Middle School Topics Course Model 1-Bundle 2
Reproduction and Growth

This is the second bundle of the Middle School Topics Course Model 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 2 Question: This bundle is assembled to address the question of "How do organisms grow and reproduce?"

Summary
The bundle organizes performance expectations with a focus on helping students understand the conditions of successful reproduction, development, and growth. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs
All living things are made up of cells. In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions (LS1. As in MS-LS1-3). These specialized tissues and organs support organisms as they grow and reproduce. Animals engage in characteristic behaviors that increase the odds of reproduction and plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (LS1.B as in MS-LS1-4). The nervous system is made up of specialized nerve cells. These nerve cells enable each sense receptor to respond to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories (LS1.D as in MS-LS1-8) further enabling animals to grow and reproduce.

The ideas about reproduction in this bundle connect to the concept that organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (LS1.B as in MS-LS3-2). The concept of sexual reproduction and transfer of genetic information connects to the idea that variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes inherited (LS3.A as in MS-LS3-2). Another connection to sexual reproduction is the idea that in sexually reproducing organisms, each parent contributes half of the genes acquired by the offspring, thus 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 (LS3.B as in MS-LS3-2). Additionally, genetic factors as well as local conditions affect the growth of the adult plant (LS1.B as in MS-LS1-5).

Finally, specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (ETS1.A as in MS-ETS1-1), and there are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B as in MS-ETS1-2, MS-ETS1-3). Although the design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design (ETS1.C as in MS-ETS1-3). Thus, a solution needs to be tested, and then modified on the basis of the test results, in order to improve it (ETS1.B as in MS-ETS1-4). These engineering design concepts could connect to many different science ideas, including about how animals and plants may have specialized features that increase the odds of reproduction (LS1.B as in MS-LS1-4), how each sense receptor responds to different inputs, transmitting them as signals that travel along nerve cells to the brain where they result in immediate behaviors or memories (LS1.D as in MS-LS1-8), and how local conditions affect the growth of plants (LS1.B as in MS-LS1-5). Connections could be made through an engineering design task by identifying criteria and constraints including those that could limit possible solutions (ETS1.A as in MS-ETS1-1) for how a local zoo could optimize the habitat of animals and plants to increase the odds of reproduction (LS1.B as in MS-LS1-4) or for designing lighting systems in a greenhouse to maximize the growth of plants (LS1.B as in MS-LS1-5).

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Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of defining problems (MS-ETS1-1), developing and using models (MS-LS3-2 and MS-ETS1-4), analyzing and interpreting data (MS-ETS1-3), constructing explanations (MS-LS1-5), engaging in argument from evidence (MS-LS1-3, MS-LS1-4, and MS-ETS1-2), and obtaining, evaluating, and communicating information (MS-LS1-8). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Cause and Effect (MS-LS1-4, MS-LS1-5, MS-LS1-8, and MS-LS3-2), and Systems and System Models (MS-LS1-3). Many other crosscutting concept elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations MS-LS1-3 and MS-LS1-8 are partially assessable	**MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.] **MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds; and, creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.] **MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.] **MS-LS1-8 Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.] **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.** [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.]

Performance Expectations (Continued)	MS-ETS1-1 **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.** MS-ETS1-2 **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.** MS-ETS1-3 **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.** MS-ETS1-4 **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**
Example Phenomena	A male peacock has a spectacular display of colorful feathers. In times of drought, some plants lose their leaves.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between independent and dependent variables and relationships in models. Students could *ask questions to* [seek information about] *relationships between independent and dependent variables* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Developing and Using Models** • Evaluate limitations of a model for a proposed object or tool. Students could *evaluate limitations of a model* [used to determine which parental] ***genes*** [end up in the] ***offspring of sexual reproducing organisms***. MS-LS3-2 **Planning and Carrying Out Investigations** • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions. Students could *collect data to serve as the basis for evidence to answer scientific questions* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Analyzing and Interpreting Data** • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). Students could *consider limitations of data analysis* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5

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Additional Practices Building to the PEs (Continued)	**Using Mathematical and Computational Thinking** • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. Students could *use digital tools to analyze very large data sets for patterns and trends* [about how] ***animals engage in characteristic behaviors that increase the odds of reproduction***. MS-LS1-4 **Constructing Explanations and Designing Solutions** • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events. Students could *apply scientific ideas, principles, and/or evidence to construct an explanation* [for how] ***variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes inherited***. MS-LS3-2 **Engaging in Argument from Evidence** • Respectfully provide and receive critiques about one's explanations, procedures, models and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could *respectfully provide critiques about models by citing relevant evidence and posing questions that elicit pertinent elaboration and detail* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world. Students could *critically read scientific text to determine the central ideas to describe evidence* [for how] ***animals engage in characteristic behaviors that increase the odds of reproduction*** and [how] ***plants sometimes depend on animal behavior and specialized features for reproduction***. MS-LS1-4
Additional Crosscutting Concepts Leading to PE	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could analyze data to *classify relationships as causal or correlational* [for how] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **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 and designed structures/systems can be analyzed to determine how they function. Students could analyze *complex structures to describe how their function depends on the shapes, composition, and relationships among its* parts [related to how] ***plants sometimes depend on animal behavior and specialized features for reproduction***. MS-LS1-4

Additional Crosscutting Concepts Leading to PE (Continued)	**Stability and Change** • Stability might be disturbed either by sudden events or gradual changes that accumulate over time. Students could analyze data about how *sudden events or gradual changes* in **local conditions affect the growth of the adult plant**. MS-LS1-5
Additional Connections to Nature of Science	**Scientific Investigations us a Variety of Methods** • Science depends on evaluating proposed explanations. Students could construct an argument for why *science depends on evaluating proposed explanations,* [including for how] **genetic factors as well as local conditions affect the growth of the adult plant**. MS-LS1-5 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. Students could construct an argument [for how the assumption] *that events in natural systems occur in consistent patterns that are understandable through measurement and observation* [affects their understanding that] **genetic factors as well as local conditions affect the growth of the adult plant**. MS-LS1-5

MS-LS1-3　From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-3. **Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.** [Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.] [*Assessment Boundary: Assessment does not include the mechanism of one body system independent of others. Assessment is limited to the circulatory, excretory, digestive, respiratory, muscular, and nervous systems.*]

The performance expectation above was 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
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Use an oral and written argument supported by evidence to support or refute an explanation or a model for a phenomenon.	**LS1.A: Structure and Function** • In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.	**Systems and System Models** • Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. - ***Connections to Nature of Science*** **Science is a Human Endeavor** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

	Observable features of the student performance by the end of the course:	
1	Supported claims	
	a	Students make a claim to be supported, related to a given explanation or model of a phenomenon. In the claim, students include the idea that the body is a system of interacting subsystems composed of groups of cells.
2	Identifying scientific evidence	
	a	Students identify and describe* the given evidence that supports the claim (e.g., evidence from data and scientific literature), including evidence that:
	i.	Specialized groups of cells work together to form tissues (e.g., evidence from data about the kinds of cells found in different tissues, such as nervous, muscular, and epithelial, and their functions).
	ii.	Specialized tissues comprise each organ, enabling the specific organ functions to be carried out (e.g., the heart contains muscle, connective, and epithelial tissues that allow the heart to receive and pump blood).
	iii.	Different organs can work together as subsystems to form organ systems that carry out complex functions (e.g., the heart and blood vessels work together as the circulatory system to transport blood and materials throughout the body).
	iv.	The body contains organs and organ systems that interact with each other to carry out all necessary functions for survival and growth of the organism (e.g., the digestive, respiratory, and circulatory systems are involved in the breakdown and transport of food and the transport of oxygen throughout the body to cells, where the molecules can be used for energy, growth, and repair).
3	Evaluating and critiquing the evidence	
	a	Students evaluate the evidence and identify the strengths and weaknesses of the evidence, including:
	i.	Types of sources.

		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence and why the evidence supports the student's claim, as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the appropriate evidence to the claim. Students describe* the following chain of reasoning in their argumentation:	
		i.	Every scale (e.g., cells, tissues, organs, organ systems) of body function is composed of systems of interacting components.
		ii.	Organs are composed of interacting tissues. Each tissue is made up of specialized cells. These interactions at the cellular and tissue levels enable the organs to carry out specific functions.
		iii.	A body is a system of specialized organs that interact with each other and their subsystems to carry out the functions necessary for life.
	b	Students use oral or written arguments to support or refute an explanation or model of a phenomenon.	

MS-LS1-4   From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-4.   Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

The performance expectation above was 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
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • 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.	**LS1.B: Growth and Development 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.	**Cause and Effect** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

	Observable features of the student performance by the end of the course:	
1	**Supported claims**	
	a	Students make a claim to support a given explanation of a phenomenon. In their claim, students include the idea that characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
2	**Identifying scientific evidence**	
	a	Students identify the given evidence that supports the claim (e.g., evidence from data and scientific literature), including:
		i. Characteristic animal behaviors that increase the probability of reproduction.
		ii. Specialized plant and animal structures that increase the probability of reproduction.
		iii. Cause-and-effect relationships between:
		1. Specialized plant structures and the probability of successful reproduction of plants that have those structures.
		2. Animal behaviors and the probability of successful reproduction of animals that exhibit those behaviors.
		3. Plant reproduction and the animal behaviors related to plant reproduction.
3	**Evaluating and critiquing the evidence**	
	a	Students evaluate the evidence and identify the strengths and weaknesses of the evidence used to support the claim, including:
		i. Validity and reliability of sources.
		ii. Sufficiency — including relevance, validity, and reliability — of the evidence to make and defend the claim.
		iii. Alternative interpretations of the evidence and why the evidence supports the student's claim, as opposed to any other claims.

4	Reasoning and synthesis	
	a	Students use reasoning to connect the appropriate evidence to the claim, using oral or written arguments. Students describe* the following chain of reasoning in their argumentation:
		i. Many characteristic animal behaviors affect the likelihood of successful reproduction.
		ii. Many specialized plant structures affect the likelihood of successful reproduction.
		iii. Sometimes, animal behavior plays a role in the likelihood of successful reproduction in plants.
		iv. Because successful reproduction has several causes and contributing factors, the cause-and-effect relationships between any of these characteristics, separately or together, and reproductive likelihood can be accurately reflected only in terms of probability.

MS-LS1-5 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-5.   **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [*Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.*]

The performance expectation above was 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
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.	**LS1.B: Growth and Development of Organisms** • Genetic factors as well as local conditions affect the growth of the adult plant.	**Cause and Effect** • Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.

	Observable features of the student performance by the end of the course:	
1	Articulating the explanation of phenomena	
	a	Students articulate a statement that relates the given phenomenon to a scientific idea, including the idea that both environmental and genetic factors influence the growth of organisms.
	b	Students use evidence and reasoning to construct a scientific explanation for the given phenomenon.
2	Evidence	
	a	Students identify and describe* evidence (e.g., from students' own investigations, observations, reading material, archived data) necessary for constructing the explanation, including:
		i. Environmental factors (e.g., availability of light, space, water; size of habitat) and that they can influence growth.
		ii. Genetic factors (e.g., specific breeds of plants and animals and their typical sizes) and that they can influence growth.
		iii. Changes in the growth of organisms as specific environmental and genetic factors change.
	b	Students use multiple valid and reliable sources of evidence to construct the explanation.
3	Reasoning	
	a	Students use reasoning, along with 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, to connect the evidence and support an explanation for a phenomenon involving genetic and environmental influences on organism growth. Students describe* their chain of reasoning that includes:
		i. Organism growth is influenced by multiple environmental (e.g., drought, changes in food availability) and genetic (e.g., specific breed) factors.

| | | ii. | Because both environmental and genetic factors can influence organisms simultaneously, organism growth is the result of environmental and genetic factors working together (e.g., water availability influences how tall dwarf fruit trees will grow). |
| | | iii. | Because organism growth can have several genetic and environmental causes, the contributions of specific causes or factors to organism growth can be described only using probability (e.g., not every fish in a large pond grows to the same size). |

MS-LS1-8 From Molecules to Organisms: Structures and Processes

Students who demonstrate understanding can:

MS-LS1-8. **Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.** [*Assessment Boundary: Assessment does not include mechanisms for the transmission of this information.*]

The performance expectation above was 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
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 6-8 builds on K-5 experiences and progresses to evaluating the merit and validity of ideas and methods. • Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.	**LS1.D: Information Processing** • Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural systems.

		Observable features of the student performance by the end of the course:
1		Obtaining information
	a	Students gather and synthesize information from at least two sources (e.g., text, media, visual displays, data) about a phenomenon that includes the relationship between sensory receptors and the storage and usage of sensory information by organisms. Students gather information about:
		i. Different types of sensory receptors and the types of inputs to which they respond (e.g., electromagnetic, mechanical, chemical stimuli).
		ii. Sensory information transmission along nerve cells from receptors to the brain.
		iii. Sensory information processing by the brain as:
		1. Memories (i.e., stored information).
		2. Immediate behavioral responses (i.e., immediate use).
	b	Students gather sufficient information to provide evidence that illustrates the causal relationships between information received by sensory receptors and behavior, both immediate and over longer time scales (e.g., a loud noise processed via auditory receptors may cause an animal to startle immediately or may be encoded as a memory, which can later be used to help the animal react appropriately in similar situations).
2		Evaluating information
	a	Students evaluate the information based on:
		i. The credibility, accuracy, and possible bias of each publication and the methods used to generate and collect the evidence.
		ii. The ability of the information to provide evidence that supports or does not support the idea that sensory receptors send signals to the brain, resulting in immediate behavioral changes or stored memories.
		iii. Whether the information is sufficient to allow prediction of the response of an organism to different stimuli based on cause and effect relationships between the responses of sensory receptors and behavioral responses.

MS-LS3-2 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

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.** [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.]

The performance expectation above was 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 Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena.	**LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. *(secondary)* **LS3.A: Inheritance of Traits** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. **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.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural systems.

	Observable features of the student performance by the end of the course:	
1		Components of the model
	a	Students develop a model (e.g., Punnett squares, diagrams, simulations) for a given phenomenon involving the differences in genetic variation that arise from sexual and asexual reproduction. In the model, students identify and describe* the relevant components, including:
		i. Chromosome pairs, including genetic variants, in asexual reproduction:
		1. Parents.
		2. Offspring.
		ii. Chromosome pairs, including genetic variants, in sexual reproduction:
		1. Parents.
		2. Offspring.
2		Relationships
	a	In their model, students describe* the relationships between components, including:
		i. During reproduction (both sexual and asexual), parents transfer genetic information in the form of genes to their offspring.
		ii. Under normal conditions, offspring have the same number of chromosomes, and therefore genes, as their parents.
		iii. During asexual reproduction, a single parent's chromosomes (one set) are the source of genetic material in the offspring.
		iv. During sexual reproduction, two parents (two sets of chromosomes) contribute genetic material to the offspring.

3		Connections		
	a	Students use the model to describe* a causal account for why sexual and asexual reproduction result in different amounts of genetic variation in offspring relative to their parents, including that:		
		i.	In asexual reproduction:	
			1.	Offspring have a single source of genetic information, and their chromosomes are complete copies of each single parent pair of chromosomes.
			2.	Offspring chromosomes are identical to parent chromosomes.
		ii.	In sexual reproduction:	
			1.	Offspring have two sources of genetic information (i.e., two sets of chromosomes) that contribute to each final pair of chromosomes in the offspring.
			2.	Because both parents are likely to contribute different genetic information, offspring chromosomes reflect a combination of genetic material from two sources and therefore contain new combinations of genes (genetic variation) that make offspring chromosomes distinct from those of either parent.
	b	Students use cause-and-effect relationships found in the model between the type of reproduction and the resulting genetic variation to predict that more genetic variation occurs in organisms that reproduce sexually compared to organisms that reproduce asexually.		

MS-ETS1-1   Engineering Design

Students who demonstrate understanding can:

MS-ETS1-1. **Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.**

The performance expectation above was 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
Asking Questions and Defining Problems	**ETS1.A: Defining and Delimiting Engineering Problems**	**Influence of Science, Engineering, and Technology on Society and the Natural World**
Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.	• The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	• All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.
• Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.		• The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

	Observable features of the student performance by the end of the course:	
1		Identifying the problem to be solved
	a	Students describe* a problem that can be solved through the development of an object, tool, process, or system.
2		Defining the process or system boundaries and the components of the process or system
	a	Students identify the system in which the problem is embedded, including the major components and relationships in the system and its boundaries, to clarify what is and is not part of the problem. In their definition of the system, students include:
	i.	Which individuals or groups need this problem to be solved.
	ii.	The needs that must be met by solving the problem.
	iii.	Scientific issues that are relevant to the problem.
	iv.	Potential societal and environmental impacts of solutions.
	v.	The relative importance of the various issues and components of the process or system.
3		Defining criteria and constraints
	a	Students define criteria that must be taken into account in the solution that:
	i.	Meet the needs of the individuals or groups who may be affected by the problem (including defining who will be the target of the solution).
	ii.	Enable comparisons among different solutions, including quantitative considerations when appropriate.
	b	Students define constraints that must be taken into account in the solution, including:
	i.	Time, materials, and costs.
	ii.	Scientific or other issues that are relevant to the problem.
	iii.	Needs and desires of the individuals or groups involved that may limit acceptable solutions.
	iv.	Safety considerations.
	v.	Potential effect(s) on other individuals or groups.
	vi.	Potential negative environmental effects of possible solutions or failure to solve the problem.

MS-ETS1-2   Engineering Design

Students who demonstrate understanding can:

MS-ETS1-2. **Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.**

The performance expectation above was 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
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	

	Observable features of the student performance by the end of the course:	
1	Identifying the given design solution and associated claims and evidence	
	a	Students identify the given supported design solution.
	b	Students identify scientific knowledge related to the problem and each proposed solution.
	c	Students identify how each solution would solve the problem.
2	Identifying additional evidence	
	a	Students identify and describe* additional evidence necessary for their evaluation, including:
		i. Knowledge of how similar problems have been solved in the past.
		ii. Evidence of possible societal and environmental impacts of each proposed solution.
	b	Students collaboratively define and describe* criteria and constraints for the evaluation of the design solution.
3	Evaluating and critiquing evidence	
	a	Students use a systematic method (e.g., a decision matrix) to identify the strengths and weaknesses of each solution. In their evaluation, students:
		i. Evaluate each solution against each criterion and constraint.
		ii. Compare solutions based on the results of their performance against the defined criteria and constraints.
	b	Students use the evidence and reasoning to make a claim about the relative effectiveness of each proposed solution based on the strengths and weaknesses of each.

MS-ETS1-3 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-3. **Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.**

The performance expectation above was 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
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.	

	Observable features of the student performance by the end of the course:	
1	**Organizing data**	
	a	Students organize given data (e.g., via tables, charts, or graphs) from tests intended to determine the effectiveness of three or more alternative solutions to a problem.
2	**Identifying relationships**	
	a	Students use appropriate analysis techniques (e.g., qualitative or quantitative analysis; basic statistical techniques of data and error analysis) to analyze the data and identify relationships within the datasets, including relationships between the design solutions and the given criteria and constraints.
3	**Interpreting data**	
	a	Students use the analyzed data to identify evidence of similarities and differences in features of the solutions.
	b	Based on the analyzed data, students make a claim for which characteristics of each design best meet the given criteria and constraints.
	c	Students use the analyzed data to identify the best features in each design that can be compiled into a new (improved) redesigned solution.

MS-ETS1-4 Engineering Design

Students who demonstrate understanding can:

MS-ETS1-4.   **Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.**

The performance expectation above was 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 Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • Models of all kinds are important for testing solutions. **ETS1.C: Optimizing the Design Solution** • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	

	Observable features of the student performance by the end of the course:	
1	Components of the model	
	a	Students develop a model in which they identify the components relevant to testing ideas about the designed system, including:
	i.	The given problem being solved, including criteria and constraints.
	ii.	The components of the given proposed solution (e.g., object, tools, or process), including inputs and outputs of the designed system.
2	Relationships	
	a	Students identify and describe* the relationships between components, including:
	i.	The relationships between each component of the proposed solution and the functionality of the solution.
	ii.	The relationship between the problem being solved and the proposed solution.
	iii.	The relationship between each of the components of the given proposed solution and the problem being solved.
	iv.	The relationship between the data generated by the model and the functioning of the proposed solution.
3	Connections	
	a	Students use the model to generate data representing the functioning of the given proposed solution and each of its iterations as components of the model are modified.
	b	Students identify the limitations of the model with regards to representing the proposed solution.
	c	Students describe* how the data generated by the model, along with criteria and constraints that the proposed solution must meet, can be used to optimize the design solution through iterative testing and modification.