Utah Science Core Curriculum
Biology

Introduction

Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Science Core Curriculum places emphasis on understanding and using skills. Students should be active learners. It is not enough for students to read about science; they must do science. They should observe, inquire, question, formulate and test hypotheses, analyze data, report, and evaluate findings. The students, as scientists, should have hands-on, active experiences throughout the instruction of the science curriculum.

The Science Core describes what students should know and be able to do at the end of each course. It was developed, critiqued, piloted, and revised by a community of Utah science teachers, university science educators, State Office of Education specialists, scientists, expert national consultants, and an advisory committee representing a wide diversity of people from the community. The Core reflects the current philosophy of science education that is expressed in national documents developed by the American Association for the Advancement of Science and the National Academies of Science. This Science Core has the endorsement of the Utah Science Teachers Association. The Core reflects high standards of achievement in science for all students.

Organization of the Science Core

The Core is designed to help teachers organize and deliver instruction. Elements of the Core include the following:

- ✓ Each grade level begins with a brief course description.
- ✓ The INTENDED LEARNING OUTCOMES (ILOs) describe the goals for science skills and attitudes. They are found at the beginning of each grade, and are an integral part of the Core that should be included as part of instruction.
- ✓ The SCIENCE BENCHMARKS describe the science content students should know. Each grade level has three to five Science Benchmarks. The ILOs and Benchmarks intersect in the Standards, Objectives and Indicators.
- ✓ A STANDARD is a broad statement of what students are expected to understand. Several Objectives are listed under each Standard.
- ✓ An OBJECTIVE is a more focused description of what students need to know and be able to do at the completion of instruction. If students have mastered the Objectives associated with a given Standard, they are judged to have mastered that Standard at that grade level. Several Indicators are described for each Objective.
- ✓ An INDICATOR is a measurable or observable student action that enables one to judge whether a student has mastered a particular Objective. Indicators are not meant to be classroom activities, but they can help guide classroom instruction.
- ✓ SCIENCE LANGUAGE STUDENTS SHOULD USE is a list of terms that students and teachers should integrate into their normal daily conversations around science topics. These are **not** vocabulary lists for students to memorize.

Seven Guidelines Were Used in Developing the Science Core

Reflects the Nature of Science: Science is a way of knowing, a process for gaining knowledge and understanding of the natural world. The Core is designed to produce an integrated set of Intended Learning Outcomes (ILOs) for students.

As described in these ILOs, students will:

- Use science process and thinking skills.
- Manifest science interests and attitudes.
- Understand important science concepts and principles.
- Communicate effectively using science language and reasoning.
- Demonstrate awareness of the social and historical aspects of science.
- Understand the nature of science.

Coherent: The Core has been designed so that, wherever possible, the science ideas taught within a particular grade level have a logical and natural connection with each other and with those of earlier grades. Efforts have also been made to select topics and skills that integrate well with one another and with other subject areas appropriate to grade level. In addition, there is an upward articulation of science concepts, skills, and content. This spiraling is intended to prepare students to understand and use more complex science concepts and skills as they advance through their science learning.

Developmentally Appropriate: The Core takes into account the psychological and social readiness of students. It builds from concrete experiences to more abstract understandings. The Core describes science language students should use that is appropriate to their grade level. A more extensive vocabulary should not be emphasized. In the past, many educators may have mistakenly thought that students understood abstract concepts (such as the nature of the atom) because they repeated appropriate names and vocabulary (such as "electron" and "neutron"). The Core resists the temptation to describe abstract concepts at inappropriate grade levels; rather, it focuses on providing experiences with concepts that students can explore and understand in depth to build a foundation for future science learning.

Encourages Good Teaching Practices: It is impossible to accomplish the full intent of the Core by lecturing and having students read from textbooks. The Science Core emphasizes student inquiry. Science process skills are central in each standard. Good science encourages students to gain knowledge by doing science: observing, questioning, exploring, making and testing hypotheses, comparing predictions, evaluating data, and communicating conclusions. The Core is designed to encourage instruction with students working in cooperative groups. Instruction should connect lessons with students' daily lives. The Core directs experiential science instruction for all students, not just those who have traditionally succeeded in science classes. The vignettes listed on the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science for each of the Core standards provide examples, based on actual practice, that demonstrate that excellent teaching of the Science Core is possible.

Comprehensive: The Science Core does not cover all topics that have traditionally been in the science curriculum; however, it does provide a comprehensive background in science. By emphasizing depth rather than breadth, the Core seeks to empower students rather than intimidate them with a collection of isolated and forgettable facts. Teachers are free to add related concepts and skills, but they are expected to teach all the standards and objectives specified in the Core for their grade level.

Useful and Relevant: This curriculum relates directly to student needs and interests. It is grounded in the natural world in which we live. Relevance of science to other endeavors enables students to transfer skills gained from science instruction into their other school subjects and into their lives outside the classroom.

Encourages Good Assessment Practices: Student achievement of the standards and objectives in this Core is best assessed using a variety of assessment instruments. The purpose of an assessment should be clear to the teacher as it is planned, implemented, and evaluated. Performance tests are particularly appropriate to evaluate student mastery of science processes and problem-solving skills. Teachers should use a variety of classroom assessment approaches in conjunction with standard assessment instruments to inform their instruction. Sample test items, keyed to each Core Standard, may be located on the Utah Science Home Page http://www.usoe.k12.ut.us/curr/science. Observation of students engaged in science activities is highly recommended as a way to assess students' skills as well as attitudes in science. The nature of the questions posed by students provides important evidence of students' understanding of and interest in science.

Intended Learning Outcomes for Biology

The Intended Learning Outcomes (ILOs) describe the skills and attitudes students should learn as a result of science instruction. They are an essential part of the Science Core Curriculum and provide teachers with a standard for evaluation of student learning in science. Instruction should include significant science experiences that lead to student understanding using the ILOs.

The main intent of science instruction in Utah is that students will value and use science as a process of obtaining knowledge based upon observable evidence.

By the end of science instruction in high school, students will be able to:

1. Use Science Process and Thinking Skills

a. Observe objects, events and patterns and record both qualitative and quantitative information.
b. Use comparisons to help understand observations and phenomena.
c. Evaluate, sort, and sequence data according to given criteria.
d. Select and use appropriate technological instruments to collect and analyze data.
e. Plan and conduct experiments in which students may:
   - Identify a problem.
   - Formulate research questions and hypotheses.
   - Predict results of investigations based upon prior data.
   - Identify variables and describe the relationships between them.
   - Plan procedures to control independent variables.
   - Collect data on the dependent variable(s).
   - Select the appropriate format (e.g., graph, chart, diagram) and use it to summarize the data obtained.
   - Analyze data, check it for accuracy and construct reasonable conclusions.
   - Prepare written and oral reports of investigations.
f. Distinguish between factual statements and inferences.
g. Develop and use classification systems.
h. Construct models, simulations and metaphors to describe and explain natural phenomena.
i. Use mathematics as a precise method for showing relationships.
j. Form alternative hypotheses to explain a problem.

2. Manifest Scientific Attitudes and Interests

a. Voluntarily read and study books and other materials about science.
b. Raise questions about objects, events and processes that can be answered through scientific investigation.
c. Maintain an open and questioning mind toward ideas and alternative points of view.
d. Accept responsibility for actively helping to resolve social, ethical and ecological problems related to science and technology.
e. Evaluate scientifically related claims against available evidence.
f. Reject pseudoscience as a source of scientific knowledge.

3. Demonstrate Understanding of Science Concepts, Principles and Systems

a. Know and explain science information specified for the subject being studied.
b. Distinguish between examples and non-examples of concepts that have been taught.
c. Apply principles and concepts of science to explain various phenomena.
d. Solve problems by applying science principles and procedures.

4. Communicate Effectively Using Science Language and Reasoning

a. Provide relevant data to support their inferences and conclusions.
b. Use precise scientific language in oral and written communication.
c. Use proper English in oral and written reports.
d. Use reference sources to obtain information and cite the sources.
e. Use mathematical language and reasoning to communicate information.

5. Demonstrate Awareness of Social and Historical Aspects of Science

a. Cite examples of how science affects human life.
b. Give instances of how technological advances have influenced the progress of science and how science has influenced advances in technology.
c. Understand the cumulative nature of scientific knowledge.
d. Recognize contributions to science knowledge that have been made by both women and men.

6. Demonstrate Understanding of the Nature of Science

a. Science is a way of knowing that is used by many people, not just scientists.
b. Understand that science investigations use a variety of methods and do not always use the same set of procedures; understand that there is not just one "scientific method."
c. Science findings are based upon evidence.
d. Understand that science conclusions are tentative and therefore never final. Understandings based upon these conclusions are subject to revision in light of new evidence.
e. Understand that scientific conclusions are based on the assumption that natural laws operate today as they did in the past and that they will continue to do so in the future.
f. Understand the use of the term "theory" in science, and that the scientific community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence.
g. Understand that various disciplines of science are interrelated and share common rules of evidence to explain phenomena in the natural world.
h. Understand that scientific inquiry is characterized by a common set of values that include logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results and honest and ethical reporting of findings. These values function as criteria in distinguishing between science and non-science.
i. Understand that science and technology may raise ethical issues for which science, by itself, does not provide solutions.

Science language students should use:	generalize, conclude, hypothesis, theory, variable, measure, evidence, data, inference, infer, compare, predict, interpret, analyze, relate, calculate, observe, describe, classify, technology, experiment, investigation, tentative, assumption, ethical, replicability, precision, skeptical, methods of science

Biology Core Curriculum

The Biology Core Curriculum has two primary goals: (1) students will value and use science as a process of obtaining knowledge based on observable evidence, and (2) students' curiosity will be sustained as they develop and refine the abilities associated with scientific inquiry.

Theme

The Biology Core has three major concepts for the focus of instruction: (1) the structures in all living things occur as a result of necessary functions. (2) Interactions of organisms in an environment are determined by the biotic and abiotic components of the environment. (3) Evolution of species occurs over time and is related to the environment in which the species live.

Inquiry

Biology students should design and perform experiments, and value inquiry as the fundamental scientific process. They should be encouraged to maintain an open and questioning mind, to pose their own questions about objects, events, processes, and results. They should have the opportunity to plan and conduct their own experiments, and come to their own conclusions as they read, observe, compare, describe, infer, and draw conclusions. The results of their experiments need to be compared for reasonableness to multiple sources of information. They should be encouraged to use reasoning as they apply biology concepts to their lives.

Good science instruction requires hands-on science investigations in which student inquiry is an important goal. Teachers should provide opportunities for **all** students to experience many things. Students should investigate living organisms from each kingdom. Laboratory investigations should be frequent and meaningful components of biology instruction. Students should enjoy science as a process of discovering and understanding the natural world.

Relevance

Biology Core concepts should be integrated with concepts and skills from other curriculum areas. Reading, writing, and mathematics skills should be emphasized as integral to the instruction of science. Personal relevance of science in students' lives is an important part of helping students to value science and should be emphasized at this grade level. Developing students' writing skills in science should be an important part of science instruction in biology. Students should regularly write descriptions of their observations and experiments. Lab journals are an effective way to emphasize the importance of writing in science.

Providing opportunities for students to gain insights into science related careers adds to the relevance of science learning. Biology provides students with an opportunity to investigate careers in genetics, biotechnology, wildlife management, environmental science, and many fields of medicine. Resources related to careers in science may be found at the Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science .

Character

Value for honesty, integrity, self-discipline, respect, responsibility, punctuality, dependability, courtesy, cooperation, consideration, and teamwork should be emphasized as an integral part of science learning. These relate to the care of living things, safety and concern for self and others, and environmental stewardship. Honesty in all aspects of research, experimentation, data collection, and reporting is an essential component of science.

Instructional Resources
This Core was designed using the American Association for the Advancement of Science's *Project 2061: Benchmarks For Science Literacy* and the National Academy of Science's *National Science Education Standards* as guides to determine appropriate content and skills.

The Biology Core has many online resources designed to help with classroom instruction. The Utah Science Home Page at http://www.usoe.k12.ut.us/curr/science is an ongoing report of resources available and aligned to the Biology Core Curriculum.

Safety Precautions
The hands-on nature of science learning increases the need for teachers to use appropriate precautions in the classroom and field. Proper handling and disposal of chemicals is crucial for a safe classroom. The chemistry described in biology can be accomplished using safe household chemicals and microchemistry techniques. It is important that all students understand the rules for a safe classroom.

Appropriate Use of Living Things in the Science Classroom
It is important to maintain a safe, humane environment for animals in the classroom. Field activities should be well thought out and use appropriate and safe practices. Student collections should be done under the guidance of the teacher with attention to the impact on the environment. The number and size of the samples taken for the collections should be considered in light of the educational benefit. Some organisms should not be taken from the environment, but rather observed and described using photographs, drawings, or written descriptions to be included in the student's collection. Teachers must adhere to the published guidelines for the proper use of animals, equipment, and chemicals in the classroom. These guidelines are available on the Utah Science Home Page.

The Most Important Goal
Science instruction should cultivate and build on students' curiosity and sense of wonder. Effective science instruction engages students in enjoyable learning experiences. Science instruction should be as thrilling an experience for a student as opening a rock and seeing a fossil, tracing and interpreting a pedigree, or observing the affects of some chemical on the heartbeat of daphnia. Science is not just for those who have traditionally succeeded in the subject, and it is not just for those who will choose science-related careers. In a world of rapidly expanding knowledge and technology, all students must gain the skills they will need to understand and function responsibly and successfully in the world. The Core provides skills in a context that enables students to experience the joy of doing science.

Biology Core Curriculum

Science Benchmark

Ecosystems are shaped by interactions among living organisms and their physical environment. Ecosystems change constantly, either staying in a state of dynamic balance or shifting to a new state of balance. Matter cycles in ecosystems, and energy flows from outside sources through the system. Humans are part of ecosystems and can deliberately or inadvertently alter an ecosystem.

STANDARD I: Students will understand that living organisms interact with one another and their environment.

Objective 1: Summarize how energy flows through an ecosystem.

a. Arrange components of a food chain according to energy flow.
b. Compare the quantity of energy in the steps of an energy pyramid.
c. Describe strategies used by organisms to balance the energy expended to obtain food to the energy gained from the food (e.g., migration to areas of seasonal abundance, switching type of prey based upon availability, hibernation or dormancy).
d. Compare the relative energy output expended by an organism in obtaining food to the energy gained from the food (e.g., hummingbird - energy expended hovering at a flower compared to the amount of energy gained from the nectar, coyote - chasing mice to the energy gained from catching one, energy expended in migration of birds to a location with seasonal abundance compared to energy gained by staying in a cold climate with limited food).
e. Research food production in various parts of the world (e.g., industrialized societies' greater use of fossil fuel in food production, human health related to food product).

Objective 2: Explain relationships between matter cycles and organisms.

a. Use diagrams to trace the movement of matter through a cycle (i.e., carbon, oxygen, nitrogen, water) in a variety of biological communities and ecosystems.
b. Explain how water is a limiting factor in various ecosystems.
c. Distinguish between inference and evidence in a newspaper, magazine, journal, or Internet article that addresses an issue related to human impact on cycles of matter in an ecosystem and determine the bias in the article.
d. Evaluate the impact of personal choices in relation to the cycling of matter within an ecosystem (e.g., impact of automobiles on the carbon cycle, impact on landfills of processed and packaged foods).

Objective 3: Describe how interactions among organisms and their environment help shape ecosystems.

a. Categorize relationships among living things according to predator-prey, competition, and symbiosis.
b. Formulate and test a hypothesis specific to the effect of changing one variable upon another in a small ecosystem.
c. Use data to interpret interactions among biotic and abiotic factors (e.g., pH, temperature, precipitation, populations, diversity) within an ecosystem.
d. Investigate an ecosystem using methods of science to gather quantitative and qualitative data that describe the ecosystem in detail.
e. Research and evaluate local and global practices that affect ecosystems.

Science language students should use:	predator-prey, symbiosis, competition, ecosystem, carbon cycle, nitrogen cycle, oxygen cycle, population, diversity, energy pyramid, consumers, producers, limiting factor, competition, decomposers, food chain, biotic, abiotic, community, variable, evidence, inference, quantitative, qualitative

Science Benchmark

Cells are the basic unit of life. All living things are composed of one or more cells that come from preexisting cells. Cells perform a variety of functions necessary to maintain homeostasis and life. The structure and function of a cell determines the cell's role in an organism. Living cells are composed of chemical elements and molecules that form large, complex molecules. These molecules form the basis for the structure and function of cells.

STANDARD II: Students will understand that all organisms are composed of one or more cells that are made of molecules, come from preexisting cells, and perform life functions.

Objective 1: Describe the fundamental chemistry of living cells.

a. List the major chemical elements in cells (i.e., carbon, hydrogen, nitrogen, oxygen, phosphorous, sulfur, trace elements).
b. Identify the function of the four major macromolecules (i.e., carbohydrates, proteins, lipids, nucleic acids).
c. Explain how the properties of water (e.g., cohesion, adhesion, heat capacity, solvent properties) contribute to maintenance of cells and living organisms.
d. Explain the role of enzymes in cell chemistry.

Objective 2: Describe the flow of energy and matter in cellular function.

a. Distinguish between autotrophic and heterotrophic cells.
b. Illustrate the cycling of matter and the flow of energy through photosynthesis (e.g., by using light energy to combine CO_2 and H_2O to produce oxygen and sugars) and respiration (e.g., by releasing energy from sugar and O_2 to produce CO_2 and H_2O).
c. Measure the production of one or more of the products of either photosynthesis or respiration.

Objective 3: Investigate the structure and function of cells and cell parts.

a. Explain how cells divide from existing cells.
b. Describe cell theory and relate the nature of science to the development of cell theory (e.g., built upon previous knowledge, use of increasingly more sophisticated technology).
c. Describe how the transport of materials in and out of cells enables cells to maintain homeostasis (i.e., osmosis, diffusion, active transport).
d. Describe the relationship between the organelles in a cell and the functions of that cell.
e. Experiment with microorganisms and/or plants to investigate growth and reproduction.

Science language students should use:	organelles, photosynthesis, respiration, cellular respiration, osmosis, diffusion, active transport, homeostasis, cell theory, organic, carbohydrate, fermentation, protein, fat, nucleic acid, enzyme, chlorophyll, cell membrane, nucleus, cell wall, solvent, solute, adhesion, cohesion, microorganism

Science Benchmark

Structure relates to function. Organs and organ systems function together to provide homeostasis in organisms. The functioning of organs depends upon multiple organ systems.

STANDARD III: Students will understand the relationship between structure and function of organs and organ systems.

Objective 1: Describe the structure and function of organs.

a. Diagram and label the structure of the primary components of representative organs in plants and animals (e.g., heart - muscle tissue, valves and chambers; lung - trachea, bronchial, alveoli; leaf - veins, stomata; stem - xylem, phloem, cambium; root - tip, elongation, hairs; skin - layers, sweat glands, oil glands, hair follicles; ovaries - ova, follicles, corpus luteum).
b. Describe the function of various organs (e.g. heart, lungs, skin, leaf, stem, root, ovary).
c. Relate the structure of organs to the function of organs.
d. Compare the structure and function of organs in one organism to the structure and function of organs in another organism.
e. Research and report on technological developments related to organs.

Objective 2: Describe the relationship between structure and function of organ systems in plants and animals.

a. Relate the function of an organ to the function of an organ system.
b. Describe the structure and function of various organ systems (i.e., digestion, respiration, circulation, protection and support, nervous) and how these systems contribute to homeostasis of the organism.
c. Examine the relationships of organ systems within an organism (e.g., respiration to circulation, leaves to roots) and describe the relationship of structure to function in the relationship.
d. Relate the tissues that make up organs to the structure and function of the organ.
e. Compare the structure and function of organ systems in one organism to the structure and function in another organism (e.g., chicken to sheep digestive system; fern to peach reproductive system).

Science language students should use:	organ, organ system, organism, hormonal modification, stomata, tissue, homeostasis, structure, function

Science Benchmark

Information passed from parent to offspring is coded in DNA (deoxyribonucleic acid) molecules. The fundamental DNA structure is the same for all living things; the sequence of DNA differs between each organism and each species. Changes in the DNA sequence may alter genetic expression. The genetic information in DNA provides the instructions for assembling protein molecules in cells. The code used is virtually the same for all organisms. There are predictable patterns of inheritance. Sexual reproduction increases the genetic variation of a species. Asexual reproduction provides offspring that have the same genetic code as the parent.

STANDARD IV: Students will understand that genetic information coded in DNA is passed from parents to offspring by sexual and asexual reproduction. The basic structure of DNA is the same in all living things. Changes in DNA may alter genetic expression.

Objective 1: Compare sexual and asexual reproduction.

a. Explain the significance of meiosis and fertilization in genetic variation.
b. Compare the advantages/disadvantages of sexual and asexual reproduction to survival of species.
c. Formulate, defend, and support a perspective of a bioethical issue related to intentional or unintentional chromosomal mutations.

Objective 2: Predict and interpret patterns of inheritance in sexually reproducing organisms.

a. Explain Mendel's laws of segregation and independent assortment and their role in genetic inheritance.
b. Demonstrate possible results of recombination in sexually reproducing organisms using one or two pairs of contrasting traits in the following crosses: dominance/recessive, incomplete dominance, codominance, and sex-linked traits.
c. Relate Mendelian principles to modern-day practice of plant and animal breeding.
d. Analyze bioethical issues and consider the role of science in determining public policy.

Objective 3: Explain how the structure and replication of DNA are essential to heredity and protein synthesis.

a. Use a model to describe the structure of DNA.
b. Explain the importance of DNA replication in cell reproduction.
c. Summarize how genetic information encoded in DNA provides instructions for assembling protein molecules.
d. Describe how mutations may affect genetic expression and cite examples of mutagens.
e. Relate the historical events that lead to our present understanding of DNA to the cumulative nature of science knowledge and technology.
f. Research, report, and debate genetic technologies that may improve the quality of life (e.g., genetic engineering, cloning, gene splicing).

Science language students should use:	DNA, replication, fertilization, dominant trait, recessive trait, genetic engineering, gene splicing, phenotype, genotype, sexual reproduction, asexual reproduction, chromosome, gene, mutation, cloning, inheritance, bioethics, pedigree

Science Benchmark

Evolution is central to modern science's understanding of the living world. The basic idea of biological evolution is that Earth's present day species developed from earlier species. Evolutionary processes allow some species to survive with little or no change, some to die out altogether, and other species to change, giving rise to a greater diversity of species. Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as science strives for explanations of the world.

STANDARD V: Students will understand that biological diversity is a result of evolutionary processes.

Objective 1: Relate principles of evolution to biological diversity.

a. Describe the effects of environmental factors on natural selection.
b. Relate genetic variability to a species' potential for adaptation to a changing environment.
c. Relate reproductive isolation to speciation.
d. Compare selective breeding to natural selection and relate the differences to agricultural practices.

Objective 2: Cite evidence for changes in populations over time and use concepts of evolution to explain these changes.

a. Cite evidence that supports biological evolution over time (e.g., geologic and fossil records, chemical mechanisms, DNA structural similarities, homologous and vestigial structures).
b. Identify the role of mutation and recombination in evolution.
c. Relate the nature of science to the historical development of the theory of evolution.
d. Distinguish between observations and inferences in making interpretations related to evolution (e.g., observed similarities and differences in the beaks of Galapagos finches leads to the inference that they evolved from a common ancestor; observed similarities and differences in the structures of birds and reptiles leads to the inference that birds evolved from reptiles).
e. Review a scientific article and identify the research methods used to gather evidence that documents the evolution of a species.

Objective 3: Classify organisms into a hierarchy of groups based on similarities that reflect their evolutionary relationships.

a. Classify organisms using a classification tool such as a key or field guide.
b. Generalize criteria used for classification of organisms (e.g., dichotomy, structure, broad to specific).
c. Explain how evolutionary relationships are related to classification systems.
d. Justify the ongoing changes to classification schemes used in biology.

Science language students should use:	evolution, fossil record, geologic record, molecular, homologous, vestigial structures, mutation, recombination, hierarchy, classification scheme, theory, natural selection, adaptation, evidence, inference, speciation, biodiversity, taxonomy, kingdom, virus, protist, fungi, plant, animal, dichotomy