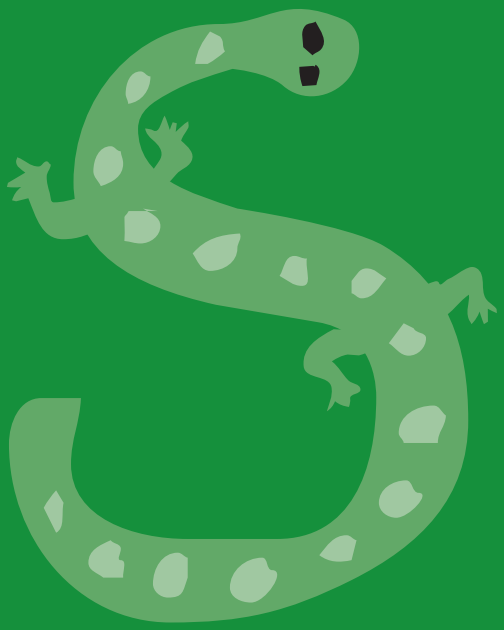
9TH GRADE-12TH GRADE

Life Science

Content Standard C:

As a result of their activities in grades 9-12, all students should develop understanding of

- **The cell**
- **Molecular basis of heredity**
- **Biological evolution**
- **Interdependence of organisms**
- **Matter, energy, and organization in living systems**
- **Behavior of organisms**



Content Summary

National Science Education Content Standards

K-4

Characteristics of organisms

Life cycles of organisms

Organisms and environments

5-8

Structure and function in living systems

Reproduction and heredity

Regulation and behavior

Populations and adaptions of organisms

9-12

The cell

Molecular basis of heredity

Biological evolution

Interdependence of organisms

Matter, energy, and organization in living systems

Behavior of organisms

Minnesota Graduation Standards

Primary Level

Direct Science Experience:

Understand basic science concepts through direct experience

Intermediate Level

Living and Non-living Systems:

Understand how individuals and objects interact in life, earth/space systems and physical systems

Middle Level

Living Systems:

Understand interactions and interdependence of living systems

High School Level

Concepts in Biology:

Understand biological concepts through investigation and analysis of cells, organisms, and ecosystems

Focus K-12

Grade	Early	Late
K-4	The focus of instruction for all students early in this grade range is on building understandings of biological concepts through direct experiences with living things, their life cycles, and their habitats.	The focus of instruction later in this grade range is on providing opportunities for all students to investigate how organisms live in their environments and developing a basic understanding of interdependence.
5-8	The focus of instruction for all students early in this grade range is on developing a basic understanding of the organization of living systems and an awareness of the diversity and interdependence among organisms.	The focus of instruction for all students later in this grade range is on developing an understanding of human biology, recognizing patterns in ecosystems and basic understandings about the cellular dimensions of living systems.
9-12	The focus of instruction in life science for all students at the high school level is on developing an understanding of cell structure and function, the relationship of matter and energy in biological systems, heredity, biological evolution, the behavior and interdependence of organisms and apply their understandings in a variety of situations.	The focus of instruction for students pursuing further study in life science is on providing opportunities to explore and expand their understandings of molecular genetics, biological evolution and interactions, the structure and function of living systems, natural ecosystems and apply their understandings in a variety of situations.

Close-up 9-12

The focus of instruction in life science for all students at the high school level is on developing an understanding of cell structure and function, the relationship of matter and energy in biological systems, heredity, biological evolution, the behavior and interdependence of organisms and apply their understandings in a variety of situations.

All high school students build on their basic understanding of the life sciences gained in grades K-8. Experiences range from studying the chemical basis of life to the structure and function of the biosphere. Students develop an understanding of cells by investigating differences in their structure and function and how cells respond and adapt to changes in their environment. They develop physical and conceptual models of DNA and cell reproduction, and may learn how to extract DNA. In their study of the genetic basis of heredity, students identify inherited traits and discuss how variations are passed from generation to generation which result in change over time. An understanding of biodiversity is enhanced through study of the fossil record, analysis of the mechanisms of biological evolution, and the use of classification systems. Students investigate a variety of ecosystems to understand ecosystem structure and function. They trace complex food webs in varied environments and describe them in terms of energy flow. Students and teachers observe established science safety procedures.

The focus of instruction for students pursuing further study in life science is on providing opportunities to explore and expand their understandings of molecular genetics, biological evolution and interactions, the structure and function of living systems, natural ecosystems and apply their understandings in a variety of situations.

Students pursuing further study expand their study of biology to include more conceptual knowledge such as the structure and function of DNA, molecular biology, the relationships among matter, energy, and the organization of living things, evolutionary studies, and the interdependence of organisms, including behavioral biology. Their investigations of photosynthesis and respiration illustrate and emphasize the transfer and release of energy in living organisms. They expand their study of human biology begun in middle school to include structure and function, and regulation in a variety of living things. Students understand that biological classifications are used to show evolutionary relationships. They investigate the occurrence of new variations in a population and the potential effect of those variations on the long-term survival of the species. Student study of ecosystems may include the effects of biotic and abiotic factors on the distribution and abundance of organisms. Students' ability and understanding should allow them to work independently as they investigate these concepts. Students and teachers observe established science safety procedures.

On Location 9-12

Ms. L's biology students are studying adaptation and natural selection. This simulation provides the opportunity for students to explore the relationship between form and function, along with concepts of competition, random variation, and natural selection.

In this activity Ms. L's students simulate birds, using common tools as beaks. Prior to the activity, Ms. L collects an assortment of tools, making sure that she has at least one for every pair of students, plus one or two extra. Examples are a clothes pin, an assortment of pliers, wire cutters, clamps, and other grasping tools she can find. She also purchases a supply of sunflower and popcorn seeds.

As a class, they describe the attributes of the tools for grasping and compare them to the beaks of a variety of birds. The students draw the tools, write detailed descriptions of how they work, and evaluate their potential to pick up seeds. Then, in pairs, they choose one tool to serve as their "beak" for the next activity.

Ms. L facilitates a class discussion on how the tools could be tested to see which one is best suited for picking up seeds. After lively deliberation, the class decides that each group will get a supply of seeds and the "beaks" must remove one seed at a time from a large container and deposit it into a paper cup. After a short practice session, each group completes four trials (each lab partner does two) that are averaged to ensure the accuracy of their results. The average number of each kind of seed collected by each tool is recorded on a data table in the front of the room. The "beak" that retrieves the most seed in 30 seconds is judged the most successful.

After the students have completed their trials, Ms. L tells the class that in nature, it isn't always so easy as having only one "beak" in a bowl. To demonstrate this, Ms. L divides the class into three or four groups and has four "beaks" feeding from the same bowl at a time. The rules are the same, and everyone participates. The number of seeds in the bowl remains the same, and the students compete for seeds. After making predictions about which "beaks" will be the most successful, they complete four trials, average them, and record their data. The top eight groups are invited to a second round of competition, while the low feeding birds, who have "starved", observe. A third round is held with the top four groups. During this part of the activity, Ms. L exchanges one of the extra tools with the tool that one of the groups is using. This introduces a random variation in their "beak" that may or may not improve the chances that the bird will survive.

Another round like the previous one takes place, but this time, Ms. L limits the amount of one kind of seed. Using their collected data, predictions are made, and the students complete the trials.

As a culminating activity, Ms. L raises the competition level even more, simulating a famine. She moves the lab tables away and puts the feeding bowl in the center of the room. The entire simulation is repeated, but with all of the lab groups feeding out of the same bowl at one time.

Post-lab activities include discussions about the attributes of the "tools" and their effectiveness at each level of the competition, and written reflections on competition, random variation, survival and natural selection. The students also read selections from *Natural Selection and Darwin's Finches* by Peter Grant and *The Beak of the Finch* by Jonathan Weiner and respond through writing and discussion.

National Science Education Content Standards

9-12 Content Standard C

The Cell

- Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.
- Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to carry out the many functions of the cell.
- Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.
- Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.
- Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems.
- Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues and organs that comprise the final organism. This differentiation is regulated through the expression of different genes.

The Molecular Basis of Heredity

- In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.
- Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.
- Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring.

National Science Education Content Standards

9-12 Content Standard C (continued)

Biological Evolution

- Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.
- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.
- Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.
- The millions of different species of plants, animals, and micro-organisms that live on earth today are related by descent from common ancestors.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

The Interdependence of Organisms

- The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.
- Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.
- Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.
- Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms.
- Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

National Science Education Content Standards

9-12 Content Standard C (continued)

Matter, Energy, and Organization in Living Standards

- All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate.
- The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.
- The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells usually store this energy temporarily in phosphate bonds of a small high-energy compound called ATP.
- The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.
- The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.
- As matter and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

The Behavior of Organisms

- Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them.
- Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli.
- Like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles.
- Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology.

Minnesota Graduation Standards

High School Level

Concepts in Biology:

Understand biological concepts, theories and principles through investigation and analysis of cells, organisms and ecosystems.

What students should know:

1. Understand cell theory (e.g., differentiation, homeostasis)
2. Understand mechanisms of heredity (e.g., DNA, traits, reproduction)
3. Understand biological change over time (e.g., natural selection, biodiversity)
4. Understand the interdependence of organisms (e.g., cooperation/competition)
5. Understand material cycles and energy flow in living systems (e.g., photosynthesis, nitrogen cycle)
6. Understand the behavior of organisms (e.g., cause/effect, stimulus/response)
7. Understand the historical significance of major scientific advances (e.g., vaccines, genetics)

What students should do:

1. Design and conduct an experiment to investigate a question and test a hypothesis in biology
2. Design and conduct one investigation through a problem-based study, service learning project or field study
   a. identify scientific issues based on observations and the corresponding scientific concepts
   b. analyze data to clarify scientific issues or define scientific questions
   c. compare results to current models and/or personal experience
3. Use scientific evidence to defend or refute an idea in an historical or contemporary context:
   a. identify scientific concepts found in evidence
   b. evaluate the validity of the idea in relationship to scientific information
   c. analyze the immediate and long-term impact on the individual and/or society in the areas of technology, economics and the environment

In Addition:

1. Students are encouraged to communicate to an audience outside of the school setting whenever possible.
2. Students must demonstrate basic safety procedures and skills when using tools and equipment.