

Biology

Cellular Reproduction



ESSENTIAL QUESTION

BIG IDEAS

How do organisms grow and develop?

- Students understand how cells reproduce themselves.
- Students understand the basic functions of cell reproduction (maintenance, growth, repair, reproduction) in the life cycles of organisms.
- Students understand how loss of regulation of the cell cycle leads to cancer.

GUIDING QUESTIONS

Content:

- What is the structure of a chromosome?
- What are the changes that DNA goes through during the cell cycle?
- What are the stages of the cell cycle?
- What happens during each stage of the cell cycle?
- What is the difference between sexual and asexual reproduction?
- What are the defining characteristics of stem cells?
- Why is cell differentiation an important part of the development of a multicellular organism?
- What is the difference between embryonic and adult stem cells?
- How do factors external and internal to the cell increase the risk for cancer?
- What is the difference between benign and malignant tumors?

Process:

- How can a model show that the process of cell reproduction contributes to maintenance, growth, and repair? [[Developing and Using Models](#)]
- How can we use cell division mechanisms to construct an explanation as to why mitosis and meiosis are both necessary during the human life cycle? [[Constructing Explanations and Designing Solutions](#)]
- How can evidence of mutations caused by environmental factors be used to make and defend a claim about mutations as a potential source of genetic variation in organisms? [[Engaging in Argument from Evidence](#)]

Reflective:

- Why do our bodies use cell division for growth, repair, and replacement?
- What are the current developments for stem cell research?
- How can exposing your body to certain environmental factors increase the chance for mutations to occur leading to cancer?
- How does cancer affect the human body?

Biology

Chemistry of Life



ESSENTIAL QUESTION

BIG IDEAS

How do the elements make “life”?

- Students will understand the importance of organic molecules and water in living organisms.
- Students will understand the importance of chemical reactions in energy exchange within organisms.

GUIDING QUESTIONS

Content:

- What are the four primary elements essential for life that make up macromolecules?
- What is the relationship between chemical reactions and changes in the energy of the molecules involved?
- How does water's unique properties contribute to the function of organisms?
- What is the basic structure and function of the four macromolecules of life: carbohydrates, lipids, nucleic acids, and proteins (including enzymes)?
- Why do factors such as pH and temperature affect how an enzyme works?
- How do enzymes function as catalysts and lower activation energy?

Process:

- Using evidence from models of the structure of various organic molecules, how can we explain the formation of amino acids and other large carbon-based molecules from the atoms found in sugars? [[Developing and Using Models](#), [Constructing Explanations and Designing Solutions](#)]

Reflective:

- Why is carbon called the building block of life?
- Why must organisms take in matter from their surroundings and rearrange the atoms through chemical reactions?

FOCUS STANDARDS

- **LS1.C: Organization for Matter and Energy Flow in Organisms**
 - The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as proteins or DNA), used for example to form new cells. [[HS-LS1-6](#)]
 - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. [[HS-LS1-6](#)]



Biology

Classical Genetics

ESSENTIAL QUESTION

How are traits passed from parents to offspring?

BIG IDEAS

- Students will understand why offspring produced by sexual reproduction are genetically diverse.
- Students will understand how a phenotype is affected by various patterns of inheritance.

GUIDING QUESTIONS

Content:

- How did Mendel's experiments provide evidence against the blending hypothesis of inheritance?
- Why are offspring produced by sexual reproduction genetically diverse?
- How does the independent assortment of chromosomes during meiosis contribute to genetic variation?
- How are homologous chromosomes alike and how do they differ?
- How does crossing over contribute to genetic variation?
- How do the various alleles of a gene work together to determine an organism's physical traits?
- How do dominant and recessive alleles interact to determine an organism's phenotype?
- How does the location of a gene on either an autosome or sex chromosome affect gene expression?
- How do alleles interact in complex inheritance patterns that go beyond simple dominance (i.e. incomplete/intermediate inheritance, codominance, multiple alleles, polygenic inheritance)?
- What is the role of the environment in determining an organism's phenotype?
- How is it possible to predict certain genetic disorders?

Process:

- How can statistics and probability be used to explain the variation and distribution of expressed traits in a population?
- How can Punnett squares be used to model genetic crosses involving one trait (i.e. monohybrid cross) and to predict the genotypes and phenotypes of possible offspring given any two parental genotypes?
- How can we use a pedigree to track a trait or disorder within a family?
- How can the relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring be clarified by asking questions?

Reflective:

- How have our ideas about inheritance changed over time?
- Why do family members look different from one another?

FOCUS STANDARDS

- **LS3.B: Variation of Traits:**
 - In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. [[HS-LS3-2](#)], [[HS-LS3-3](#)]
- **LS3.A: Inheritance of Traits:**
 - Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. [[HS-LS3-1](#)]

Biology

Ecology



ESSENTIAL QUESTION

BIG IDEAS

How do ecological interactions influence the structure of ecosystems?

- Students will explain how interactions among species influence populations, communities, and ecosystems.
- Students will describe biodiversity and explain its importance to ecosystems.
- Students will evaluate the impacts of human activities on the environment and biodiversity.

GUIDING QUESTIONS

Content:

- What are the different levels of ecological study?
- How does an organism's habitat and niche relate to its role within an ecosystem?
- What are key biotic and abiotic limiting factors that influence a population's growth and carrying capacity?
- What are the various types of community interactions?
- How do ecologists define populations and communities?
- What is population density and how does it affect a population's growth?
- What are patterns of exponential and logistic growth?
- How do density-dependent and density-independent factors affect a population's growth?
- What are the two types of ecological succession and how do they change communities over time?
- In what ways is the climate a key abiotic factor that can be influenced by human activity?
- What are the effects of human population growth on the biosphere?

Process:

- How do mathematical and/or computational representations help support explanations of factors that affect the carrying capacity of ecosystems at different scales?
- How can mathematical representations be used to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales?
- What factors can be used to evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem?
- What solutions can be designed for reducing the impacts of human activities on the environment and biodiversity and how do we evaluate and refine these solutions?
- How can we help to mitigate adverse impacts of human activities on biodiversity by creating or revising simulations?

Reflective:

- How does the process of natural selection shape community interactions?
- What can be learned from the history of human population growth that might allow us to prepare for the future?

- How can we use conservation methods to help protect and restore ecosystems?
- Why is biodiversity important and how can we use conservation ecology to help sustain biodiversity?

Biology

Evolution

ESSENTIAL QUESTION

BIG IDEAS

How do species evolve over time?

- Students will explore and evaluate the various categories of evidence of evolution.
- Students will understand and explain the major mechanisms of evolutionary change that lead to descent with modification.
- Students will understand how evolutionary principles are applied to solve real world problems.

GUIDING QUESTIONS

Content:

- What are the factors that Darwin and Wallace considered when developing the Theory of Evolution?
- What is the process of natural selection and how can it lead to descent with modification?
- How do fossils, structural and developmental similarities, biogeographical distribution, and molecular biology provide evidence of the evolutionary history of life?
- What are the methods used to determine the age of fossils?
- How can existing structures within organisms take on new functions through evolution?
- What are the sources and significance of genetic variation within a population?
- How are gene pools significant to understanding evolution?
- What is the biological species concept and what are the barriers that can exist between species?
- How does evolution occur through methods other than natural selection, including sexual selection, genetic drift, gene flow, and mutation?
- How has the diversity of life on Earth led to the need for a system of taxonomy and how has our classification system changed over time?
- What evidence confirms the conclusion that humans are the product of evolution?
- What evidence confirms that all organisms, including humans, are still evolving

Process:

- How are cladograms used to explain evolutionary relationships between species?
- How does understanding group behavior allow us to evaluate its role in individual and species' chances to survive and reproduce?
- What scientific information can be used to communicate that common ancestry and biological evolution are supported by multiple lines of empirical evidence?
- How can we construct an explanation based on evidence for the primary factors that influence the process of evolution?
- What evidence can we evaluate to support claims that changes in environmental conditions lead to the increase, emergence, and extinction of species?

Reflective:

- How does antibiotic resistance evolve in bacteria?
- How can evolutionary theory be used to solve real world problems that have a biological basis?

- How do all living organisms share a common ancestry?

FOCUS STANDARDS

- **LS2.D: Social Interactions and Group Behavior**
 - Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives. [[HS-LS2-8](#)]
- **LS4.C: Adaptation**
 - Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. [[HS-LS4-6](#)]
- **LS4.D: Biodiversity and Humans**
 - Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). [secondary to [HS-LS2-7](#)]
 - Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. [secondary to [HS-LS2-7](#)], [[HS-LS4-6](#)]
- **LS4.A : Evidence of Common Ancestry and Diversity**
 - Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. [[HS-LS4-1](#)]
- **LS4.B: Natural Selection**
 - Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. [[HS-LS4-2](#)], [[HS-LS4-3](#)]
 - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. [[HS-LS4-3](#)]
- **LS4.C: Adaptation**
 - Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment’s limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. [[HS-LS4-2](#)]
 - Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically , behaviorally , and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a

population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. [[HS-LS4-3](#)], [[HS-LS4-4](#)]

- Adaptation also means that the distribution of traits in a population can change when conditions change. [[HS-LS4-3](#)]
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline—and sometimes the extinction—of some species. [[HS-LS4-5](#)]
- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. [[HS-LS4-5](#)]

Biology

Hierarchy of Multicellular Life



ESSENTIAL QUESTION

BIG IDEAS

How do organ systems rely on each other within an organism?

- Students will understand the hierarchy of specialized cells build to interacting organ systems in a multicellular organism.
- Students will understand how cells coordinate their function.
- Students will relate the movement of materials across membranes to the maintenance of homeostasis.

GUIDING QUESTIONS

Content:

- What is the difference between eukaryotic and prokaryotic cells?
- What are the special structures within cells that are responsible for particular functions?
- How do systems of specialized cells help organisms perform the essential functions of life?
- How does the function of an organ dictate the combination of specialized cells that form these organs?
- What is the structure and function of cellular membranes?
- How do cells communicate with each other?
- How do feedback mechanisms impact a living system?
- What are the various mechanisms by which materials move across a cell membrane?
- How does osmosis relate to solute concentration (free water)?

Process:

- How can we develop and/or use a model to describe the structure of the cell membrane and explain how the structure regulates movement of molecules across a membrane? [[Developing and Using Models](#)]
- How can an experiment be used to demonstrate how feedback mechanisms impact a living system? [[Planning and Carrying Out Investigations](#)]
- How can we develop a model in which we identify and describe the relevant parts (e.g., organ system, organs, and their component tissues) and processes (e.g., transport of fluids, motion) of body systems in multicellular organisms? [[Developing and Using Models](#)]

Reflective:

- How do the principles of the cell theory contribute to our understanding of the similarity of cell structure and function among living organisms?
- If a certain organ or organ system doesn't function properly, how does that impact an organism's ability to maintain homeostasis?

FOCUS STANDARDS

- **LS1.A: Structure and Function**

- Systems of specialized cells within organisms help them perform the essential functions of life. [[HS-LS1-1](#)]
- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. [[HS-LS1-2](#)]
- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. [[HS-LS1-3](#)]

Biology

Matter and Energy in Organisms and Ecosystems



ESSENTIAL QUESTION

BIG IDEAS

How do matter and energy move through ecosystems?

- Students will understand how matter cycles and energy flows through ecosystems.
- Students will understand why photosynthesis is important to so many other organisms.
- Students will understand why cellular respiration is necessary for organisms to convert food into usable energy.

GUIDING QUESTIONS

Content:

- What molecule acts as the energy currency for cellular work?
- How does the flow of energy and the cycling of chemicals in ecosystems differ?
- How do autotrophs and heterotrophs obtain the matter and energy they require?
- How are trophic levels related to food chains and food webs?
- What are the overall reactants and products of photosynthesis?
- What are the overall reactants and products of cellular respiration?
- How do cells release chemical energy from food?
- How do mitochondria and chloroplasts play a role in the cycling of carbon and oxygen?
- What is the importance of anaerobic processes in energy production and how can these processes be harnessed for commercial uses?

Process:

- How can we design an experiment to test environmental factors that can affect the processes of cellular respiration and/or photosynthesis?
- How can we construct and/or revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions?
- How can we develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere?

Reflective:

- How does breathing relate to cellular respiration?
- How does cellular respiration harvest energy from food?
- Why do trees change color in the fall?
- How are photosynthesis and cellular respiration related to climate change?

FOCUS STANDARDS

- **LS1.C: Organization for Matter and Energy Flow in Organisms**
 - The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. [[HS-LS1-5](#)]
 - As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. [[HS-LS1-7](#)]
 - As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment. [[HS-LS1-7](#)]
- **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**
 - Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. [[HS-LS2-3](#)]
 - Plants or algae form the lowest level of the food web. At each link upward in a food web, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level. Given this inefficiency, there are generally fewer organisms at higher levels of a food web. Some matter reacts to release energy for life functions, some matter is stored in newly made structures, and much is discarded. The chemical elements that make up the molecules of organisms pass through food webs and into and out of the atmosphere and soil, and they are combined and recombined in different ways. At each link in an ecosystem, matter and energy are conserved. [[HS-LS2-4](#)].
 - Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes. [[HS-LS2-5](#)]

Biology

Molecular Genetics



ESSENTIAL QUESTION

BIG IDEAS

Why do organisms differ from one another?

- Students will understand the structure of DNA and how it is replicated.
- Students will understand the flow of information from DNA to RNA to protein.
- Students will understand current techniques that are used to study and manipulate DNA.

GUIDING QUESTIONS

Content:

- What are the building blocks of DNA?
- What are the rules for base pairing and DNA structure?
- How is DNA replicated using a template mechanism?
- How is the information in DNA used to create a protein?
- How are the processes of transcription and replication similar? How are they different?
- How are RNA molecules translated into proteins?
- How do differences in gene expression account for the various cell types of a multicellular organism?
- How can mutations in DNA potentially affect the structure and function of a protein?

Process:

- What properties of DNA can be observed in a test tube?
- How can we create a model that simulates DNA replication?
- How can evidence of the structure of DNA and RNA be used to construct an explanation for how the information coded in DNA determines the structure of proteins and an organism's resulting traits?
- How can evidence of errors during replication be used to make and defend a claim about mutations as a potential source of genetic variation in organisms?

Reflective:

- How is our ever-increasing knowledge of DNA changing society?
- What are the cause and effect relationships between DNA, the proteins it codes for, and the resulting traits observed in an organism?
- What are the limitations, risks, and potential outcomes involved in genetic medicine and gene therapy?

FOCUS STANDARDS

- **LS1.A: Structure and Function:**
 - All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. [[HS-LS1-1](#)]
- **LS3.A: Inheritance of Traits:**
 - Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species'

characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. [[HS-LS3-1](#)]