Middle School Phenomenon Model Course 2 – Bundle 5
Growth and Reproduction of Organisms

This is the fifth bundle of the Middle School Phenomenon Model Course 2. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 5 Question: This bundle is assembled to address the question "why do some parents and offspring look different?"

Summary

The bundle organizes performance expectations with a focus on helping students build understanding of how organisms grow and reproduce. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, and recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring (LS1.B as in MS-LS3-2). In order to increase the odds of reproduction, animals engage in characteristic behaviors, and plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction (LS1.B as in MS-LS1-4). Genetic information is passed from parent to offspring in the form of genes, which are located in the chromosomes of cells. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual (LS3.A as in MS-LS3-1).

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). In sexually reproducing organisms, each parent contributes half of the genes acquired by the offspring. Individuals have two of each chromosome and hence two alleles of each gene. These versions may be identical or may differ from each other (LS3.B as in MS-LS3-2). In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations (LS3.B as in MS-LS3-1). Though rare, mutations to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits (LS3.A as in MS-LS3-1). Some changes are beneficial, others harmful, and some neutral to the organism (LS3.B as in MS-LS3-1). Furthermore, genetic factors as well as local conditions affect the growth of the adult plant (LS1.B as in MS-LS1-5).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of developing and using models (MS-LS3-1 and MS-LS3-2), constructing explanations (MS-LS1-5), and engaging in argument (MS-LS1-4). 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, and MS-LS3-2) and Structure and Function (MS-LS3-1). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	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-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.** [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-LS3-2. **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.]
Example Phenomena	Some species of lizards don't need males to reproduce. A child can have red hair even if no one else in their family has red hair.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation to seek additional information* [about how] ***specific proteins affect the traits of the individual***. MS-LS3-1 **Developing and Using Models** • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. Students could develop a model to show relationships among variables [of] ***animals engaging in characteristic behaviors and the odds of reproduction***. MS-LS1-4

Additional Practices Building to the PEs (Continued)	**Planning and Carrying Out Investigations** • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. Students could *conduct an investigation to produce data to serve as the basis for evidence* [that] ***genetic factors, as well as local conditions, affect the growth of adult plants***. MS-LS1-5 **Analyzing and Interpreting Data** • Analyze and interpret data to provide evidence for phenomena. Students could *analyze and interpret data to provide evidence* [that] ***mutations are rare.*** MS-LS3-1 **Using Mathematical and Computational Thinking** • Use mathematical representations to describe and/or support scientific conclusions and design solutions. Students could *use mathematical representations to describe* [that] ***genetic factors as well as local conditions affect the growth of the adult plant***. MS-LS1-5 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [of how] ***plants reproduce in a variety of ways***. MS-LS1-4 **Engaging in Argument from Evidence** • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. Students could *compare and critique two arguments* [about how] ***variations of inherited traits between parent and offspring arise from genetic differences*** *and analyze whether they emphasize similar or different evidence*. MS-LS3-2 **Obtaining, Evaluating, and Communicating Information** • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. Students could *evaluate data, hypotheses, and/or conclusions in light of competing information* [about how] ***genetic factors as well as local conditions affect the growth of the adult plant.*** MS-LS1-5
Additional Crosscutting Concepts Building to the PEs	**Patterns** • Graphs, charts, and images can be used to identify patterns in data. Students could *use graphs, charts, and images to identify patterns in data* [of how] ***local conditions affect the growth of adult plants***. MS-LS1-5

Additional Crosscutting Concepts Building to the PEs (Continued)	**Cause and Effect** • Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation. Students could construct an argument for how the *relationship between* ***changes to proteins and traits of the individual*** *can be classified as causal or correlational, and that correlation does not necessarily imply causation.* MS-LS3-1 **Stability and Change** • Stability might be disturbed by either sudden events or gradual changes that accumulate over time. Students could construct an argument for how *stability* ***in inherited traits between parent and offspring*** [over generations] *might be disturbed by either sudden events or gradual changes* [(mutations)] *that accumulate over time*. MS-LS3-2
Additional Connections to Nature of Science	**Scientific Knowledge is Open to Revision in Light of New Evidence** • Scientific explanations are subject to revision and improvement in light of new evidence. Students could obtain, evaluate, and communicate information about how *scientific explanations* [of how] ***each gene chiefly controls the production of specific proteins*** [have been] *revised and improved in light of new evidence*. MS-LS3-1 **Science Addresses Questions About the Natural and Material World** • Scientific knowledge is constrained by human capacity, technology, and materials. Students could construct an argument about how *scientific knowledge* [about] ***genetic factors affecting the growth of plants*** *is constrained by human capacity, technology, and materials*. MS-LS1-5

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

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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

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

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.

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- Genetic factors as well as local conditions affect the growth of the adult plant.

Crosscutting Concepts

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-LS3-1 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

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.**[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.*]

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

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.

Disciplinary Core Ideas

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 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.

LS3.B: Variation of Traits

- 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.

Crosscutting Concepts

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.

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 relevant components for making sense of a given phenomenon involving the relationship between mutations and the effects on the organism, including:	
		i.	Genes, located on chromosomes.
		ii.	Proteins.
		iii.	Traits of organisms.
2	Relationships		
	a	In their model, students describe* the relationships between components, including:	
		i.	Every gene has a certain structure, which determines the structure of a specific set of proteins.
		ii.	Protein structure influences protein function (e.g., the structure of some blood proteins allows them to attach to oxygen, the structure of a normal digestive protein allows it break down particular food molecules).
		iii.	Observable organism traits (e.g., structural, functional, behavioral) result from the activity of proteins.
3	Connections		
	a	Students use the model to describe* that structural changes to genes (i.e., mutations) may result in observable effects at the level of the organism, including why structural changes to genes:	
		i.	May affect protein structure and function.

		ii. May affect how proteins contribute to observable structures and functions in organisms.
		iii. May result in trait changes that are beneficial, harmful, or neutral for the organism.
	b	Students use the model to describe* that beneficial, neutral, or harmful changes to protein function can cause beneficial, neutral, or harmful changes in the structure and function of organisms.

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

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.

Disciplinary Core Ideas

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.

Crosscutting Concepts

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.