

Unit Summary		
<i>How are characteristics from one generation related to the previous generation?</i>		
<p>Students analyze data develop models to make sense of the relationship between DNA and chromosomes in the process of cellular division, which passes traits from one generation to the next. Students determine why individuals of the same species vary in how they look, function, and behave. Students develop <i>conceptual models</i> of the role of DNA in the unity of life on Earth and <i>use statistical models</i> to explain the importance of variation within populations for the survival and evolution of species. Ethical issues related to genetic modification of organisms and the nature of science are described. Students explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expressions. The crosscutting concepts of <i>structure and function, patterns, and cause and effect</i> are used as organizing concepts for the disciplinary core ideas. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.</p>		
Student Learning Objectives		
<p>Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. <i>[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]</i> (HS-LS1-4)</p>		
<p>Explain <i>how</i> the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. <i>[Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]</i> (LS1.B)</p>		
<p>Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. <i>[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</i> (HS-LS3-1)</p>		
<p>Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)</p>		
<p>Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. <i>[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.]</i> <i>[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</i> (HS-LS3-2)</p>		
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Unit Sequence	
Part A: <i>What can't two roses ever be identical?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. 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 the 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, as yet, no known function. Empirical evidence is required to differentiate between cause and correlation and to make claims about the role of DNA and chromosomes in coding the instructions for the characteristic traits passed from parents to offspring. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Ask questions that arise from examining models or a theory to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parent to offspring. Use empirical evidence to differentiate between cause and correlation and make claims about the role of DNA and chromosomes in coding the instructions for characteristics passed from parents to offspring.

Unit Sequence	
Part B: <i>How does inheritable genetic variation occur?</i>	
Concepts	Formative Assessment
<ul style="list-style-type: none"> 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. Environmental factors also affect expression of traits, and hence affect the 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> Make and defend a claim based on evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors. Use data to support arguments for the ways inheritable genetic variation occurs. Use empirical evidence to differentiate between cause and correlation and

<p>probability of occurrence of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.</p> <ul style="list-style-type: none"> • Empirical evidence is required to differentiate between cause and correlation and to make claims about inheritable genetic variations resulting from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors. 	<p>make claims about the ways inheritable genetic variation occurs.</p>
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Unit Sequence	
Part C: Can a zoologist predict the distribution of expressed traits in a population?	
Concepts	Formative Assessment
<ul style="list-style-type: none"> • Environmental factors affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variations and distributions of traits observed depend on both genetic and environmental factors. • Algebraic thinking is used to examine scientific data and predict the distribution of traits in a population as they relate to the genetic and environmental factors (e.g., linear growth vs. exponential growth). • Technological advances have influenced the progress of science, and science has influenced advances in technology. • Science and engineering are influenced by society, and society is influenced by science and engineering. 	<p><i>Students who understand the concepts are able to:</i></p> <ul style="list-style-type: none"> • Apply concepts of statistics and probability (including determining function fits to data, slope, intercepts, and correlation coefficient for linear fits) to explain the variation and distribution of expressed traits in a population. • Use mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits. • Use algebraic thinking to examine scientific data on the variation and distribution of traits in a population and predict the effect of a change in probability of traits as it relates to genetic and environmental factors.

What It Looks Like in the Classroom
<p>Previously, students learned how environmental factors influence changes in population. They also learned how changes in the physical environment (whether naturally occurring or human induced) contribute to the expansion of some species. These concepts are important to understanding in the current unit, because environmental factors and mutagens can cause mutations resulting in new genetic combinations.</p> <p>Students also have an understanding that all cells contain genetic information in the form of DNA molecules, and that these DNA molecules contain the instructions for forming species' characteristics. In the current unit, students should identify the terms genes, chromosomes, and histones to develop an understanding that genes are regions in the DNA that contain the instructions that code for the formation of proteins. In addition, students should know that each chromosome consists of a single, very long DNA molecule, and that each gene on the chromosome is a particular segment of that DNA.</p> <p>Students might demonstrate that all cells in an organism have the same genetic content by using paper models, manipulatives, or computer simulations to simulate DNA replication. Students could examine the concept that genes used (expressed) by the cell may be regulated in different ways through a study of changes that occur during puberty, such as development of secondary sexual characteristics and the influence that hormones have on this gene expression process. Focus should</p>

be on student questions that arise from examination of models.

Students should synthesize information and cite specific evidence from texts, experiments, or simulations to gain a coherent understanding of and support explanations about the relationship between the role of DNA and chromosomes in coding instructions for characteristic traits passed from parents to offspring. Students should also research and investigate types of DNA, including DNA that codes for proteins, hemoglobin, actin, myosin), DNA that is involved in regulatory or structural functions (cell membrane proteins, cyclins) and DNA that has no known function (introns).

To understand environmental influence on gene expression, a study and evaluation of empirical evidence detailing frequencies of different forms of cancer could be correlated with specific environmental factors (climate, diet, pollution, lifestyle). Students should then determine whether cause-and-effect relationships exist. Students should also make claims about the relationship between the role of DNA and chromosomes in coding for characteristic traits passed from parent to offspring. Students might also conduct research on examples of genetic engineering, such as post-HIV infection treatment using the genetically engineered CCR5delta32 gene, to expand their claims about the role of DNA and chromosomes.

New genetic combinations are the result of sexual reproduction, crossing over during meiosis, mutations due to errors in DNA replication, or environmental influences. Students should make and defend claims, citing evidence from text, about how inheritable genetic variations may result from new genetic combinations. Conducting experiments with fruit flies, radiated plant seeds, and computer models will provide students with the necessary data to evaluate and defend findings. Using data from these or other experiments, students can support arguments for the ways inheritable genetic variation occurs. Ideally, student-conducted experiments will yield empirical evidence correlating the inheritable variation to the cause. Students should make and defend claims about the ways variation occurs using this empirical evidence. Students must understand that although DNA replication is tightly regulated, mutation can occur and can result in genetic variations.

Environmental factors affect the expression of the inherited traits. To illustrate this, students might collect empirical data (possibly by visiting local zoos) on populations of Arctic Fox. They might then focus on the role that temperature plays in influencing coat color and density in response to cold and warm air. Other studies on the role of temperature in gene expression might address the development of sexual organs among reptiles. Additional organisms, including earthworms, grouper fish, damselfish and some frog species, may illustrate how environmental triggers, such as gender density, can influence gene expression.

Students should be provided with the opportunity to determine the probability of occurrence of traits in a population using mathematical models. Through these activities, students will observe and predict the variation and distributions of traits and connect their expression to both genetic and environmental factors. In developing mathematical models to represent the variation and distribution of expressed traits, students should make sense of quantities and relationships in order to make predictions about the expression of traits.

The variation and distribution of traits depend on both genetic and environmental factors. Students should understand how environmental factors affect the expression of traits and the probability of trait occurrences in populations. Data showing the relationship between environmental factors and the expression of traits can be used to examine trait variation within a population. Students should be able make predictions as they relate to gene frequencies in populations affected by both genetic and environmental factors. Punnett Squares, graphing, Chi square analysis, and Hardy Weinberg calculations could be used to apply concepts of statistics and probability to gene expression and frequency. Algebraic thinking should be used to examine scientific data and to predict the distribution of traits in a population. Through the use of graphs, linear growth can be compared to exponential growth as these types of growth relate to traits within the population.

Students should be aware that technology and science are related and that technological advances have influenced the progress of science. Science in turn influences advances in technology, such as in the development of gene therapies. Students should have an understanding of how science and engineering are influenced by society (e.g., need for cures for genetic diseases), and how society is influenced by science and technology (e.g., the bio-ethics and economics of genetically modified foods). Previously, students learned how environmental factors influence changes in population. They also learned how changes in the physical environment (whether naturally occurring or human induced) contribute to the expansion of some species. These concepts are important to understanding in the current unit, because environmental factors and mutagens can cause mutations resulting in new genetic combinations.

Connecting with English Language Arts/Literacy and Mathematics

English Language Arts/Literacy

- Cite specific textual evidence to support analysis of science and technical texts describing the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring, resolving conflicting information when possible.
- Cite specific textual evidence to support analysis of science and technical texts describing the ways that inheritable genetic variation occurs, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Write arguments, based on evidence, that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors.

Mathematics

- Represent symbolically evidence that inheritable genetic variations may result from new genetic combinations through meiosis, viable errors occurring during replication, and/or mutations caused by environmental factors, and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the ways in which inheritable genetic variation occurs.
- Represent the variation and distribution of expressed traits in a population symbolically and manipulate the representing symbols. Make sense of quantities and relationships to describe and predict the variation and distribution of expressed traits in a population.

Modifications

Teacher Note: Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.

- Restructure lesson using UDL principals (<http://www.cast.org/our-work/about-udl.html# VXmoXcfD UA>)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.

- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.

Research on Student Learning

When asked to explain how physical traits are passed from parents to offspring, elementary-school, middle-school, and some high-school students express the following misconceptions: Some students believe that traits are inherited from only one of the parents (for example, the traits are inherited from the mother, because she gives birth or has most contact as children grow up; or the same-sex parent will be the determiner). Other students believe that certain characteristics are always inherited from the mother and others come from the father. Some students believe in a "blending of characteristics." It may not be until the end of 5th grade that some students can use arguments based on chance to predict the outcome of inherited characteristics of offspring from observing those characteristics in the parents.

Early middle-school students explain inheritance only in observable features, but upper middle-school and high-school students have some understanding that characteristics are determined by a particular genetic entity which carries information translatable by the cell. Students of all ages believe that some environmentally produced characteristics can be inherited, especially over several generations ([NSDL, 2015](#)).

Prior Learning

By the end of Grade 8, students understand that:

Life science

- Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.
- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.
- In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.
- Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Growth of organisms and population increases are limited by access to

resources.

- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
- Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes.
- In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.

Connections to Other Courses

Environmental science-

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- 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.
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.

Sample of Open Education Resources

[Structure and Function: Stem Cell](#): Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

[DNA Transcription and Translation Simulation](#): Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.

[Growth and Development](#): Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data

support the explanation or conclusion.

[Mitosis](#): Develop and/or use a model to generate data to support explanations, predict phenomena, analyze systems, and/or problems.

[Embryonic Development](#): Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field with available resources and, when appropriate, frame a hypothesis based on a model or theory.

[Inheritance and Variation: Genetic Variation](#): Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.

[Genetics](#): Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.

Appendix A: NGSS and Foundations for the Unit		
<p>Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. <i>[Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.]</i> (HS-LS1-4)</p>		
<p>Explain <i>how</i> the process of meiosis results in the passage of traits from parent to offspring, and how that results in increased genetic diversity necessary for evolution. <i>[Clarification Statement: The emphasis is on how meiosis results in genetic diversity, not the rote memorization of the steps of meiosis.]</i> (LS1.B)</p>		
<p>Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. <i>[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</i> (HS-LS3-1)</p>		
<p>Create a visual representation to illustrate how changes in a DNA nucleotide sequence can result in a change in the polypeptide produced. (LS3.B)</p>		
<p>Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. <i>[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.]</i> <i>[Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</i> (HS-LS3-2)</p>		
<p>The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:</p>		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p>Asking Questions and Defining Problems</p> <ul style="list-style-type: none"> Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1) <p>Constructing Explanations and Designing Solutions</p> <ul style="list-style-type: none"> Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS1-1) <p>Engaging in Argument from Evidence</p> <ul style="list-style-type: none"> Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. 	<p>LS1.A: Structure and Function</p> <ul style="list-style-type: none"> 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. (secondary to HS-LS3-1) <p>LS3.A: Inheritance of Traits</p> <ul style="list-style-type: none"> 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 	<p>Cause and Effect</p> <ul style="list-style-type: none"> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HLS3-1; HSL3-2) <p>Scale, Proportion, and Quantity</p> <ul style="list-style-type: none"> Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3)

<p>(HS-LS3-2)</p> <ul style="list-style-type: none"> • Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon. (MS-LS1-3) • Use an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-LS1-4) 	<p>functions, and some have no as-yet known function. (HS-LS3-1)</p> <p>LS3.B: Variation of Traits</p> <ul style="list-style-type: none"> • 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) 	
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English Language Arts	Mathematics
<p>Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. WHST.9-12.7 (HS-LS1-3)</p> <p>Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. WHST.11-12.8 (HS-LS1-3)</p> <p>Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. SL.11-12.5 (HS-LS1-2)</p>	<p>N/A</p>

