City of Hope Genetics: Grades 6–8

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 Fate of My Traits

In this session, students explore case studies of traits that exhibit non-Mendelian patterns of inheritance, studying codominance, incomplete dominance, and X-linked traits. They use Punnett squares as tools to help make predictions about the outcomes of crosses.

Objectives

Students will:

- Recognize various patterns of inheritance, including: incomplete dominance, codominance, X-linked, and multi-allelic, and how these patterns can contribute to genetic variation. (NRC Frameworks LS3.B: Variation of Traits)
- Cite specific textual evidence to support analysis of science and technical texts. (ELA/Literacy.RST.6-8.1)

Activity 2: So Many Combinations!

Overview

In this session, students consider just how much genetic variety can be created by DNA/chromosomes. They create fictional organisms using alleles selected randomly. They explore the variety of organisms that can be created with five different randomly chosen traits, and compare this to the variation that could be produced by organisms that reproduce asexually.

Objectives

Students will:

- Recognize that variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (NRC Frameworks LS3.A: Inheritance of Traits)
- Describe how, in sexually reproducing organisms, each parent contributes half the genes acquired (at random) by the offspring. In organisms with diploid genomes,

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. (NRC Frameworks LS3.B: Variation of Traits)

- Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information as the parents, and sexual reproduction results in offspring with genetic variation. (NGSS MS-LS3-2)
- Follow a multistep procedure precisely when carrying out experiments, taking measurements, or performing technical tasks. (ELA/Literacy.RST.6-8.3)

Activity 3: Getting the Message Right

Students follow DNA "recipes" to explore how a mutation can profoundly affect the final outcome of gene expression. They learn about how DNA codes for proteins and that proteins play a critical role in the body. If a protein is not created properly, part of an organism may not function or may not be formed correctly.

Objectives

Students will:

- Develop and use a model to describe how structural changes to genes (mutations) located on chromosomes can affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the encoded proteins and the organism. (NGSS MS-LS3-1)
- Follow a multistep procedure precisely when carrying out experiments, taking measurements, or performing technical tasks. (ELA/Literacy.RST.6-8.3)

Activity 4: Competing for Eating

In this session, the students participate in an experiment in which they compete for food. Each student must gather enough food in a short period of time to enable their survival.

Objectives

Students will:

- Describe how natural selection leads to the predominance of certain traits in a population and the suppression of others. (NRC Frameworks LS4.B: Natural Selection)

Activity 5: Podcasting Genetics

Human beings have long influenced the inheritance of traits in organisms that we breed and grow. Recently, humans have begun to use technology to help combat human diseases through gene therapy. In this activity, student teams research the various ways that humans have influenced the genes of non-human organisms, and they will develop podcasts to explain what they have learned using language targeted to the general public.

Objectives

Students will:

- Gather and synthesize information about the technologies that have changed the way that humans influence the inheritance of desired traits in organisms. (NGSS MS-LS4-5)
- Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. (ELA/Literacy.RST.6-8.8)
- Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate. (ELA/Literacy.SL.6.6)

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).

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	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena. (MS-LS3-1),(MS-LS3-2)	**LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2) **LS3.A: Inheritance of Traits** • Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific 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,	**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)

* Standards in bold are addressed in the unit.

	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)	

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

Articulation of DCIs 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 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (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)

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

Disciplinary Core Ideas

LS4.C: Adaptation

- For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.

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

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships are routinely identified and used to explain change.

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

[*] Standards in bold are addressed in the unit.

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 realworld 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)

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

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)

	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)	

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),(MSLS4-6); MS.ESS1.C (MS-LS4-1),(MS-LS4-2),(MS-LS4-6); MS.ESS2.B (MS-LS4-1)

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),(MSLS4-2),(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, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (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)□

Background Information

Activity 1: The Fate of My Traits

Gregor Mendel

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

Mendel explored these principles of inheritance using pea plants. He explored seven pea plant traits: pea pod shape and color; plant height; seed shape and color; and flower position and color. Mendel carefully and selectively 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, meaning only one gene is responsible for the expression of the trait. 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 alleles are present, the recessive trait will appear.

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, four o'clock flowers (*Mirabilis jalapa*) show incomplete dominance in their inheritance of color. When the organism inherits the allele for red color and the allele for white color, pink flowers are produced

Type of Organism	Name of Organism	Description of Trait
Plant	Snapdragons	Crossing red and white snapdragons produces pink snapdragons.
Bird	Andalusian chickens	Breeding black and white Andalusian chickens results in blue chickens.
Mammal	Horses	Palamino horses are produced by the incompletely dominant modifier *cream* gene (which dilutes red color to yellow).

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*. In some varieties of chickens, the alleles for black-colored feathers and the alleles for white-colored feathers show co-dominant inheritance patterns. When the allele for black feathers and the allele for white feathers are both present, the chicken will exhibit *erminette* coloration.

Type of Organism	Name of Organism	Description of Trait
Plant	Camellias	Flowers of pink and white plants that are crossed show pink and white patches.
Mammal	Horses	Crossing a red horse and a white horse results in a roan horse, which is a horse that has a mixture of red hairs and white hairs.
Mammal	Humans	Blood type in humans is codominant.
Mammal	Humans	The HBB gene provides instructions for making beta-globin, which is a component of hemoglobin, the oxygen-carrying molecule in red blood cells. When someone inherits two recessive alleles, they have a disease called sickle cell disease. People with this disorder have atypical hemoglobin molecules, which cause red blood cells to become misshapen. These sickle-shaped cells break down prematurely and can also clog small blood vessels, causing a variety of symptoms. In heterozygotes, blood shows both sickled and normal shapes. It is beneficial to carriers (heterozygotes) of the sickle cell gene, as it provides a survival advantage to them when they are infected with malaria.

X-linked Inheritance

In humans and many other organisms, males have an X and a Y chromosome and females have two X chromosomes. These chromosomes carry genes just like other chromosomes. X-linked recessive traits are more common in males than females, as

males only have one X chromosome. If they inherit the recessive allele carried by the X chromosome, it will be expressed, whereas in females two recessive alleles (on both X chromosomes) must be inherited to be expressed.

Type of Organism	Name of Organism	Description of Trait
Insect	Fruit fly	White eye color is a sex-linked trait in fruit flies.
Mammal	Cats	The gene that codes for orange/black fur in cats is on the X chromosome.
Mammal	Humans	Color-blindness in humans is a sex-linked trait.

Activity 2: So Many Combinations!

Just a few different traits, each with a few variants, allow a large number of different phenotypes of an organism to occur. To determine how many different phenotypes are possible, multiply the number of possibilities for each trait together. For example, if an organism has three possible facial shapes and two possible eye colors, there are six possible phenotypic combinations that can result.

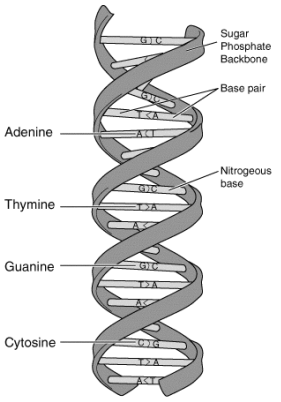
Asexual Reproduction

In organisms that reproduce sexually, each parent contributes genetic material to the offspring. However, organisms that reproduce asexually can only pass on one set of genetic material (their own) to their offspring. Thus, the offspring are genetically identical to their parent.

Activity 3: Getting the Message Right

DNA (deoxyribonucleic acid)

DNA is the hereditary material in most organisms on Earth. DNA stores the information that codes for an organism and is found in the nucleus of each cell. DNA is made up of four chemical bases: adenine (A), guanine (G), cytosine (C), and thymine (T). In humans, DNA exists as a double-stranded helix, with strict rules about the pairing of bases in the two strands: adenine pairs with thymine, guanine pairs with cytosine. Each base attaches to a sugar molecule (deoxyribose) and a phosphate molecule to form a nucleotide. Nucleotides are linked to each other within a strand through the phosphate moiety and bases are paired between strands via hydrogen bonding. Humans have about 3 billion base/nucleotide pairs that make up their DNA.



"DNA-structure-and-bases.png" is in the public domain.

DNA Replication

DNA replicates itself in a complex process that is mediated by enzymes. First, the two strands of DNA unwind and separate under the influence of an enzyme called a helicase. After the strands are separated, DNA polymerase makes a copy of each strand. DNA polymerases work in concert with many more enzymes in the process.

The video DNA Replication Process [3D Animation] is a nice representation of the process of replication.

What Does DNA Do?

DNA is the coded set of instructions that allow organisms to grow, survive and reproduce. The instructions contained in DNA sequences must be decoded into proteins, which are the building blocks for life. These proteins work together to run the cells, like the various components of a living machine.

The decoding process begins with a process called *transcription*. In transcription, the DNA unwinds and the code is converted into a single-stranded messenger RNA (mRNA). mRNA is a slightly different form of nucleic acid that leaves the nucleus of the cell and moves into the ribosome, where it is *translated* into a protein.

In the *translation* process, the ribosome reads the mRNA strand and translates it into a protein. The codes contained in mRNA are arranged in triplets called *codons*. Each codon corresponds to a specific amino acid, with the exception of three of the triplets. Those special triplets tell the process of protein synthesis to stop. Beginning at the sequence AUG (which codes for the amino acid methionine), the ribosome "reads" the mRNA codons and assembles amino acids into a protein, stopping at one of the three STOP sequences (UAA, UAG, or UGA).

The video Transcription and Translation by Bozeman Science provides a detailed explanation of the process of transcription and translation. A more humorous take on the process of protein synthesis can be found in the video Protein Synthesis and the Lean, Mean Ribosome Machines by the Amoeba Sisters.

Mutations

A mutation is a permanent change to a nucleotide sequence in the DNA of an organism. Some mutations do not alter the protein products of the DNA, while others can have catastrophic effects. Mutations occur fairly often when DNA is copied—about once every 100,000 nucleotides. Some mutations are substitutions, in which a different base is substituted for the proper base, others are deletions in which a nucleotide is omitted, and still others result from the addition of a nucleotide (additions). Most of these mutations occur in non-coding DNA, so they have no effect on the organism. When a mutation occurs in a gene, it can have a beneficial effect, no effect, or a detrimental effect—not all mutations are bad.

Activity 4: Competing for Eating

Natural Selection

Natural selection is a process by which heritable traits gradually become more common or less common in a population based on whether they are advantageous or disadvantageous to organisms in that population. Simply put, a trait that allows an organism to grow up, attract a mate, and reproduce effectively will be more likely to be passed down than one that makes an organism less likely to do so. Natural selection is a cornerstone of evolution.

Activity 5: Podcasting Genetics

Humans have long manipulated the genetics of organisms such as crops and livestock through selective breeding. More recently, humans have begun to more directly manipulate genetic material through genetic engineering. In genetic engineering, scientists add new genes (often from a different species of organism) to the DNA of existing cells in order to alter the traits expressed by those cells. Usually, gene(s) from one organism (such as the gene that produces bioluminescence in fireflies) is/are added to a different organism's DNA (such as that of a plant), causing that organism to express the new trait (in this case creating a plant that is bioluminescent).

Ethics and Politics of Genetically Modified Organisms (GMOs)

GMOs have been called everything from unsafe to dangerous to even *Frankenfoods*. A quick search on the Internet will reveal many sites proclaiming GMOs unsafe and some sites that make the case that GMOs are harmless. Although much of the discussion is alarmist, students might find it scary or downright terrifying. Some articles that provide scientifically accurate information are the following:

- Theresa Phillips, Ph.D., (2008). Genetically Modified Organisms (GMOs): Transgenic Crops and Recombinant DNA Technology. *Nature Education* 1(1):213.
- Miriam Schulman. (2000). Attack of the Killer Tomatoes? *Santa Clara Magazine* Summer 2000.
- Marci Rosenberg & Connie Liu. (10/5/2011). Genetically Modified Organisms: A Question of Ethics. *The Journal of Youths in Science* (JOURNYS).

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/advantage 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: A gene variant. 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 within an organism, they are called *homozygous*.

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

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.

Codominance: A situation in which both the recessive and dominant alleles are expressed equally.

Dominant allele: An allele that is expressed in an organism, hiding the effect of the recessive allele when present (i.e. in a heterozygous condition).

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

Genetic engineering: A set of technologies used to manipulate the DNA of cells. Genetic engineering usually involves moving genes from one species to another to produce new or "improved" organisms.

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.

Incomplete dominance: A form of genetic expression in which the dominant allele is not completely expressed over the recessive allele causing a mixed trait.

Mutation: A permanent 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 in somatic (non-reproductive) cells can affect the function or behavior of the individual that carries those mutations, sometimes resulting in disease. 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.

Phenotype: The physical manifestations that result 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.

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).

X-linked inheritance: Genes found on the X chromosome are called X-linked. X-linked recessive traits are always expressed when they are inherited by males, because males have one X and one Y chromosome; females have two X chromosomes.

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