Unit 6: Inheritance and Variation of Traits

Instructional Days: 20

Unit Summary
Why do kids look similar to their parents?   Students develop and use models to describe how gene mutations and sexual reproduction contribute to genetic variation. Students understand how genetic factors determine the growth of an individual organism. They also demonstrate understanding of the genetic implications of sexual and asexual reproduction. The crosscutting concepts of *cause and effect* and *structure and function* provide a framework for understanding how gene structure determines differences in the functioning of organisms. Students are expected to demonstrate proficiency in *developing and using models*. Students use these science and engineering practices to demonstrate understanding of the disciplinary core ideas.
Student Learning Objectives
Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. *[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]* **(MS-LS3-1)**
Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. *[Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]* **(MS-LS3-2)**

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MS-LS3-1	Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism
MS-LS3-2	Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation
LS1.B	Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring
LS3.A	Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes.
LS3.B	Each parent contributes half of the genes acquired by the offpsring

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Quick Links		

Enduring Understandings

- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to
- 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 affects 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.

Essential Questions

- How do organisms grow and develop?
- How are traits inherited?
- Why is there variation between organisms?

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Unit Sequence	
Part A: *How do structural changes to genes (mutations) located on chromosomes affect proteins or affect the structure and function of an organism?*	
Concepts	**Formative Assessment**
• Complex and microscopic structures and systems, such as genes located on chromosomes, can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among the parts of the system; therefore, complex natural structures/systems can be analyzed to determine how they function. • 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. • In addition to variations that arise from sexual reproduction, genetic information can be altered due to mutations. • Some changes to genetic material are beneficial, others harmful, and some neutral to the organism. • Changes in genetic material may result in the production of different proteins. • Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of	*Students who understand the concepts are able to:* • Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

the organism and thereby change traits. • Structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism • Though rare, mutations may result in changes to the structure and function of proteins.	

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Unit Sequence	
Part B: *How do asexual reproduction and sexual reproduction affect the genetic variation of offspring?*	
Concepts	**Formative Assessment**
• Organisms reproduce either sexually or asexually and transfer their genetic information to their offspring. • Asexual reproduction results in offspring with identical genetic information. • Sexual reproduction results in offspring with genetic variation. • 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. • Punnett squares, diagrams, and simulations can be used to describe the cause-and-effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.	*Students who understand the concepts are able to:* • Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information. • Develop and use a model to describe why sexual reproduction results in offspring with genetic variation. • Use models such as Punnett squares, diagrams, and simulations to describe the cause-and effect-relationship of gene transmission from parent(s) to offspring and resulting genetic variation.

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What It Looks Like in the Classroom
Using models, such as electronic simulations, physical models, or drawings, students will learn that genes are located in the chromosomes of cells and each chromosome pair contains two variants of each gene. Students will need to make distinctions between chromosomes and genes and understand the connections between them. DNA will be introduced in high school. Students will learn that chromosomes are the genetic material that is found in the nucleus of the cell and that chromosomes are made up of genes. They will also learn that each gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual. Students should be given opportunities to use student-developed conceptual models to visualize how a mutation of genetic material could have positive, negative, or neutral impact on the expression of traits in organisms. Emphasis in this unit is on conceptual understanding that mutations of the genetic material may result in making different proteins; therefore, models and activities that focus on the expression of genetic traits, rather than on the molecular-level mechanisms for protein synthesis or specific types of mutations, are important for this unit of study. For example, models that assign genetic information to specific segments of model chromosomes could be used. Students could add, remove, or exchange genes located on the chromosomes and see that changing or altering a gene can result in a change in gene expression (proteins and therefore traits). Students will continue this unit of study by describing two of the most common sources of genetic variation, sexual and asexual reproduction. Students will be able to show that in sexual reproduction, each parent contributes half of the genes acquired by offspring, whereas in asexual reproduction, a single parent contributes the genetic makeup of offspring. Using models such as Punnett squares, diagrams, and simulations, students will describe the cause-and-effect relationship between gene transmission from parents(s) to offspring and the resulting genetic variation. Using symbols to represent the two alleles of a gene, one acquired from each parent, students can use Punnett squares to model how sexual reproduction results in offspring that may or may not have a genetic makeup that is different from either parent. Students can observe the same mixing of genetic information using colored counters or electronic simulations. Using other models, students can show that asexual reproduction results in offspring with the same combination of genetic information as the parents. Students can summarize the numerical data they collect during these activities as part of their description of why asexual reproduction results in offspring with identical genetic combinations and sexual reproduction results in offspring with genetic variations. As a culmination of this unit of study, students could make multimedia presentations to demonstrate their understanding of the key concepts. Students could participate in a short research project and cite the specific textual evidence used to support the analysis of any scientific information they gather. They could integrate quantitative or technical information

as part of their presentation. For example, students can take data collected during investigations of genetic mutations and provide a narrative description of their results. They could use data collected during their investigation of sexual and asexual reproduction. They could also include diagrams, graphs, or tables to clarify their data.

Connecting with English Language Arts/Literacy and Mathematics
English Language Arts • Cite specific textual evidence to support analysis of science and technical texts about structural changes to genes (mutations) located on chromosomes that may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. • Determine the meaning of symbols, key terms, and other domain-specific phrases as they are used to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. • Integrate quantitative or technical information about why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism that is expressed in words with a version of that information expressed visually in a flowchart, diagram, model, graph, or table. • Include multimedia components and visual displays in presentations about structural changes to genes (mutations) located on chromosomes that may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism to clarify claims and findings and emphasize salient points. • Cite specific textual evidence for why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation to support analysis of science and technical texts. • Determine the meaning of symbols, key terms, and other domain-specific phrases as they are used to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. • Integrate quantitative or technical information that describes why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation that is expressed in words with a version of that information that is expressed visually in a flowchart, diagram, model, graph, or table.

- Include multimedia components and visual displays in presentations that describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation to clarify claims and findings and emphasize salient points.

Mathematics

- Use mathematics to model why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- Summarize numerical data sets that describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation in relation to their context.

Modifications

(Note: Teachers identify the modifications that they will use in the unit. See NGSS Appendix D: All Standards, All Students/Case Studies for vignettes and explanations of the modifications.)

- 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.
- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)

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. By the end of 5th grade, students know that babies result from the fusion of sperm and eggs. However, they often don't understand how the fusion brings new life. Before students have an early understanding of genetics, they may believe that the baby exists in the sperm but requires the egg for food and protection, or that the baby exists in the egg and requires the sperm as trigger to growth (NSDL, 2015).

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Prior Learning
By the end of Grade 5, students understand that: • Many characteristics of organisms are inherited from parents. • Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. • Different organisms vary in how they look and function because they have different inherited information. • The environment also affects the traits that an organism develops.

Future Learning
Life science • Systems of specialized cells within organisms help the organisms perform the essential functions of life. • 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, which carry out most of the work of cells. • 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. • Feedback mechanisms maintain a living system's internal conditions, within certain limits, and mediate behaviors, allowing the system to remain alive and functional even as external conditions change, within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (through negative feedback) what is going on inside the living system. • In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. • 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, as yet, no known function.

- 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 probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.

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Connections to Other Units
Grade 6 Unit 1: Growth, Development and Reproduction of Organisms • Animals engage in characteristic behaviors that increase the odds of reproduction. • Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. • Genetic factors as well as local conditions affect the growth of the adult plant. **Grade 7 Unit 4: Structure and Function** • All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). • Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. **Grade 8 Unit 2: Selection and Adaptation** • Natural selection leads to the predominance of certain traits in a population, and the suppression of others. • In artificial selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring. • 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.

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Sample of Open Education Resources
Meiosis: How Does the Process of Meiosis Reduce the Number of Chromosomes in Reproductive Cells? This lab activity introduces students to the process of meiosis at the chromosomal level. The guiding question for the investigation is: How does the process of meiosis reduce the number of chromosomes in reproductive cells? Students develop an explanatory model based on their knowledge of mitosis and how cells divide. Students are provided with pictures showing various stages of meiosis. Students sequence the pictures and provide a description of what they think may be going on during each stage. The book provides a link (www.nsta.org/publications/press/extras/argument.aspx) to download images of meiosis (sequencing activity). Students use pop bead chromosomes (provided by the teacher) to create a valid model that explains : what happens to the chromosomes inside a cell as it goes through meiosis, why reproductive cells have half the number of chromosomes of the individuals who produce them, and why there are no pairs of chromosomes in reproductive cells. When students have finished the model, and after they have collected and analyzed the data, they develop an initial argument. They prepare a whiteboard presentation that includes the guiding question, claim, evidence, and justification of evidence and present it to the whole-class using a round-robin format. After collecting feedback, students return to their original small groups for editing and revising before writing a final report. Each lab ends with a list of checkout questions. The book includes an option to extend the lesson by asking students to complete a double-blind peer review of the argument using a rubric provided in the appendix. To provide additional support, four appendixes are included: standards alignment matrixes, options for implementing argument-driven inquiry lab investigations, investigation proposal options, and peer-review guide and instructor scoring rubric. A detailed step-by-step guide that explains the argument-driven inquiry is included for teachers not familiar with the model. Pedigrees and the Inheritance of Lactose Intolerance: In this activity students analyze a family's pedigrees to make a claim based on evidence about mode of inheritance of a lactose intolerance trait, determine the most likely inheritance pattern of a trait, and analyze variations in DNA to make a claim about which variants are associated with specific traits. This activity serves as a supplement to the film Got Lactose? The Co-evolution of Genes and Culture (http://www.hhmi.org/biointeractive/making-fittest-got-lactase-co-evolution-genes-and-culture). The film shows a scientist as he tracks down the genetic changes associated with the ability to digest lactose as adults. A detailed teacher's guide that includes curriculum connections, teaching tips, time requirements, answer key and a student guide can be downloaded at http://www.hhmi.org/biointeractive/pedigrees-and-inheritance-lactose-intolerance. Six supporting resource and two "click and learn" activities are also found on the link. How do Siamese Cats Get Their Color? This resource is an article from the January 2016 issue of The Science Teacher. The unit focuses on an essential question: How do Siamese cats develop their coloration? Students develop explanations by

making connections among genes, proteins, and traits. The unit is designed to be implemented over six or seven instructional days. However, each activity can be used as a stand-alone instructional strategy. During the instructional cycle, students develop an initial model to explain how Siamese cats get their coat coloration, learn about enzyme structure and function, use a computer model to see how proteins interact, experiment with Jell-O to see enzymes in action, learn about molecular motor proteins to see how structure relates to function, revise their model of coat coloration, and experiment with precursors of melanin to see how proteins can lead to observable traits. The unit is designed to help teachers extend the central dogma concept beyond the idea that proteins are the final products in the process. The unit provides opportunities for students to develop a conceptual understanding that proteins are important in cellular functions as well as trait-producing mechanisms. The article includes a teacher guide which describes how each activity is aligned to the Next Generation Science Standards. Unit handouts for students and the teacher guide are found on the NSTA website at www.nsta.org/highschool/connections.aspx.

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Appendix A: NGSS and Foundations for the Unit		
Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. *[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]* **(MS-LS3-1)**		
Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. *[Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]* **(MS-LS3-2)**		
The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**
Developing and Using Models • Develop and use a model to describe phenomena. (MS-LS3-1),(MS-LS3-2)	**LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. *(secondary to MS-LS3-2)* **LS3.A: Inheritance of Traits** • 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	**Structure and Function** • Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function. (MS-LS3-1) **Cause and Effect** • Cause and effect relationships may

	proteins, which in turn affects 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. (MS-LS3-1) • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2) **LS3.B: Variation of Traits** • 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. (MS-LS3-2) • 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.	be used to predict phenomena in natural systems. (MS-LS3-2)

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	Some changes are beneficial, others harmful, and some neutral to the organism. (MS-LS3-1)	

English Language Arts	Mathematics
Cite specific textual evidence to support analysis of science and technical texts. (MS-LS3-1),(MS-LS3-2) **RST.6-8.1** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. (MS-LS3-1),(MS-LS3-2) **RST.6-8.4** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS3-1),(MS-LS3-2) **RST.6-8.7** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-LS3-1),(MS-LS3-2) **SL.8.5**	Model with mathematics. (MS-LS3-2) **MP.4** Summarize numerical data sets in relation to their context. (MS-LS3-2) **6.SP.B.5**

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Common Vocabulary	
Cell	Chromosome
Development	Formation
Instruction	Gene
Recognizable	Genetic
Version	Variation
Allele	Molecule
Contribute	Protein
Hereditary information	Sexual reproduction
Identical	Structural
Punnett square	Subset
Random	Chromosome pair
Transmission	DNA
Asexual reproduction	