CENTRAL SOUTHERN TIER
RAEN
REGIONAL ADULT EDUCATION NETWORK

Genetics: Applying the Next Generation Science Core Disciplinary Ideas and Science Practices to:

Inheritance, Variability, and Adaptation

Central/Southern Tier RAEN, November 9 & 10, 2015

Tom Trocco, Director of Program Support for OACE, ttrocco@schools.nyc.gov

Agenda

Introductions
Objectives/Where we are now
I. The Structure of the TASC
TASC Test Design

II. Next Gen Standards
Disciplinary Core Idea Progressions

Break

A. Exploring LS3.A: Inheritance of Traits
Some Genes Are Dominant
Mendel's Laws of Genetic Inheritance
Punnett Squares-Monsters
Discussion

B. Exploring LS3.B: Variation of Traits
Variation: Seeds, Leaves, Fingers
Discussion

Lunch

C. Exploring LS4.B: Natural Selection
The Peppered Moth
Discussion

III. Online exploration

Evaluations

Science Achievement on the TASC™

Genetics: Investigating the Next Generation Science Core Disciplinary Ideas of Inheritance, Variability, and Adaptation

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Learning Objectives

Currently, 36% of the TASC™ Science section assesses Life Science content and practices…

1. Understanding the organization of the Framework of the Next Generation Science Standards
2. Using strategies and resources to engage students in science content in two related indicators:
   - Life Science 3: Heredity: Inheritance and Variation of Traits
   - Life Science 4: Biological Evolution: Unity and Diversity
3. Experiencing some hands-on activities to support students in these indicators.

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Agenda

- Objectives
- Introductions
- Where we are now…
- Revised Structure of the TASC™
- The Next Generation Science Standards Organization
- Hands-on Practice with:
  - LS-3: **Dominant & Recessive Genes**
  - LS-3: **Mendel's Laws of Genetic Inheritance**
  - LS-3: **Genetic Variation**
  - LS-4: **Natural Selection and Adaptation**

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Where We Are Now…

Turn and Talk about TASC Science

- What successes have your students had?
- What challenges do they face?
- What are you wondering…

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TASC™ Science Structure*

	TASC
Content Area	
• Physical Sciences	36%
• Life Sciences	36%
• Earth and Space Sciences	28%
• Scientific and Engineering Practices	Integrated
• Cross-Cutting Concepts	Integrated
Testing Time	85 min (90 min Spanish)
Number of Questions	48/49 MC (8 stimuli) 1 Constructed Response 1 Technology-Enhanced Item

* as of March, 2015

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TASC™ Readiness Test Observations

Knowledge Required	% Questions
Prior Knowledge Required	70%
Cross-Cutting Concepts (cause-and-effect, proportion)	78%
Computation	35%

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TASC™ Science Structure

- Includes items for the disciplines of
  - Physical Science
  - Life Science
  - Earth and Space Science
- Each discipline is subdivided into several Core Ideas
- Each Core Idea contains multiple performance expectations.

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TASC™ Science Disciplinary Core Ideas

Life Sciences

- LS1 From Molecules to Organisms: Structures and Processes
- LS2 Ecosystems: Interactions, Energy, and Dynamics
- LS3 Heredity: Inheritance and Variation of Traits
- LS4 Biological Evolution: Unity and Diversity

Earth and Space Sciences

- ESS1 Earth's Place in the Universe
- ESS2 Earth's Systems
- ESS3 Earth and Human Activity

Physical Sciences

- PS1 Matter and Its Interactions
- PS2 Motion and Stability: Forces and Interactions
- PS3 Energy
- PS4 Waves and Their Applications in Technologies for Information Transfer

Core Ideas build from ES to MS to HS

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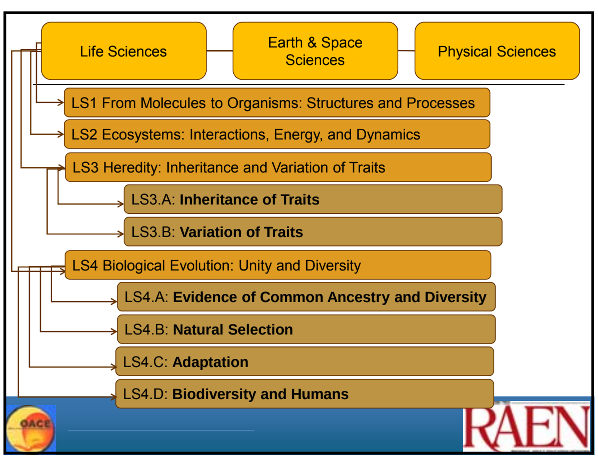

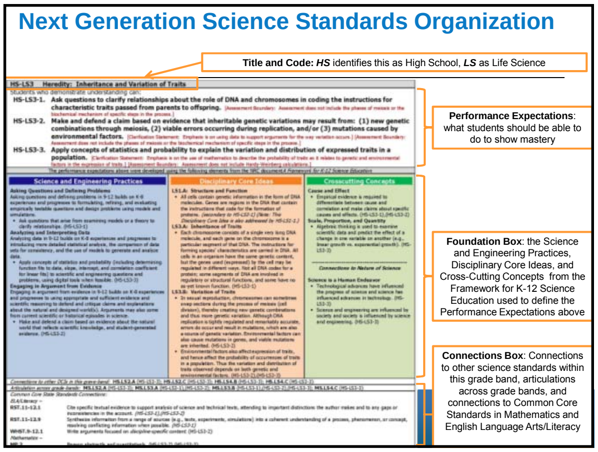

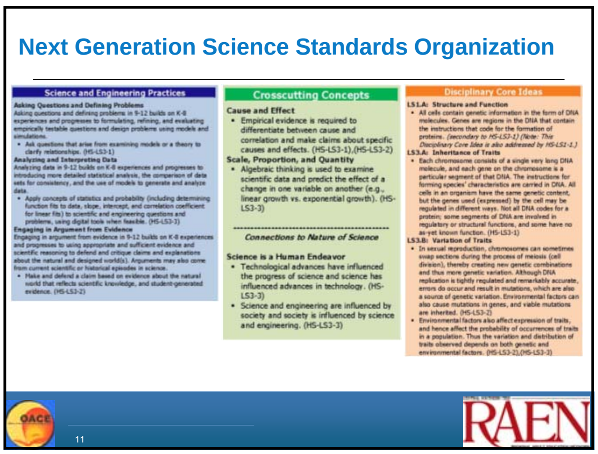

Disciplinary Core Idea Progression

Performance Indicator	ES Science	MS Science	HS Science
LS3.A: **Inheritance of Traits**			
LS3.B: **Variation of Traits**			

What Do Students Need to Master at Each Level of the LS3 Performance Indicator?

How Does this Mastery Progress?

TASC™ Test Science

What are the implications of this sequence for

- Curriculum,
- Instruction, and
- Assessment?

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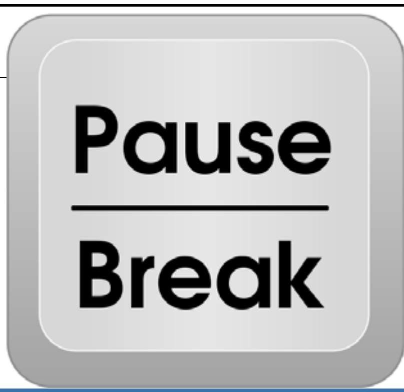


What Do You Have in Common with…

Your pet?

A Blue Whale?

An Amoeba?

A Maple Tree?

A Mushroom?

Some Genes Are Dominant Discussion

Some Genes Are Dominant from PBS Learning Media

1. If yellow pea color is dominant over green pea color, then why haven't all pea plants become yellow seeded?
2. If the cross between a pure-bred plant with green peas and a pure-bred plant with yellow peas resulted in 100 offspring, how many would have green peas and how many would have yellow? Explain.
3. You are using pea flower color as a trait to do plant breeding experiments. You have a pure-bred purple flower plant and a pure-bred white flower plant. How do you find out which color is dominant?

Mendel's Laws of Genetic Inheritance Discussion

Mendel's Laws of Genetic Inheritance from PBS Learning Media

- What is meant by a 3-to-1 ratio?
- If the two hybrid plants (Yy) that were crossed in the interactive activity produced 100 pea seeds, how many would you expect to be yellow? green?
- Imagine these same two plants produced 100 seeds and you put them in a bag. You picked 20 of them at random out of the bag. How many would you expect to be green?
- Next: try Punnett Squares-Monsters as a self-Assessment , which can be found in http://www.livebinders.com/play/play?id=1853656

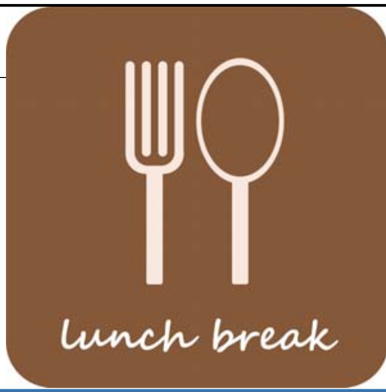
Variation: Seeds, Leaves, and Fingers

Procedure:

- Measure the length of 10 seeds in millimeters. Sort the seeds according to length. Place the seeds in the labeled jars corresponding to the length of the seeds.
- On graph paper, draw a graph and label the horizontal and vertical axes. Plot the height of the seeds in each jar according to the size of the seeds.

Discussion Questions:

- What is the range of measurements for the bean seeds?
- The mode is the most frequently occurring value. What is the mode for the bean seeds?
- Describe the shapes of each of your graphs.
- What does this tell you about variation within a species?



Genetic Variability: The Peppered Moth

Genetic Variability: The Peppered Moth

Preparation:

- We will go through several rounds which represent fluctuations in the peppered moth population of pre- and postindustrial revolution in England. The strips represent trees.
- The beans represent the moth population; white beans represent peppered moths while black beans represent melanin moths.
- One cup is the pouring pot, which holds the moths (or genes) to be used in the current round.
- The second cup, is the reserve pot, which holds the moths that do not survive the current round(s).

Genetic Variability: The Peppered Moth

Procedure:

- If a white bean falls on a black tree, that moth will be visible and will be eaten.
- If a black bean falls on a white tree, that moth will also be visible eaten.
  - These moths, obviously, do not survive and are placed in the reserve pot.
- If a moth survives by landing completely on a tree that is the same color as the moth (camouflaged), the moth is successful and reproduces. When this happens, add two moths of that same color (successful reproduction) to the pouring pot for the next round.
- Moths that do not land on any trees also survive—they just do not reproduce this time—and are returned (no additional beans) to the pouring pot for the next round.
- If any round, all of the populations of either color of moths get eaten, you may import three of that color—due to migration—for the next round.

Genetic Variability: The Peppered Moth

Questions:

1. In the predator-prey relationship involving peppered moths and birds, which is the predator and which is the prey?
2. By the late 1890s, black moths formed more than 95% of the population in English industrial areas. As new modern air pollution controls attempt to clean up the air and have an impact on air quality, what do you think might happen to the number of black peppered moths? What do you think might happen to the number of white peppered moths? Explain your answers.

Genetic Variability: The Peppered Moth

Questions:

3. Charles Darwin believed that evolution was such a slow process that it could never be observed directly. The observations of the peppered moth show that he was wrong. The force that causes this change is called Natural Selection. The tendency for dark-colored forms to replace light colored forms in polluted areas is called industrial melanism. This tendency has also been observed in some 100 species of moths in the Pittsburgh, Penn. area, where industrialization is heavy. Explain the changes in the population of dots as the rounds progressed.

Next Generation Science Standards Activities

Classroom Sample Tasks

Middle School Sample Tasks

- Antibiotic Resistance (LS4-4, LS4-6)
- Four Cities (ESS2-6)
- Ocean Waves (PS2-3, PS4-1, PS4-2)
- Watershed (ESS2-4)

High School Sample Tasks

- Analyzing Floods (ESS2-2, ESS3-1, ESS3-5)
- Bee Colony Numbers (LS2-2, LS2-6)
- Solar Cooker (PS3-1, PS3-2, PS3-3)
- Sub-Zero (PS1-2, PS1-4, PS3-4)
- Unraveling Earth's Early History (ESS1-6)

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Scope, Sequence, and Coordination

http://dev.nsta.org/ssc/

The NSF-funded project on Scope, Sequence, and Coordination of Secondary School Science (SS&C) was initiated by the National Science Teachers Association (NSTA)

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Scope, Sequence, and Coordination

Indicator	Skill/Description	SS&C Modules
LS3.A: Inheritance of Traits	• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)	**902 Variation and Heredity** Student Materials | Teacher Materials **1002 Genetic Variability** Student Materials | Teacher Materials
LS3.B: Variation of Traits	• In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)	**903 Variations in Living Things** **Student Materials | Teacher Materials** **1005 Mitosis and Meiosis** Student Materials | Teacher Materials

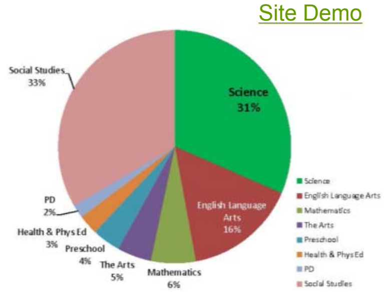
Scope, Sequence, and Coordination

Indicator	Skill/Description	SS&C Modules
LS4.A: Evidence of Common Ancestry and Diversity	• Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)	**1002 Genetic Variability** Student Materials | Teacher Materials **905 Structures that Reveal Common Ancestry** Student Materials | Teacher Materials
LS4.B: Natural Selection	• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3) • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)	**903 Variations in Living Things** **Student Materials | Teacher Materials** **1005 Mitosis and Meiosis** Student Materials | Teacher Materials
LS4.C: Adaptation	• Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals…, (3) competition for … limited… resources…, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) • Natural selection leads to adaptation… HS-LS4-3),(HS-LS4-4) • Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) • Changes in the physical environment… have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5),(HS-LS4-6) • Species become extinct because they can no longer survive and reproduce in their altered environment… (HS-LS4-5)	**904 Adaptations to Niches and Habitats** Student Materials | Teacher Materials **956 Limiting Factors for Populations** Student Materials | Teacher Materials **1003 Structural Factors in Evolution** Student Materials | Teacher Materials **Evolution and the Fossil Record** Student Materials | Teacher Materials
LS4.D: Biodiversity and Humans	• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, over-exploitation, habitat destruction, pollution, introduction of invasive species, and climate change…. (HS-LS4-6)	**955 Populations** Student Materials | Teacher Materials

PBS LearningMedia New York

- Self-registration, free of charge
- Browse by Standard, Grade, Subject, Media Type, Language, Permitted Use
- Many with Closed Captioning, many in Spanish
- Ability to add to Favorites

Site Demo



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RAEN

PBS Learning Media

Indicator	Skill/Description	PBS Learning Media Resources
LS3.A: Inheritance of Traits	• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)	311 resources for grades 9-12 with video and lesson plans, including: • **Some Genes Are Dominant** • **Mendel's Laws of Genetic Inheritance** • **The Expression of Genetic Information** • **Heredity | Crash Course Biology #9**
LS3.B: Variation of Traits	• In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2) • Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)	269 resources for grades 9-12 with video and lesson plans, including: • **Genetic Variation** • **A Mutation Story**

PBS Learning Media

Indicator	Skill/Description	PBS Learning Media Resources
LS4.A: Evidence of Common Ancestry and Diversity	• Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)	
LS4.B: Natural Selection	• Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3) • The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)	Evolution 101
LS4.C: Adaptation	• Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals…, (3) competition for … limited… resources…, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) • Natural selection leads to adaptation… HS-LS4-3),(HS-LS4-4) • Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) • Changes in the physical environment… have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5),(HS-LS4-6) • Species become extinct because they can no longer survive and reproduce in their altered environment… (HS-LS4-5)	
LS4.D: Biodiversity and Humans	• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, over-exploitation, habitat destruction, pollution, introduction of invasive species, and climate change…. (HS-LS4-6)	

Online Resources

- Next Generation Science Standards:
  - http://www.nextgenscience.org/
  - http://www.nextgenscience.org/classroom-sample-assessment-tasks
- PBS Learning Media: http://ny.pbslearningmedia.org/
  - Some Genes Are Dominant
  - Mendel's Laws of Genetic Inheritance
- Glencoe Virtual Science
  - Punnett Squares-Monsters
- Scope, Sequence, and Coordination Micro-units
  - http://dev.nsta.org/ssc/
- CTB McGraw-Hill's TASC™ webpage:
  - http://www.tasctest.com/

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TAPPS: Thinking Aloud Paired Problem Solving

🗣 Speaker:
- Flip over your postcard
- The "Problem": How does this image represent your takeaways from today?
- Say aloud everything you are thinking as you solve the problem

👂 Listener:
- Take notes on what your speaker is saying
- Remind the speaker to talk if there is silence
- You may ask clarifying questions, but do not help solve the problem
- Be prepared to share what you heard

After one round, switch roles

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The Builder

Objective: This is an icebreaker that helps teams quickly understand that communication is key, and there are different ways to explain things to people.

Materials:

- 2 bags
- 2 chairs
- Using the larger size LEGOs, it works best.
- In one bag are there are the same pieces (size, color, and number). Use about 7 blocks
- In the other bag, there are the same pieces (size, color, and number) Use about 7 blocks

Set-Up

1. Place two chairs back to back.
2. Ask for volunteers and have them sit in each chair.
3. Hand one bag of LEGOs to one participant (The Builder, Creator, and Developer/Giver of Information).
4. Hand one bag of Legos to the other participant (The receiver, Replicator, Copycat….)

Once seated, they may not turn around; ask each other questions, clarifying questions etc... as they work, they may NOT show their product to their partner behind them.

<u>Assign the other persons in the room to visit each group.</u>

During their visit, they are NOT to speak to the Builder or Receiver. They are to use their graphic organizer to take "Low Inference Notes" ***Low-inference notes describe what is taking place without drawing conclusions or making judgments***. ***Only record what you see and what you hear.***

Let the Low Inference Note takers know that: If they hear the Builder or Receiver talking, they are to call them out to the community.

Total time: 10 minutes for team to work and observers to take "Low Inference Notes."

Adopted from: The Builder by, **Laura Moushey** http://www.squarewheels.com/content/legotrdev.html

Debrief:

After 10 minutes have the Builder and Receiver turn around and look at what they have created. Then have everyone return to their tables. Upon their return, set the rules for discussion/sharing out.
1st ask the observers to share their, "Low Inference Notes".
2nd After hearing a few responses, ask the builders to share their experience, and then ask the receiver to share their experience.
3rd Then ask what implication does this have for the classroom?
4th Can you see yourself replicating this in the classroom, if so, how, if not, what would be the barrier?

Additional notes

1. We all communicate differently.
2. There are other words to use to make people understand.
3. Sometimes we need a 3rd party to help us hear each other.
4. Working together is important and a process. Sometimes it takes more time than we think to reach our goal but with understanding and patience, we can achieve our goals

LEGO Low-Inference Notes Sheet

Low-inference notes describe what is taking place without drawing conclusions or making judgments.

- **What do you see and hear?**

Life Science Disciplinary Core Ideas 3 & 4

Middle School Life Science

Students in middle school develop understanding of key concepts to help them make sense of life science. The ideas build upon students' science understanding from earlier grades and from the disciplinary core ideas, science and engineering practices, and crosscutting concepts of other experiences with physical and earth sciences. There are four life science disciplinary core ideas in middle school: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, 4) Biological Evolution: Unity and Diversity. The performance expectations in middle school blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge across the science disciplines. While the performance expectations in middle school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many science and engineering practices integrated in the performance expectations.

The performance expectations in **LS3: Heredity: Inheritance and Variation of Traits** help students formulate an answer to the question, "How do living organisms pass traits from one generation to the next?" The LS3 Disciplinary Core Idea from the NRC Framework includes two sub-ideas: Inheritance of Traits, and Variation of Traits. Students can use models to describe ways gene mutations and sexual reproduction contribute to genetic variation. Crosscutting concepts of cause and effect and structure and function provide students with a deeper understanding of how gene structure determines differences in the functioning of organisms.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, "How do organisms change over time in response to changes in the environment?" The LS4 Disciplinary Core Idea is divided into four sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, Adaptation, and Biodiversity and Humans. Students can construct explanations based on evidence to support fundamental understandings of natural selection and evolution. They can use ideas of genetic variation in a population to make sense of organisms surviving and reproducing, hence passing on the traits of the species. They are able to use fossil records and anatomical similarities of the relationships among organisms and species to support their understanding. Crosscutting concepts of patterns and structure and function contribute to the evidence students can use to describe biological evolution.

Life Science Disciplinary Core Ideas 3 & 4

High School Life Sciences

Students in high school develop understanding of key concepts that will help them make sense of life science. The ideas are built upon students' science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades. There are four life science disciplinary core ideas in high school: 1) From Molecules to Organisms: Structures and Processes, 2) Ecosystems: Interactions, Energy, and Dynamics, 3) Heredity: Inheritance and Variation of Traits, 4) Biological Evolution: Unity and Diversity. The performance expectations for high school life science blend core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge that can be applied across the science disciplines. While the performance expectations in high school life science couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices underlying the performance expectations.

The performance expectations in **LS3: Heredity: Inheritance and Variation of Traits** help students formulate answers to the questions: "How are characteristics of one generation passed to the next? How can individuals of the same species and even siblings have different characteristics?" The LS3 Disciplinary Core Idea from the NRC Framework includes two subideas: Inheritance of Traits, and Variation of Traits. Students are able to ask questions, make and defend a claim, and use concepts of probability to explain the genetic variation in a population. Students demonstrate understanding of why individuals of the same species vary in how they look, function, and behave. Students can explain the mechanisms of genetic inheritance and describe the environmental and genetic causes of gene mutation and the alteration of gene expression. Crosscutting concepts of patterns and cause and effect are called out as organizing concepts for these core ideas.

The performance expectations in **LS4: Biological Evolution: Unity and Diversity** help students formulate an answer to the question, "What evidence shows that different species are related? The LS4 Disciplinary Core Idea involves four sub-ideas: Evidence of Common Ancestry and Diversity, Natural Selection, Adaptation, and Biodiversity and Humans. Students can construct explanations for the processes of natural selection and evolution and communicate how multiple lines of evidence support these explanations. Students can evaluate evidence of the conditions that may result in new species and understand the role of genetic variation in natural selection. Additionally, students can apply concepts of probability to explain trends in populations as those trends relate to advantageous heritable traits in a specific environment. The crosscutting concepts of cause and effect and systems and system models play an important role in students' understanding of the evolution of life on Earth.

1-LS3 Heredity: Inheritance and Variation of Traits

1-LS3 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

1-LS3-1. Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents. [Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents but is not exactly the same.] [Assessment Boundary: Assessment does not include inheritance or animals that undergo metamorphosis or hybrids.]

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
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions. ▪ Make observations (firsthand or from media) to construct an evidence-based account for natural phenomena. (1-LS3-1)	**LS3.A: Inheritance of Traits** ▪ Young animals are very much, but not exactly like, their parents. Plants also are very much, but not exactly, like their parents. (1-LS3-1) **LS3.B: Variation of Traits** ▪ Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (1-LS3-1)	**Patterns** ▪ Patterns in the natural world can be observed, used to describe phenomena, and used as evidence. (1-LS3-1)

Connections to other DCIs in first grade: N/A

Articulation of DCIs across grade-levels: **3.LS3.A** (1-LS3-1); **3.LS3.B** (1-LS3-1)

Common Core State Standards Connections:

ELA/Literacy –

RI.1.1 Ask and answer questions about key details in a text. (1-LS3-1)

W.1.7 Participate in shared research and writing projects (e.g., explore a number of "how-to" books on a given topic and use them to write a sequence of instructions). (1-LS3-1)

W.1.8 With guidance and support from adults, recall information from experiences or gather information from provided sources to answer a question. (1-LS3-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. *(1-LS3-1)*

MP.5 Use appropriate tools strategically. *(1-LS3-1)*

1.MD.A.1 Order three objects by length; compare the lengths of two objects indirectly by using a third object. *(1-LS3-1)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.

3-LS3 Heredity: Inheritance and Variation of Traits

3-LS3 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

3-LS3-1. Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms. [Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.] [Assessment Boundary: Assessment does not include genetic mechanisms of inheritance and prediction of traits. Assessment is limited to non-human examples.]

3-LS3-2. Use evidence to support the explanation that traits can be influenced by the environment. [Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted; and, a pet dog that is given too much food and little exercise may become overweight.]

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

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
When possible and feasible, digital tools should be used.

- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS3-1)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Use evidence (e.g., observations, patterns) to support an explanation. (3-LS3-2)

Disciplinary Core Ideas

LS3.A: Inheritance of Traits

- Many characteristics of organisms are inherited from their parents. (3-LS3-1)
- Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-2)

LS3.B: Variation of Traits

- Different organisms vary in how they look and function because they have different inherited information. (3-LS3-1)
- The environment also affects the traits that an organism develops. (3-LS3-2)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort and classify natural phenomena. (3-LS3-1)

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change. (3-LS3-2)

Connections to other DCIs in third grade: N/A

Articulation of DCIs across grade-levels: **1.LS3.A** (3-LS3-1); **1.LS3.B** (3-LS3-1); **MS.LS1.B** (3-LS3-2); **MS.LS3.A** (3-LS3-1); **MS.LS3.B** (3-LS3-1)

Common Core State Standards Connections:

ELA/Literacy –

RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. (3-LS3-1),(3-LS3-2)

RI.3.2 Determine the main idea of a text; recount the key details and explain how they support the main idea. *(3-LS3-1),(3-LS3-2)*

RI.3.3 Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. (3-LS3-1),*(3-LS3-2)*

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. *(3-LS3-1),*(3-LS3-2)

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. *(3-LS3-1),(3-LS3-2)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(3-LS3-1),(3-LS3-2)*

MP.4 Model with mathematics. *(3-LS3-1),(3-LS3-2)*

3.MD.B.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. *(3-LS3-1),(3-LS3-2)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

MS-LS3 Heredity: Inheritance and Variation of Traits

MS-LS3 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.]

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 expectations above were 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. (MS-LS3-1),(MS-LS3-2)

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

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS3-2)

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)

Connections to other DCIs in this grade-band: **MS.LS1.A** (MS-LS3-1); **MS.LS4.A** (MS-LS3-1)

Articulation across grade-bands: **3.LS3.A** (MS-LS3-1),(MS-LS3-2); **3.LS3.B** (MS-LS3-1),(MS-LS3-2); **HS.LS1.A** (MS-LS3-1); **HS.LS1.B** (MS-LS3-1),(MS-LS3-2); **HS.LS3.A** (MS-LS3-1),(MS-LS3-2); **HS.LS3-B** (MS-LS3-1),(MS-LS3-2)

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-LS3-1),(MS-LS3-2)*
RST.6-8.4	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.6-8.7	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)
SL.8.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-LS3-1),(MS-LS3-2)*

Mathematics –

MP.4	Model with mathematics. *(MS-LS3-2)*
6.SP.B.5	Summarize numerical data sets in relation to their context. *(MS-LS3-2)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.

HS-LS3 Heredity: Inheritance and Variation of Traits

HS-LS3 Heredity: Inheritance and Variation of Traits

Students who demonstrate understanding can:

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.]

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

Asking Questions and Defining Problems
Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
- Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1)

Analyzing and Interpreting Data
Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS3-3)

Engaging in Argument from Evidence
Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.
- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)

Disciplinary Core Ideas

LS1.A: Structure and Function
- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)*

LS3.A: Inheritance of Traits
- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)

LS3.B: Variation of Traits
- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)

Crosscutting Concepts

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1),(HS-LS3-2)

Scale, Proportion, and Quantity
- Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (HS-LS3-3)

Connections to Nature of Science

Science is a Human Endeavor
- Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3)
- Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3)

Connections to other DCIs in this grave-band: **HS.LS2.A** (HS-LS3-3); **HS.LS2.C** (HS-LS3-3); **HS.LS4.B** (HS-LS3-3); **HS.LS4.C** (HS-LS3-3)

Articulation across grade-bands: **MS.LS2.A** (HS-LS3-3); **MS.LS3.A** (HS-LS3-1),(HS-LS3-2); **MS.LS3.B** (HS-LS3-1),(HS-LS3-2),(HS-LS3-3); **MS.LS4.C** (HS-LS3-3)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS3-1),(HS-LS3-2)*

RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. *(HS-LS3-1)*

WHST.9-12.1 Write arguments focused on *discipline-specific content.* (HS-LS3-2)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-LS3-2),(HS-LS3-3)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.
The section entitled "Disciplinary Core Ideas" is reproduced verbatim from A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas. Integrated and reprinted with permission from the National Academy of Sciences.

2-LS4 Biological Evolution: Unity and Diversity

2-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

2-LS4-1. Make observations of plants and animals to compare the diversity of life in different habitats. [Clarification Statement: Emphasis is on the diversity of living things in each of a variety of different habitats.] [Assessment Boundary: Assessment does not include specific animal and plant names in specific habitats.]

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
Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. ▪ Make observations (firsthand or from media) to collect data which can be used to make comparisons. (2-LS4-1) --- ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** ▪ Scientists look for patterns and order when making observations about the world. (2-LS4-1)	**LS4.D: Biodiversity and Humans** ▪ There are many different kinds of living things in any area, and they exist in different places on land and in water. (2-LS4-1)	

Connections to other DCIs in second grade: N/A

Articulation of DCIs across grade-levels: **3.LS4.C** (2-LS4-1); **3.LS4.D** (2-LS4-1); **5.LS2.A** (2-LS4-1)

Common Core State Standards Connections:

ELA/Literacy –

W.2.7 Participate in shared research and writing projects (e.g., read a number of books on a single topic to produce a report; record science observations). (2-LS4-1)

W.2.8 Recall information from experiences or gather information from provided sources to answer a question. (2-LS4-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. *(2-LS4-1)*

MP.4 Model with mathematics. *(2-LS4-1)*

2.MD.D.10 Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems. *(2-LS4-1)*

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3-LS4 Biological Evolution: Unity and Diversity

3-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

3-LS4-1. Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago. [Clarification Statement: Examples of data could include type, size, and distributions of fossil organisms. Examples of fossils and environments could include marine fossils found on dry land, tropical plant fossils found in Arctic areas, and fossils of extinct organisms.] [Assessment Boundary: Assessment does not include identification of specific fossils or present plants and animals. Assessment is limited to major fossil types and relative ages.]

3-LS4-2. Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing. [Clarification Statement: Examples of cause and effect relationships could be plants that have larger thorns than other plants may be less likely to be eaten by predators; and, animals that have better camouflage coloration than other animals may be more likely to survive and therefore more likely to leave offspring.]

3-LS4-3. Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all. [Clarification Statement: Examples of evidence could include needs and characteristics of the organisms and habitats involved. The organisms and their habitat make up a system in which the parts depend on each other.]

3-LS4-4. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.* [Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.]

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

Analyzing and Interpreting Data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used.
- Analyze and interpret data to make sense of phenomena using logical reasoning. (3-LS4-1)

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.
- Use evidence (e.g., observations, patterns) to construct an explanation. (3-LS4-2)

Engaging in Argument from Evidence
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).
- Construct an argument with evidence. (3-LS4-3)
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem. (3-LS4-4)

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- When the environment changes in ways that affect a place's physical characteristics, temperature, or availability of resources, some organisms survive and reproduce, others move to new locations, yet others move into the transformed environment, and some die. *(secondary to 3-LS4-4)*

LS4.A: Evidence of Common Ancestry and Diversity
- Some kinds of plants and animals that once lived on Earth are no longer found anywhere. *(Note: moved from K-2)* (3-LS4-1)
- Fossils provide evidence about the types of organisms that lived long ago and also about the nature of their environments. (3-LS4-1)

LS4.B: Natural Selection
- Sometimes the differences in characteristics between individuals of the same species provide advantages in surviving, finding mates, and reproducing. (3-LS4-2)

LS4.C: Adaptation
- For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all. (3-LS4-3)

LS4.D: Biodiversity and Humans
- Populations live in a variety of habitats, and change in those habitats affects the organisms living there. (3-LS4-4)

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships are routinely identified and used to explain change. (3-LS4-2),(3-LS4-3)

Scale, Proportion, and Quantity
- Observable phenomena exist from very short to very long time periods. (3-LS4-1)

Systems and System Models
- A system can be described in terms of its components and their interactions. (3-LS4-4)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Knowledge of relevant scientific concepts and research findings is important in engineering. (3-LS4-4)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science assumes consistent patterns in natural systems. (3-LS4-1)

Connections to other DCIs in third grade: **3.LS4.C** (3-LS4-2); **3.ESS2.D** (3-LS4-3); **3.ESS3.B** (3-LS4-4)

Articulation of DCIs across grade-levels: **K.ESS3.A** (3-LS4-3)(3-LS4-4); **K.ETS1.A** (3-LS4-4); **1.LS3.A** (3-LS4-2); **2.LS2.A** (3-LS4-3),(3-LS4-4); **2.LS4.D** (3-LS4-3),(3-LS4-4); **4.ESS1.C** (3-LS4-1); **4.ESS3.B** (3-LS4-4); **4.ETS1.A** (3-LS4-4); **MS.LS2.A** (3-LS4-1),(3-LS4-2),(3-LS4-3),(3-LS4-4); **MS.LS2.C** (3-LS4-4); **MS.LS3.B** (3-LS4-2); **MS.LS4.A** (3-LS4-1); **MS.LS4.B** (3-LS4-2),(3-LS4-3); **MS.LS4.C** (3-LS4-3),(3-LS4-4); **MS.ESS1.C** (3-LS4-1),(3-LS4-3),(3-LS4-4); **MS.ESS2.B** (3-LS4-1); **MS.ESS3.C** (3-LS4-4)

Common Core State Standards Connections:

ELA/Literacy –

RI.3.1 Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers. *(3-LS4-1),(3-LS4-2),(3-LS4-3) (3-LS4-4)*

RI.3.2 Determine the main idea of a text; recount the key details and explain how they support the main idea. *(3-LS4-1),(3-LS4-2),(3-LS4-3),(3LS4-4)*

RI.3.3 Describe the relationship between a series of historical events, scientific ideas or concepts, or steps in technical procedures in a text, using language that pertains to time, sequence, and cause/effect. *(3-LS4-1),(3-LS4-2),(3-LS4-3),(3-LS4-4)*

W.3.1 Write opinion pieces on topics or texts, supporting a point of view with reasons. *(3-LS4-1)*,(3-LS4-3),*(3-LS4-4)*

W.3.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly. *(3-LS4-1)*,(3-LS4-2),*(3-LS4-3),(3-LS4-4)*

W.3.8 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories. (3-LS4-1)

SL.3.4 Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. *(3-LS4-2),(3-LS4-3),(3-LS4-4)*

Mathematics –

MP.2 Reason abstractly and quantitatively. *(3-LS4-1),(3-LS4-2),(3-LS4-3),(3-LS4-4)*

MP.4 Model with mathematics. *(3-LS4-1),(3-LS4-2),(3-LS4-3),(3-LS4-4)*

MP.5 Use appropriate tools strategically. *(3-LS4-1)*

3.MD.B.3 Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step "how many more" and "how many less" problems using information presented in scaled bar graphs. *(3-LS4-2),(3-LS4-3)*

3.MD.B.4 Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units—whole numbers, halves, or quarters. *(3-LS4-1)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

MS-LS4 Biological Evolution: Unity and Diversity

MS-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]

MS-LS4-2. Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships. [Clarification Statement: Emphasis is on explanations of the evolutionary relationships among organisms in terms of similarity or differences of the gross appearance of anatomical structures.]

MS-LS4-3. Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy. [Clarification Statement: Emphasis is on inferring general patterns of relatedness among embryos of different organisms by comparing the macroscopic appearance of diagrams or pictures.] [Assessment Boundary: Assessment of comparisons is limited to gross appearance of anatomical structures in embryological development.]

MS-LS4-4. Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. [Clarification Statement: Emphasis is on using simple probability statements and proportional reasoning to construct explanations.]

MS-LS4-5. Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms. [Clarification Statement: Emphasis is on synthesizing information from reliable sources about the influence of humans on genetic outcomes in artificial selection (such as genetic modification, animal husbandry, gene therapy); and, on the impacts these technologies have on society as well as the technologies leading to these scientific discoveries.]

MS-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time. [Clarification Statement: Emphasis is on using mathematical models, probability statements, and proportional reasoning to support explanations of trends in changes to populations over time.] [Assessment Boundary: Assessment does not include Hardy Weinberg calculations.]

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

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 displays of data to identify linear and nonlinear relationships. (MS-LS4-3)
- Analyze and interpret data to determine similarities and differences in findings. (MS-LS4-1)

Using Mathematics and Computational Thinking
Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.
- Use mathematical representations to support scientific conclusions and design solutions. (MS-LS4-6)

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 ideas, principles, and theories.
- Apply scientific ideas to construct an explanation for real-world phenomena, examples, or events. (MS-LS4-2)
- Construct an explanation that includes qualitative or quantitative relationships between variables that describe phenomena. (MS-LS4-4)

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. (MS-LS4-5)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-LS4-1)

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity
- The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. (MS-LS4-1)
- Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record, enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. (MS-LS4-2)
- Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully-formed anatomy. (MS-LS4-3)

LS4.B: Natural Selection
- Natural selection leads to the predominance of certain traits in a population, and the suppression of others. (MS-LS4-4)
- 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. (MS-LS4-5)

LS4.C: Adaptation
- 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. (MS-LS4-6)

Crosscutting Concepts

Patterns
- Patterns can be used to identify cause and effect relationships. (MS-LS4-2)
- Graphs, charts, and images can be used to identify patterns in data. (MS-LS4-1),(MS-LS4-3)

Cause and Effect
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-4),(MS-LS4-5),(MS-LS4-6)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology
- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-LS4-5)

Connections to Nature of Science

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. (MS-LS4-1),(MS-LS4-2)

Science Addresses Questions About the Natural and Material World
- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. (MS-LS4-5)

Connections to other DCIs in this grade-band: **MS.LS2.A** (MS-LS4-4),(MS-LS4-6); **MS.LS2.C** (MS-LS4-6); **MS.LS3.A** (MS-LS4-2),(MS-LS4-4); **MS.LS3.B** (MS-LS4-2),(MS-LS4-4),(MS-LS4-6); **MS.ESS1.C** (MS-LS4-1),(MS-LS4-2),(MS-LS4-6); **MS.ESS2.B** (MS-LS4-1)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Articulation across grade-bands: **3.LS3.B** (MS-LS4-4); **3.LS4.A** (MS-LS4-1),(MS-LS4-2); **3. LS4.B** (MS-LS4-4); **3.LS4.C** (MS-LS4-6); **HS.LS2.A** (MS-LS4-4),(MS-LS4-6); **HS.LS2.C** (MS-LS4-6); **HS.LS3.B** (MS-LS4-4),(MS-LS4-5),(MS-LS4-6); **HS.LS4.A** (MS-LS4-1),(MS-LS4-2),(MS-LS4-3); **HS.LS4.B** (MS-LS4-4),(MS-LS4-6); **HS.LS4.C** (MS-LS4-4),(MS-LS4-5),(MS-LS4-6); **HS.ESS1.C** (MS-LS4-1),(MS-LS4-2)

Common Core State Standards Connections:

ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-LS4-1),*(MS-LS4-2)*,(MS-LS4-3),(MS-LS4-4),*(MS-LS4-5)
RST.6-8.7	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-LS4-1),(MS-LS4-3)
RST.6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. *(MS-LS4-3),(MS-LS4-4)*
WHST.6-8.2	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-LS4-2),(MS-LS4-4)
WHST.6-8.8	Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. *(MS-LS4-5)*
WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-LS4-2),(MS-LS4-4)
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. *(MS-LS4-2),(MS-LS4-4)*
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. *(MS-LS4-2),(MS-LS4-4)*

Mathematics –

MP.4	Model with mathematics. (MS-LS4-6)
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. *(MS-LS4-4),(MS-LS4-6)*
6.SP.B.5	Summarize numerical data sets in relation to their context. *(MS-LS4-4),(MS-LS4-6)*
6.EE.B.6	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. *(MS-LS4-1),(MS-LS4-2)*
7.RP.A.2	Recognize and represent proportional relationships between quantities. *(MS-LS4-4),(MS-LS4-6)*

HS-LS4 Biological Evolution: Unity and Diversity

HS-LS4 Biological Evolution: Unity and Diversity

Students who demonstrate understanding can:

HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. [Clarification Statement: Emphasis is on using evidence to explain the influence each of the four factors has on number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning.] [Assessment Boundary: Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution.]

HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. [Clarification Statement: Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations.] [Assessment Boundary: Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations.]

HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]

HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.]

HS-LS4-6. Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]

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

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. (HS-LS4-3)

Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Create or revise a simulation of a phenomenon, designed device, process, or system. (HS-LS4-6)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-LS4-2),(HS-LS4-4)

Engaging in Argument from Evidence

Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science.

- Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS4-5)

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12

Disciplinary Core Ideas

LS4.A: Evidence of Common Ancestry and Diversity

- Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)

LS4.B: Natural Selection

- Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-2),(HS-LS4-3)
- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-3)

LS4.C: Adaptation

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)
- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4)
- Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3)
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. (HS-LS4-5),(HS-LS4-6)

Crosscutting Concepts

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-LS4-1),(HS-LS4-3)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-2),(HS-LS4-4),(HS-LS4-5),(HS-LS4-6)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-1),(HS-LS4-4)

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. ▪ Communicate scientific information (e.g., about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-LS4-1) -- ***Connections to Nature of Science*** **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** ▪ A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (HS-LS4-1)	▪ Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5) **LS4.D: Biodiversity and Humans** ▪ Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. (HS-LS4-6) *(Note: This Disciplinary Core Idea is also addressed by HS-LS2-7.)* **ETS1.B: Developing Possible Solutions** ▪ When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. *(secondary to HS-LS4-6)* ▪ Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. *(secondary to HS-LS4-6)*	

Connections to other DCIs in this grade-band: **HS.LS2.A** (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); **HS.LS2.D** (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); **HS.LS3.A** (HS-LS4-1); **HS.LS3.B** (HS-LS4-1),(HS-LS4-2) (HS-LS4-3),(HS-LS4-5); **HS.ESS1.C** (HS-LS4-1); **HS.ESS2.D** (HS-LS4-6); **HS.ESS2.E** (HS-LS4-2),(HS-LS4-5),(HS-LS4-6); **HS.ESS3.A** (HS-LS4-2),(HS-LS4-5),(HS-LS4-6); **HS.ESS3.C** (HS-LS4-6); **HS.ESS3.D** (HS-LS4-6)

Articulation across grade-bands: **MS.LS2.A** (HS-LS4-2),(HS-LS4-3),(HS-LS4-5); **MS.LS2.C** (HS-LS4-5),(HS-LS4-6); **MS.LS3.A** (HS-LS4-1); **MS.LS3.B** (HS-LS4-1),(HS-LS4-2),(HS-LS4-3); **MS.LS4.A** (HS-LS4-1); **MS.LS4.B** (HS-LS4-2),(HS-LS4-3),(HS-LS4-4); **MS.LS4.C** (HS-LS4-2),(HS-LS4-3),(HS-LS4-4),(HS-LS4-5); **MS.ESS1.C** (HS-LS4-1); **MS.ESS3.C** (HS-LS4-5),(HS-LS4-6)

Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS4-1),*(HS-LS4-2),*(HS-LS4-3),*(HS-LS4-4)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-LS4-5)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. *(HS-LS4-1),*(HS-LS4-2),*(HS-LS4-3),*(HS-LS4-4)
WHST.9-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. *(HS-LS4-6)*
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-LS4-6)
WHST.9-12.9	Draw evidence from informational texts to support analysis, reflection, and research. *(HS-LS4-1),*(HS-LS4-2),*(HS-LS4-3),*(HS-LS4-4),(HS-LS4-5)
SL.11-12.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation. *(HS-LS4-1),(HS-LS4-2)*

Mathematics –

MP.2	Reason abstractly and quantitatively. *(HS-LS4-1),*(HS-LS4-2),(HS-LS4-3),*(HS-LS4-4),(HS-LS4-5)*
MP.4	Model with mathematics. *(HS-LS4-2)*

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.
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Some Genes Are Dominant

Background Essay

Over the course of eight years, beginning in 1856, an amateur scientist and Augustinian monk named Gregor Mendel crossed, or mated, common pea plants he grew in his garden. He crossed long-stemmed plants with short-stemmed plants, plants that bore round peas with those that bore wrinkled ones, and plants with purple flowers with those with white flowers. By crossing subsequent generations of offspring, he was able to observe just what happened to certain physical traits over time.

Even though Mendel's work went largely unnoticed in his lifetime, he introduced the seminal idea that traits are determined by paired units that he called "factors," now called "genes." He also proposed three principles that are fundamental to modern genetics. The first is the principle of dominance.

Mendel observed that crossing parent plants—one with green peas, the other with yellow—produced offspring that were always either green or yellow, and not a blend, which is what the scientific community at the time contended should happen. He also found that traits appeared with a predictable 3-to-1 frequency. Mendel called the more common trait "dominant" and the less common one "recessive."

Because traits did not blend, Mendel concluded that if either parent contributed one dominant allele, or part of a gene pair, the offspring's physical appearance, or phenotype, would reflect that of the dominant trait—even if its genetic makeup, or genotype, contained the recessive trait.

Thus, yellow peas would appear with greater frequency than green ones because yellow is the dominant trait for pea color. (Note: The terms *allele*, *phenotype*, and *genotype* were not coined until the early 1900s.)

Interestingly, Mendel's work demonstrated that even if a trait was not evident in an offspring's phenotype, it could still be passed on through subsequent generations. When a hybrid parent—one that has a genotype consisting of one dominant and one recessive gene (we'll call this Yy)—crosses with another hybrid parent (also Yy), the chances are three in four that an offspring will display the dominant trait. This is because both YY and Yy genotypes exhibit the dominant trait. But there is also a one-in-four chance that an offspring will be yy and instead display the recessive trait.

Discussion Questions

- If yellow pea color is dominant over green pea color, then why haven't all pea plants become yellow seeded?
- If the cross between a pure-bred plant with green peas and a pure-bred plant with yellow peas resulted in 100 offspring, how many would have green peas and how many would have yellow? Explain.
- You are using pea flower color as a trait to do plant breeding experiments. You have a pure-bred purple flower plant and a pure-bred white flower plant. How do you find out which color is dominant?

Mendel's Laws of Genetic Inheritance

Modern genetics is founded on three principles that explain how traits for physical characteristics such as height and coloration are transmitted from one generation to the next. These principles were first explained by Gregor Mendel, an Augustinian friar and scientist from Moravia, in the 1850s. Mendel performed experiments using common pea plants. He observed inheritance patterns that arose when he mated, or crossed, parents with known genetic traits, and then allowed subsequent generations of offspring to self-pollinate. The hereditary mechanisms derived from the results of these experiments can be applied to other complex living organisms, including humans.

Mendel's first main conclusion concerned dominance. He observed that crossing parent plants with pure lines—one with green peas, the other with yellow—produced offspring that were always either green or yellow, and not a blend. He also found that yellow peas appeared more often than green peas in a predictable 3-to-1 frequency in the subsequent generation. Mendel called the more common traits "dominant" and the less common ones "recessive."

According to Mendel's second principle, called the principle of segregation, each parent contributes one and only one allele, or part of a gene pair, to an egg or sperm. When fertilization occurs, the offspring's gene pair is determined by which allele each sex cell carried. The allele that gets segregated, or separated, from each parent's pair is a matter of chance. So, for a given trait such as pea color, a hybrid (heterozygous) parent that carries two different alleles would contribute either the dominant allele (for yellow color) or the recessive one (for green color). A purebred (homozygous) parent that carries two identical alleles could only contribute the allele for that trait.

Finally, Mendel's third principle, the principle of independent assortment, states that the pairs of alleles needed for each trait are passed on to offspring independently of one another. This means that offspring can possess combinations of genes that neither parent possesses. For example, because the inheritance of flower color has no effect on the inheritance of seed color, a white-flowered plant that produces green peas can descend from white-flowered parents (or a white-flowered parent, if self-pollinating) that produced yellow peas.

These three principles account for the many combinations of traits seen over several generations of offspring. The fact that some human traits are controlled by more than one gene pair adds even more complexity. Siblings may share a few traits in common, such as hair color and handedness. But they are not likely to share all of their traits, including other hair characteristics (e.g., straightness or curliness), eye color, and height.

Discussion Questions

- What is meant by a 3-to-1 ratio?
- If the two hybrid plants (Yy) that were crossed in the interactive activity produced 100 pea seeds, how many would you expect to be yellow? green?
- Imagine these same two plants produced 100 seeds and you put them in a bag. You picked 20 of them at random out of the bag. How many would you expect to be green?

Science as Inquiry

Seeds, Leaves, and Fingers

How can you demonstrate and illustrate variation in living things?

Overview:

It is said that no two snowflakes are exactly alike. Can the same be said for living things? How can you determine and show the amount of variation within individuals of the same species? Is variation good for a species? In this activity you will examine variation in seeds and leaves and among students' index fingers. A basic component of Darwin's theory of natural selection is that populations that reproduce sexually show great variation in the physical expression of the genes of the organism. In terms of adapting to the environment, is one variation better than another? How would you decide the answer to such a question?

Procedures:

Part A

Measure the length of 10 seeds in millimeters. Sort the seeds according to length. Place the seeds in the labeled jars corresponding to the length of the seeds.

On graph paper, draw a graph and label the horizontal and vertical axes. Plot the height of the seeds in each jar according to the size of the seeds.

Part B

Measure the length in centimeters of each of 10 leaf blades of the same species. Record your data and give it to your teacher. When the class data have been collected and placed on the chalkboard, draw a graph and plot the data.

Part C

Measure the length of your index finger from the base to the tip. Record your data. When the class totals have been placed on the chalkboard, draw a graph and plot the data.

Questions:

1. What is the range of measurements for the bean seeds?

2. What is the range of measurements for the leaf blades?

3. What is the range of measurements for index fingers?

4. The mode is the most frequently occurring value. What is the mode for the bean seeds, the leaf blades, and the index fingers?

5. Describe the shapes of each of your graphs.

6. What does this tell you about variations within a species?

Science as Inquiry

Dry Bones

How do living things vary? Are the bones of the forelimbs of vertebrates similar in structure and function?

Overview:

French biologist Jean Baptiste Lamarck suggested that when body parts or organs of different living things are similar in structure the organisms are biologically related. He called such similar body parts or organs *homologous*. What do you think? When different animals have similar structures, is it because they are related or because they share similar environments that place similar physical demands on all creatures that live there? Perhaps you can think of another hypothesis. If it can be shown that different animals have homologous structures, what would that indicate about their evolutionary history? In this activity you will study the bones of various animals, considering the differences as well as the similarities and what connections there might be between structures and adaptation to niches and habitats.

Procedure:

Compare the vertebrate forelimbs on the attached sheet. Shade in the bones that are similar among them using the same color.

Questions:

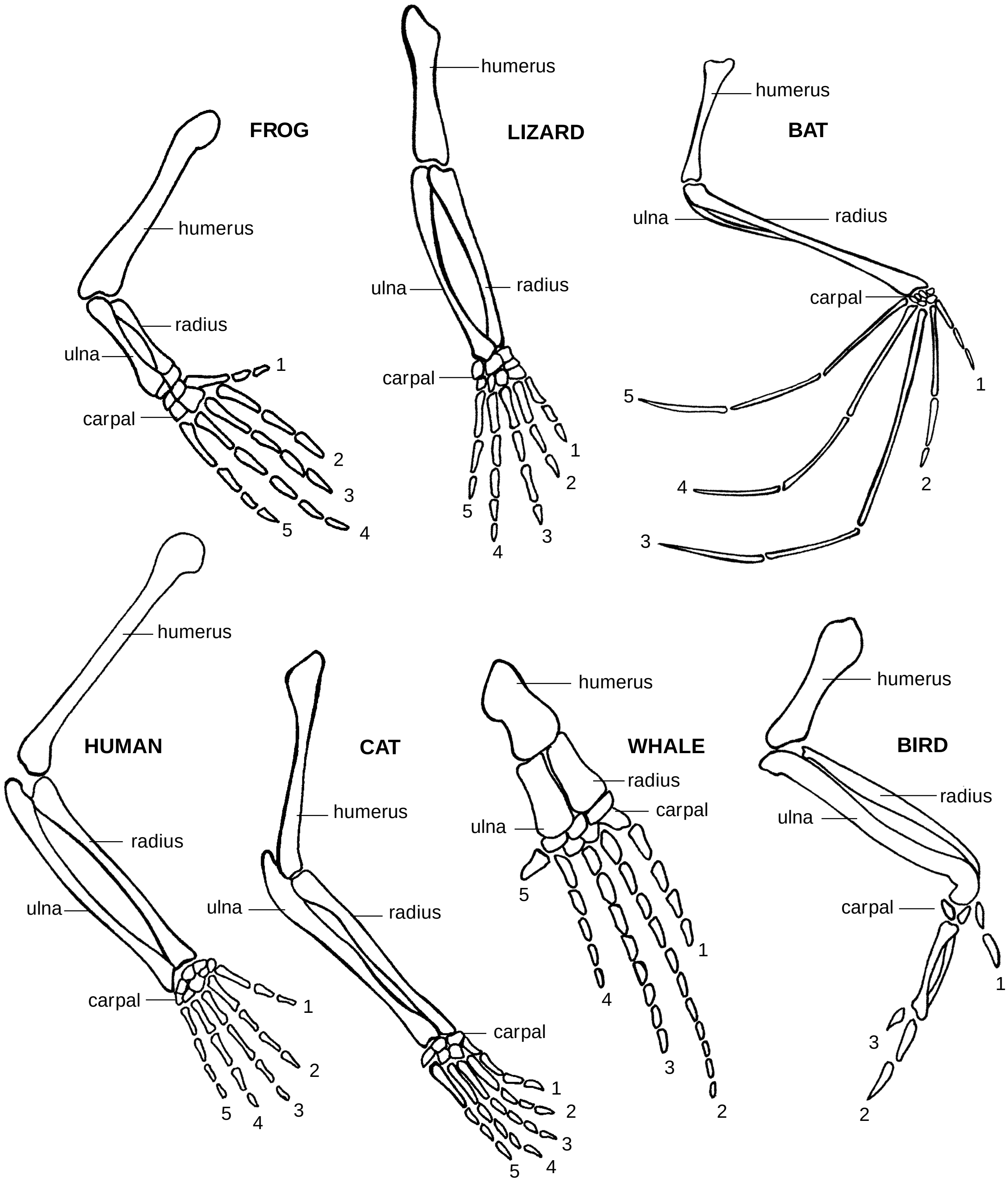
1. Are the forelimbs of these vertebrates made up of the same bones?

2. Why do individual bones differ among these vertebrates?

3. Of the forelimbs shown, describe how each is suited for the environment and habitat of the animal it belongs to.

4. What are the forelimbs of humans used for? How is the human forelimb adapted for this purpose?

5. Do all forelimbs have the same structure and function? Explain your answer.


FROG
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Science as Inquiry

Seeds, Leaves, and Fingers

How can you demonstrate and illustrate variation in living things?

Overview:

Students measure and make observations of seeds, leaves, and their own index fingers to document and quantify variation in individuals of the same species.

Materials:

Per class:
jars or large test tubes, 8

Per lab group (2 students):
metric ruler
pinto bean seeds or other dried bean seeds, 10
graph paper, 3 pieces
leaves, 10 from the same tree species

Procedures:

Part A

Working in pairs, students measure the length of each of their seeds in millimeters and then sort the seeds according to length. Provide 8 to 10 jars or large test tubes of uniform size, labeled in millimeter intervals corresponding to the range of distribution in size you might find among the seeds. Students add their seeds to the appropriate jars and then measure the height of the seeds in each jar in centimeters. Write these measurements on the chalkboard. A continuous normal curve of distribution results.

Students then plot on graph paper the height of the beans in each jar (vertical axis) as a function of size of the seeds (horizontal axis).

If the seeds are kept dry, they can be saved from year to year for this activity.

Part B

Working in pairs, students measure the length of each of the 10 tree leaves from the end of the petiole to the tip of the leaf (in centimeters). Record the measurements on the chalkboard, organized by the number of leaves that measure within a given range of values. Students then draw a graph and plot the data as before.

Part C

Each student measures his or her index finger from the base of the finger to the tip. Record their measurements on the board and have them graph the data as before in Parts A and B.

Background:

A basic component of Darwin's theory of natural selection is that populations that reproduce sexually show great variation in phenotype (the physical expression of the genes of the organism). The occurrence of variations within the members of a species is a basic requirement for the mechanism of natural selection. In some cases, a variation in a species will cause some members to survive and reproduce better than others. Over time the variation will become the norm as those members of the species with the variation survive in greater numbers than do those members without the variation. However, most of the time, as in the example of length of index fingers, simple phenotypic variations within a species do not confer any special reproductive advantage for the members that express them.

If a given sample population is large enough and the environment for that organism is stable, the statistics for a given variation will reveal that the mode = mean = median. Under such stable conditions, most variations from the norm, arising through mutation or recombination of existing alleles of genes, are likely to be harmful. The organisms most likely to reproduce successfully are those with a phenotype that is close to the average for the population. The variants are less likely to reproduce and so are at a selective disadvantage compared to the norm. This is stabilizing selection; variants at the extremes of the range are eliminated.

Variations:

Students could extend this activity by comparing the degree of variation of several species of plant leaves. Students could calculate mode, mean, and range of variation for each species to determine if any generalizations can be made based on plant type, age, or location. Is there a difference between native species and imported ones?

Adapted from: none

Teacher Sheet

Science as Inquiry

Dry Bones

How do living things vary? Are the bones of the forelimbs of vertebrates similar in structure and function?

Overview:

In this activity, students compare drawings of forelimb bones of seven different animals. By investigating variation between various phyla, students consider how each is adapted to its particular niche and habitat.

Materials:

Per lab group:
colored pencils, at least five different colors
drawings of forelimbs (included with Student Materials)

Procedure:

Students color the bones of each forelimb a different color, e.g., the humerus red, the ulna blue, etc. They determine which of these forelimb bones are similar and how the bones differ (each bone has been modified to perform a different function). They should describe how similar structures relate to evolutionary origins.

Background:

French biologist Jean Baptiste de Lamarck suggested a theory of evolution based on the anatomy or structure of living things. He suggested that when body parts or organs are similar in structure in different organisms, the organisms are related and the parts are said to be homologous. The existence of homologous structures has been used as evidence that many organisms evolved from a common ancestor. Each separate species became better adapted to its respective environment as the structure of its bones gradually changed to those found in modern animals.

A key concept is the difference between homologous structures and analogous structures. Analogous structures have the same function but not the same biological structure (e.g., the wings of bats, birds, and insects). Homologous structures have the same underlying biological structure although they may perform different functions (e.g., the foreleg of a horse and the flipper of a seal).

Although Larmarck was one of the first scientists to recognize that evolution had occurred, his theories about how and why evolution took place proved to be incorrect. Nonetheless, the specific idea of homologous structures is consistent with accepted evolutionary theory.

Variations:

Use skeletons (if available) of various animals and have students compare various homologous structures.

Adapted from: none

Science as Inquiry/
History and Nature of Science

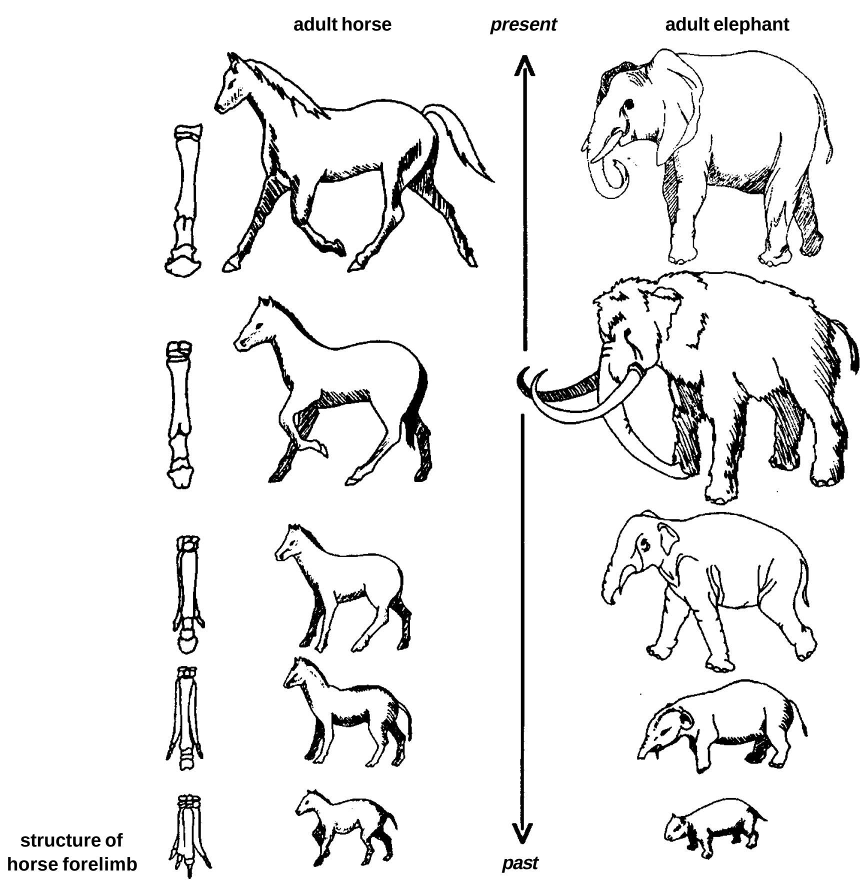
Organic Evolution

Item:
Look at the diagram below, which shows the probable stages in the evolution of the horse and elephant.

A. One of the most obvious changes in the elephant's lineage is the development of the long trunk. Explain how the environment of the elephant's ancestors could have favored animals with long trunks.

B. According to the chart, both species evolved into larger forms. Explain how this would be adaptive for each species.

Evolution of the Horse and Elephant



Answer:

Students should explain in specific terms that adaptive characteristics seen in all animals are such that they provide species with the ability to better take advantage of their habitat or in some other way enhance their ability to survive (e.g., predator avoidance).

Science as Inquiry

The Peppered Moth

Is this an example of industrial melanism?

Overview:

With the coming of rudimentary technology, the world's atmosphere began to change. The burning of coal in England during the Industrial Revolution caused a shift in the population of the mottled colored Peppered Moth.

Procedure:

Prepare materials (provided) for "rounds." The large sheet of construction paper represents the ground. Cut out four $1^1/_2$ x 11 strips of black and of white construction paper for a total of eight strips of paper. These strips of paper represent trees. Punch-out black and white dots from the remaining construction paper (100 of each color). These dots represent moths. Label one cup as your pouring cup (successful reproduction) and the other as your reserve cup.

Listen to your teacher as he/she reviews the story of the Industrial Revolution in England and follow the instructions closely. As you proceed through the rounds, describe what condition you believe your trees are in—and how many black tree strips you should place on the background paper for the next round—as well how many moths you now have. Record your results for each round (as instructed) on a data table.

Round 1. Pre-Industrial Revolution

In this pristine world, there was little smoky pollution. The trees were unaffected by wood smoke and by the little coal that was burned in some homes for heating.

Round 2. Early Industrial Revolution

In the early stages of industrialization, England experienced an increase in coal smoke pollution. The stuff stuck everywhere, choking out the lichen and turning everything dark.

Round 3. Mid-Industrial Revolution

As pollution continues, the number of dark trees and rocks increases.

Round 4. Late Industrial Revolution

Now things are really getting bad. Coal smoke hangs in the air. Water from clothes being washed has a definite coal color tinge and the smell is in the air.

Round 5. England at Its Worst

The eyes burn from the pollution. Mucus from the nose is darkened. Tree bark—and trees—darken and die. Factories burn hundreds of tons of coal everyday in manufacturing. The lichens have all died.

After completing this activity, read "Evolution's Link to Development Explored" (Reading 1).

Questions:

1. In the predator-prey relationship involving peppered moths and birds, which is the predator and which is the prey?

2. By the late 1890s, black moths formed more than 95% of the population in English industrial areas. As new modern air pollution controls attempt to clean up the air and have an impact on air quality, what do you think might happen to the number of black peppered moths? What do you think might happen to the number of white peppered moths? Explain your answers.

3. Charles Darwin believed that evolution was such a slow process that it could never be observed directly. The observations of the peppered moth show that he was wrong. The force that causes this change is called Natural Selection. The tendency for dark-colored forms to replace light colored forms in polluted areas is called industrial melanism. This tendency has also been observed in some 100 species of moths in the Pittsburgh, Penn. area, where industrialization is heavy. Explain the changes in the population of dots as the rounds progressed.

4. How did the inheritance of the mutant dominant black gene affect the moths?

5. Humans are constantly altering the environment. How do these changes affect other organisms?

History and Nature of Science

The Peppered Moth

Is this an example of industrial melanism?

Overview:

Students will simulate the forces of predation and pollution on black and light moths to see how this form of natural selection as a result of a mutant dominant gene can cause a population change. After completing this activity, have students read “Evolution’s Link to Development Explored” (Reading 1).

Materials:

Per lab group (2–4 students):

construction paper, 1 large sheet any color except black or white, 11 x 17
construction paper, black, 8 1/2 x 11, 2 sheets
construction paper, white, 8 1/2 x 11, 2 sheets
paper cups, 5-oz or larger, 2
hole puncher, hand-held
scissors

Procedure:

As a time saver, teachers prepare materials for the “rounds,” otherwise, students prepare materials for the rounds. These rounds represent fluctuations in the peppered moth population of pre- and post-industrial revolution in England. Students cut four strips of black construction paper and four strips of white construction paper, 1 1/2 x 11 inches per strip. These strips represent trees. With the remaining white and black construction paper, students punch out a minimum of 100 white dots and 100 black dots. These dots represent the moth population. White dots represent peppered moths while black dots represent melanin moths. One cup is the pouring pot, which holds the moths (or genes) to be used in the current round. The second cup, is the reserve pot, which holds the moths that do not survive the current round(s).

Before the students begin the actual experiment, explain the parameters in this manner:

The moths are represented by dots. If a white dot falls on a black tree, that moth will be visible to birds and will be eaten. If a black dot falls on a white tree, that moth likewise, will be visible to birds and be eaten. These moths, obviously, do not survive and are placed in the reserve pot.

If a moth survives by landing completely on a tree that is the same color as the moth (camouflaged), the moth is successful and reproduces. When this happens, students add two moths of that same color (successful reproduction) to the pouring pot for the next round. Again, moths that do not land on any trees also survive—they just do not reproduce this time—and are returned (no additional dots) to the pouring pot for the next round.

If any round, all of the populations of either color of moths get eaten, students may import three of that color—due to migration—for the next round.

Now, begin the experiment by telling the story of the Industrial Revolution in England (read the italicized text immediately after the words, “Round 1,” etc., in the instructions that follow). As you proceed through the rounds, elicit responses from the students as to what condition they believe their trees are in—and how many strips/black trees they should place on their background paper.

Round 1. Pre-Industrial Revolution.

In this pristine world, there was little smoky pollution. The trees were unaffected by wood smoke and by the little coal that was burned in some homes for heating.

The students place four white strips of paper on the background sheet in a random manner—but not overlapping. They place 20 white dots and 5 black dots into their pouring pot. They then sprinkle these randomly (so that the dots are fairly evenly distributed) onto the background sheet from a height of about 30 cm (about a foot). Students pick up any dots/moths that miss the paper completely, and re-sprinkle these dots until all the moths have landed either on the “ground” or on a tree. They then remove any visible moths from the trees—those that land against a different colored tree, i.e., easily seen—and place these in the reserve pot.

Students count the total number of remaining moths (by color) and record on their chart for round one. They then add these moths to the pouring pot. Be sure to indicate to the students that the moths (from the “ground” area) do survive—they just did not reproduce in this instance and are therefore candidates for the next round.

Round 2. Early Industrial Revolution

In the early stages of industrialization, England experienced an increase in coal smoke pollution. The cool ashes stuck everywhere, choking out the lichen and turning everything dark.

The students place three white strips and one black strip in a random order and fashion on the background paper and sprinkle the moths from the pouring pot onto the paper as before. They repeat the procedure, removing the visible moths from the trees and placing them in the reserve pot. They count the moths as record as before. However, this time, before picking up the remaining moths, students put two moths (of the same color as the parent moth) for each moth that successfully reproduced (camouflaged) into the pouring pot. (Note: moths added to the pouring pot due to successful reproduction will be counted in the next round.) They then pick up all the moths for the next round.

Round 3. Mid-Industrial Revolution

As pollution continues, the number of dark trees and rocks increases.

The students repeat the above procedure—only this time they use two white strips and two black strips placed in random order and fashion.

Round 4. Late Industrial Revolution

Now things are really getting bad. Coal smoke hangs in the air. Water from clothes being washed has a definite coal color tinge and the smell is in the air.

The students now use only one white strip [there is a little hope] and three black strips, again placing the strips in random order and fashion, and repeating the procedure as before.

Round 5. England at Its Worst

The eyes burn from the pollution. Mucus from the nose is darkened. Tree bark— and trees— darken and die. Factories burn hundreds of tons of coal everyday in manufacturing. The lichens have all died.

Students repeat the above procedures using only four black strips and no white strips (the lichen is dead and the bark is dark.) They are to repeat the removal and reproductive instructions and record the final set of data.

After a post-lab discussion, students should read “Evolution’s Link to Development Explored” (Reading 1).

Background:

Peppered moths (Biston betularia) were known to British naturalists who noted that they were found on light colored lichen-covered trees and rocks. Against this background, the light mottled coloring of these moths made them almost invisible to predatory birds. Until 1845, all reported specimens of peppered moths had been light-colored. As the Industrial Revolution developed in England, excessive smoke was produced in the industrial areas. This smoke killed the lichens and left the trees and rocks black. In 1845, a black specimen of the peppered moth was found. This black form of moth (Biston betularai carbonaria) was able to reproduce and spread because it became invisible against the new dark background. Though this moth carried a dominant mutant gene, B, soon the dark form accounted for 98% of the peppered moth population at the height of England’s pollution in about 1890. It was thought that this mutant gene was responsible for creating a form of moth that was less readily visible to birds. Thus natural selection against the light form of moth was greater during the years of heavy pollution than against the dark form.

Years later, several experiments were conducted by H. B. D. Kettlewell to prove his hypothesis that the color of the moths protected them from predators. By filming the actual episodes, he was able to demonstrate that when equal numbers of black and white peppered moths were available on black trees, the birds ate 43 white moths and only 14 black moths. On light trees, in a less industrialized area, the birds ate 164 black moths but only 26 of the light form.

In recent years, controls on pollution have increased and the levels of smoke have decreased. Many of the trees have returned to their original normal colors and the numbers of the light form of Biston have significantly increased.

Natural Selection is practical and picks traits (favors them) that increase survival in the current situation. The successful individual today may not be the successful individual of tomorrow.

Variations:

Similar scenarios can be created using other organisms. Varying colors of lizards and butterflies may provide similar results.

Adapted from:

Original material by Diane Schranck (Yates H. S.) and Tom Ivy (Lee H. S.), Houston, Texas.

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Science as Inquiry

Changes in Gene Frequency, II

Item:

The darker moths became numerous over the lighter variation in England because of which of the following?

A. The smog killed the lichen.
B. The smog killed the lighter variety.
C. The birds ate the lighter variety which landed on the darker lichen.
D. A genetic shift in the lighter variety occurred because of the smog.

Justification:

Explain your answer to the above question.

Answer:

C. As the pollution became worse, the light lichen died and the tree bark became darker. The lighter variety of moths were able to be seen to be eaten. This allowed the darker variety to be better camouflaged. Because the darker variety had a better chance at survival and to produce offspring, the dark gene was passed on at a higher frequency.

Life Sciences Standard 3 Core Ideas: Heredity: Inheritance and Variation of Traits

	Grade 1	Grade 3	Middle School	High School
LS3.A: Inheritance of Traits				

LS3.B: Variation of Traits				