WHAT DO STUDENTS NEED TO LEARN WHEN IT COMES TO SCIENCE?

This is one of the biggest questions parents and teachers have and also one of the hardest to answer accurately, especially since the Common Core and NGSS have recently been released.

This document will help alleviate some of the stress and confusion regarding what to teach and how to teach it so you can confidently serve your students in the best way possible.

In the United States, we're expecting the new curriculum that is currently being developed to be released around 2016, so in the meantime, here's the best of what I have to cover your bases and get your kids moving in the right direction.

At the end of the document, you'll find the index that shows the performance expectations that you can use as milestones along your path.

~Aurora Lipper

Supercharged Science

Of Special Note to Teachers, Parents, and Students in the United States:

One of the two biggest misconceptions is that there are new Common Core Standards for science. There is no Common Core for Science. The only science in the Common Core deals with literacy, and it's minimal.

The other big misconception is that the NGSS is a curriculum that lets teachers and parents know what to teach their kids. It's not… it's a set of performance expectations that indicate what students should be able to do at the end of the year (or years) of instruction. The NGSS doesn't specify how to teach or plan instruction to help students achieve the performance levels specified.

The NGSS is expected to begin implementation in schools that have adopted these standards starting in 2017 at the earliest. The science curriculum framework based on NGSS has not yet been written (it is underway and should be completed in 2016).

Click here for the Standards based on Grade level.

Click here for the Topic Arrangements of the NGSS.

First Grade Science Content Standards

Physical Sciences

1. **Materials come in different forms (states) including solids, liquids, and gases.**
   As a basis for understanding this concept, students know:
   a. solids, liquids, and gases have different properties.
   b. the properties of substances can change when the substances are mixed, cooled, or heated.

Life Sciences

2. **Plants and animals meet their needs in different ways.**
   As a basis for understanding this concept, students know:
   a. different plants and animals inhabit different kinds of environments and have external features that help them thrive in different kinds of places.
   b. plants and animals both need water; animals need food, and plants need light.
   c. animals eat plants or other animals for food and may also use plants or even other animals for shelter and nesting.
   d. how to infer what animals eat from the shapes of their teeth (e.g., sharp teeth: eats meat; flat teeth: eats plants).
   e. roots are associated with the intake of water and soil nutrients, green leaves with making food from sunlight.

Earth Sciences

3. Weather can be observed, measured and described.
As a basis for understanding this concept, students know:
a. how to use simple tools (e.g., thermometer, wind vane) to measure weather conditions and record changes from day to day and over the seasons.
b. the weather changes from day to day, but trends in temperature or of rain (or snow) tend to be predictable during a season.
c. the sun warms the land, air, and water.

Investigation and Experimentation

4. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. draw pictures that portray some features of the thing being described.
b. record observations and data with pictures, numbers, and/or written statements.
c. record observations on a bar graph.
d. describe the relative position of objects using two references (e.g., above and next to, below and left of).
e. make new observations when discrepancies exist between two descriptions of the same object or phenomena.

Second Grade Science Content Standards

Physical Sciences

1. The motion of objects can be observed and measured.
As a basis for understanding this concept, students know:
a. the position of an object can be described by locating it relative to another object or the background.
b. an object's motion can be described by recording the change in its position over time.
c. the way to change how something is moving is to give it a push or a pull. The size of the change is related to the strength, or the amount of "force," of the push or pull.
d. tools and machines are used to apply pushes and pulls (forces) to make things move.
e. objects near the Earth fall to the ground unless something holds them up.
f. magnets can be used to make some objects move without being touched.
g. sound is made by vibrating objects and can be described by its pitch and volume.

Life Sciences

2. Plants and animals have predictable life cycles.
As a basis for understanding this concept, students know:
a. organisms reproduce offspring of their own kind. The offspring resemble their parents and each other.
b. the sequential stages of life cycles are different for different animals, for example butterflies, frogs, and mice.
c. many characteristics of an organism are inherited from the parents. Some characteristics are caused by, or influenced by, the environment.
d. there is variation among individuals of one kind within a population.
e. the germination, growth, and development of plants can be affected by light, gravity, touch, or environmental stress.
f. in plants flowers and fruits are associated with reproduction.

Earth Sciences

3. Earth is made of materials that have distinct properties and provide resources for human activities.
As the basis for understanding this concept, students know:
a. how to compare the physical properties of different kinds of rocks and that rock is composed of different combinations of minerals.
b. smaller rocks come from the breakage and weathering of larger rocks.
c. soil is made partly from weathered rock and partly from organic materials, and that soils differ in their color, texture, capacity to retain water, and ability to support the growth of many kinds of plants.
e. rock, water, plants and soil provide many resources including food, fuel, and building materials that humans use.

Investigation and Experimentation

4. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. make predictions based on patterns of observation rather than random guessing.
b. measure length, weight, temperature, and liquid volume with appropriate tools and express measurements in standard and non-standard units.
c. compare and sort common objects based on two or more physical attributes (including color, shape, texture, size, weight).
d. write or draw descriptions of a sequence of steps, events, and observations.
e. construct bar graphs to record data using appropriately labeled axes.

f. write or draw descriptions of a sequence of steps, events and observations, and include the use of magnifiers or microscopes to extend senses.
g. follow verbal instructions for a scientific investigation.

Third Grade Science Content Standards

Physical Sciences

1. Energy and matter have multiple forms and can be changed from one form to another.
As a basis for understanding this concept, students know:
a. energy comes from the sun to the Earth in the form of light.
b. sources of stored energy take many forms, such as food, fuel, and batteries.
c. machines and living things convert stored energy to motion and heat.
d. energy can be carried from one place to another by waves, such as water waves and sound, by electric current, and by moving objects.
e. matter has three forms: solid, liquid and gas.
f. evaporation and melting are changes that occur when the objects are heated.
g. when two or more substances are combined a new substance may be formed that can have properties that are different from those of the original materials.
h. all matter is made of small particles called atoms, too small to see with our eyes.
i. people once thought that earth, wind, fire, and water were the basic elements that made up all matter. Science experiments show that there are over 100 different types of atoms which are displayed on the Periodic Table of the Elements.

2. Light has a source and travels in a direction.
As a basis for understanding this concept, students know:
a. sunlight can be blocked to create shadows.
b. light is reflected from mirrors and other surfaces.
c. the color of light striking an object affects how our eyes see it.
d. we see objects when light traveling from an object enters our eye.

Life Sciences

3. Adaptations in physical structure or behavior may improve an organism's chance for survival.
As a basis for understanding this concept, students know:
a. plants and animals have structures that serve different functions in growth, survival, and reproduction.
b. examples of diverse life forms in different environments, such as oceans, deserts, tundra, forests, grasslands, and wetlands.
c. living things cause changes in the environment where they live; some of these changes are detrimental to the organism or other organisms, whereas others are beneficial.
d. when the environment changes, some plants and animals survive and reproduce, and others die or move to new locations.
e. some kinds of organisms that once lived on Earth have completely disappeared; some of these resembled others that are alive today.

Earth Sciences

4. Objects in the sky move in regular and predictable patterns.
As a basis for understanding this concept, students know:
a. the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.

b. how the moon's appearance changes during the four-week lunar cycle.
c. telescopes magnify the appearance of some distant objects in the sky, including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.
d. the Earth is one of several planets that orbit the sun, and the moon orbits the Earth.
e. the position of the sun in the sky changes during the course of the day and from season to season.

Investigation and Experimentation

5. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. repeat observations to improve accuracy, and know that the results of similar scientific investigations seldom turn out exactly the same because of differences in the things being investigated, methods being used, or uncertainty in the observation.
b. differentiate evidence from opinion, and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.
c. use numerical data in describing and comparing objects, events and measurements.
d. predict the outcome of a simple investigation, and compare the result to the prediction.
e. collect data in an investigation and analyze them to develop a logical conclusion.

Fourth Grade Science Content Standards

Physical Sciences

1. Electricity and magnetism are related effects that have many useful applications in everyday life.
As a basis for understanding this concept, students know:
a. how to design and build simple series and parallel circuits using components such as wires, batteries, and bulbs.
b. how to build a simple compass and use it to detect magnetic effects, including Earth's magnetic field.
c. electric currents produce magnetic fields and how to build a simple electromagnet.
d. the role of electromagnets in the construction of electric motors, electric generators, and simple devices such as doorbells and earphones.
e. electrically charged objects attract or repel each other.
f. magnets have two poles, labeled north and south, and like poles repel each other while unlike poles attract each other.
g. electrical energy can be converted to heat, light and motion.

Life Sciences

2. All organisms need energy and matter to live and grow.
As a basis for understanding this concept, students know:
a. plants are the primary source of matter and energy entering most food chains.
b. producers and consumers (herbivores, carnivores, omnivores, and decomposers) are related in food chains and food webs, and may compete with each other for resources in an ecosystem.
c. decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

3. Living organisms depend on one another and on their environment for survival.
As a basis for understanding this concept, students know:
a. ecosystems can be characterized in terms of their living and nonliving components.
b. for any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.

c. many plants depend on animals for pollination and seed dispersal, while animals depend on plants for food and shelter.
d. most microorganisms do not cause disease and many are beneficial.

Earth Sciences

4. The properties of rocks and minerals reflect the processes that formed them.
As a basis for understanding this concept, students know:
a. how to differentiate among igneous, sedimentary, and metamorphic rocks by their properties
b. how to identify common rock-forming minerals (including quartz, calcite, feldspar, mica, and hornblende) and ore minerals using a table of diagnostic properties.

5. Waves, wind, water, and ice shape and reshape the Earth's land surface.
As a basis for understanding this concept, students know:
a. some changes in the Earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.
b. natural processes, including freezing/thawing and growth of roots, cause rocks to break down into smaller pieces.
c. moving water erodes landforms, reshaping the land by taking it away from some places and depositing it as pebbles, sand, silt, and mud in other places (weathering, transport, and deposition).

Investigation and Experimentation

6. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. differentiate observation from inference (interpretation), and know that scientists' explanations come partly from what they observe and partly from how they interpret their observations.
b. measure and estimate weight, length, or volume of objects.
c. formulate predictions and justify predictions based on cause and effect relationships.
d. conduct multiple trials to test a prediction and draw conclusions about the relationships between results and predictions.
e. construct and interpret graphs from measurements.
f. follow a set of written instructions for a scientific investigation.

Fifth Grade Science Content Standards

Physical Sciences

1. Elements and their combinations account for all the varied types of matter in the world.
As a basis for understanding this concept, students know:
a. during chemical reactions, the atoms in the reactants rearrange to form products with different properties.
b. all matter is made of atoms, which may combine to form molecules.
c. metals have properties in common, such as electrical and thermal conductivity. Some metals, such as aluminum (Al), iron (Fe), nickel (Ni), copper (Cu), silver (Ag), gold (Au), are pure elements while others, such as steel and brass, are composed of a combination of elemental metals.
d. each element is made of one kind of atom. These elements are organized in the Periodic Table by their chemical properties.
e. scientists have developed instruments that can create images of atoms and molecules showing that they are discrete and often occur in well ordered arrays.

f. differences in chemical and physical properties of substances are used to separate mixtures and identify compounds.
g. properties of solid, liquid, and gaseous substances, such as sugar ($C_6H_{12}O_6$), water (H_2O) helium (He), oxygen (O_2), nitrogen (N_2),and carbon dioxide (CO_2).
h. living organisms and most materials are composed of just a few elements.
i. common properties of salts, such as sodium chloride (NaCl).

Life Sciences

2. Plants and animals have structures for respiration, digestion, waste disposal, and transport of materials.
As a basis for understanding this concept, students know:
a. many multicellular organisms have specialized structures to support the transport of materials.
b. how blood circulates through the heart chambers, lungs, and body, and how carbon dioxide (CO_2) and oxygen (O_2) are exchanged in the lungs and tissues.
c. the sequential steps of digestion, and the roles of teeth and mouth, esophagus, stomach, small intestine, large intestine, and colon in the function of the digestive system.
d. the role of the kidney in removing cellular wastes from blood and converting them into urine, which is stored in the bladder.
e. how sugar, water, and minerals are transported in a vascular plant.
f. plants use carbon dioxide (CO_2) and energy from sunlight to build molecules of sugar and release oxygen.
g. plant and animal cells break down sugar to obtain energy, forming carbon dioxide (CO_2) and water (respiration).

Earth Sciences

3. Water on Earth moves between the oceans and land through the processes of evaporation and condensation.
As a basis for understanding this concept, students know:
a. most of the Earth's water is present as salt water in the oceans, which cover most of the Earth's surface.
b. when liquid water evaporates, it turns into water vapor in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water.
c. water moves in the air from one place to another in the form of clouds or fog, which are tiny droplets of water or ice, and falls to the Earth as rain, hail, sleet, or snow.
d. the amount of fresh water, located in rivers, lakes, underground sources, and glaciers, is limited, and its availability can be extended through recycling and decreased use.
e. the origin of water used by their local communities.

4. Energy from the sun heats the Earth unevenly, causing air movements resulting in changing weather patterns.
As a basis for understanding this concept, students know:
a. uneven heating of the Earth causes air movements (convection currents).
b. the influence of the ocean on weather, and the role of the water cycle in weather.
c. causes and effects of different types of severe weather.
d. how to use weather maps and weather forecasts to predict local weather, and that prediction depends on many changing variables.
e. the Earth's atmosphere exerts a pressure that decreases with distance above the Earth's surface, and is the same in all directions.

5. The solar system consists of planets and other bodies that orbit the sun in predictable paths.
As a basis for understanding this concept, students know:
a. the sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
b. the solar system includes the Earth, moon, sun, eight other planets and their satellites, and smaller objects such as asteroids and comets.

c. the path of a planet around the sun is due to the gravitational attraction between the sun and the planet.

Investigation and Experimentation

6. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. classify objects (e.g., rocks, plant, leaves) based on appropriate criteria.
b. develop a testable question.
c. plan and conduct a simple investigation based on a student-developed question, and write instructions others can follow to carry out the procedure.
d. identify the dependent and controlled variables in an investigation.
e. identify a single independent variable in a scientific investigation and explain what will be learned by collecting data on this variable.
f. select appropriate tools (e.g., thermometers, meter sticks, balances, and graduated cylinders) and make quantitative observations.
g. record data using appropriate graphic representation (including charts, graphs, and labeled diagrams), and make inferences based on those data.
h. draw conclusions based on scientific evidence and indicate whether further information is needed to support a specific conclusion.
i. write a report of an investigation that includes tests conducted, data collected or evidence examined, and conclusions drawn.

Sixth Grade Science Content Standards

Plate Tectonics and Earth's Structure

1. Plate tectonics explains important features of the Earth's surface and major geologic events.
As the basis for understanding this concept, students know:
a. the fit of the continents, location of earthquakes, volcanoes, and midocean ridges, and the distribution of fossils, rock types, and ancient climatic zones provide evidence for plate tectonics.
b. the solid Earth is layered with cold, brittle lithosphere; hot, convecting mantle; and dense, metallic core.
c. lithospheric plates that are the size of continents and oceans move at rates of centimeters per year in response to movements in the mantle.
d. earthquakes are sudden motions along breaks in the crust called faults, and volcanoes/fissures are locations where magma reaches the surface.
g. how to determine the epicenter of an earthquake and that the effects of an earthquake vary with its size, distance from the epicenter, local geology, and the type of construction involved.

Shaping the Earth's Surface

2. Topography is reshaped by weathering of rock and soil and by the transportation and deposition of sediment.
As the basis for understanding this concept, students know:
b. rivers and streams are dynamic systems that erode and transport sediment, change course, and flood their banks in natural and recurring patterns.
c. beaches are dynamic systems in which sand is supplied by rivers and moved along the coast by wave action.
d. earthquakes, volcanic eruptions, landslides, and floods change human and wildlife habitats.

Heat (Thermal Energy) (Physical Science)

3. Heat moves in a predictable flow from warmer objects to cooler objects until all objects are at the same temperature.

As a basis for understanding this concept, students know:

a. energy can be carried from one place to another by heat flow, or by waves including water waves, light and sound, or by moving objects.

b. when fuel is consumed, most of the energy released becomes heat energy.

c. heat flows in solids by conduction (which involves no flow of matter) and in fluids by conduction and also by convection (which involves flow of matter).

d. heat energy is also transferred between objects by radiation; radiation can travel through space.

Energy in the Earth System

4. Many phenomena on the Earth's surface are affected by the transfer of energy through radiation and convection currents.

As a basis for understanding this concept, students know:

a. the sun is the major source of energy for phenomena on the Earth's surface, powering winds, ocean currents, and the water cycle.

b. solar energy reaches Earth through radiation, mostly in the form of visible light.

c. heat from Earth's interior reaches the surface primarily through convection.

d. convection currents distribute heat in the atmosphere and oceans.

e. differences in pressure, heat, air movement, and humidity result in changes of weather.

Ecology (Life Science)

5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.

As a basis for understanding this concept, students know:

a. energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis, and then from organism to organism in food webs.

b. over time, matter is transferred from one organism to others in the food web, and between organisms and the physical environment.

c. populations of organisms can be categorized by the functions they serve in an ecosystem.

d. different kinds of organisms may play similar ecological roles in similar biomes.

e. the number and types of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition.

Resources

6. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation.

As a basis for understanding this concept, students know:

a. the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

b. different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and classify them as renewable or nonrenewable.
c. natural origin of the materials used to make common objects.

Investigation and Experimentation

7. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. develop a hypothesis.
b. select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
c. construct appropriate graphs from data and develop qualitative statements about the relationships between variables.
d. communicate the steps and results from an investigation in written reports and verbal presentations.
e. recognize whether evidence is consistent with a proposed explanation.
f. read a topographic map and a geologic map for evidence provided on the maps, and construct and interpret a simple scale map.
g. interpret events by sequence and time from natural phenomena (e.g., relative ages of rocks and intrusions).
h. identify changes in natural phenomena over time without manipulating the phenomena (e.g., a tree limb, a grove of trees, a stream, a hillslope).

Seventh Grade Science Content Standards

Cell Biology

1. All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope.
As a basis for understanding this concept, students know:
a. cells function similarly in all living organisms.
b. the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.
c. the nucleus is the repository for genetic information in plant and animal cells.
d. mitochondria liberate energy for the work that cells do, and chloroplasts capture sunlight energy for photosynthesis.
e. cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.
f. as multicellular organisms develop, their cells differentiate.

Genetics

2. A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences.
As a basis for understanding this concept, students know:
a. the differences between the life cycles and reproduction of organisms.
b. reproduction produces offspring that inherit half their genes from each parent.
c. an inherited trait can be determined by one or more genes.

d. plant and animal cells contain many thousands of different genes, and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.
e. DNA is the genetic material of living organisms, and is located in the chromosomes of each cell.

Structure and Function in Living Systems

5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function.
As a basis for understanding this concept, students know:
a. plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.
b. organ systems function because of the contributions of individual organs, tissues, and cells. The failure of any part can affect the entire system.
c. how bones and muscles work together to provide a structural framework for movement.
e. the function of the umbilicus and placenta during pregnancy.
f. the structures and processes by which flowering plants generate pollen and ovules, seeds, and fruit.
g. how to relate the structures of the eye and ear to their functions.

Physical Principles in Living Systems (Physical Science)

6. Physical principles underlie biological structures and functions.
As a basis for understanding this concept, students know:
a. visible light is a small band within a very broad electromagnetic spectrum.
b. for an object to be seen, light emitted by or scattered from it must enter the eye.
c. light travels in straight lines except when the medium it travels through changes.
d. how simple lenses are used in a magnifying glass, the eye, camera, telescope, and microscope.
e. white light is a mixture of many wavelengths (colors), and that retinal cells react differently with different wavelengths.
f. light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).
g. the angle of reflection of a light beam is equal to the angle of incidence.
h. how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).
i. how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.
j. contractions of the heart generate blood pressure, and heart valves prevent backflow of blood in the circulatory system.

Investigation and Experimentation

7. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
b. utilize a variety of print and electronic resources (including the World Wide Web) to collect information as evidence as part of a research project.
c. communicate the logical connection among hypothesis, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
d. construct scale models, maps and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).
e. communicate the steps and results from an investigation in written reports and verbal presentations.

Eighth Grade Science Content Standards

Motion

1. The velocity of an object is the rate of change of its position.
As a basis for understanding this concept, students know:
a. position is defined relative to some choice of standard reference point and a set of reference directions.
b. average speed is the total distance traveled divided by the total time elapsed. The speed of an object along the path traveled can vary.
c. how to solve problems involving distance, time, and average speed.
d. to describe the velocity of an object one must specify both direction and speed.
e. changes in velocity can be changes in speed, direction, or both.
f. how to interpret graphs of position versus time and speed versus time for motion in a single direction.

Forces

2. Unbalanced forces cause changes in velocity.
As a basis for understanding this concept, students know:
a. a force has both direction and magnitude.
b. when an object is subject to two or more forces at once, the effect is the cumulative effect of all the forces.
c. when the forces on an object are balanced, the motion of the object does not change.
d. how to identify separately two or more forces acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.
e. when the forces on an object are unbalanced the object will change its motion (that is, it will speed up, slow down, or change direction).
f. the greater the mass of an object the more force is needed to achieve the same change in motion.
g. the role of gravity in forming and maintaining planets, stars and the solar system.

Structure of Matter

3. Elements have distinct properties and atomic structure. All matter is comprised of one or more of over 100 elements.
As a basis for understanding this concept, students know:
a. the structure of the atom and how it is composed of protons, neutrons and electrons.
b. compounds are formed by combining two or more different elements. Compounds have properties that are different from the constituent elements.
c. atoms and molecules form solids by building up repeating patterns such as the crystal structure of NaCl or long chain polymers.
d. the states (solid, liquid, gas) of matter depend on molecular motion.
e. in solids the atoms are closely locked in position and can only vibrate, in liquids the atoms and molecules are more loosely connected and can collide with and move past one another, while in gases the atoms or molecules are free to move independently, colliding frequently.
f. how to use the Periodic Table to identify elements in simple compounds.

Earth in the Solar System (Earth Science)

4. The structure and composition of the universe can be learned from the study of stars and galaxies.
As a basis for understanding this concept, students know:
a. galaxies are clusters of billions of stars, and may have different shapes.
b. the sun is one of many stars in our own Milky Way galaxy. Stars may differ in size, temperature, and color.
c. how to use astronomical units and light years as measures of distance between the sun, stars, and Earth.

d. stars are the source of light for all bright objects in outer space. The moon and planets shine by reflected sunlight, not by their own light.
e. the appearance, general composition, relative position and size, and motion of objects in the solar system, including planets, planetary satellites, comets, and asteroids.

Reactions

5. Chemical reactions are processes in which atoms are rearranged into different combinations of molecules.
As a basis for understanding this concept, students know:
a. reactant atoms and molecules interact to form products with different chemical properties.
b. the idea of atoms explains the conservation of matter: in chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.
c. chemical reactions usually liberate heat or absorb heat.
d. physical processes include freezing and boiling, in which a material changes form with no chemical reaction.
e. how to determine whether a solution is acidic, basic or neutral.

Chemistry of Living Systems (Life Science)

6. Principles of chemistry underlie the functioning of biological systems.
As a basis for understanding this concept, students know:
a. carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.
b. living organisms are made of molecules largely consisting of carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur.
c. living organisms have many different kinds of molecules including small ones such as water and salt, and very large ones such as carbohydrates, fats, proteins and DNA.

Periodic Table

7. The organization of the Periodic Table is based on the properties of the elements and reflects the structure of atoms.
As a basis for understanding this concept, students know:
a. how to identify regions corresponding to metals, nonmetals and inert gases.
b. elements are defined by the number of protons in the nucleus, which is called the atomic number. Different isotopes of an element have a different number of neutrons in the nucleus.
c. substances can be classified by their properties, including melting temperature, density, hardness, heat, and electrical conductivity.

Density and Buoyancy

8. All objects experience a buoyant force when immersed in a fluid.
As a basis for understanding this concept, students know:
a. density is mass per unit volume.
b. how to calculate the density of substances (regular and irregular solids, and liquids) from measurements of mass and volume.
c. the buoyant force on an object in a fluid is an upward force equal to the weight of the fluid it has displaced.
d. how to predict whether an object will float or sink.

Investigation and Experimentation

9. Scientific progress is made by asking meaningful questions and conducting careful investigations.
As a basis for understanding this concept, and to address the content the other three strands, students should develop their own questions and perform investigations. Students will:
a. plan and conduct a scientific investigation to test a hypothesis.
b. evaluate the accuracy and reproducibility of data.
c. distinguish between variable and controlled parameters in a test.
d. recognize the slope of the linear graph as the constant in the relationship y=kx and apply this to interpret graphs constructed from data.
e. construct appropriate graphs from data and develop quantitative statements about the relationships between variables.
f. apply simple mathematical relationships to determine one quantity given the other two (including speed = distance/time, density = mass/volume, force = pressure x area, volume=area x height).
g. distinguish between linear and non-linear relationships on a graph of data.

Grades 9-12 Physics Content Standards

Motion and Forces

1. Newton's laws predict the motion of most objects.
As a basis for understanding this concept, students know:
a. how to solve problems involving constant speed and average speed.
b. when forces are balanced no acceleration occurs, and thus an object continues to move at a constant speed or stays at rest (Newton's First Law).
c. how to apply the law F=ma to solve one-dimensional motion problems involving constant forces (Newton's Second Law).
d. when one object exerts a force on a second object, the second object always exerts a force of equal magnitude and opposite direction. (Newton's Third Law).
e. the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of the Earth.
f. applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (for example, the Earth's gravitational force causes a satellite in a circular orbit to change direction but not speed).
g. circular motion requires application of a constant force directed toward the center of the circle.
h.* Newton's Laws are not exact but they provide very good approximations unless an object is moving close to the speed of light or is small enough that the quantum effects are important.
i.* how to solve two-dimensional trajectory problems.
j.* how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components.
k.* how to solve two-dimensional problems involving balanced forces (statics).
l.* how to solve problems in circular motion, using the formula for centripetal acceleration in the following form: $a=v^2/r$.
m.* how to solve problems involving the forces between two electric charges at a distance (Coulomb's Law) or the forces between two masses at a distance (Universal gravitation).

Conservation of Energy and Momentum

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.
As a basis for understanding this concept, students know:

a. how to calculate kinetic energy using the formula $E=(1/2)mv^2$.
b. how to calculate changes in gravitational potential energy near the Earth using the formula (change in potential energy) =mgh (change in the elevation).
c. how to solve problems involving conservation of energy in simple systems such as falling objects.
d. how to calculate momentum as product mv.
e. momentum is a separately conserved quantity, different from energy.
f. an unbalanced force on an object produces a change in its momentum.
g. how to solve problems involving elastic and inelastic collisions in one dimension using the principles of conservation of momentum and energy.
h.* how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs.

Heat and Thermodynamics

3. Energy cannot be created or destroyed although in many processes energy is transferred to the environment as heat.
As a basis for understanding this concept, students know:
a. heat flow and work are two forms of energy transfer between systems.
b. the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (First Law of Thermodynamics) and that this is an example of the law of conservation of energy.
c. thermal energy (commonly called heat) consists of random motion and the vibrations and rotations of atoms and molecules. The higher the temperature, the greater the atomic or molecular motion.
d. most processes tend to decrease the order of a system over time, and energy levels are eventually distributed uniformly.
e. entropy is a quantity that measures the order or disorder of a system, and is larger for a more disordered system.
f.* the statement "entropy tends to increase" is a law of statistical probability that governs all closed systems (Second Law of Thermodynamics).
g.* how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines have some heat flow out.

Waves

4. Waves have characteristic properties that do not depend on the type of wave.
As a basis for understanding this concept, students know:
a. waves carry energy from one place to another.
b. how to identify transverse and longitudinal waves in mechanical media such as springs, ropes, and the Earth (seismic waves).
c. how to solve problems involving wavelength, frequency, and wave speed.
d. sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
e. radio waves, light and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in vacuum is approximately 3x108 m/s (186,000 miles/second).
f. how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

Electronic and Magnetic Phenomena

5. Electric and magnetic phenomena are related and have many practical applications.
As a basis for understanding this concept, students know:
a. how to predict the voltage or current in simple direct current electric circuits constructed from batteries, wires, resistors, and capacitors.
b. how to solve problems involving Ohm's law.

c. any resistive element in a DC circuit dissipates energy which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = (potential difference IR) times (current I) = I2R.
d. the properties of transistors and their role in electric circuits.
e. charged particles are sources of electric fields and experience forces due to the electric fields from other charges.
f. magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and experience forces due to magnetic fields of other sources.
g. how to determine the direction of a magnetic field produced by a current flowing in a straight wire or in a coil.
h. changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors.
i. plasmas, the fourth state of matter, contain ions and/or free electrons and conduct electricity.
j.* electric and magnetic fields contain energy and act as vector force fields.
k.* the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle.
l.* how to calculate the electric field resulting from a point charge.
m.* static electric fields have as their source some arrangement of electric charges.
n.* the force on a moving particle (with charge q) in a magnetic field is qvB sin(a) where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force.
o.* how to apply the concepts of electrical and gravitational potential energy to solve problems involving conservation of energy.

Grades 9-12 Chemistry Content Standards

Atomic and Molecular Structure

1. The Periodic Table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.
As a basis for understanding this concept, students know:
a. how to relate the position of an element in the Periodic Table to its atomic number and atomic mass.
b. how to use the Periodic Table to identify metals, semimetals, nonmetals, and halogens.
c. how to use the Periodic Table to identify alkali metals, alkaline earth metals and transition metals, and trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.
d. how to use the Periodic Table to determine the number of electrons available for bonding.
e. the nucleus is much smaller in size than the atom yet contains most of its mass.
f.* how to use the Periodic Table to identify the lanthanides and actinides, and transactinide elements, and know that the transuranium elements were man made.
g.* how to relate the position of an element in the periodic table to its quantum electron configuration, and reactivity with other elements in the table.
h.* the experimental basis for Thomson's discovery of the electron, Rutherford's nuclear atom, Millikan's oil drop experiment, and Einstein's explanation of the photoelectric effect.
i.* the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom.
j.* spectral lines are a result of transitions of electrons between energy levels. Their frequency is related to the energy spacing between levels using Planck's relationship (E=hn).

Chemical Bonds

2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds based on electrostatic forces between electrons and protons, and between atoms and molecules.
As a basis for understanding this concept, students know:
a. atoms combine to form molecules by sharing electrons to form covalent or metallic bonds, or by exchanging electrons to form ionic bonds.

b. chemical bonds between atoms in molecules such as H2, CH4, NH3, H2CCH2, N2, Cl2, and many large biological molecules are covalent.
c. salt crystals such as NaCl are repeating patterns of positive and negative ions held together by electrostatic attraction.
d. in a liquid the inter-molecular forces are weaker than in a solid, so that the molecules can move in a random pattern relative to one-another.
e. how to draw Lewis dot structures.
f.* how to predict the shape of simple molecules and their polarity from Lewis dot structures.
g.* how electronegativity and ionization energy relate to bond formation.
h.* how to identify solids and liquids held together by Van der Waals forces or hydrogen bonding, and relate these forces to volatility and boiling/melting point temperatures.

Conservation of Matter and Stoichiometry

3. The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants.
As a basis for understanding this concept, students know:
a. how to describe chemical reactions by writing balanced equations.
b. the quantity one mole is defined so that one mole of carbon 12 atoms has a mass of exactly 12 grams.
c. one mole equals 6.02x1023 particles (atoms or molecules).
d. how to determine molar mass of a molecule from its chemical formula and a table of atomic masses, and how to convert the mass of a molecular substance to moles, number of particles or volume of gas at standard temperature and pressure.
e. how to 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 masses.
f.* how to calculate percent yield in a chemical reaction.
g.* how to identify reactions that involve oxidation and reduction and how to balance oxidation-reduction reactions.

Gases and their Properties

4. The Kinetic Molecular theory describes the motion of atoms and molecules and explains the properties of gases.
As a basis for understanding this concept, students know:
a. the random motion of molecules and their collisions with a surface create the observable pressure on that surface.
b. the random motion of molecules explains the diffusion of gases.
c. how to apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases.
d. the values and meanings of standard temperature and pressure (STP).
e. how to convert between Celsius and Kelvin temperature scales.
f. there is no temperature lower than 0 Kelvin.
g.* the kinetic theory of gases relates the absolute temperature of a gas to the average kinetic energy of its molecules or atoms.
h.* how to solve problems using the ideal gas law in the form PV=nRT.
i.* how to apply Dalton's Law of Partial Pressures to describe the composition gases, and Graham's Law to describe diffusion of gases.

Acids and Bases

5. Acids, bases, and salts are three classes of compounds that form ions in water solutions.
As a basis for understanding this concept, students know:
a. the observable properties of acids, bases and salt solutions.

b. acids are hydrogen-ion-donating and bases are hydrogen-ion-accepting substances.
c. strong acids and bases fully dissociate and weak acids and bases partially dissociate.
d. how to use the pH scale to characterize acid and base solutions.
e.* the Arrhenius, Bronsted-Lowry, and Lewis acid-base definitions.
f.* how to calculate pH from the hydrogen ion concentration.
g.* buffers stabilize pH in acid-base reactions.

Solutions

6. Solutions are homogenous mixtures of two or more substances.
As a basis for understanding this concept, students know:
a. definitions of solute and solvent.
b. how to describe the dissolving process as a result of random molecular motion.
c. temperature, pressure, and surface area affect the dissolving process.
d. how to calculate the concentration of a solute in terms of grams per liter, molarity, parts per million and percent composition.
e.* the relationship between the molality of solute in a solution, and the solution's depressed freezing point or elevated boiling point.
f.* how molecules in solution are separated or purified by the methods of chromatography and distillation.

Chemical Thermodynamics

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter.
As a basis for understanding this concept, students know:
a. how to describe temperature and heat flow in terms of the motion of molecules (or atoms)
b. chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.
c. energy is released when a material condenses or freezes and absorbed when a material evaporates or melts.
d. how to solve problems involving heat flow and temperature changes, using known values of specific heat, and latent heat of phase change.
e.* how to apply Hess's Law to calculate enthalpy change in a reaction.
f.* how to use the Gibbs free energy equation to determine whether a reaction would be spontaneous.

Reaction Rates

8. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules.
As a basis for understanding this concept, students know:
a. the rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with time.
b. how reaction rates depend on such factors as concentration, temperature, and pressure.
c. the role a catalyst plays in increasing the reaction rate.
d.* the definition and role of activation energy in a chemical reaction.

Chemical Equilibrium

9. Chemical equilibrium is a dynamic process at the molecular level.
As a basis for understanding this concept, students know:
a. how to use LeChatelier's Principle to predict the effect of changes in concentration, temperature and pressure.
b. equilibrium is established when forward and reverse reaction rates are equal.
c.* how to write and calculate an equilibrium constant expression for a reaction.

Organic and Biochemistry

10. The bonding characteristics of carbon lead to many different molecules with varied sizes, shapes, and chemical properties, providing the biochemical basis of life.
As a basis for understanding this concept, students know:
a. large molecules (polymers) such as proteins, nucleic acids, and starch are formed by repetitive combinations of simple sub-units.
b. the bonding characteristics of carbon lead to a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
c. amino acids are the building blocks of proteins.

Nuclear Processes

11. Nuclear processes are those in which an atomic nucleus changes, including radioactive decay of naturally occurring and man-made isotopes, nuclear fission, and nuclear fusion.
As a basis for understanding this concept, students know:
a. protons and neutrons in the nucleus are held together by strong nuclear forces which are stronger than the electromagnetic repulsion between the protons.
b. the energy release per gram of material is much larger in nuclear fusion or fission reactions than in chemical reactions: change in mass (calculated by E=mc_) is small but significant in nuclear reactions.
c. many naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.
d. the three most common forms of radioactive decay (alpha, beta, gamma) and how the nucleus changes in each type of decay.
e. alpha, beta, and gamma radiation produce different amounts and kinds of damage in matter and have different penetrations.
f.* how to calculate the amount of a radioactive substance remaining after an integral number of half lives have passed.
g.* protons and neutrons have substructure and consist of particles called quarks.

Grades 9-12 Biology/Life Sciences Content Standards

Cell Biology

1. Fundamental life processes of plants and animals depend on a variety of chemical reactions that are carried out in specialized areas of the organism's cells.
As a basis for understanding this concept, students know:
a. cells are enclosed within semi-permeable membranes that regulate their interaction with their surroundings.
b. enzymes are proteins and catalyze biochemical reactions without altering the reaction equilibrium. The activity of enzymes depends on the temperature, ionic conditions and pH of the surroundings.
c. how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.
d. the Central Dogma of molecular biology outlines the flow of information from transcription of RNA in the nucleus to translation of proteins on ribosomes in the cytoplasm.
e. the role of the endoplasmic reticulum and Golgi apparatus in secretion of proteins.
f. usable energy is captured from sunlight by chloroplasts, and stored via the synthesis of sugar from carbon dioxide.
g. the role of the mitochondria in making stored chemical bond energy available to cells by completing the breakdown of glucose to carbon dioxide.
h. most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.
i.* how chemiosmotic gradients in the mitochondria and chloroplast store energy for ATP production.

j* how eukaryotic cells are given shape and internal organization by a cytoskeleton and/or cell wall.

Genetics

2. Mutation and reproduction lead to genetic variation in a population.
As a basis for understanding this concept, students know:
a. meiosis is an early step in reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
b. only certain cells in a multicellular organism undergo meiosis.
c. how random chromosome segregation explains the probability that a particular allele will be in a gamete.
d. new combinations of alleles may be generated in a zygote through fusion of male and female gametes (fertilization).
e. why approximately half of an individual's DNA sequence comes from each parent.
f. the role of chromosomes in determining an individual's sex.
g. how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.

3. A multicellular organism develops from a single zygote, and its phenotype depends on its genotype, which is established at fertilization.
As a basis for understanding this concept, students know:
a. how to predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (autosomal or X-linked, dominant or recessive).
b. the genetic basis for Mendel's laws of segregation and independent assortment.
c.* how to predict the probable mode of inheritance from a pedigree diagram showing phenotypes.
d.* how to use data on frequency of recombination at meiosis to estimate genetic distances between loci, and to interpret genetic maps of chromosomes.

4. 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 know:
a. the general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.
b. how to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.
c. how mutations in the DNA sequence of a gene may or may not affect the expression of the gene, or the sequence of amino acids in an encoded protein.
d. specialization of cells in multicellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.
e. proteins can differ from one another in the number and sequence of amino acids.
f.* why proteins having different amino acid sequences typically have different shapes and chemical properties.

5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells.
As a basis for understanding this concept, students know:
a. the general structures and functions of DNA, RNA, and protein.
b. how to apply base-pairing rules to explain precise copying of DNA during semi-conservative replication, and transcription of information from DNA into mRNA.
c. how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.
d.* how basic DNA technology (restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation) is used to construct recombinant DNA molecules.
e.* how exogenous DNA can be inserted into bacterial cells in order to alter their genetic makeup and support expression of new protein products.

Ecology

6. Stability in an ecosystem is a balance between competing effects.
As a basis for understanding this concept, students know:
a. biodiversity is the sum total of different kinds of organisms, and is affected by alterations of habitats.
b. how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of non-native species, or changes in population size.
c. how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.
d. how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles via photosynthesis and respiration.
e. a vital part of an ecosystem is the stability of its producers and decomposers.
f. at each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat and this can be represented in a food pyramid.
g.* how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.

Physiology

9. As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic), despite changes in the outside environment.
As a basis for understanding this concept, students know:
a. how the complementary activity of major body systems provides cells with oxygen and nutrients, and removes toxic waste products such as carbon dioxide.
b. how the nervous system mediates communication between different parts of the body and interactions with the environment.
c. how feedback loops in the nervous and endocrine systems regulate conditions within the body.
d. the functions of the nervous system, and the role of neurons in transmitting electrochemical impulses.
e. the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.
f.* the individual functions and sites of secretion of digestive enzymes (amylases, proteases, nucleases, lipases), stomach acid, and bile salts.
g.* the homeostatic role of the kidneys in the removal of nitrogenous wastes, and of the liver in blood detoxification and glucose balance.
h.* the cellular and molecular basis of muscle contraction, including the roles of actin, myosin, Ca+2, and ATP.
i.* how hormones (including digestive, reproductive, osmoregulatory) provide internal feedback mechanisms for homeostasis at the cellular level and in whole organisms.

10. Organisms have a variety of mechanisms to combat disease.
As a basis for understanding the human immune response, students know:
a. the role of the skin in providing nonspecific defenses against infection.
b. the role of antibodies in the body's response to infection.
c. how vaccination protects an individual from infectious diseases.
d. there are important differences between bacteria and viruses, with respect to their requirements for growth and replication, the primary defense of the body against them, and effective treatment of infections they cause.
e. why an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections of microorganisms that are usually benign.
f.* the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Grades 9-12 Earth Science Content Standards

Earth's Place in the Universe

1. Astronomy and planetary exploration reveal the structure, scale, and change of the solar system over time.
As a basis for understanding this concept, students know:
a. how the differences and similarities among the sun, the terrestrial planets, and the gas planets may have been established during the formation of the solar system.
d. evidence that the planets are much closer than the stars.
e. the sun is a typical star and is powered by nuclear reactions, primarily the fusion of hydrogen to form helium.
f. evidence for the dramatic effects of asteroid impacts in shaping the surface of planets and their moons, and in mass extinctions of life on Earth.
g.* evidence for the existence of planets orbiting other stars.

2. Earth-based and space-based astronomy reveals the structure, scale, and change over time of stars, galaxies and the universe.
As a basis for understanding this concept, students know:
a. the solar system is located in an outer edge of the disc-shaped Milky Way galaxy which spans 100,000 light years.
b. galaxies are made of billions of stars and form most of the visible mass of the universe.
d. stars differ in their life cycles, and visual, radio, and X-ray telescopes collect data that reveal these differences.
e.* accelerators boost subatomic particles to energy levels that simulate conditions in the stars and in early history of the universe before stars formed.

Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea, and mountains on the Earth's surface.
As the basis for understanding this concept, students know:
a. features of the ocean floor (magnetic patterns, age, and sea floor topography) provide evidence for plate tectonics.
b. the principal structures that form at the three different kinds of plate boundaries.
d. why and how earthquakes occur, and the scales used to measure their intensity and magnitude.
e. two kinds of volcanoes, one with violent eruptions producing steep slopes and the other with voluminous lava flows producing gentle slopes.
f.* explanation for the location and properties of volcanoes that are due to hot spots and those that are due to subduction.

Energy in the Earth System

4. Energy enters the Earth system primarily as solar radiation and eventually escapes as heat.
As a basis for understanding this concept, students know:
a. the relative amount of incoming solar energy compared with Earth’s internal energy and the energy used by society.
b. the fate of incoming solar radiation in terms of reflection, absorption, and photosynthesis.
c. the different atmospheric gases that absorb the Earth’s thermal radiation, and the mechanism and significance of the greenhouse effect.
d.* the different greenhouse conditions on Earth, Mars, and Venus, their origins and climatic consequences.

5. Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
As a basis for understanding this concept, students know:

a. how differential heating of the Earth results in circulation patterns in the atmosphere and oceans that globally distribute the heat.
b. the relationship between the rotation of the Earth and the circular motion of ocean currents and air in pressure centers.
c. the origin and effects of temperature inversions.
d. properties of ocean water such as temperature and salinity can be used to explain the layered structure of the oceans, generation of horizontal and vertical ocean currents, and the geographic distribution of marine organisms.
e. the distribution of rain forests and deserts on Earth in bands at specific latitudes.
f.* the interaction of wind patterns, ocean currents, and mountain ranges that results in the global pattern of latitudinal bands of rain forests and deserts.
g.* features of the ENSO cycle (El Ni–o) in terms of sea-surface and air temperature variations across the Pacific, and some climatic results of this cycle.

6. Climate is the long term average of a region's weather and depends on many factors.
As a basis for understanding this concept, students know:
a. weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere.
b. effects on climate of latitude, elevation, topography, as well as proximity to large bodies of water and cold or warm ocean currents.
c. how the Earth's climate has changed over time, corresponding to changes in the Earth's geography, atmospheric composition and/or other factors (solar radiation, plate movement, etc.).
d.* use of computer models to predict the effects of increasing greenhouse gases on climate for the planet as a whole and for specific regions.

Biogeochemical cycles

7. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and organisms as part of biogeochemical cycles.
As a basis for understanding this concept, students know:
a. the carbon cycle of photosynthesis and respiration, and the nitrogen cycle.
b. the global carbon cycle in terms of the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, and fossil fuels, and the movement of carbon among these reservoirs.
c. movement of matter among reservoirs is driven by the Earth's internal and external sources of energy.
d.* the relative residence times and flows of carbon in and out of its different reservoirs.

Structure and Composition of the Atmosphere

8. Life has changed Earth's atmosphere and changes in the atmosphere affect conditions for life.
As a basis for understanding this concept, students know:
a. the thermal structure and chemical composition of the atmosphere.
c. the location of the ozone layer in the upper atmosphere, its role in absorbing ultraviolet radiation and how it varies both naturally and in response to human activities.

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*Standards without asterisks represent those that all students are expected to achieve in the course of their studies. Standards with asterisks represent those that all students should have the opportunity to learn.

**Science Standards vary by state. This document is intended as a guideline only. If you need to cover evolution, please refer to your state guidelines for specific requirement details.

Earth Space Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
ESS1.A The universe and its stars	Patterns of movement of the sun, moon, and stars as seen from Earth can be observed, described, and predicted.	Stars range greatly in size and distance from Earth and this can explain their relative brightness.	The solar system is part of the Milky Way, which is one of many billions of galaxies.	Light spectra from stars are used to determine their characteristics, processes, and lifecycles. Solar activity creates the elements through nuclear fusion. The development of technologies has provided the astronomical data that provide the empirical evidence for the Big Bang theory.
ESS1.B Earth and the solar system		The Earth's orbit and rotation, and the orbit of the moon around the Earth cause observable patterns.	The solar system contains many varied objects held together by gravity. Solar system models explain and predict eclipses, lunar phases, and seasons.	Kepler's laws describe common features of the motions of orbiting objects. Observations from astronomy and space probes provide evidence for explanations of solar system formation. Changes in Earth's tilt and orbit cause climate changes such as Ice Ages.
ESS1.C The history of planet Earth	Some events on Earth occur very quickly; others can occur very slowly.	Certain features on Earth can be used to order events that have occurred in a landscape.	Rock strata and the fossil record can be used as evidence to organize the relative occurrence of major historical events in Earth's history.	The rock record resulting from tectonic and other geoscience processes as well as objects from the solar system can provide evidence of Earth's early history and the relative ages of major geologic formations.
ESS2.A Earth materials and systems	Wind and water change the shape of the land.	Four major Earth systems interact. Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, organisms, and gravity break rocks, soils, and sediments into smaller pieces and move them around.	Energy flows and matter cycles within and among Earth's systems, including the sun and Earth's interior as primary energy sources. Plate tectonics is one result of these processes.	Feedback effects exist within and among Earth's systems.
ESS2.B Plate tectonics and large-scale system interactions	Maps show where things are located. One can map the shapes and kinds of land and water in any area.	Earth's physical features occur in patterns, as do earthquakes and volcanoes. Maps can be used to locate features and determine patterns in those events.	Plate tectonics is the unifying theory that explains movements of rocks at Earth's surface and geological history. Maps are used to display evidence of plate movement.	Radioactive decay and residual heat of formation within Earth's interior contribute to thermal convection in the mantle.

	K-2	3-5	6-8	9-12
ESS2.C The roles of water in Earth's surface processes	Water is found in many types of places and in different forms on Earth.	Most of Earth's water is in the ocean and much of the Earth's fresh water is in glaciers or underground.	Water cycles among land, ocean, and atmosphere, and is propelled by sunlight and gravity. Density variations of sea water drive interconnected ocean currents. Water movement causes weathering and erosion, changing landscape features. --- Complex interactions determine local weather patterns and influence climate, including the role of the ocean.	The planet's dynamics are greatly influenced by water's unique chemical and physical properties.
ESS2.D Weather and climate	Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region and time. People record weather patterns over time.	Climate describes patterns of typical weather conditions over different scales and variations. Historical weather patterns can be analyzed.		The role of radiation from the sun and its interactions with the atmosphere, ocean, and land are the foundation for the global climate system. Global climate models are used to predict future changes, including changes influenced by human behavior and natural factors.
ESS2.E Biogeology	Plants and animals can change their local environment.	Living things can affect the physical characteristics of their environment.	[Content found in LS4.A and LS4.D]	The biosphere and Earth's other systems have many interconnections that cause a continual co-evolution of Earth's surface and life on it
ESS3.A Natural resources	--- Living things need water, air, and resources from the land, and they live in places that have the things they need. Humans use natural resources for everything they do.	Energy and fuels humans use are derived from natural sources and their use affects the environment. Some resources are renewable over time, others are not.	Humans depend on Earth's land, ocean, atmosphere, and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.	Resource availability has guided the development of human society and use of natural resources has associated costs, risks, and benefits.
ESS3.B Natural hazards	In a region, some kinds of severe weather are more likely than others. Forecasts allow communities to prepare for severe weather.	A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	Mapping the history of natural hazards in a region and understanding related geological forces.	Natural hazards and other geological events have shaped the course of human history at local, regional, and global scales.
ESS3.C Human impacts on Earth systems	Things people do can affect the environment but they can make choices to reduce their impacts.	Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth's resources and environments.	Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.	Sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources, including the development of technologies.

ESS3.D Global climate change	N/A	N/A	Human activities affect global warming. Decisions to reduce the impact of global warming depend on understanding climate science, engineering capabilities, and social dynamics.	Global climate models used to predict changes continue to be improved, although discoveries about the global climate system are ongoing and continually needed.

Life Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
LS1.A Structure and function	All organisms have external parts that they use to perform daily functions.	Organisms have both internal and external macroscopic structures that allow for growth, survival, behavior, and reproduction.	All living things are made up of cells. In organisms, cells work together to form tissues and organs that are specialized for particular body functions.	Systems of specialized cells within organisms help perform essential functions of life. Any one system in an organism is made up of numerous parts. Feedback mechanisms maintain an organism's internal conditions within certain limits and mediate behaviors.
LS1.B Growth and development of organisms	Parents and offspring often engage in behaviors that help the offspring survive.	Reproduction is essential to every kind of organism. Organisms have unique and diverse life cycles.	Animals engage in behaviors that increase the odds of reproduction. An organism's growth is affected by both genetic and environmental factors.	Growth and division of cells in organisms occurs by mitosis and differentiation for specific cell types.
LS1.C Organization for matter and energy flow in organisms	Animals obtain food they need from plants or other animals. Plants need water and light.	Food provides animals with the materials and energy they need for body repair, growth, warmth, and motion. Plants acquire material for growth chiefly from air, water, and process matter and obtain energy from sunlight, which is used to maintain conditions necessary for survival.	Plants use the energy from light to make sugars through photosynthesis. Within individual organisms, food is broken down through a series of chemical reactions that rearrange molecules and release energy.	The hydrocarbon backbones of sugars produced through photosynthesis are used to make amino acids and other molecules that can be assembled into proteins or DNA. Through cellular respiration, matter and energy flow through different organizational levels of an organism as elements are recombined to form different products and transfer energy.
LS1.D Information Processing	Animals sense and communicate information and respond to inputs with behaviors that help them grow and survive.	Different sense receptors are specialized for particular kinds of information; Animals use their perceptions and memories to guide their actions.	Each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain; The signals are then processed in the brain, resulting in immediate behavior or memories.	N/A

	K-2	3-5	6-8	9-12
LS2.A Interdependent relationships in ecosystems	Plants depend on water and light to grow, and also depend on animals for pollination or to move their seeds around.	The food of almost any animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants, while decomposers restore some materials back to the soil.	Organisms and populations are dependent on their environmental interactions both with other living things and with nonliving factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared.	Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem.
LS2.B Cycles of matter and energy transfer in ecosystems	[Content found in LS1.C and ESS3.A]	Matter cycles between the air and soil and among organisms as they live and die.	The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.	Photosynthesis and cellular respiration provide most of the energy for life processes. Only a fraction of matter consumed at the lower level of a food web is transferred up, resulting in fewer organisms at higher levels. At each link in an ecosystem elements are combined in different ways and matter and energy are conserved. Photosynthesis and cellular respiration are key components of the global carbon cycle.
LS2.C Ecosystem dynamics, functioning, and resilience	N/A	When the environment changes some organisms survive and reproduce, some move to new locations, some move into the transformed environment, and some die.	Ecosystem characteristics vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.	If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosystem, depending on the complex set of interactions within the ecosystem.
LS2.D Social interactions and group behavior	N/A	Being part of a group helps animals obtain food, defend themselves, and cope with changes.	N/A	Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives.

	K-2	3-5	6-8	9-12
LS3.A Inheritance of traits	Young organisms are very much, but not exactly, like their parents and also resemble other organisms of the same kind.	Different organisms vary in how they look and function because they have different inherited information; the environment also affects the traits that an organism develops.	Genes chiefly regulate a specific protein, which affect an individual's traits.	DNA carries instructions for forming species' characteristics. Each cell in an organism has the same genetic content, but genes expressed by cells can differ
LS3.B Variation of traits			In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.	The variation and distribution of traits in a population depend on genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication, or from chromosomes swapping sections during meiosis.
LS4.A Evidence of common ancestry and diversity	N/A	Some living organisms resemble organisms that once lived on Earth. Fossils provide evidence about the types of organisms and environments that existed long ago.	The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. The fossil record and comparisons of anatomical similarities between organisms enables the inference of lines of evolutionary descent.	The ongoing branching that produces multiple lines of descent can be inferred by comparing DNA sequences, amino acid sequences, and anatomical and embryological evidence of different organisms.
LS4.B Natural selection	N/A	Differences in characteristics between individuals of the same species provide advantages in surviving and reproducing.	Both natural and artificial selection result from certain traits giving some individuals an advantage in surviving and reproducing, leading to predominance of certain traits in a population.	Natural selection occurs only if there is variation in the genes and traits between organisms in a population. Traits that positively affect survival can become more common in a population.
LS4.C Adaptation	N/A	Particular organisms can only survive in particular environments.	Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.	Evolution results primarily from genetic variation of individuals in a species, competition for resources, and proliferation of organisms better able to survive and reproduce. Adaptation means that the distribution of traits in a population, as well as species expansion, emergence or extinction, can change when conditions change.
LS4.D Biodiversity and humans	A range of different organisms lives in different places.	---------- Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there.	Changes in biodiversity can influence humans' resources and ecosystem services they rely on.	Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.

Physical Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
PS1.A Structure of matter (includes PS1.C Nuclear processes)	Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	Because matter exists as particles that are too small to see, matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.	The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart.
PS1.B Chemical reactions	Heating and cooling substances cause changes that are sometimes reversible and sometimes not.	Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.	Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.	Chemical processes are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.
PS2.A Forces and motion	Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	Newton's 2nd law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.
PS2.B Types of interactions			Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields.
PS2.C Stability & instability in physical systems	N/A	N/A	N/A	N/A
PS3.A Definitions of energy	N/A	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.	The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects). --- Systems move toward stable states.
PS3.B Conservation of energy and energy transfer	[Content found in PS3.D]			

	K-2	3-5	6-8	9-12
PS3.C Relationship between energy and forces	Bigger pushes and pulls cause bigger changes in an object's motion or shape.	When objects collide, contact forces transfer energy so as to change the objects' motions.	When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them.	Fields contain energy that depends on the arrangement of the objects in the field.
PS3.D Energy in chemical processes and everyday life	Sunlight warms Earth's surface.	Energy can be "produced," "used," or "released" by converting stored energy. Plants capture energy from sunlight, which can later be used as fuel or food.	Sunlight is captured by plants and used in a reaction to produce sugar molecules, which can be reversed by burning those molecules to release energy.	Photosynthesis is the primary biological means of capturing radiation from the sun; energy cannot be destroyed, it can be converted to less useful forms.
PS4.A Wave properties	Sound can make matter vibrate, and vibrating matter can make sound.	Waves are regular patterns of motion, which can be made in water by disturbing the surface. Waves of the same type can differ in amplitude and wavelength. Waves can make objects move.	A simple wave model has a repeating pattern with a specific wavelength, frequency, and amplitude, and mechanical waves need a medium through which they are transmitted. This model can explain many phenomena including sound and light. Waves can transmit energy.	The wavelength and frequency of a wave are related to one another by the speed of the wave, which depends on the type of wave and the medium through which it is passing. Waves can be used to transmit information and energy.
PS4.B Electromagnetic radiation	Objects can be seen only when light is available to illuminate them.	Object can be seen when light reflected from their surface enters our eyes.	The construct of a wave is used to model how light interacts with objects.	Both an electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.
PS4.C Information technologies and instrumentation	People use devices to send and receive information.	---------- Patterns can encode, send, receive and decode information.	Waves can be used to transmit digital information. Digitized information is comprised of a pattern of 1s and 0s.	Large amounts of information can be stored and shipped around as a result of being digitized.