SUCCESS ACADEMY EDUCATION INSTITUTE

Life Science:
Unit 2

Cell Division and Genetics: Introduction

Purpose: The Why, What, and How of This Unit

Essential Question: Do I have more in common with my friends or my family?

Unit Storyline Synopsis: Does everyone always tell you that you've got your dad's nose? Or that you got Grandma's freckles, which "skipped a generation"? The fact that we share inherited traits with our family members feels like an understanding we might arrive at even without the help of science. After all, it's right there, in plain sight. But on a more serious note, what about our risk for cancer? Or heart disease? With an unlucky combination of inherited traits, we could be next in line for an unfavorable future.

In this unit, your scholars will survey their own observable traits as well as those of others, explore genetic variation, and learn how organisms go from one cell to a multicellular organism with trillions of specialized cells. They will also study the mechanism of DNA replication and the causes and effects of mutations in genetic code. At the end of the unit, they will apply this understanding to the Essential Question: Do I have more in common with my friends or my family? Although this may seem a simple question to answer at the beginning of the unit (scholars tend to think they are most similar to their friends), throughout the unit scholars will find ample evidence to the contrary that they must consider.

Why This Unit? The main focus of this unit will be Mendelian genetics, which laid the foundation for our understanding of the field (more modern genetics research later followed, adding new information and filling in the blanks in Mendel's work). Gregor Johann Mendel is often considered "the father of genetics" because of his revolutionary work, as described below by the Cold Spring Harbor Laboratory's DNA Learning Center:

Gregor Mendel, through his work on pea plants, discovered the fundamental laws of inheritance. He deduced that genes come in pairs and are inherited as distinct units, one from each parent. Mendel tracked the segregation of parental genes and their appearance in the offspring as dominant or recessive traits. He recognized the mathematical patterns of inheritance from one generation to the next. Mendel's Laws of Heredity are usually stated as:

1) The Law of Segregation: Each inherited trait is defined by a gene pair. Parental genes are randomly separated to the sex cells so that sex cells contain only one gene of the pair. Offspring therefore inherit one genetic allele from each parent when sex cells unite in fertilization.

2) The Law of Independent Assortment: Genes for different traits are sorted separately from one another so that the inheritance of one trait is not dependent on the inheritance of another.

3) The Law of Dominance: An organism with alternate forms of a gene will express the form that is dominant.

The genetic experiments Mendel did with pea plants took him eight years (1856–1863), and he published his results in 1865. During this time, Mendel grew over 10,000 pea plants, keeping track of progeny number and type. Mendel's work and his Laws of Inheritance were not appreciated in his time. It wasn't until 1900, after the rediscovery of his Laws, that his experimental results were understood.

Studying heredity and mapping the human genome have already yielded immensely beneficial results, but some genetic mysteries continue to stump scientists all over the world. For example, there is still much to be learned about the cause and prevention of some of the world's deadliest diseases. On an adult level, genetics has seemingly endless puzzles to solve. On the scholar level, this unit, always a kid favorite, will prepare your classes to tackle later Grade 6 units (such as Evolution) and prepare for high school Biology.

What Is the Bottom Line?

Big Idea 1: Simple Mendelian genetics reveals simple patterns of predictability in the inheritance of many traits.

- When studying an organism's traits, scientists differentiate between **genotype** (the genetic constitution of an organism) and **phenotype** (the set of observable characteristics of an organism).
- Genotype and phenotype are described using specific and important language, including **heterozygous**, **homozygous**, **dominant allele**, and **recessive allele**.
- For any trait, each parent's alleles split and one passes from each parent to an offspring. Which particular gene in a pair gets passed on is completely up to chance.
- Different pairs of alleles are passed on to the offspring independently of each other. Inheritance of genes at one location in a genome does not influence the inheritance at another location.
- Scientists use models to track and predict patterns of inheritance (such as pedigree charts to track traits through several generations and Punnett squares to calculate the odds of offspring's inheriting a certain trait from a specific set of parents).

Big Idea 2: Modern technology revealed the role of cell division in the passing of genetic information from one organism to another, proving Mendel's original conclusions to be true.

- **Mitosis** is a type of cell division that results in two daughter cells, each with the same number and kind of chromosomes as the parent nucleus.

- **Meiosis** is a type of cell division that results in four daughter cells, each with half the number of chromosomes of the parent cell, as in the production of gametes.
- In sexually reproducing organisms, each parent contributes half of the genes acquired by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. In asexually reproducing organisms, one parent contributes all of the genes acquired by the offspring, making offspring genetically identical to their parent.
- Genes are located in the chromosomes of cells, with each chromosome pair containing two corresponding variants (alleles) of each of many genes. Genes affect the traits of an individual.
- Our understanding of inheritance can be applied to increase the probability of desirable traits in an organism through selective breeding or genetic engineering.

Big Idea 3: Modern genetics provided new evidence for other modes of inheritance that were not able to be explained with simple Mendelian ideas.

- Rarely, random mutations to genes result in changes to proteins, which can affect the structures and functions of an organism. These mutations can be beneficial, neutral, or harmful.
- Allele pairs may have a variety of dominance relationships, such as incomplete dominance or codominance.

How do Next Generation Science Standards practices and crosscutting concepts support mastery of the Big Ideas? Science and Engineering Practices highlighted in this unit:

- **Developing and Using Models**
    - Develop and/or use a model to predict and/or describe phenomena.
    - Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs and those at unobservable scales.
- **Constructing Explanations and Designing Solutions**
    - Construct an explanation using models or representations.
    - Apply scientific ideas, principles, and/or evidence to construct, revise, and/or use an explanation for real-world phenomena, examples, or events.

Crosscutting Concepts highlighted in this unit:

- **Patterns**
    - Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
- **Cause and Effect**
    - Phenomena may have more than one cause, and some cause-and-effect relationships in systems can only be described using probability.

Safety

Plan carefully for safety in all lessons. The top safety risks in this unit include:

- In Lesson 1, scholars use phenylthiocarbamide (PTC paper) to see whether or not they inherited a specific trait from their parents. Review all **safety information** and the Safety Data Sheet for **PTC paper** and ensure proper precautions are taken before conducting this lesson. When tasted quickly, the chemical substance is harmless; however, PTC paper can be toxic if ingested in large quantities. Ensure that scholars do not ingest the paper and that all PTC paper is discarded immediately after use.
- In Lesson 12, scholars use gummy bears. Be conscious of the allergies your scholars have whenever using food products in the classroom. If scholars have severe allergies to the gummy bears needed for Lesson 12, you will need to find an alternative. Ensure that scholars wear proper personal protective equipment (PPE) during this activity (gloves, goggles, and aprons).

Important Note: These lesson plans highlight some of the safety risks you should be aware of while teaching these lessons. These safety suggestions are not meant to take the place of a formal science safety training. Please be sure to follow all safety rules from your district, as well as all local, state, and federal science safety guidelines.

Unit Storyline

Engage: After years of studying the traits of various plants, animals, and fungi in elementary science classes, scholars stop to think about themselves. What traits do they possess, and how did they get them? Through this introductory lesson, scholars ask themselves, "Do I have more in common with my friends or my family?"

- **Lesson 1: Introduction to Heredity: Genetic Diversity.** What are the traits that make us unique? Where do they come from? Scholars play Traits Bingo to kick off a unit-long investigation to answer the Essential Question.

Explore: Scholars begin their explanation starting with what scientists know about heredity through research and modeling parts of modern genetics. This allows them an entry point into genetics through their prior knowledge from the Cells unit. As they uncover the basic mechanisms of sexual and asexual reproduction, they develop deeper, more complex questions about patterns of inheritance. Maybe that Essential Question is a little more difficult to answer than they thought....

- **Lesson 2: Mitosis and Meiosis** Scholars will explore the processes involved in making new cells and create their own models of mitosis and meiosis in action.
- **Lesson 3: Sexual and Asexual Reproduction** Scholars study sexual and asexual reproduction to uncover their connection to our genes.
- **Lesson 4: Generations of Simple Traits** If your father has black hair, does that mean you'll be born with black hair too? Scholars study and model the causes of genetic diversity.

Explain: Scholars solidify their understanding of heredity through mathematical modeling and debunk former misconceptions about inheritance by going back in time to visit Mendel's Laws. By

the end of these lessons, scholars will have the information they need to develop an initial answer to the Essential Question.

- **Lesson 5: Mendelian Genetics and Plant Breeding** Do other organisms inherit traits from their parents too? Scholars learn how traits are passed along through generations of plants as they simulate some of Mendel's most famous experiments.
- **Lesson 6: Modeling Genetic Frequency** Scholars may be surprised to discover that the probability of inheriting a certain trait can often be calculated! In this lesson, they learn to model mathematically with Punnett squares.
- **Lesson 7: More Complex Patterns of Inheritance** Often, one trait is dominant over another and is expressed in an organism's phenotype. Sometimes, however, combinations of traits lead to results that do not follow this simple pattern. In this lesson, scholars explore codominance and incomplete dominance.
- **Lesson 8: Patterns in Pedigrees** To track the presence of a trait through several generations, scientists use models such as pedigree charts. Scholars study pedigree charts to learn how they work and try their hand at creating their own!
- **Lesson 9: Cell Specialization, Gene Expression, and Mutations** If all of our cells contain the same DNA, how is it possible that a blood cell looks so different from a skin cell? Scholars research cell specialization to find the answer. They also learn that replication of DNA is an imperfect process and that random mutations sometimes occur. These seemingly tiny alterations to an organism's DNA can lead to a stunning variety of outcomes.

Elaborate: Humans have been trying to manipulate the outcomes of the genetic lottery for thousands of years. After all, bigger fruits, fatter chickens, and foods that resist diseases support the survival of our species! Scholars learn the ways in which humans attempt to beat genetics at its own game and consider whether these actions have ethical implications.

- **Lesson 10: Selective Breeding** Scholars apply their understanding of simple patterns of inheritance as they act as farmers working to raise the largest chickens and make more money than their competitors!
- **Lesson 11: Genetic Engineering** Scholars study the difference between selective breeding and genetic engineering and then discuss and debate the ethical concerns over various forms of genetic engineering.

Evaluate: Scholars demonstrate their mastery of unit content and skills through one final challenge. Given a bag of baby (gummy) bears, scholars are tasked with accurately classifying them and ultimately identifying their parents. To succeed, scholars must string together their newfound understandings from multiple lessons.

- **Lesson 12: Gummy Bear Genetics** Scholars are put to the test! Can they successfully synthesize their understanding from throughout the unit to correctly classify the baby bears?

Extra Resources

In addition to the resources linked to throughout the guide, use the following materials to help you prepare to launch this unit with scholars:

- **Printable Exit Tickets**
- **Printable Lab Notebook**