (proton) acceptor.

High School Chemistry

THE ATOM

C.4. Broad Concept: An atom is a discrete unit. The atomic model can help us to understand the interaction of elements and compounds observed on a macroscopic scale. As a basis for understanding this concept, students:

1. Detail the development of atomic theory from the ancient Greeks to the present (Democritus, Dalton, Rutherford, Bohr, quantum theory).
2. Explain Dalton's atomic theory in terms of the laws of conservation of matter, definite composition, and multiple proportions.
3. Demonstrate and explain how chemical properties depend almost entirely on the configuration of the outer electron shell, which in turn depends on the proton number.
4. Explain the historical importance of the Bohr model of the atom.
5. Construct a diagram and describe the number and arrangement of subatomic particles within an atom or ion.
6. Describe that spectral lines are the result of transitions of electrons between energy levels.
7. Describe that spectral lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's formula ($E = h\nu$) in calculations.

C.5. Broad Concept: Periodicity of physical and chemical properties relates to atomic structure and led to the development of the periodic table. As a basis for understanding this concept, students:

1. Relate an element's position on the periodic table to its atomic number (number of protons).
2. Relate the position of an element in the periodic table and its reactivity with other elements to its quantum electron configuration.
3. Use the periodic table to compare trends in periodic properties, such as ionization energy, electronegativity, electron affinity, and relative size of atoms and ions.
4. Use an element's location in the periodic table to determine its number of valence electrons, and predict what stable ion or ions an element is likely to form in reacting with other specified elements.

High School Chemistry

NUCLEAR PROCESSES

C.6. Broad Concept: Nuclear processes are those in which an atomic nucleus changes; they include radioactive decay of naturally occurring and man-made isotopes and nuclear fission and fusion processes. As a basis for understanding this concept, students:

1. Explain how protons and neutrons in the nucleus are held together by strong nuclear forces that just balance the electromagnetic repulsion between the protons in a stable nucleus.
2. Describe that the energy release per gram of material is roughly six orders of magnitude larger in nuclear fusion or fission reactions than in chemical reactions. Know that a small decrease in mass produces a large amount of energy in nuclear reactions as well as in chemical reactions, but the mass change in chemical reactions is negligibly small.
3. Know that many naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.
4. Describe the process of radioactive decay as the spontaneous breakdown of certain unstable (radioactive) elements into new elements (radioactive or not) through the spontaneous emission by the nucleus of alpha or beta particles, or gamma radiation.
5. Predict and explain that the alpha, beta, and gamma radiation produced in radioactive decay produce different amounts and kinds of damage in matter and have different ranges of penetration.
6. Explain that the half-life of a radioactive element is the time it takes for the radioactive element to lose one-half its radioactivity, and calculate the amount of radioactive substance remaining after an integral number of half-lives have passed.

High School Chemistry

CHEMICAL BONDS

C.7. Broad Concept: The enormous variety of physical, chemical, and biological properties of matter depends upon the ability of atoms to form bonds. This ability results from the electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept, students:

1. Explain how Arrhenius' discovery of the nature of ionic solutions contributed to the understanding of a broad class of chemical reactions.
2. Predict and explain how atoms combine to form molecules by sharing electrons to form covalent or metallic bonds, or by transferring electrons to form ionic bonds.
3. Recognize names and chemical formulas for simple molecular compounds (such as N_2O_3), ionic compounds, including those with polyatomic ions, simple organic compounds, and acids, including oxyacids (such as $HClO_4$).
4. Explain the hydrogen bond as an intermolecular attraction that can exist between a hydrogen atom on one molecule and an electronegative element like fluorine, oxygen, or nitrogen on another molecule.
5. Demonstrate and explain that chemical bonds between identical or similar atoms in molecules such as H_2, O_2, CH_4, NH_3, C_2H_4, N_2, H_2O and many large biological molecules tend to be covalent; some of these molecules may have hydrogen bonds between them. In addition, molecules have other forms of intermolecular bonds, such as London dispersion forces and/or dipole bonding.
6. Explain that in solids, particles can only vibrate around fixed positions, but in liquids, they can slide randomly past one another, and in gases, they are free to move between collisions with one another.
7. Draw Lewis dot structures for atoms, molecules, and polyatomic ions.
8. Predict the geometry and polarity of simple molecules, and explain how these influence the intermolecular attraction between molecules.
9. Predict the chemical formulas based on the number of valence electrons.
10. Predict the formulas of ionic compounds based on the charges on the ions.
11. Identify solids held together by London dispersion forces or hydrogen bonding.

High School Chemistry

CONSERVATION OF MATTER

C.8. Broad Concept: The microscopic conservation of atoms in chemical reactions implies the macroscopic principle of conservation of matter and the ability to calculate the mass of products and reactants. As a basis for understanding this concept, students:

1. Name substances and describe their reactions based on Lavoisier's system and explain how this system contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity.
2. Describe chemical reactions by writing balanced chemical equations and balancing redox equations.
3. Classify reactions of various types such as single and double replacement, synthesis, decomposition, and acid/base neutralization.
4. Calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic or molecular masses).
5. Calculate the percent of composition by mass of a compound when given the formula.
6. Determine molar mass of a molecule given its chemical formula and a table of atomic masses.
7. Convert the mass of a molecular substance to moles, number of particles, or volume of gas at standard temperature and pressure.
8. Use Avogadro's law to make mass-volume calculations for simple chemical reactions.
9. Define oxidation and reduction and oxidizing and reducing agents.
10. Use changes in oxidation states to recognize electron transfer reactions, and identify the substance(s) losing and gaining electrons in an electron transfer reaction.
11. Describe the effect of changes in reactant concentration, changes in temperature, the surface area of solids, and the presence of catalysts on reaction rates.

GASES AND THEIR PROPERTIES

C.9. Broad Concept: The behavior of gases can be explained by the kinetic molecular theory. As a basis for understanding this concept, students:

1. Explain the kinetic molecular theory and use it to explain changes in gas volumes, pressure, and temperature.
2. Apply the relationship between pressure and volume at constant temperature (Boyle's law, pV = constant at constant temperature and number of moles), and between volume and temperature (Charles' law or Gay-Lussac's law, V/T = constant at constant pressure and number of moles) and the relationship between pressure and temperature that follows from them.
3. Solve problems using the Ideal Gas law, $pV = nRT$, and the combined gas law, $p_1V_1/T_1 = p_2V_2/T_2$.
4. Apply Dalton's Law of Partial Pressures.
5. Apply Graham's Law of Diffusion.

High School Chemistry

CHEMICAL EQUILIBRIUM

C.10. Broad Concept: Chemical equilibrium is a dynamic process at the molecular level. As a basis for understanding this concept, students:

1. Explain how equilibrium is established when forward- and reverse-reaction rates are equal.
2. Describe the factors that affect the rate of a chemical reaction (temperature, concentration) and the factors that can cause a shift in equilibrium (concentration, pressure, volume, temperature).
3. Explain why rates of reaction are dependent on the frequency of collisions, energy of collisions, and orientation of colliding molecules.
4. Observe and describe the role of activation energy and catalysts in a chemical reaction.
5. Use LeChâtelier's principle to predict the effect of changes in concentration, temperature, volume, and pressure on a system at equilibrium.
6. Write the equilibrium expression for a given reaction and calculate the equilibrium constant for the reaction from given concentration data.

SOLUTIONS

C.11. Broad Concept: Solutions are mixtures of two or more substances that are homogeneous on the molecular level. As a basis for understanding this concept, students:

1. Define *solute* and *solvent*.
2. Predict and describe how the temperature, concentration, pressure and surface area of solids affect the dissolving process.
3. Explain that, for a closed system at constant temperature and pressure, a solid in contact with its saturated solution may reach dynamic equilibrium when the rate of solid dissolving equals the rate of solid precipitating.
4. Calculate the concentration units of solutions such as molarity, percent by mass or volume, parts per million (ppm), or parts per billion (ppb).
5. Determine the concentration of a solution in terms of molarity and molality.
6. Calculate the theoretical freezing-point depression and boiling-point elevation of an ideal solution as a function of solute concentration.
7. Prepare a specified volume of a solution of given molarity.
8. Use titration data to calculate the concentration of an unknown solution.

High School Chemistry

CHEMICAL THERMODYNAMICS

C.12. Broad Concept: Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept, students:

1. Describe the concepts of temperature and heat flow in terms of the motion and energy of molecules (or atoms).
2. Determine and explain that chemical processes release (exothermic) or absorb (endothermic) thermal energy.
3. Explain how energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.
4. Solve problems involving heat flow and temperature changes, using given values of specific heat and latent heat of phase change.
5. Use Hess's law to determine the heat of a reaction and to calculate enthalpy change in a reaction.

ORGANIC AND BIOCHEMISTRY

C.13. Broad Concept: The bonding characteristics of carbon lead to the possibility of many different molecules of many sizes, shapes, and chemical properties. This provides the biochemical basis of life. As a basis for understanding this concept, students:

1. Explain how the bonding characteristics of carbon lead to a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
2. Describe how large molecules (polymers) such as proteins, nucleic acids, and starch are formed by repetitive combinations of simple subunits (monomers).
3. Explain that amino acids are the building blocks of proteins.
4. Convert between chemical formulas, structural formulas, and names of simple common organic compounds (hydrocarbons, proteins, fats, carbohydrates).

High School Physics

SCIENTIFIC INVESTIGATION AND INQUIRY

P.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions when obtaining evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), hypothesis, and theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek and to guide the interpretation of the data.
8. Identify and communicate the sources of error inherent in an experiment.
9. Identify discrepant results and identify possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying those concepts.
13. Apply mathematical relationships involving linear and quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Recognize and deal with the implications of statistical variability in experiments, and explain the need for controls in experiments.

High School Physics

MOTION AND FORCES

P.2. Broad Concept: Newton's laws of motion and gravitation describe and predict the motion of a vast variety of objects. As a basis for understanding this concept, students:

1. Explain that when the net force on an object is zero, no acceleration occurs; thus, a moving object continues to move at a constant speed in the same direction, or, if at rest, it remains at rest (Newton's first law).
2. Explain that only when a net force is applied to an object will its motion change; that is, it will accelerate (according to Newton's second law, $F = ma$).
3. Predict and explain how when one object exerts a force on a second object, the second object always exerts a force of equal magnitude but of opposite direction and force back on the first: $F_{1\ on\ 2} = -F_{2\ on\ 1}$ (Newton's third law).
4. Explain that Newton's laws of motion are not universally applicable, but they provide very good approximations, unless an object is moving close to the speed of light, has a very large mass, or is small enough that quantum effects are important.
5. Explain that every object in the universe exerts an attractive force on every other object. Know the magnitude of the force is proportional to the product of the masses of the two objects and inversely proportional to the distance between them: $F = G\, m_1 m_2 / r^2$.
6. Investigate and explain how the Newtonian model — the three laws of motion plus the law of gravitation — makes it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and Earth's equatorial bulge.
7. Explain how a force acting on an object perpendicular to the direction of its motion causes it to change direction but not speed.
8. Demonstrate that a motion at constant speed in a circle requires a force that is always directed toward the center of the circle.
9. Solve kinematics problems involving constant speed and average speed.
10. Apply the law $F = ma$ to solve one-dimensional motion problems involving constant forces (Newton's second law).
11. Use and mathematically manipulate appropriate scalar and vector quantities $(F, v, a, \Delta r, m, g)$ to solve kinematics and dynamics problems in one and two dimensions.
12. Solve problems in circular motion, using the formula for centripetal acceleration in the following form: $a = v^2/r$.
13. Create and interpret graphs of speed versus time and the position and speed of an object undergoing constant acceleration.

High School Physics

CONSERVATION OF ENERGY AND MOMENTUM

P.3. Broad Concept: The laws of conservation of energy and momentum provide independent approaches to predicting and describing the motion of objects. As a basis for understanding this concept, students:

1. Recognize that when a net force, F, acts through a distance, Δx, on an object of mass, m, which is initially at rest, work, $W = F\Delta x$, is done on the object; the object acquires a velocity, v, and a kinetic energy, $K = \frac{1}{2} mv^2 = W = F\Delta x$.
2. Describe how an unbalanced force, F, acting on an object over time, Δt, results in a change, $\Delta p = F\Delta t$, in the object's momentum.
3. Describe how kinetic energy can be transformed into potential energy and vice versa (e.g., a bouncing ball).
4. Explain that momentum is a separately conserved quantity that is defined in one dimension as $p = mv$. Know that the momentum of a system can be changed only by application of an external impulse, $J = F\Delta t$. Know that the total momentum of a closed system cannot change, regardless of the interchange of momentum within it.
5. Define power as the rate at which work is done: $P = W/\Delta t$.
6. Identify the joule, J, as the SI unit for work and energy; the unit for power is the watt, W; and the unit for impulse and momentum is the kg(m/s).
7. Describe the conditions under which each conservation law applies.
8. Calculate kinetic energy using the formula $K = \frac{1}{2} mv^2$.
9. Calculate changes in gravitational potential energy, U, due to elevation changes, Δh, near the Earth, using the relation $\Delta U = mg\Delta h$.
10. Solve problems involving conservation of energy in simple systems such as that of falling objects.
11. Apply the law of conservation of mechanical energy to simple systems.
12. Calculate the momentum of an object as the product $p = mv$.
13. Solve problems involving perfectly inelastic collisions in one dimension using the principle of conservation of momentum.
14. Calculate the changes in motion of two bodies in one-dimensional elastic collisions in which both energy and momentum are conserved.

High School Physics

MECHANICS OF FLUIDS

P.4. Broad Concept: All objects experience a buoyant force when immersed in a fluid. As a basis for understanding this concept, students:

1. Explain that the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid it has displaced.
2. Recognize that a change in the pressure at any point in a fluid is accompanied by an equal change at all other points (Pascal's principle).
3. Identify that the pressure in an incompressible fluid (e.g., water) is a function of density, ρ; depth, y; and gravitational acceleration, g.
4. Solve problems involving floating and sinking bodies using Archimedes' principle.
5. Understand that Bernoulli's principle, $p + \frac{1}{2}\rho v^2$ = constant, is a consequence of conservation of mechanical energy applied to a moving, incompressible fluid, and apply it accurately.
6. Solve problems involving a confined, isothermal gas using Boyle's law.

HEAT AND THERMODYNAMICS

P.5. Broad Concept: Energy cannot be created or destroyed; however, in many processes energy is transformed into the microscopic form called *heat energy*, that is, the energy of the disordered motion of atoms. As a basis for understanding this concept, students:

1. Recognize that heat flow and work are two forms of energy transfer between a system and its surroundings.
2. Describe and measure that the change ΔU in the internal energy of a system is equal to the sum of the heat flow, Q, into the system and the work, W, done on the system: $\Delta U = Q + W$ (first law of thermodynamics).
3. Describe and measure the work, W, done by a heat engine as the difference between the heat flow, Q_{in}, into the engine at high temperature and the heat flow, Q_{out}, out at a lower temperature: $W = Q_{in} - Q_{out}$.
4. Explain that thermal energy (commonly called *heat*) consists of random motion and the vibrations and rotations of atoms, molecules, or ions.
5. Describe how in everyday practice, temperature is measured with a thermometer, a device containing a part that has a *thermometric parameter* (a quantity that changes with temperature).
6. Investigate and describe how the absolute temperature of an object is proportional to the average kinetic energy of the thermal motion of its microscopic parts.
7. Recognize that the absolute temperature is measured in kelvins (K); 0 K is the temperature at which the average kinetic energy of the microscopic parts of the system is an irreducible minimum.
8. Explain that on the everyday Celsius scale, $0^{\circ}C = 273.15$ K, which is very close to the freezing point of pure water at atmospheric pressure, $100^{\circ}C = 373.15$ K is very close to the temperature at which pure water boils at a pressure of 1 atmosphere.
9. Describe that when two objects at different temperatures are in contact, heat energy always flows from the object at a higher temperature to the object at a lower temperature by the process of conduction until the two are at the same (intermediate) temperature.
10. Explain the process of convection: Because the density of fluids varies with temperature, the warmer parts of a fluid tend to move into and mix with the cooler parts, resulting in a transfer of heat energy from place to place.

(continued)

High School Physics

HEAT AND THERMODYNAMICS *(continued)*

P.5. Broad Concept: Energy cannot be created or destroyed; however, in many processes energy is transformed into the microscopic form called heat energy, that is, the energy of the disordered motion of atoms. As a basis for understanding this concept, students:

11. Explain that all objects emit electromagnetic radiation at a rate that rises very rapidly with their temperature. As a result, know that a warmer body that is in the line of sight with a cooler one will transfer net energy to it, cooling down while the cooler object warms up.
12. Demonstrate that in all internal energy transfers, the overall effect is that the energy is spread out uniformly.
13. Recognize that entropy is a quantity that measures the order or disorder of a system and that it is larger for a more disordered system.
14. Explain the law, "the entropy of a closed system will always either increase or remain the same," based on the statistics of the behavior of immense numbers of atoms or molecules that governs all closed systems (second law of thermodynamics).
15. Use a *p*-*V* diagram to graph simple thermodynamic processes for an ideal gas (for which $pV = nRT$); for example, an isothermal process is described by a hyperbola, an isobaric process by a horizontal straight line, and an isochoric process by a vertical straight line.
16. Use the second-law-based Carnot efficiency formula, $\eta = (T_{in} - T_{out})/T_{in}$, to calculate the maximum possible efficiency for a heat engine.
17. Given heat input and work output data, calculate the efficiency of a real heat engine or human being (e.g., a well-trained athlete working out for eight hours may consume 7,000 kcal of food (20 MJ) a day and do work at the rate of $^1/_4$ HP (187 W) over an eight-hour period during that day. What is his or her thermodynamic efficiency?).
18. Describe a refrigerator as a heat engine operated "in reverse."

WAVES

P.6. Broad Concept: Waves carry energy from place to place without the transfer of matter. As a basis for understanding this concept, students:

1. Explain that waves carry energy from one place to another.
2. Observe and describe that a mechanical wave is a disturbance in a medium. For example, a sound wave in air is a slight variation in the pressure of the air surrounding a vibrating object, such as a bell.
3. Explain that waves conform to the superposition principle: Any number of waves can pass through the same point at the same time, and the amplitude, *A*, of the resulting wave at that point at any time is the sum of the amplitudes of the superposed waves. Use the principle of superposition to describe the interference effects arising from propagation of several waves through the same medium.
4. Demonstrate how standing waves on a stretched string are the result of the superposition of the wave moving away from the source and the wave reflected back from the other end of the string.
5. Explain that longitudinal waves can propagate in any medium, but transverse waves can propagate only in solids.
6. Describe that sound in a fluid medium is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.

(continued)

High School Physics

WAVES *(continued)*

P.6. Broad Concept: Waves carry energy from place to place without the transfer of matter. As a basis for understanding this concept, students:

7. Differentiate electromagnetic waves from mechanical waves. (Electromagnetic waves are not disturbances in a medium; rather, such waves are a combination of a varying electric field and a varying magnetic field, each of which, in varying, gives rise to the other. Electromagnetic waves can therefore propagate in empty space.)
8. Know that radio waves, visible light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed, *c,* in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).
9. Explain how Scottish physicist James Clerk Maxwell used Ampère's law and Faraday's law to predict the existence of electromagnetic waves and predict that light was just such a wave. Know that these predictions were confirmed by Heinrich Hertz, whose confirmations thus made possible the fields of radio, TV, and many other technologies.
10. Predict and explain how light travels through a transparent medium at a speed, *v,* less than *c*. The index of refraction of the medium is defined to be $n = c/v$.
11. Explain that when a light ray passes from air into a transparent substance, such as glass, having index of refraction, *n,* it is refracted through an angle given by Snell's law, $n \sin \theta_i = n \sin \theta_r$, where θ_i is the angle of incidence of the ray and θ_r is the angle of refraction.
12. Describe waves in terms of their fundamental characteristics of speed, *v;* wavelength, λ; frequency, *f;* or period, *T,* and amplitude, *A,* and the relationships among them. For example, $f\lambda = v$, $f = 1/T$. Solve problems involving wavelength, frequency, and wave speed.
13. Identify transverse and longitudinal waves in mechanical media such as springs, ropes, and the Earth (seismic waves).
14. Identify the phenomena of interference (beats), diffraction, refraction, the Doppler effect, and polarization, and that these are characteristic wave properties.
15. Use Snell's law to calculate refraction angles and analyze the properties of simple optical systems.
16. Identify electromagnetic radiation as a wave phenomenon after observing interference, diffraction, and polarization of such radiation.

ELECTROMAGNETISM

P.7. Broad Concept: The phenomena that fall into the categories known as electrostatics and electromagnetism are due respectively to the behavior of stationary and moving charged particles. As a basis for understanding this concept, students:

1. Determine how an electric charge, *q,* exists in two kinds: positive (+) and negative (–). Know that like charges repel each other, and unlike charges attract each other with an *electrostatic force* whose magnitude is given by Coulomb's law, $F = kq_1q_2/r_{12}^2$, where *k* is a constant. Know that the unit of electric charge is the coulomb (C).
2. Explain that around any point charge, *Q,* there is an electric field, $E = k\,Q/r^2$. Know that another charge, q, located in this field will experience a force of magnitude $F = qE$ and that the unit of electric field is the newton per coulomb (N/C).
3. Calculate electric potential (voltage): When a charge, *q,* is pulled through a field, *E,* over a distance, *d,* work, $W = qd$, is done. The work done per unit charge, *W/q,* is the electric potential, *V.* Thus, $V = Ed$. The unit of electric potential is the volt, V; 1 V = 1 N(m/C).

(continued)

High School Physics

ELECTROMAGNETISM *(continued)*

P.7. Broad Concept: The phenomena that fall into the categories known as electrostatics and electromagnetism are due respectively to the behavior of stationary and moving charged particles. As a basis for understanding this concept, students:

4. Know that most materials fall into one of two categories: electrical conductors, through which an electric charge can flow easily under the influence of an electric field, and electrical insulators (or dielectrics), through which a charge cannot flow easily.
5. Explain that a source of electromotive force (EMF) is any device (such as a battery) that furnishes a steady potential between two terminals. Know that if a conducting loop is supplied between the two terminals, an electric current, I, will flow. Know, too, that current is measured in the number of coulombs per second that flow past a given point in the conductor, $I = q/t$, and that the unit of electric current is the ampere (A); 1 A = 1 C/s.
6. Give evidence that metals are almost all good electrical conductors; nevertheless, they do offer some resistance (*friction*) to the flow of current. Know that the greater the potential difference between the ends of the conductor, the greater the current; the greater the resistance, the less the current. Know, too, that for most metals and many other conductors, the current is determined by Ohm's law, $V = IR$. A conductor that conforms to this rule is called an *ohmic conductor.*
7. Explain that any resistive element in a DC circuit transforms electrical energy into thermal energy at a rate (power) given by Joule's law, $P = IV$, which in an ohmic element has the special form $P = I^2R = V^2/R$.
8. Recognize that plasmas, the fourth state of matter, contain ions and free electrons in such numbers that they are electrically neutral overall, but the many free charges they contain make them good conductors of electricity. Recognize that the glowing gas in a neon light is plasma.
9. Explain the properties of transistors and their role in electric circuits.
10. Explain that magnetic materials and electric currents (moving electric charges) are sources of magnetic fields, and they experience forces due to magnetic fields of other sources.
11. Demonstrate how changing magnetic fields produce electric fields (Faraday's law), thereby inducing currents in nearby conductors.
12. Explain how electric and magnetic fields are vector fields that contain energy.
13. Investigate and explain how various wavelengths in the electromagnetic spectrum have many useful applications such as radio, TV, microwave radars and ovens, cellular telephones, infrared detectors, optical cables, and X-ray machines.
14. Explain the magnitude of the force on a moving particle with charge, q, in a magnetic field, B, is $qvB \sin \theta$, where v is the speed of the particle, B is the magnitude of the magnetic field, and θ is the angle between the directions of v and B.
15. Describe the advantages to alternating current over direct current for power distribution networks.
16. Calculate the power dissipated in any resistive circuit element by using Joule's law in the appropriate form.
17. Predict the current in simple direct current electric circuits constructed from batteries, wires, and resistors.
18. Solve problems involving Ohm's law in series and parallel circuits.
19. Determine the direction of a magnetic field produced by a current flowing in a straight wire and in a coil (use the right-hand rule).
20. Explain the operation of electric generators, motors, and transformers in terms of Ampère's law and Faraday's law.

High School Physics

NUCLEAR PROCESSES

P.8. Broad Concept: Nuclear processes are those in which an atomic nucleus changes; they include radioactive decay of naturally occurring and man-made isotopes and nuclear fission and fusion processes. As a basis for understanding this concept, students:

1. Explain how the research of Marie Curie, later in collaboration with her husband, Pierre, spurred the study of radioactivity, and led to the realization that one kind of atom may change into another kind, and so atoms must be made up of smaller parts. Rutherford, Geiger, and Marsden found these parts to be small, dense nuclei surrounded by much larger clouds of electrons.
2. Recognize that the nucleus, although it contains nearly all of the mass of the atom, occupies less of the atom than the proportion of the solar system occupied by the sun.
3. Explain how the mass of a neutron or a proton is about 2,000 times greater than the mass of an electron.
4. Describe Niels Bohr's model of the atom, its electron arrangement, and the correlation with the hydrogen spectrum.
5. Explain Albert Einstein's photoelectric effect.
6. Describe Louis de Broglie's insight into the wave-particle duality.
7. Describe the Heisenberg uncertainty principle and how it arises naturally from the fact that matter has wavelike properties.
8. Explain the principle of special relativity and some of its implications, including the mass-energy equivalence equation, $E = mc^2$.
9. Demonstrate how the mass of a stable nucleus is always less than the sum of the masses of the protons and neutrons comprising it. Know this is especially true of the elements in the region of the periodic table around iron (26 protons, 30 neutrons) and generally less so of elements with greater or lesser atomic numbers than this.
10. Explain that if lighter atoms are fused to form atoms closer to iron, or heavier atoms are split to form atoms closer to iron, there is a mass loss. Explain that according to the principle of conservation of mass-energy, this mass loss must be accompanied by a release of energy according to Einstein's mass-energy equation. Know that because c^2 is such a large number ($\approx 9 \times 10^{20}$ m^2/s^2), a small mass loss leads to a large energy release.

High School Environmental Science

SCIENTIFIC INVESTIGATION AND INQUIRY

E.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations. Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis, and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error (random and systematic) inherent in an experiment.
9. Identify discrepant results and possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving linear and quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Observe natural phenomena and analyze their location, sequence, or time intervals (e.g., relative ages of rocks and succession of species in an ecosystem).

High School Environmental Science

ENVIRONMENTAL SYSTEMS

E.2. Broad Concept: The environment is a system of interdependent components affected by natural phenomena and human activity. As a basis for understanding this concept, students:

1. Understand and explain that human beings are part of Earth's ecosystems, and that human activities can, deliberately or inadvertently, alter ecosystems.
2. Explain how environmental change in one part of the world can impact seemingly distant places and systems.
3. Describe how the global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population growth.
4. Recognize and explain that in evolutionary change, the present arises from the materials of the past and in ways that can be explained (e.g., formation of soil from rocks and dead organic matter).

ECOSYSTEMS

E.3. Broad Concept: Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept, students:

1. Explain that biodiversity is the sum total of different kinds of organisms in a given ecological community or system, and is affected by alterations of habitats.
2. Know and describe how ecosystems can be reasonably stable over hundreds or thousands of years.
3. Understand and describe that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually results in a system similar to the original one.
4. Understand and explain that ecosystems tend to have cyclic fluctuations around a state of rough equilibrium, and change results from shifts in climate, natural causes, human activity, or when a new species or non-native species appears.
5. Know that organisms may interact in a competitive or cooperative relationship, such as producer/consumer, predator/prey, parasite/hosts, or as symbionts, and explain how these interactions contribute to the stability of an ecosystem.
6. Recognize and describe the difference between systems in equilibrium and systems in disequilibrium.
7. Explain how water, carbon, phosphorus, and nitrogen cycle between abiotic resources and organic matter in an ecosystem, and how oxygen cycles via photosynthesis and respiration. Diagram the cycling of carbon, nitrogen, phosphorus, and water in an ecosystem.
8. Describe the role of nitrogen and carbon cycles in the improvement of soils for agriculture.
9. Locate, identify, and explain the role of the major Earth biomes (e.g., grasslands, rainforests, arctic tundra, deserts) and discuss how the abiotic and biotic factors interact within these ecosystems.
10. Explain the process of succession, both primary and secondary, in terrestrial and aquatic ecosystems.

(continued)

High School Environmental Science

ECOSYSTEMS *(continued)*

E.3. Broad Concept: Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept, students:

11. Describe how adaptations in physical structure or behavior may improve an organism's chance for survival and impact an ecosystem.
12. Describe the concepts of niche and habitat, and explain the effects of loss of habitat on a species' survivability.
13. Explain how soil, water, and pest management are achieved in various agricultural systems (conventional and organic). Describe the tenets of sustainable agriculture.

POPULATIONS

E.4. Broad Concept: The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle organic materials from the remains of dead organisms. As a basis for understanding this concept, students:

1. Explain the concept of carrying capacity.
2. Demonstrate how resources, such as food supply, the availability of water, and shelter influence populations.
3. Demonstrate and explain how fluctuations in population size and population growth rates are determined by such factors as birth rate, death rate, and migration rate.
4. Describe the effect of overpopulation (i.e., resource depletion and potential elimination of species), the role of predators in maintaining eco-system stability, and methods of population management.
5. Describe current and historical trends in human population growth in different regions of the world.
6. Explain how the size and rate of growth of the human population in any location is affected by economic, political, religious, technological, and environmental factors.

High School Environmental Science

NATURAL RESOURCES

E.5. Broad Concept: Numerous Earth resources are used to sustain human affairs. The abundance and accessibility of these resources can influence their use. As a basis for understanding this concept, students:

1. Recognize that the Earth's resources for humans, such as fresh water, air, arable soil, and trees, are finite. Explain how these resources can be conserved through reduction, recycling, and reuse.
2. Differentiate between renewable and nonrenewable resources (including sources of energy), and compare and contrast the pros and cons of using nonrenewable resources.
3. Give examples of the various forms and uses of fossil fuels and nuclear energy in our society, and describe alternative sources of energy provided by water, the atmosphere, and the sun.
4. Demonstrate knowledge of the distribution of natural resources in the United States and the world, and explain how natural resources influence relationships among nations.
5. Recognize and describe the role of natural resources in providing the raw materials for an industrial society.
6. Analyze the trade-offs among different fuels, such as how energy use contributes to the rising standard of living in the industrially developing nations, yet also leads to more rapid depletion of Earth's energy resources and to increased environmental risks associated with the use of fossil and nuclear fuels.
7. Identify specific tools and technologies used to adapt and alter environments and natural resources to meet human physical and cultural needs.
8. Understand and describe the concept of integrated natural resource management and the values of managing natural resources as an ecological unit.

WATERSHEDS AND WETLANDS

E.6. Broad Concept: Water is continually being recycled by the hydrologic cycle through the watersheds, oceans, and the atmosphere by processes such as evaporation, condensation, precipitation runoff, and infiltration. This life-giving cycle is continually and increasingly affected by human affairs. As a basis for understanding this concept, students:

1. Compare and contrast the processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff and groundwater percolation, infiltration, and transpiration.
2. Describe the physical characteristics of wetlands and watersheds and explain how water flows into and through a watershed (e.g., precipitation, aquifers, wells, porosity, permeability, water table, capillary water, and runoff).
3. Describe how wetlands store excess water and filter sediments and excess nutrients.
4. Examine the dynamics of diverse ecosystems in watersheds and wetlands. Identify various organisms found in Potomac River wetlands and watersheds.
5. Describe the causes of, and the efforts to control, erosion in the Chesapeake Bay.

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High School Environmental Science

WATERSHEDS AND WETLANDS *(continued)*

E.6. Broad Concept: Water is continually being recycled by the hydrologic cycle through the watersheds, oceans, and the atmosphere by processes such as evaporation, condensation, precipitation runoff, and infiltration. This life-giving cycle is continually and increasingly affected by human affairs. As a basis for understanding this concept, students:

6. Investigate and describe how point and nonpoint source pollution can affect the health of a bay's watershed and wetlands.
7. Collect, record, and interpret data from physical, chemical, and biological sources to evaluate the health of the Chesapeake Bay watershed and wetlands, and describe how the Bay supports a wide variety of plant and animal life that interact with other living and nonliving things.
8. Explain the dynamics of oceanic currents, including upwelling, density, and deep water currents, the local Labrador Current and the Gulf Stream, and their relationship to global circulation within the marine environment and climate.

ENERGY IN THE EARTH SYSTEM

E.7. Broad Concept: Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept, students:

1. Explain that energy cannot be created or destroyed; however, in many processes energy is transformed into the microscopic form called *heat energy,* that is, the energy of the disordered motion of atoms.
2. Explain the meaning of radiation, convection, and conduction (three mechanisms by which heat is transferred to, through, and out of the Earth's system).
3. Understand and describe how layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Recognize that by burning these fossil fuels, people are passing stored energy back into the environment as heat and releasing large amounts of carbon dioxide.
4. Describe how the energy derived from the sun is used by green plants to produce chemical energy in the form of sugars (photosynthesis), and this energy is transferred along a food chain from producers (plants) to consumers to decomposers.
5. Ilustrate the flow of energy through various trophic levels of food chains and food webs within an ecosystem. Describe how each link in a food web stores some energy in newly made structures and how much of the energy is dissipated into the environment as heat. Understand that a continual input of energy from sunlight is needed to keep the process going.
6. Describe how the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways.

High School Environmental Science

ENVIRONMENTAL QUALITY

E.8. Broad Concept: Environmental quality is linked to natural and human-induced hazards, and the ability of science and technology to meet local, national, and global challenges. As a basis for understanding this concept, students:

1. Differentiate between natural pollution and pollution caused by humans, and give examples of each.
2. Describe sources of air and water pollution, and explain how air and water quality impact wildlife, vegetation, and human health.
3. Describe the historical and current methods of water management and recycling, including the waste treatment practices of landfills, incineration, reuse/recycle, and source reduction.
4. Understand and explain that waste management includes considerations of quantity, safety, degradability, and cost.
5. Compare and contrast the beneficial and harmful effects of an environmental stressor, such as herbicides and pesticides, on plants and animals. Give examples of secondary effects on other environmental components such as humans, water quality, and wildlife.
6. Identify natural Earth hazards, such as earthquakes and hurricanes, and identify the regions in which they occur, as well as the short-term and long-term effects on the environment and on people.
7. Recognize and describe important legislation enacted to protect environmental quality, such as the Clean Air Act and the Clean Water Act.

Glossary of Selected Terms

(with emphasis on terms that appear in K–8)

Abiotic properties: Physical and chemical aspects of an organism's environment.

Acidity: A measure of the hydrogen ion concentration in a chemical system.

Adaptation: Any modification of an organism or its parts that makes it more fit for existence under the conditions of its environment.

Aquifer: A layer of permeable rock, sand, or gravel through which groundwater flows, containing enough water to supply wells and springs.

Atmosphere: The gaseous envelope of a celestial body (as a planet).

Atom: The smallest particle of an element that has the properties of that element.

Biotechnology: Any technique that uses living organisms, or parts of organisms, to make or modify products, improve plants or animals, or develop microorganisms for specific uses.

Catalyst: A substance that increases the rate of a chemical reaction without itself undergoing any permanent change.

Cell: The structural and functional basic unit of all living things.

Chlorophyll: A substance found in green plants that is needed for photosynthesis.

Chromosomes: Threadlike structures located in the cell nuclei of organisms that determine the individual characteristics of the organism.

Circuit: The complete closed path of an electric current.

Climate: The average course or condition of the weather at a place, usually over a period of years, as exhibited by temperature, wind velocity, and precipitation.

Conductor: A material capable of transmitting a form of energy (as heat, electrical energy, or sound).

Conservation of energy: The total energy of an isolated system remains constant regardless of changes within its system.

Conservation of mass: The total mass of an isolated system is unchanged by the interaction of its parts.

Consumer: An organism requiring complex organic compounds for food, which it obtains by preying on other organisms or by eating particles of organic matter.

Convection: A heat transfer in liquids and gases by means of transport of matter from a region of one temperature to a region of a different temperature.

Covalent bond: A chemical bond in which the attractive force between atoms is created by the sharing of electrons.

Decomposer: Any of various organisms (e.g., bacteria and fungi) that return constituents of organic substances to ecological cycles by feeding on and breaking down dead protoplasm.

Density: The mass of a substance per unit volume.

Ecosystem: A group of organisms in an area that interact with one another and together with their nonliving environment.

Electric circuit: The complete path of an electric current, usually including the source of electric energy.

Electric current: A flow of electric charge.

Electromagnet: A device in which a magnetic field is produced by an electric current.

Electromagnetic radiation: Electromagnetic energy transferred through space.

Electromagnetic waves: A combination of electric and magnetic fields, each regenerating the other, that carry energy through space (light and radio waves are examples).

Element: The simplest type of pure substance; a substance consisting entirely of atoms having identical chemical properties.

Endocrine: Relates to glands that secrete hormones internally, directly into the lymph or bloodstream.

Energy: The capacity for doing work.

Equilibrium: The state of a system in which forces, influences, or reactions balance each other so there is no net change.

Erosion: The gradual wearing away of rock or soil by physical breakdown, chemical solution, and transportation of material, as caused, for example, by water, wind, or ice.

Fermentation: The chemical decomposition of an organic substance.

Food chain: An arrangement of the organisms of an ecological community, according to the order of predation, in which each uses the next, usually lower, member as a food source.

Food web: All food chains in an ecosystem that are connected.

Force: An agency or influence that if applied to a particle results in an acceleration of the particle.

Fossil: A remnant, impression, or trace of an organism of past geologic ages that has been preserved in the Earth's crust.

Gas/gaseous state: Gas is a fluid state of matter. Gas molecules do not hold together, so a gas can spread out in all directions. A body of gas changes its volume significantly with changes in pressure.

Gene: The basic unit of heredity.

Genetics: The branch of biology that deals with heredity.

Gravity: A force that attracts every object in the universe toward every other one.

Habitat: The place or environment where a plant or animal naturally or normally lives and grows.

Heat energy: The energy associated with the random motions of the molecules, atoms, and smaller structural units of which matter is composed.

Homeostasis: A state of equilibrium produced by a balance of functions and the chemical composition within a system.

Host: An organism in which or on which another organism lives.

Hypothesis: A tentative explanation for a phenomenon that is used as a basis for further investigation.

Igneous: Formed by solidification of magma.

Inertia: Resistance to acceleration. The quantitative measure of the inertia of a body is its mass.

Inherited: Received from ancestors by genetic transmission.

Insulator: A material that is a poor conductor (e.g., of electricity or heat).

Kinetic: Relating to, caused by, or producing motion.

Life cycle: The series of stages in form and functional activity through which an organism passes between successive recurrences of a specified primary stage.

Liquid/liquid state: The liquid state is a fluid state of matter. Liquid molecules hold together, but not rigidly, so liquids flow. Liquids do not change their volumes significantly with pressure changes.

Lithosphere: The solid outer layer of the Earth above the asthenosphere, consisting of the crust and upper mantle.

Magnetism: A class of physical phenomena that includes the attraction of iron by lodestones and other permanent magnets, is exhibited by both magnets and electric currents, and is inseparably associated with moving electricity.

Mass: The measure of how much matter is in an object.

Meiosis: In organisms that reproduce sexually, it is a process of cell division during which the nucleus divides into four nuclei, each of which contains half the usual number of chromosomes.

Metals: A class of chemical elements, compounds, and mixtures that are mainly shiny, bendable, and good conductors of heat and electricity.

Metamorphic rocks: Metamorphic rocks are formed from pre-existing rocks that are subject to very high pressure and temperature, which result in the rocks' structural and chemical transformation.

Metamorphosis: A marked and more-or-less abrupt developmental change in the form or structure of an animal occurring subsequent to birth or hatching (such as what happens to a butterfly or frog).

Mineral: A solid, homogeneous, crystalline chemical element or compound that results from the inorganic processes of nature.

Mitosis: A division of a cell resulting in two daughter cells that contain the same number and kind of chromosomes as the mother cell.

Motion: A change in position of an object in a certain amount of time.

Newton's law of gravitation: Gravity is an attractive force between two objects whose magnitude is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Newton's laws of motion: (1) In the absence of a net force acting on a body, its velocity (magnitude and direction) does not change. (2) The acceleration of a body is proportional to the body's mass and the magnitude of the net force acting on it, and is in the direction of the net force. (3) If one body exerts a force on a second body, there is an equal and opposite force exerted on the first body by the second body.

Orbit: A path described by one body in its revolution about another (as by the Earth about the sun).

Parasite: An organism that feeds on other living organisms.

pH: The scale used to express acidity or alkalinity of a solution.

Photosynthesis: The process by which green plants and other organisms produce simple carbohydrates from carbon dioxide and hydrogen, using light energy that chlorophyll or other organic cellular pigments absorb from radiant sources.

Plasma/plasma state: Plasma is a state of matter, often called the *fourth state*. The atoms in a plasma are largely ionized, so that there are many free positively and negatively charged particles, but the plasma is electrically neutral overall. Plasmas are often very hot, and they glow. The sun, the northern lights, lightning, and the glowing gases in neon sign tubes and fluorescent lamp tubes are examples of plasmas.

Plate tectonics: The theory that ascribes continental drift, volcanic and seismic activity, and the formation of mountain belts to moving plates of the Earth's crust that are supported on less rigid mantle rocks.

Precipitation: A deposit on the earth of hail, mist, rain, sleet, or snow; also, the quantity of water deposited.

Predator: An organism that kills and eats other organisms.

Process: A systematic sequence of actions that combines resources to produce an output.

Producer: Any of various organisms (such as a green plant) that produce their own organic compounds from simple precursors (such as carbon dioxide and inorganic nitrogen), many of which are food sources for other organisms.

Respiration: The complete chemical and physical process during which oxygen is delivered to tissues or cells of the body and carbon dioxide and water are given off.

Revolution: Motion in a closed path by a planet or satellite around another body.

Rotation: Turning about an axis.

Sedimentary rocks: Sedimentary rocks are formed from material, including debris of organic origin; deposited as sediment by water, wind, or ice; and then compressed and cemented together by pressure.

Simple machines: The simple machines are the lever, block and tackle, and inclined plane, along with their most basic modifications, the wheel and axle, wedge, and screw. A complex machine is a machine made up of two or more simple machines.

Solar system: The sun together with the group of celestial bodies that are held by its attraction and revolve around it.

Solid/solid state: The solid state is a state of matter. Solid molecules hold together rigidly and often line up in exact patterns; therefore, solids do not flow. Solids do not change their shapes or volumes.

Solubility: The measure of a substance's ability to be dissolved in a liquid.

Sound: A kind of energy that propagates as a wave through vibrating matter. Sound travels through solids, liquids, and gases. The eardrums convert this vibrational energy into signals that travel along nerves to the brain, which interprets them as voices, music, noise, etc.

Species: A category of biological classification that is composed of organisms sufficiently and closely related as to be potentially able to mate with one another.

Streak: The color of the fine powder of a mineral obtained by scratching or rubbing against a hard white surface and constituting an important distinguishing characteristic. Note: The streak color may be completely different from the color observed at the surface of the mineral.

Technology: Human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities.

Temperature: A measure of the average energy of the microscopic components of a body that can be found using a thermometer.

Texture: The nature of the surface of an object, especially as described by the sense of touch, but excluding temperature. Textures include rough, smooth, feathery, sharp, greasy, metallic, and silky.

Theory: An explanation of a range of phenomena supported by substantial evidence.

Thermodynamics: The branch of physics that deals with conversions between heat energy and mechanical energy.

Ultraviolet radiation: Electromagnetic radiation having wavelengths shorter than those of visible light but longer than those of X-rays.

Valence electron: An electron in an outer shell of an atom that can be lost to or shared with another atom to form a molecule.

Wavelength: The distance between two consecutive, similar points on a wave.

Weather: The state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, and clearness or cloudiness.

Weight: The magnitude of the force with which a body is attracted toward the Earth or a celestial body by gravitation and which is equal to the product of the mass and the local gravitational acceleration.

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Related Resources also Available

The Office of Academic Services also has developed a number of other resources to help teachers, administrators, students, parents, and community members better understand the new learning standards. These resources include:

- Grade-level curriculum guides, with sample learning activities, year at a glance references, unit roadmaps, standards-based worksheets, sample assessment items, and other resources.
- Grade-level parent guides to the standards, translated into several languages.
- Grade-level posters, which should be displayed in every classroom.

These and other materials are available on the DCPS Web site at www.k12.dc.us.

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