

BIOLOGY

Goals

The biology curriculum is designed to continue student investigations and deepen student understanding of the biological sciences. High school instruction should include concepts introduced in grades K-8 at a more abstract level. In-depth study of the following concepts is included: the cell, the molecular basis of heredity, biological evolution, the interdependence of organisms, matter, energy and organization in living systems, and the adaptive responses of organisms. For instruction, the program strands and unifying concepts should be woven through the content goals and objectives of the course. The following explanation introduces teachers to the program strands and unifying concepts. Supplemental materials, providing a more detailed explanation of the goals, objectives, unifying concepts and program strands, with specific recommendations for classroom and/or laboratory implementation, are available through the Department of Public Instruction's Publications Section.

Unifying Concepts

The following unifying concepts should unite the study of various biological topics across grade levels.

- Systems, Order and Organization.
- Evidence, Models, and Explanation.
- Constancy, Change, and Measurement.
- Evolution and Equilibrium.
- Form and Function.

Focus on the unifying concepts of science will also help students to understand the constant nature of science across disciplines and time even as scientific knowledge, understanding and procedures change.

Nature of Science

This strand includes the following sections: Science as a Human Endeavor, Historical Perspectives, and the Nature of Scientific Knowledge. This strand is designed to help students understand the human dimensions of science, the nature of scientific thought, and the role of science in society. Biology is rich in examples of science as a human endeavor, its historical perspectives, and the development of scientific understanding. As concepts are developed this strand can be interwoven to create an in-depth understanding.

Science as a Human Endeavor

Intellectual honesty and an ethical tradition are hallmarks of the practice of science. The practice is rooted in accurate data reporting, peer review, and making findings public. This aspect of the nature of science can be implemented by designing instruction that encourages students to work collaboratively in groups, to design investigations, formulate hypotheses, collect data, reach conclusions, and present their findings to their classmates.

The content studied in biology provides an opportunity to present science as the basis for medicine, ecology, forensics, biotechnology, and environmental studies. The diverse biology content allows for looking at science as a vocation. Scientist, artist, and technician are just a few of the many careers in which a biology background is necessary.

Perhaps the most important aspect of this strand is that science is an integral part of society and is therefore relevant to students' lives.

Historical Perspectives

Most scientific knowledge and technological advances develop incrementally from the labors of scientists and inventors. Although science history includes accounts of serendipitous scientific discoveries, most development of scientific concepts and technological innovation occurs in response to a specific problem or conflict. Both great advances and gradual knowledge-building in science and technology have profound effects on society. Students should appreciate the scientific thought and effort of the individuals who contributed to these advances. For example, from Mendel's story, to the work of Watson and Crick, to modern breakthroughs in gene manipulation for therapeutic purposes, history illustrates every important facet of the nature of science.

As students explore original writing by and about scientists, they will uncover human drama, such as the obscurity of Mendel's work until after his death, and the interpersonal struggles involved in the discovery of DNA. They will understand that knowledge generated by one generation maybe is expanded, modified, or even discarded by the next generation.

Nature of Scientific Knowledge

Much of what is understood about the nature of science must be explicitly addressed:

- All scientific knowledge is tentative, although many ideas have stood the test of time and are reliable for our use.
 - Theories "explain" phenomena that we observe. They are never proved; rather, they represent the most logical explanation based on currently available evidence. Theories become stronger as more supporting evidence is gathered. They provide a context for further research and give us a basis for prediction. For example, the theory of biological evolution is an explanation for phenomena such as the diversity of species, the genetic relationships between species and the fossil record. Gene theory is an explanation for relationships we observe between one generation and the next.
 - Laws are fundamentally different from theories. They are universal generalizations based on observations of the natural world, such as the nature of gravity, the relationship of forces and motion and the nature of planetary movement.
 - Scientists, in their quest for the best explanations of natural phenomena, employ rigorous methods. Scientific explanations must adhere to the rules of evidence, make predictions, be logical, and be consistent with observations and conclusions. "Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific." (National Science Education Standards, 1996, p. 201)
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Science as Inquiry

Inquiry should be the central theme in biology. Inquiry is an integral part of the learning experience and may be used in both traditional class problems and laboratory experiences. The essence of the inquiry process is to ask questions that stimulate students to think critically and to formulate their own questions. Observing, classifying, using numbers, plotting graphs, measuring, inferring, predicting, formulating models, interpreting data, hypothesizing, and experimenting all help students to build knowledge and communicate what they have learned.

Inquiry is the application of creative thinking to new and unfamiliar situations. Students should learn to design solutions to problems that interest them. This may be accomplished in a variety of ways, but situations that present a discrepant event or ones that challenge students' intuitions have been successful. Classical experiments confirming well-accepted scientific principles may be necessary to reinforce constructed understandings and to teach safe and proper use of laboratory techniques and instruments, but they should not be the whole laboratory experience.

Instead, laboratory experience should provide a foundation for exploring new questions. In biology, for example, traditional labs such as dissection and observation of plant and animal cells may be quite appropriate. They should, however, lead to open-ended explorations such as the study of a particular animal's anatomy in relation to its environment and behavior, or the effect of changing environmental conditions on the growth of yeast (or other) cells. These kinds of activities teach student how science is done - how to clarify questions, how to design and experiment, how to record and display data, how to communicate knowledge generated. If this time investment means that a memorization of the parts of the cells and their function is left undone, consider the long-term value for students and make the necessary trade-offs. A student can always consult a book if he/she needs to know about a cell organelle, but a book will not provide the experience of generating new knowledge through scientific exploration.

Biology provides potential for many inquiries. "Does the earthworm respond to light?" "Why?" "Does temperature affect the metabolic activity of yeast?" "Why?" The process of inquiry, experimental design, investigation, and analysis is as important as finding the correct answer. Students will master much more than facts and manipulative skills; they will learn to be critical thinkers.

A solid conceptual base of scientific principles, as well as knowledge of science safety is necessary for inquiry. Students should be given a supportive learning environment based on how scientists and engineers work. Adherence to all science safety criteria and guidelines for classroom, field, and laboratory experiences is imperative. Contact the Science Section at DPI for information and professional development opportunities regarding North Carolina specific Science Safety laws, codes, and

standards. The Science Section is spearheading a statewide initiative entitled *NC-The Total Science Safety System*.

Science and Technology

It would be impossible to learn science without developing some appreciation of technology. Therefore, this strand has a dual purpose: (a) developing students' knowledge and skills in technological design, and (b) enhancing their understanding of science and technology.

The methods of scientific inquiry and technological design share many common elements - objectivity, clear definition of the problem, identification of goals, careful collection of observations and data, data analysis, replication of results, and peer review. Technological design differs from inquiry in that it must operate within the limitations of materials, scientific laws, economics, and the demands of society. Together, science and technology present many solutions to problems of survival and enhance the quality of life. Technological design plays an important role in building knowledge in biology. For example, electron microscopes, graphing calculators, personal computers, and magnetic resonance images have changed our lives, increased our knowledge of biology, and improved our understanding of the universe.

Science in Personal and Social Perspectives

This strand is designed to help students formulate basic understanding and implied actions for many issues facing our society. The fundamental concepts that form the basis for this strand include:

Personal and Community Health

Biology is an excellent context for investigating the factors that affect the health of organisms in general and humans in specific. Persuading adolescents to adopt personal habits that contribute to long-term health is not always easy. Looking at issues such as nutrition, exercise, rest, and substance abuse from the perspective of an organism's needs and responses provides a less emotional atmosphere for considering health issues relevant to teenagers.

Population Growth

Biology students should develop the ability to assess the carrying capacity of a given environment and its implied limits on population growth, as well as how technology allows environmental modifications to adjust its carrying capacity.

Environmental Quality

The role of biological sciences is particularly relevant to areas where humans affect and are affected by other organisms and the non-living environment. The curriculum offers opportunities for students to make decisions based on evidence in the areas of environmental stewardship and economic realities.

Science and Technology in Local, National, and Global Challenges

This part of the science in personal and social perspectives strand examines the involvement of human decisions in the use of scientific and technological knowledge. “Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges.” (National Science Education Standards, 1996, p. 199) The *NSES* emphasizes that “students should understand the appropriateness and value of basic questions ‘What can happen?’ - ‘What are the Odds?’- and ‘How do scientists and engineers know what will happen?’” (p. 199) Students should understand the causes and extent of science-related challenges. They should become familiar with the advances and improvements that proper application of scientific principles and products has brought to environmental enhancement, wise energy use, reduced vehicle emissions, and improved human health.

BIOLOGY - Grades 9-12

Learners will study biological systems. The strands and unifying concepts provide a context for teaching content and process skill goals. Instruction should focus on the following unifying concepts:

- Systems, Order and Organization.
- Evidence, Models, and Explanation.
- Constancy, Change, and Measurement.
- Evolution and Equilibrium.
- Form and Function.

Strands: The strands are: Nature of Science, Science as Inquiry, Science and Technology, and Science in Personal and Social Perspectives. They provide the context for teaching of the content goals and objectives.

COMPETENCY GOAL 1: The learner will develop abilities necessary to do and understand scientific inquiry.

Objectives

- 1.01 Identify biological questions and problems that can be answered through scientific investigations.
- 1.02 Design and conduct scientific investigations to answer biological questions.
- Create testable hypotheses
 - Identify variables.
 - Use a control or comparison group when appropriate.
 - Select and use appropriate measurement tools.
 - Collect and record data.
 - Organize data into charts and graphs.
 - Analyze and interpret data.
 - Communicate findings.
- 1.03 Formulate and revise scientific explanations and models of biological phenomena using logic and evidence to:
- Explain observations.
 - Make inferences and predictions.
 - Explain the relationship between evidence and explanation.
- 1.04 Apply safety procedures in the laboratory and in field studies:
- Recognize and avoid potential hazards.
 - Safely manipulate materials and equipment needed for scientific investigations.

- 1.05 Analyze reports of scientific investigations from an informed, scientifically-literate viewpoint including considerations of:
- Appropriate sample.
 - Adequacy of experimental controls.
 - Replication of findings.
 - Alternative interpretations of the data.

COMPETENCY GOAL 2: The learner will develop an understanding of the physical, chemical and cellular basis of life.

Objectives

- 2.01 Compare and contrast the structure and functions of the following organic molecules:
- Carbohydrates.
 - Proteins.
 - Lipids.
 - Nucleic acids.
- 2.02 Investigate and describe the structure and functions of cells including:
- Cell organelles.
 - Cell specialization.
 - Communication among cells within an organism.
- 2.03 Investigate and analyze the cell as a living system including:
- Maintenance of homeostasis.
 - Movement of materials into and out of cells.
 - Energy use and release in biochemical reactions.
- 2.04 Investigate and describe the structure and function of enzymes and explain their importance in biological systems.
- 2.05 Investigate and analyze the bioenergetic reactions:
- Aerobic Respiration.
 - Anaerobic Respiration.
 - Photosynthesis.

COMPETENCY GOAL 3: The learner will develop an understanding of the continuity of life and the changes of organisms over time.

Objectives

- 3.01 Analyze the molecular basis of heredity including:
- DNA replication.
 - Protein synthesis (transcription, translation).
 - Gene regulation.

- 3.02 Compare and contrast the characteristics of asexual and sexual reproduction.
- 3.03 Interpret and predict patterns of inheritance.
- Dominant, recessive and intermediate traits.
 - Multiple alleles.
 - Polygenic inheritance.
 - Sex-linked traits.
 - Independent assortment.
 - Test cross.
 - Pedigrees.
 - Punnett squares.
- 3.04 Assess the impact of advances in genomics on individuals and society.
- Human genome project.
 - Applications of biotechnology.
- 3.05 Examine the development of the theory of evolution by natural selection including:
- Development of the theory.
 - The origin and history of life.
 - Fossil and biochemical evidence.
 - Mechanisms of evolution.
 - Applications (pesticide and antibiotic resistance).

COMPETENCY GOAL 4: The learner will develop an understanding of the unity and diversity of life.

Objectives

- 4.01 Analyze the classification of organisms according to their evolutionary relationships.
- The historical development and changing nature of classification systems.
 - Similarities and differences between eukaryotic and prokaryotic organisms.
 - Similarities and differences among the eukaryotic kingdoms: Protists, Fungi, Plants, Animals.
 - Classify organisms using keys.
- 4.02 Analyze the processes by which organisms representative of the following groups accomplish essential life functions including:
- Unicellular protists, annelid worms, insects, amphibians, mammals, non vascular plants, gymnosperms and angiosperms.
 - Transport, excretion, respiration, regulation, nutrition, synthesis, reproduction, and growth and development.
- 4.03 Assess, describe and explain adaptations affecting survival and reproductive success.
- Structural adaptations in plants and animals (form to function).

- Disease-causing viruses and microorganisms.
- Co-evolution.

4.04 Analyze and explain the interactive role of internal and external factors in health and disease:

- Genetics.
- Immune response.
- Nutrition.
- Parasites.
- Toxins.

4.05 Analyze the broad patterns of animal behavior as adaptations to the environment.

- Innate behavior.
- Learned behavior.
- Social behavior.

COMPETENCY GOAL 5: The learner will develop an understanding of the ecological relationships among organisms.

Objectives

5.01 Investigate and analyze the interrelationships among organisms, populations, communities, and ecosystems.

- Techniques of field ecology.
- Abiotic and biotic factors.
- Carrying capacity.

5.02 Analyze the flow of energy and the cycling of matter in the ecosystem

- Relationship of the carbon cycle to photosynthesis and respiration.
- Trophic levels - direction and efficiency of energy transfer.

5.03 Assess human population and its impact on local ecosystems and global environments:

- Historic and potential changes in population.
- Factors associated with those changes.
- Climate change.
- Resource use.
- Sustainable practices/stewardship.