LESSON PLAN A

INTRODUCTION TO GENETICS

PPT Slide Examples

Time Frame: Two 45-minute sessions

Learning Objectives:

- Learn how traits are inherited from one generation to the next.
- Gain core knowledge about Gregory Mendel, the world's first geneticist.
- Conduct an experiment that explores the concept of genetic inheritance, using pea plants in the context of Gregor Mendel's original experiment.

Overview:

This lesson introduces the concept of genetic inheritance, using pea plants in the context of Gregor Mendel's original experiment. Students explore plant reproduction and the expression of dominant and recessive traits in organisms.

Prior Knowledge:

Students need no specific prior knowledge.

Standards Alignment:

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.
LS3.A: Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.
LS3.B: 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.

Materials for Lesson Plan:

- PowerPoint deck
- Computer with Internet and projector
- Clothespins (56 for 4 groups of students; 112 for 8 groups of students)
- Small paper bags (4 or 8 lunch size bags)
- Labels for bags
- Fine-point markers for labeling clothespins

- Rulers (one per group — for clipping clothespins onto, not for measuring)
- Copies of Genetics Lesson Worksheet
- Copies of Punnett Squares Worksheet
- Copies of Punnett Squares Reference Sheet
- 2 Punnett Square Templates, laminated

Download the PowerPoint deck in the Worksheets & Downloads section at the end of this lesson. The deck includes a link to the following video, which presents a brief but engaging introduction to the scientist, his discoveries and his legacy. It also covers key vocabulary words and concepts students will use in the Pea Plants & Punnett Squares activity that follows.

TedEd Video: How Mendel's Pea Plants Helped Us Understand Genetics

LESSON PLAN B

PEA PLANTS & PUNNETT SQUARES ACTIVITY

Overview:

After learning about Mendel's experiments with pea plants, students do a quick experiment of their own (no soil or seeds required!). They begin this activity in small groups and then pair up with others to breed their (mock) plants together. Then they work out the results using Punnett squares.

Teacher Preparation:

Print two copies of the basic 4-square Punnett Square Template (found at the end of this lesson). Laminate them if possible.

Organize the following materials in advance. These quantities are for four groups of students. If you wish to divide the class into eight smaller groups, then double the quantities of clothespins and bags.

- Write the following labels: Pea Shape, Cotyledon Color, Flower Color, Pod Shape, Pod Color, Flower Position and Stem Height.
- Stick the 7 labels on your 7 bags.
- Now label your 56 clothespins. Do this carefully, and then place them in their corresponding bags immediately so you don't get confused!
  - 8 in 'Pea Shape' bag; 4 labeled 'R', 4 labeled 'r'
  - 8 in 'Cotyledon Color' bag; 4 labeled 'Y', 4 labeled 'y'
  - 8 in 'Flower Color' bag; 4 labeled 'V', 4 labeled 'v' (underline the capital V to make it easy to distinguish the upper and lower case!)
  - 8 in 'Pod Shape' bag; 4 labeled 'I', 4 labeled 'i'
  - 8 in 'Pod Color' bag; 4 labeled 'G', 4 labeled 'g'
  - 8 in 'Flower Position' bag; 4 labeled 'A', 4 labeled 'a'
  - 8 in 'Stem Height' bag; 4 labeled 'T', 4 labeled 't'

Instructions:

Part 1: Passing Down Traits

1. Split the class into 4 groups. Distribute Genetics Lesson Worksheet and Punnett Squares Worksheet, one copy of each per person.
2. Explain the setup: There are 7 bags representing 7 different traits (e.g., color, shape, stem height) and that each bag contains two different kinds of alleles for that trait. Each group will take 2 clothespins from each bag, ending up with 14 clothespins total.
3. Have representatives from each group line up in front of the 7 bags you've prepared. Instruct them to take 2 clothespins from each bag, each group taking a total of 14. Students should pick the pins at random without looking at their labels.

4. Back in their small groups, the reps distribute the clothespins, passing out 2 alleles per person. Students should then pair each type of allele and clip them to their group's ruler with the letters facing out to show the genetic makeup of their pea plant. Then ask each group, "What's your pattern?" (Answer: "Our pea plant has the following traits: A round pea, a purple flower, a tall stem…" etc.)
5. Students should fill in the allele pair for each gene on their individual Genetics Lesson Worksheets. Then they should circle the traits expressed in their group's pea plant (the dominant or recessive expression of each gene) on Table 1. (Note that all students in a group will have the same answers on their sheets.)

Part 2: Acting It Out!

1. Now bring the science to life with some dramatic play. In this mini exercise, the teacher or one selected student "plays" Gregor Mendel, and pairs groups of students to breed their plants together. (Each pair of students must be of the same of trait, e.g. color.)
2. The groups come together with one of the laminated Punnett Square sheets and complete the Punnett Squares for each trait of the two plants' offspring.
3. Groups then calculate the probability that the dominant trait will be expressed in the offspring, and the probability that the recessive trait will be expressed in the offspring.
4. Students repeat this exercise for each trait until the worksheet is complete.
5. Then students copy these probabilities onto Table 2 on their individual worksheets.

Part 3: Playing Geneticist

1. Students complete the remaining questions on their individual worksheets.

Teacher Reference:

Video: A Beginner's Guide to Punnett Squares | Bozeman's Science
This is a very useful guide for teachers. We recommend reviewing it yourself to learn or reinforce your knowledge about Punnett squares, and then deciding if it's appropriate to share with your students, based on their grade and level of understanding. The video presents a number of examples of monohybrid crosses and one example of a dihybrid cross. It also addresses major misconceptions that students have when using a Punnett square.

Extensions:

Dihybrid Cross Punnett Squares | Next Gen Science Lesson Plans
Here are more advanced lessons from the NGSS exploring genetic probability with two traits. You may wish to use these to present more complex Punnett square activities with older students. Use the blank dihybrid cross templates if you like at the end of this lesson.

Dihybrid Cross Challenges (candy optional!)
See the "Optional Extensions" worksheets at the end of this lesson. Use the more complex squares to figure out probability with two traits, following the instructions on the two dihybrid templates. Optional: Use yellow and green Skittles or other candies to mark each square. Make small dots on candies with a fine-tip marker to indicated "wrinkled" peas.

Discussion Topics:

Plant Genetics In the Field
How did Mendel lay the groundwork for modern technology? Explore some of the latest advances in plant genetics through resources like this one from the Genetic Science Learning Center and discuss as a group.

A World of Cotton | Genetic Science Learning Center, University of Utah
Cotton growers are continually dealing with environmental challenges like drought and pests. Explore the content on this site to learn more about cotton, its wild ancestors, and some of the approaches scientists are using to study and improve cotton plants. You can also learn the basic approach researchers use for genome mapping, then use one of our models to try it yourself.

What are GMOs?

GMO stands for genetically modified organism. Genetically modified (GM) foods are made from soy, corn, or other crops grown from seeds with genetically engineered DNA. According to the U.S. Department of Agriculture (USDA), GM seeds are used to plant more than 90 percent of corn, soybeans and cotton grown in the United States. Scientists genetically engineer seeds for many reasons — for example, to make a plant more resistant to insects or herbicides or more tolerant to heat, cold or drought. They may also be engineered to have a longer shelf life or to have higher levels of specific nutrients.

Agricultural Biotechnology – FAQs | USDA

Pros and Cons of GMO Crop Farming | Oxford Research Encyclopedia

GMOs: Facts About Genetically Modified Food | Live Science

What is organic farming?

Organic farmers follow strict standards and use resources and methods like green manure, compost, biological pest control, and crop rotation to produce crops, livestock and poultry. Organic farming systems contribute to soil, crop and livestock nutrition, pest and weed management, and conservation of biological diversity. Per the USDA's National Organic Program, the use of genetically modified organisms (GMOs) is prohibited in organic products.

USDA Introduction to Organic Practices
https://www.ams.usda.gov/publications/content/introduction-organic-practices

Organic Farming | Encyclopedia Britannica
https://www.britannica.com/topic/organic-farming

More Lesson Plans and Activities:

Farming, Food & Heredity | USDA: National Agriculture in the Classroom
Students will apply their knowledge of heredity as they develop a breeding plan for a scenario in which they inherit a tomato farm that has been suffering from a blight fungus.

4-H Idea Starter: Discovering Genetics
This 4-H Project Idea Starter helps you learn some basic genetic terms and information, explore your family history, and pay attention to genetic influences. Discover how working with genes has led to healthier lives, and understand how farmers use genetics to grow better crops.

A Recipe for (Dog) Traits | Genetic Science Learning Center, U. of Utah
Students create and decode a "DNA recipe" for man's best friend to observe how variations in DNA lead to the inheritance of different traits.

Crazy Traits | Museum of Science and Industry – Chicago
Students will see how chance affects an organism's genetic make-up in this hands-on, minds-on activity about human traits.

Articles About Agricultural Biotechnology:

From Idea to Supermarket: The Process of Berry Breeding | USDA: Agricultural Research Service
How are berries bred? Read about the step-by-step procedure from a scientist at the Horticultural Crops Research Laboratory in Oregon. Read the shorter summary here:
What's the Difference Between a Strawberry and a Strawberry?

A 'Fitbit' for Plants? | Science Daily: American Society of Agronomy
Scientists are working to develop technology that makes phenotyping much easier. The Phenocart tool measures plant vital signs like growth rate and color, the same way a Fitbit monitors human health signals like blood pressure and physical activity.
Read more articles here: *Science Daily | Plant Breeding Articles*

Home Connection:

Family Traits Traditions and Trivia Games
This website from the Teach Genetics Center at the University of Utah provides take-home games using picture cards that identify traits. There's also a fun memory match game focused on inherited vs. learned/environmental traits.

Worksheets & Downloads:

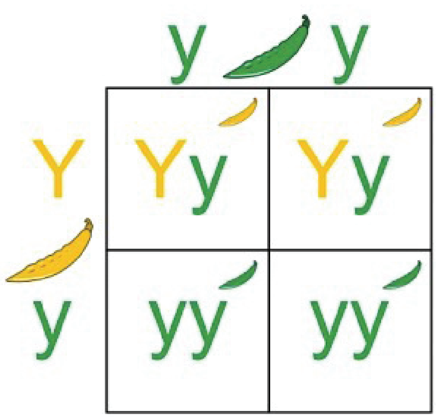
Student Reference Sheet

Gregor Mendel is considered the father of genetics. His experiments with garden pea plants in the 1800s were ground-breaking and we still study them today. By carefully experimenting with 22 kinds of pea plants over a decade, he figured out how genes are passed from generation to generation. This laid the foundation for the field of **genetics** and established the rules for **heredity**, also known as **Mendelian Inheritance**.

We now know that **genes** determine different physical **traits** (also called **phenotypes**) in all organisms. Genes are located in the **chromosomes** of the cell. All cells contain a pair of chromosomes — except for reproductive cells called **gametes**, which contain a single set of chromosomes (either male or female).

When plants sexually reproduce, two **gametes** fuse together to form a new pair of **chromosomes** with two copies of each **gene**. The two copies of the gene, known as **alleles**, can be the same or different from each other. If they are different, then they can produce different **traits** when bred together.

Some alleles override others. These are called **dominant** alleles, while **non-dominant** ones are called **recessive**. How can you tell which is which? The **dominant** allele is always represented by a **capital letter**, and the **recessive** allele is always represented by a **lowercase letter**.



Source: https://en.wikipedia.org/wiki/Punnett_square

In this example, the yellow allele is dominant (as shown by the capital '**Y**') and the green allele is recessive (as shown by the lowercase '**y**').

Recessive alleles can only manifest in offspring if both parents give recessive alleles to their offspring. The parents do not necessarily have to display the recessive trait but must have the allele in their genetic material. When an organism has one dominant allele and one recessive allele, it will display the dominant trait but can pass down the recessive allele. In this case, its offspring may display the recessive trait in future generations.

Why choose pea plants?

Mendel did his experiments on pea plants because it was easy to control the breeding of the plants. Pea plants naturally **self-pollinate**: The pollen from the male part of the flower, the anther, pollinates the female part of the same flower, the stigma. This means that the plant's offspring has genetic material from its parent and no other plant.

But, Mendel realized that he could also **cross-pollinate**: Taking pollen from one pea plant and using it to fertilize another pea plant. This would give the offspring two parents instead of one. Cross-pollination can also occur naturally, if birds or insects pollinate different plants.

Genotypes and phenotypes
Mendel studied seven different **phenotypes** (also called traits) in his pea plants: Pea Shape, Cotyledon Color, Flower Color, Pod Shape, Pod Color, Flower Position and Stem Height. He found that some traits were dominant in the plants' offspring and others were not. We now know that the phenotype of an organism is determined by the **genotype** of its parent organisms.

Advances moving forward
Mendel did not know about the genetic building blocks that produce the characteristics he observed in his garden. As we have made advances in the fields of biology and genetics, we now better understand how to produce favorable **phenotypes** in our plants and crops, as well as eliminate harmful **traits**. Today we can learn about **genes** and study their effects by analyzing the DNA of seeds, giving us more precision than ever and letting farmers and scientists make calculated decisions about how to breed crops. Being aware of the **genotypes** of plants, we have been able to make crops healthier, more productive and immune to destructive diseases.

Vocabulary

Alleles: (pronounced "al-eels") Different forms of the same gene. You inherit one allele for each gene from your father and one allele for each gene from your mother. The **dominant** allele is represented by a capital letter; the **recessive** allele is represented by a lowercase letter.

Chromosomes: X-shaped objects found in the nucleus of most cells. They consist of long strands of DNA. Humans have 23 pairs of chromosomes. Pea plants have 14 pairs of chromosomes.

Cotyledon: (pronounced with a long "e") The first leaves of a seedling. The number of cotyledons is one characteristic used to classify flowering plants (angiosperms). Species with one cotyledon are called monocots. Those with two are called dicots.

Dominant vs. Recessive: A dominant allele masks a recessive one. A dominant allele is expressed even if it is paired with a recessive allele. A recessive allele is only visible when paired with another recessive allele.

DNA: Complex molecules that carry the genetic code of a living thing. DNA stands for deoxyribonucleic acid.

Gametes: The reproductive cells of plants. Also referred to as sex cells. Unlike humans, plants produce both types of these cells.

Gene: A short section of DNA that has the genetic code for making a particular protein. Genes determine different physical traits (phenotypes) in all organisms. Genes are located in the chromosomes of the cell.

Genetics: The study of the patterns of inheritance of specific traits.

Genome: The entire set of DNA in an organism. All the genetic material in all the chromosomes of a particular organism.

Genotype: The genetic identity of an individual. Genotype often is evident by outward characteristics, but may also be reflected in more subtle biochemical ways not visually evident. Your genotype is the genetic code of your cells. This code is responsible for many of your traits.

Heterozygous: Having two different alleles for a trait (for example, **Rr**).

Homozygous: Having two identical alleles for a trait (for example, **RR** or **rr**).

Phenotype: What an organism looks like as a consequence of the interaction of its genotype and the environment. Same as trait (color of flower, eyes or fur, for example).

Genotype vs. Phenotype: Genotype is the genetic makeup (Bb, BB, bb); phenotype is the physical trait (color, shape or height, for example).

Heredity: The passing on of traits from parents to their offspring. Heredity is passed through genes in the DNA molecule. In biology, the study of heredity is called genetics.

Plant breeding: The use of cross-pollination, selection and certain other techniques involving crossing plants to produce varieties with particular desired characteristics (traits) that can be passed on to future plant generations.

Plant reproduction: Flowers are important for sexual reproduction by plants. They produce male sex cells and female sex cells. These must meet for reproduction to begin, a process called pollination.

Trait: Same as phenotype. Refers to a physical trait (color, shape or height, for example).

Genetics Student Worksheet

Table 1

	Student's Genotype	Dominant Trait	Recessive Trait
Pea Color		Round	Wrinkled
Cotyledon Color		Yellow	Green
Flower Color		Violet	White
Pod Shape		Inflated	Constricted
Pod Color		Green	Yellow
Flower Position		Axial	Terminal
Stem Height		Tall	Short

What do the clothespins represent in this exercise?

____

What dominant traits are expressed in your pea plant?

____

What recessive traits are expressed in your pea plant?

____

Table 2

	% Chance Offspring Will Express…	
	Dominant Trait	Recessive Trait
Pea Color		
Cotyledon Color		
Flower Color		
Pod Shape		
Pod Color		
Flower Position		
Stem Height		

Are there any traits the offspring of your two plants will definitely express?

Are there any traits the offspring of your two plants will definitely not express?

Genetics Student Worksheet (page 2)

Table 3

Plant A	Plant B	Plant C
T,t v,v	T,T V,v	t,t v,v

Note: The boxes above represent plants and the letters inside represent their genes.
Stem Height: T = Tall, t = Short / Flower Color: V = Violet, v = White

1. In order to get a plant with a tall stem 100% of the time, which two plants would you breed together?
2. In order to get a plant with white flowers 100% of the time, which two plants would you breed together?
3. In order to get a plant with white flowers 50% of the time, which two plants would you breed together?

Genetics Student Worksheet (Answer Key)

Table 1

1. What do the clothespins represent in this exercise? **[Alleles]**
2. What dominant traits are expressed in your pea plant? **[Any trait for which they had <u>one or more dominant alleles</u>; will depend on the student's experiment]**
3. What recessive traits are expressed in your pea plant? **[Any trait for which they have <u>two recessive alleles</u>; will depend on the student's experiment]**

Table 2

1. Are there any traits the offspring of your two plants will definitely have? **[Any trait where all four sections of the Punnett square show a single phenotype; will depend on the student's experiment]**
2. Are there any traits the offspring of your plant will definitely <u>not</u> have? **[Any trait where none of the four sections of the Punnett square show a certain phenotype; will depend on the student's experiment]**
3. Phenotype is the physical expression of what? [**The genotype**]

Question Three

Plant A	Plant B	Plant C
T,t v,v	T,T V,v	t,t v,v

The boxes above represent plants and the letters inside represent their genes.

1. In order to get a plant with a tall stem 100% of the time, which two plants would you breed together? **[Plant A and Plant B]**
2. In order to get a plant with white flowers 100% of the time, which two plants would you breed together? **[Plant A and Plant C]**
3. In order to get a plant with white flowers 50% of the time, which two plants would you breed together? **[Plant B and Plant A or C]**

Punnett Square Reference Sheet

	R	r
R	RR	Rr
r	Rr	rr

Punnett Squares Explained
A Punnett square shows all the possible combinations of alleles from a genetic cross. We use this to determine the probability that offspring will inherit a certain genotype.

The **dominant** allele is represented by a **capital letter**; the **recessive** allele is represented by a **lowercase letter**.

Homozygous: Having two identical alleles for a trait. (RR or rr)
Heterozygous: Having two different alleles for a trait. (Rr)

Punnett Square Types:
- Monohybrid Cross: Shows the cross of one trait (contains 4 squares).
- Dihybrid Cross: Shows the cross of two traits (contains 16 squares).

Punnett Square Template

Found on Pinterest: https://www.google.co.uk/search?q=punnett+square+template&rlz=1C5CHFA_enUS510US510&source=lnms&tbm=isch&sa=X&ved=0ahUKEwji_cuvtlbeAhVGdcAKHS5OAeQQ_AUIDigB&biw=1411&bih=780#imgrc=GYnQeHH9oUEYTM:

https://www.pinterest.com/pin/560064903644235356/?lp=true

Punnett Square Worksheet

Name: ______________________________ Date: ______________

Monohybrid Cross

Pea Color	
Notes	

Flower Color	
Notes	

Flower Color	
Notes	

Cotyledon Color	
Notes	

Pod Shape	
Notes	

Stem Height	
Notes	

Flower Position	
Notes	

Optional Extension: Show the Cross of Two Traits

Dihybrid Cross #1				
	______	______	______	______
______				
______				
______				
______				
Notes:				

Dihybrid Cross #2				
	______	______	______	______
______				
______				
______				
______				
Notes:				

Optional Extension

Cross: A pea plant that is heterozygous for round, yellow seeds. (Hint: Looking for the second parent? The term "heterozygous" is your clue.)

What percentage are round, yellow? ______ round, green? ______
What percentage are wrinkled, yellow? ______ wrinkled, green? _____

Cross: A pea plant with round, yellow seeds with one with wrinkled, green seeds.

What percentage are round, yellow? ______ round, green? ______
What percentage are wrinkled, yellow? ______ wrinkled, green? _____

Optional Extension: Answer Key

	RY	Ry	ry	rY
RY	RRYY round, yellow	RRYy round, yellow	RrYy round, yellow	RrYY round, yellow
Ry	RRYy round, yellow	RRyy round, green	Rryy round, green	RrYy round, yellow
ry	RrYy round, yellow	Rryy round, green	rryy wrinkled, green	rrYy wrinkled, yellow
rY	RrYY round, yellow	RrYy round, yellow	rrYy wrinkled, yellow	rrYY wrinkled, yellow

What percentage are round, yellow? **9/16** round, green? **3/16**
What percentage are wrinkled, yellow? **3/16** wrinkled, green? **1/16**

	RY	Ry	rY	ry
ry	RrYy round, yellow	Rryy round, green	rrYy wrinkled, yellow	rryy wrinkled, green
ry	RrYy round, yellow	Rryy round, green	rrYy wrinkled, yellow	Rryy wrinkled, green
ry	RrYy round, yellow	Rryy round, green	rrYy wrinkled, yellow	Rryy wrinkled, green
ry	RrYy round, yellow	Rryy round, green	rrYr wrinkled, yellow	Rryy wrinkled, green

What percentage are round, yellow? **1/4** round, green? **1/4**
What percentage are wrinkled, yellow? **1/4** wrinkled, green? **1/4**