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Patterns, Persistence & Predictability

Do you ever wonder how you were the only one in your family to get your grandmother's striking blue eyes or your great-grandfather's crooked nose? Well, you are not the first to wonder how you came to possess your traits. In fact, back in the mid 1800s, **Gregor Mendel**, an Austrian Monk, worked diligently, meticulously and persistently studying the characteristics of pea plants that were transferred from one generation to the next. Over the course of eight years, he studied almost 30,000 pea plants which greatly expanded the understanding of genetic inheritance before the knowledge of genes or DNA had yet to be discovered.

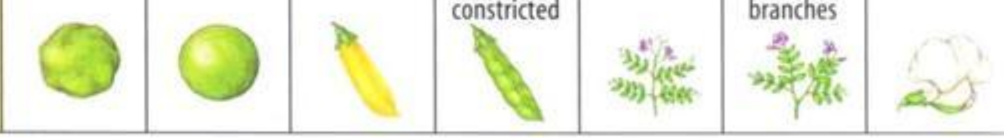
Mendel's observations led to a fundamental hypothesis that is the basis for our modern understanding of **genetics** (study of how genes are inherited) and how those genes are passed from parents to offspring called **heredity**. Before Mendel's research, most people thought an offspring's traits were the result of a "blending" of the traits from each parent. However, Mendel discovered each parent plant had two "factors" for each trait. Only one "factor" would be passed onto the offspring. This "factor" today is known as a gene.
Finally, Mendel noticed patterns of dominance and recessiveness within these "factors". Some of the traits would show up in the plants over and over no matter what he cross-bred them with and others tended to "hide". Mendel determined which traits in the plants were dominant or had the tendency to mask/hide their recessive partner (allele). In this activity, you will model Mendel's experiment to help you understand and then predict the outcome of a cross between parents. Your model will help you predict the genetic combination of traits (**genotype**) and the physical appearance of the offspring (**phenotype**).

Focus Questions

1. What is the difference between dominant and recessive traits?
2. How do you predict the possible genetic combinations and physical appearance of offspring?

To learn more about Mendel's research, below is a chart of all the traits he examined in the pea plants and the variations for each. Furthermore, the table identifies which Mendel discovered to be dominant and which he determined to be recessive after many generations of crossing them.

Table 1 Traits Compared by Mendel

Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Position of Flowers	Flower Color
Dominant trait 	Round	Yellow	Green	Full	Tall	At leaf junctions	Purple
Recessive trait 	Wrinkled	Green	Yellow	Flat, constricted	short	At tips of branches	White

Biologists refer to the outward physical appearance of the an organism as the **phenotype**. We discovered in the our introduction to traits in "Nature vs. Nurture" that the phenotype is determined by the presence of the dominant allele. If an organism receives one dominant allele and one recessive allele, then the organism is **hybrid** for the trait. If the organism inherits two of the same alleles (two dominant or two recessive), then the organism is **purebred** for that trait. The phenotype for the hybrid organism will always be the dominant trait and the phenotype for the purebred can only be dominant trait if it has 2 dominant alleles or recessive trait if has the two recessive alleles.

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Practice—To produce the parents plants for the cross you are about to simulate, a purebred dominant plant and a purebred recessive plant were crossed. The **parent plants in your cross are now hybrid for each of the five traits** we will examine.

1) Describe the phenotype (physical appearance) of each of the hybrid parents for the five traits:

Plant height—
Position of flower—
Flower color—
Pod color—
Pod shape—

2) Which two alleles (form of the gene) do the parent plants have for each trait?

Production of Offspring

Reminder*—a parent has a pair of genes and only one of this pair is passed to an offspring. There is an equal chance that either gene in the pair will be the one the offspring receives. Since the parents are hybrid, they can pass the dominant or the recessive for any of the 5 selected traits for this simulation.*

Procedure

Step 1 Count 20 cards. Spread all 20 cards on the table face up. There are two different colors…one to represent genes from one parent and one to represent genes from the other. Each offspring will only receive one gene from each parent for each trait.

Step 2 Sort the cards according to the 5 traits, so you have 5 distinct groups with 4 cards in each group. Turn the cards face down so the traits are not visible.

Step 3 One student randomly selects one card of each color from each trait group. The student should have 10 cards…5 of each color. These cards represent the pairs of genes for the five traits for one offspring of the cross. **The second student should NOT take the remaining cards.**

Step 4 Using the chart below, the student should record the number of genes for dominant and recessive genes selected for each trait (0, 1, 2) and return the cards back to their correct groups as shown in step 2. Make sure they are upside down and mix them up within their groups.

Step 5 Now the second student repeats steps 3 and 4.

Step 6 Carefully clean up your cards and make sure all 20 get returned to their bags.

Plant Trait	Dominant	# of Genes	Recessive	# of Genes	Phenotype of offspring
Height	Tall		Short		
Position of flowers	Side of stem		Tip of stem		
Flower color	Purple		White		
Pod color	Green		Yellow		
Pod shape	Full		Flat		

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Step 7 Determine the phenotype of your offspring for each trait and record it in the table above. Remember hybrid organisms will show a dominant trait and purebred organisms will show whatever trait they have both of.

Step 8 Sketch your offspring in the space provided and provide a key for traits.

Analysis

1) Observe several other sketches…do all the offspring show the same combination of traits? Why or why not—consider that they all came from the same exact parent plants?

2) Select one plant trait to observe on all sketches and record the ratio of dominant to recessive.

Name of the plant trait	_______________________
Number of plants with that dominant trait	_______________________
Number of plants with that recessive trait	_______________________
Ratio of dominant to recessive phenotype for this trait	___________ **:** ___________

3) In Mendel's research with his plant experiments, he observed a 3:1 ratio with hybrid parents, how does this ratio compare to the ratio you discovered for yours? What might account for the differences if any?

Application

1) Is it possible for an offspring to look different from its parent? Support your answer with results from the simulated cross you performed in this activity.

2) In sheep, white wool is dominant over black. Explain how it is possible for two white-woolen sheep to produce black-woolen offspring.

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Part 2

In the previous activity, you developed a model that simulated a cross between parents that were hybrid for five dominant traits and drew pictures to document the phenotypes of their offspring. In this activity, you are going to use a tool called a **Punnett Square** to predict not only the phenotype but also the **genotype**, or actual genetic makeup (expressed using 2 letters), of the offspring of cross between parents with known genotypes. This convenient method for predicting probable ratios of phenotypes and genotypes was developed by British geneticist, Reginald Punnett, and shows all the gene combinations for an offspring when the parent genotypes are known.

Using Punnett Squares

The Punnett Square below shows the possible allele combinations for an offspring of one parent with two dominant alleles for height, which we would say has a **homozygous** dominant genotype and represent with two capital letters (TT), and one parent with two different alleles for height, which we would say is **heterozygous** and represent with a capital and lowercase letter (Tt). *(*what might the genotype for **homozygous recessive** be? _______)*

	Parent #1 Alleles	
Parent #2 Alleles	Possible offspring gene combination	Possible offspring gene combination
	Possible offspring gene combination	Possible offspring gene combination

	T	**T**
T	**TT**	**TT**
t	**Tt**	**Tt**

Example: T= Tall t= short
TT X Tt

Predicted Results of This Cross

Phenotypic ratio: 4 tall to 0 short (4:0)
Genotypic ratio: 2TT: 2Tt: 0tt (2:2:0)
Probability of producing tall offspring: 100%
Probability of producing short offspring: 0%

Prediction

Now you try! In corn, the ability to produce chlorophyll is dominant and the inability to produce chlorophyll is a genetic **mutation** and a recessive trait. On occasion there is some environmental, natural or random factor that may cause a permanent change in the gene or chromosome that can be passed from generation to generation then a mutation occurs. Mutations can be harmful, helpful or have no effect on the organism at all. In the case of the corn, at some point there was a mutation in a reproductive cell that carried the gene for making chlorophyll. Since chlorophyll traps the sunlight needed to help the plant make its food, a seed that inherits two recessive alleles will grow into a colorless (albino) plant unable to make food and survive long term. Complete the Punnett Square to determine the probability of the phenotypes that can be produced from the cross of two heterozygous (Gg) green plants.

G=______________

g= ______________

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Phenotypic ratio: ____________

Genotypic ratio: ____________

If you were to plant 12 seeds, how many plants do you predict will be green? _____

If you were a farmer, which of type of corn plant, albino or normal green, would you choose to grow for their desirable traits? Explain your answer.

Practice: Always following the six steps you have been giving to solve Punnett Squares…solve the following genetics problems and show all your steps.

1) Green (G) is the dominant color for pea pods. Yellow (g) is the recessive color. Use a Punnett Square to show the cross between a pure green pea pod plant and a hybrid green pea pod plant.

a) What are the possible phenotypes for the offspring?

b) What are the possible genotypes?

c) If 100 seeds are produced when the parent plants are crossed and all of them sprout and grow, about how many of them will produce green pea pods?

2) In cabbage butterflies, White wings are dominant to yellow wings. If a heterozygous butterfly is crossed with a homozygous recessive butterfly?

a) What are the possible phenotypes of their offspring?

b) What are the possible genotypes?

c) If there are 800 offspring, how many do you predict will have yellow wings?

3) In dogs, there is a hereditary type of deafness caused by a recessive gene. Two dogs who carry the gene for deafness but have normal hearing are mated.

a) What are the possible phenotypes of their offspring?

b) What are the possible genotypes?

c) What percent of a litter of 8 will be deaf?

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4) The gene for purple pea plant flowers is dominant over the gene for white flowers. What are the phenotypic and genotypic ratios expected from a cross between two hybrid pea plants?

a) If there are 800 offspring, how many do you predict will have purple flowers?

b) Pick two offspring from the cross above and show what the genotypic and phenotypic ratios would be for your F2 generations.

5) In guinea pigs, short hair is dominant over long hair. Consider the results of a cross between a guinea pig that has a homozygous genotype for short hair and a guinea pig that has a heterozygous genotype for short hair.

a) What is the probability that a baby guinea pig born to these parents will have long hair?

b) What are all the possible genotypes that could result from this cross?

6) White coat is dominant over black in sheep. What are the possible colors of the offspring if a purebred black sheep is crossed with a purebred white sheep?

a) What must be the phenotypes of the parents if a sheep farmer wants to have all black baby sheep? Use a Punnett Square to defend your answer.

b) A sheep farmer learned that if he always used his purebred white ram (male) in a cross, it did not matter what color the ewe (female) was; the offspring would always be white. Use Punnett Squares to show all possible crosses and tell why the offspring were always white.