City of Hope Genetics: Grades 3–5

Why Study Genetics?

As human genetics and genetic technologies increasingly impact individuals, families, and society, it has become essential for young people to understand and appreciate the science of genetics. By the end of eighth grade, students need to know that all organisms have genes and that the information contained within these genes is affected by the physical and social environment in which the organisms live. Knowledge of genetics will allow students to grow into thoughtful members of society who can better understand advances in the science of genetics and how such advances affect their own health and their society. With a foundation in genetics, young people will be able to think critically about how genetic science impacts them and their society and—if they so choose—to contribute to developments in genetic science and technology in the future.

NOTE
The background information presented here is a resource for the teacher. It is not meant to be taught directly to students.

Unit Flow

Activity 1: The Friar Who Grew Peas

In this session, students listen to the story *Gregor Mendel: The Friar Who Grew Peas* and discuss Mendel's life and his experiments with peas. They explore peas and their traits. The students learn to make Punnett squares to help determine the ratios of offspring genotypes and phenotypes. They make predictions about the results of the crosses of particular pea plants, and evaluate their predictions after learning the results of a cross.

Objectives

Students will:

- Analyze and interpret data to provide evidence that pea plants have traits inherited from parents and that variation of these traits exists in a group of similar organisms (NGSS 3-LS3-1)
- Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for their answers (ELA/Literacy RI.3.1)

Activity 2: The Story of the Deer Mouse

In this session, students consider why a certain trait might make a plant or animal more or less likely to survive. They conduct an experiment in which they act as predatory birds and try to capture "deer mice" of different colors from different habitats. Students then graph how many of each type of deer mouse they captured and make hypotheses about why they captured more or less of each variant.

Objectives

Students will:

- 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 (NGSS 3-LS4-2)

- Use evidence to support the explanation that traits can be influenced by the environment (NGSS 3-LS3-2)
- Draw a scaled bar graph to represent a data set with several categories (Grade 3: Mathematics 3.MD.B.3)
- Make a line plot to display a data set (Grades 4 and 5: Mathematics 4.MD.B.4 and Mathematics 5.MD.B.2)

Activity 3: The Right Tool for the Job

In this session, student teams explore how effectively different models of beak types can gather different types of foods, and determine which model of beak is most effective at gathering which type of food. They hypothesize how a change to a bird's beak, through a mutation, might make the bird more or less likely to be able to survive to reproductive age, and what that might mean for "fixing" the mutation in future generations.

Objectives

Students will:

- 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 (NGSS 3-LS4-2)
- Draw a scaled bar graph to represent a data set with several categories (Mathematics: 3.MD.B.3)
- Analyze and interpret data and use logical reasoning to make sense of phenomena (NRC Science Practice 4)
- Use evidence to support an explanation (NRC Science Practice 6)
- Write informative/explanatory texts to examine a topic and convey ideas and information clearly (ELA/Literacy W3.2)

Activity 4: Awesome Adaptations

In this session, students explore animals' adaptations to their environments. They examine some of the adaptations of the opossum, considering how some adaptations are physical and others are behavioral. In teams, they choose an animal to research, and each team creates a presentation on the animal's behavioral and physical adaptations. As an extension, each team is given a habitat description and asked to invent an organism that would survive well in that habitat.

Objectives

Students will:

- Construct an argument with evidence that in a particular habitat some organisms can survive well, some can survive less well, and some cannot survive at all (NGSS 3-LS4-3)
- Gather information from print and digital sources, take brief notes on sources, and sort evidence into provided categories (ELA/Literacy W.3.8)
- Conduct a short research project that builds their knowledge of animal adaptations (ELA/Literacy.W.4.7)

Next Generation Science Standards

For additional guidance and clarification on these standards, please refer to "How to Read the Next Generation Science Standards" (http://www.nextgenscience.org/how-to-read-the-standards).

*3. Inheritance and Variation of Traits: Life Cycles and Traits**

Students who demonstrate understanding can:

3-LS1-1. Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death. [Clarification Statement: Changes organisms go through during their life form a pattern.] [Assessment Boundary: Assessment of plant life cycles is limited to those of flowering plants. Assessment does not include details of human reproduction.]

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.]

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.]

The performance expectations above were developed using the following elements from the NRC document A Framework for K-12 Science Education:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. • Develop models to describe phenomena. (3-LS1-1) **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	**LS1.B: Growth and Development of Organisms** • Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles. (3-LS1-1) **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)	**Patterns** ▪ **Similarities and differences in patterns can be used to sort and classify natural phenomena.** (3-LS3-1) ▪ **Patterns of change can be used to make predictions.** (3-LS1-1) **Cause and Effect** ▪ **Cause and effect relationships are routinely identified and used to explain change.** (3-LS3-2),(3-LS4-2)

* Standards in bold are addressed in the unit.

and predict phenomena and in designing multiple solutions to design problems. • **Use evidence (e.g., observations, patterns) to support an explanation.** (3-LS3-2) • **Use evidence (e.g., observations, patterns) to construct an explanation.** (3-LS4-2) **----------** **Connections to Nature of Science** **Scientific Knowledge is Based on Empirical Evidence** ▪ Science findings are based on recognizing patterns. (3-LS1-1)	• **The environment also affects the traits that an organism develops.** (3-LS3-2) **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)	

Connections to other DCIs in third grade: **3.LS4.C** (3-LS4-2)

Articulation of DCIs across grade-levels: **1.LS3.A** (3-LS3-1),(3-LS4-2); **1.LS3.B** (3-LS3-1); **MS.LS1.B** (3-LS1-1), (3-LS3-2); **MS.LS2.A** (3-LS4-2); **MS.LS3.A** (3-LS3-1); **MS.LS3.B** (3-LS3-1),(3-LS4-2); **MS.LS4.B** (3-LS4-2)

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),(3-LS4-2)**

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),(3-LS4-2)

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),(3-LS4-2)

RI.3.7 Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur). (3-LS1-1)

W.3.2 **Write informative/explanatory texts to examine a topic and convey ideas and information clearly**. (3-LS3-1),(3-LS3-2),(3-LS4-2)

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),(3-LS4-2)

SL.3.5 Create engaging audio recordings of stories or poems that demonstrate fluid reading at an understandable pace; add visual displays when appropriate to emphasize or enhance certain facts or details. (3-LS1-1)

Mathematics –

MP.2 Reason abstractly and quantitatively. (3-LS3-1),(3-LS3-2),(3-LS4-2)

MP.4 Model with mathematics. (3-LS1-1),(3-LS3-1),(3-LS3-2),(3-LS4-2)

3.NBT Number and Operations in Base Ten (3-LS1-1)

3.NF Number and Operations—Fractions (3-LS1-1)

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.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)

*3-LS4-3. Biological Evolution: Unity and Diversity**

Students who demonstrate understanding can:

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.]

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
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.**	**LS4.C: Adaptation** • For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.	**Cause and Effect** • Cause and effect relationships are routinely identified and used to explain change.

Connections to other DCIs in third grade:
3.ESS2.D

Articulation of DCIs across grade-levels:
K.ESS3.A ; 2.LS2.A ; 2.LS4.D ; MS.LS2.A ; MS.LS4.B ; MS.LS4.C ; MS.ESS1.C

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-LS4-3)

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

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-LS4-3)

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

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

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-LS4-3)

Mathematics –

MP.2 Reason abstractly and quantitatively. (3-LS4-3)

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-LS4-3)☐

* Standards in bold are addressed in the unit.

Background Information

Activity 1: The Friar Who Grew Peas

Gregor Mendel

Gregor Johann Mendel (1822–1884) is known as the father of genetics. While human beings had been breeding plants and animals to create more desirable offspring for centuries, Mendel was the first to successfully demonstrate some of the rules of inheritance, known today as the laws of Mendelian inheritance.

Mendel explored seven pea plant traits: pea pod shape and color; plant height; seed shape and color; and flower position and color. Mendel carefully pollinated pea plants to determine how traits were passed down from one generation to the next. He deemed that invisible "factors"—which we now call *genes*—were responsible for determining how traits were passed from one generation to the next.

It is important to note that the traits Mendel examined are very simple genetic traits. Each trait shows a simple dominant/recessive pattern of inheritance (see below).

Patterns of Inheritance: Mendelian

Autosomal Dominance

When a trait shows a dominant/recessive pattern of inheritance, the presence of a dominant *allele* will cause the dominant trait to appear even if a recessive allele is also present. However, when only the recessive allele is present, the recessive trait will appear.

Co-Dominance

When an organism has one dominant and one recessive allele, but neither allele is dominant and both are completely manifested, the alleles are called *co-dominant*. An example of co-dominance is AB blood type inheritance.

Incomplete Dominance

When an organism has one dominant and one recessive allele, but one is not completely dominant over the other, the alleles are said to exhibit *incomplete dominance*. For example, some flowers show incomplete dominance in their inheritance of color, with the allele for red color and the allele for white color producing a pink flower (such as in tulips).

Activity 2: The Story of the Deer Mouse

Research on the Deer Mice of the Sand Hills of Nebraska

Until a few thousand years ago, the deer mice living in Nebraska all had dark fur, like most deer mice found in North America. However, most deer mice in the light-colored Sand Hills area have light-colored fur. Scientists at Harvard University concluded that the light color is coded by a single gene that they call the *Agouti* gene. Researchers found that the *Agouti* gene only appeared in the deer mice in Sand Hills around 4,000 years ago, which was not long, relatively (just a few thousand years), after the mice moved into the area. In the 4,000 years since, the *Agouti* gene has taken over due to *natural selection*, or the ability of the light-colored (and thus better camouflaged) mice to survive to the age of reproduction better than their dark-colored counterparts.

An interesting look at natural selection can be found in a YouTube video titled "What Is Natural Selection?", part of the *Stated Clearly* series.

Activity 3: The Right Tool for the Job

Charles Darwin's Finches

In 1831, Charles Darwin was invited to be a naturalist aboard the H.M.S. *Beagle* on a two-year survey of South America. During that voyage (which lasted five years), Darwin took specimens of various birds living on different islands in the Galapagos. After returning to England, experts there determined that many of the birds that Darwin sampled were finches and that finches from different islands had different types of beaks. While visiting the islands, Darwin had noted that the environment on each island was distinct and that the birds on each island had a different food source. From these observations, Darwin formed his theory that the finches had all developed from a common ancestor, though each had changed or evolved by means of natural selection to be better adapted to its island home. Much like the deer mice of Nebraska, the finches that were best able to survive to the age of reproduction on a particular island were the ones that passed along their beak types to their offspring, which then became "fixed" traits in the corresponding habitats.

For an interesting article with many pictures of bird beaks, see the BBC's "The Wonderful World of Bird Beaks" (http://www.bbc.com/earth/story/20150223-the-weird-world-of-bird-beaks).

Activity 4: Awesome Adaptations

Adaptations are traits that give organisms advantages that allow individuals and species to survive. Due to natural selection, organisms that possess the advantageous traits are more able to survive to reproductive age and, therefore, are more likely to pass down their traits from one generation to the next.

Glossary

Acquired trait: A physical characteristic of an organism that is not passed down genetically. These traits are not coded in the organism's DNA and are a result of the environment's influence on the organism. Examples of acquired traits include tattoos and large muscles (such as those of a body builder).

Adaptation: A trait that is common in a population because it provides some improved function to an organism. Adaptations are the result of natural selection, in which a trait makes the survival and reproduction of an organism more likely. Adaptations can be to the physical form of an organism or to the behaviors that the organism exhibits.

Allele: An alternative form of a gene. In diploid organisms, such as mammals, alleles come in pairs—two alleles for each trait—and they are each located at a specific position on a specific chromosome. When the alleles of a gene are different (known as *heterozygous*), one may be *dominant* and the other *recessive*. When the alleles of a gene are the same, they are called *homozygous*.

Behavioral adaptation: Behaviors that help to ensure the survival of an individual organism and its species.

Camouflage: An adaptation that enables species to blend with their surroundings.

Carnivore: A meat-eating organism.

Chromosome: A structure in the nucleus of most living cells composed of nucleic acids and protein. Chromosomes carry genetic information in the form of genes.

Dominant allele: An allele that is expressed in an organism, hiding the effect of the recessive allele when present.

Gene: A unit of heredity that is transferred from a parent to offspring and determines some characteristic of the offspring.

Genotype: The full complement of genes or alleles that determines the manifestation of the characteristics or traits of an organism.

Habitat: The natural home where an animal, plant, or other organism lives and grows.

Mutation: A change in the structure of a gene, which can result in a variant form that may be passed on to the offspring of an organism. Some mutations do not affect organisms at all, while others lead to changes (large and small) in form or function. Only mutations in *germline* (reproductive) cells are passed on to offspring. Mutations can be caused by the alteration of single nucleotides of DNA or substitutions, deletions, insertions, or rearrangements of larger sections of genes or chromosomes.

Natural selection: The process by which organisms having traits that are better adapted to their habitat are more likely to survive and reproduce in greater numbers than others of their kind, and in so doing ensure that their genetic material is perpetuated in future generations.

Ploidy: The number of sets of chromosomes in a cell. *Haploid* cells (of which reproductive cells are the most common) have one set of each chromosome. *Diploid* cells (found in most higher organisms, such as mammals) have two sets of each chromosome.

Phenotype: The physical appearance of an organism that results from the expression of genes and that can be influenced by the environment.

Physical adaptation: A characteristic or modification in an organism's form that helps it survive better in its habitat.

Predator: An animal that kills and eats other animals.

Prey: An animal that is caught and eaten by another animal.

Punnett square: A tool that helps to show all possible alleles of two parents with known genotypes; it is used to predict the possible allele combinations of their offspring.

Recessive: A recessive allele is one in which the effect is not perceptible if it is in the presence of the dominant allele. The recessive allele is manifested when two recessive alleles are present (or one recessive allele in the case of a sex-linked trait in a XY organism).

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