DARWIN 2009
Exploration is Never Extinct

Family Trees
Classroom Experience
grades 4-12

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Lesson Plan by **Brinley Kantorski, Kylie LaSota,** and **Allison Pogue**
Layout Design by **Kevin Miller**

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Produced by Regenerative Medicine Parnership for Education
Duquesne University
Director **John A. Pollock** - pollock@duq.edu
Art Director **Joana Ricou** - jiricou@gmail.com

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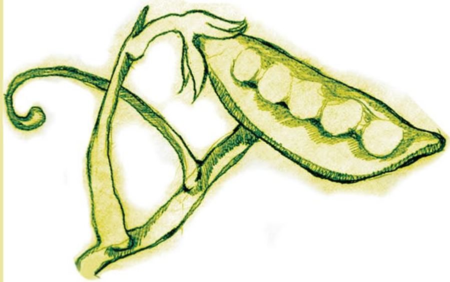


Introduction

Family Trees

for all grades

DARWIN 2009

Exploration is Never Extinct

This lesson plan was developed as part of the "Darwin 2009: Exploration is Never Extinct" initiative in Pittsburgh. Darwin2009 includes a suite of lesson plans, multimedia, on-line resources and art. Find all information on-line at: **www.sepa.duq.edu/darwin.**

This lesson plan was originally developed for the Phipps Conservatory in Pittsburgh, PA.

Special Thanks to **Erin Melbert**, **Laura Micco, Sarah Presogna,** and **Marie Radebaugh.**

PHIPPS

Time of Lesson:

Introduction 40-50 minutes
Activity 30 minutes
Wrap-up 40-50 minutes

Goals

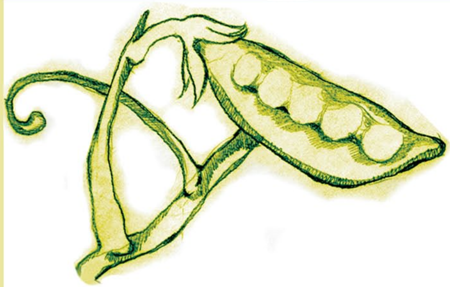
1. The students will understand the basic principles of genetic inheritance.
2. The students will learn about flower reproduction, through self- and cross-fertilization.
3. The students will become familiar with three very influential scientists: Charles Darwin, Gregor Mendel, and Reginald Punnett.
4. For advanced students, basic genetics and Punnett squares will be introduced.

Learning Objectives

1. Students will be able to distinguish the difference between self- and cross-fertilization in flowers.
2. Students will be able to identify the contributions of Darwin, Mendel, and Punnett.
3. Advanced students will be able to define the main concepts of genetics, as well as discover a basic understanding of dominance.
4. Advanced students will be able to complete Punnet squares for various combinations of parents and offspring.

Materials, Resources, and Preparation

1. Diagram of plant reproduction *(page 4)*
2. Copies of "Darwin, Mendel and Punnett.doc" *(separate document)*
3. Print out "SelfCrossFert.pdf" *(separate document, preferably laminated)*
4. Paper/Pencils/Crayons or Markers
5. Clear Cups
6. Food Coloring (yellow)
7. Permanent Marker
8. Water and Pitchers
9. Bucket for waste water
10. Materials as needed for each chosen activity



Teacher Pages

Family Trees

for all grades

Vocabulary

1. **Naturalist** – A scientist who studies nature through observation. Charles Darwin is a famous naturalist.
2. **Variation** – Differences between individuals of a species.
3. **Inheritance**- The passing of genetic traits from parent to offspring.
4. **Fertilization** - Known as flower reproduction, the pollen from a flower's anther is transferred to the stigma of either the same flower or a different flower.
5. **Self-fertilization** – A form of plant reproduction where the pollen from a flower is transferred to the stigma of the same flower.
6. **Cross-fertilization** - A form of plant reproduction where the pollen from a flower is transferred to the stigma of a different flower.
7. **Trait** - A characteristic; in a biological context, it usually refers to an organism or species (Ex: eye color, hair color, hair texture, etc.).
8. **Laws of Inheritance** - Mendel's discoveries about how genetic traits are passed from the parents to their offspring.
9. **Asexual Reproduction** - Involves only one parent.

Overview

Mendel's Contribution to Inheritance

One famous scientist, Gregor Mendel, performed experiments with self-fertilization and cross-fertilization of pea plants in an attempt to understand the mechanisms of inheritance. Mendel hypothesized about what the offspring of various pea plants would look like. From these experiments, he discovered the "Laws of Inheritance." The Laws of Inheritance state that traits of the parents are passed to their offspring. Mendel's discoveries provide the basis for all ideas surrounding modern genetics.

Inheritance

Have you ever noticed that everyone looks like a combination of characteristics from both of their parents? In fact, when observing others, one can note that all life forms reproduce and create children that look like their parents. In reproduction, children, called offspring, receive all of their traits from their parents. This is defined as inheritance. Hair color, eye color, and hair texture are examples of traits that are inherited.

For All Students:

"Family Trees" explains the basic inheritance and reproduction principles of plants.

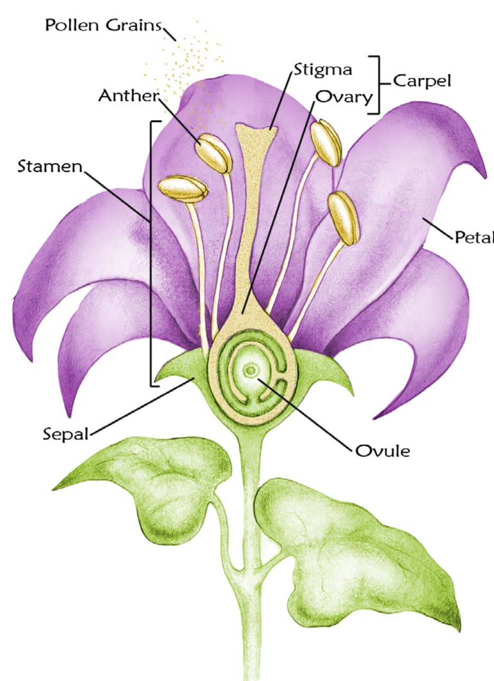
Charles Darwin

Charles Darwin, a naturalist who studied plants, performed experiments with self-fertilization and cross-fertilization like Mendel. Darwin concluded that **cross-fertilization allows for greater genetic variation by introducing more genes into the gene pool.** Genes are parts of DNA that produce specific characteristics, or traits. This means that because two parents are contributing their genes to the new offspring, there are essentially more genes to "pick from" for the offspring's genome. Offspring can have a new combination of the parents' genes. For example, the offspring of a small white cat and a big black cat might be small and black. A genome is the organism's collection of genes. The genome of the offspring will be a new combination of the parents' genomes.

Darwin wrote about variation in his most famous publication, *On the Origin of Species*. Although he was unaware of how variation arose, he knew it was a key component of the process of evolution by natural selection.

Angiosperm Reproduction and Inheritance

Flowering plants, such as daisies and roses, are known as angiosperms. They can reproduce, and thus pass traits on to their offspring, in two ways: self-fertilization and cross-fertilization. Self-fertilization is asexual reproduction where a single plant can create offspring, while cross-fertilization requires a partner of the same species. Self-fertilization is defined as the transfer of pollen from the anther of one flower to the stigma of the same flower. Cross-fertilization is the transfer of pollen from the anther of one flower to the stigma of a different flower. Self-fertilization produces offspring that look identical to the parent, while cross-fertilization produces offspring that look like a combination of the traits from both parents.

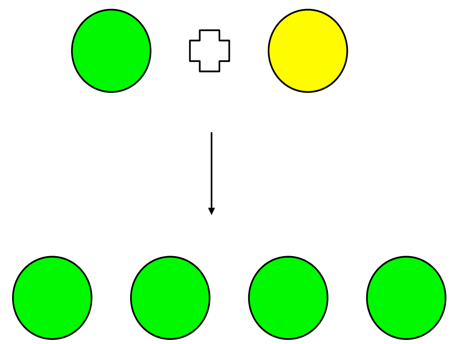


The reproductive organs of a flowering plant.

Mendelian Genetics

Like mentioned before, Mendel experimented with reproducing plants to try to understand inheritance. In one famous experiment, Mendel predicted that crossing a pea plant with a green pod with a pea plant with a yellow pod would produce a plant with a yellow-green pod, as the characteristics of each parent would blend together to form the offspring. However, he was very surprised to find that all of the pea plants in the next generation (F1) had green pods.

Parent Generation:
One green pod x One yellow pod

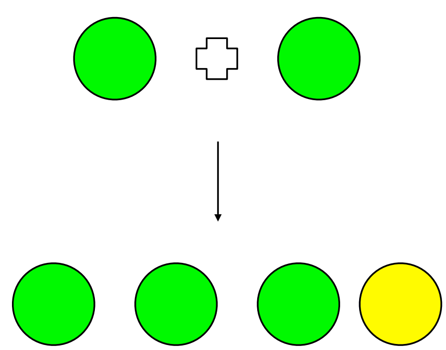


Offspring Generation 1:
All green pods

Example 1. Crossing a yellow and a green pod.

After performing more crosses with the offspring of the original generation, he was even more surprised to see the pea plant with yellow pods reappear in the second generation of offspring (F2).

New Parent Generation (Offspring Generation 1)
One green pod x One green pod



Offspring Generation 2:
Green and yellow pods

Example 2. Crossing the offspring of a yellow and a green pod.

for grades 8-12

Why did this occur?

Although he was unaware of how monumental his results truly were, Mendel had discovered one mechanism of inheritance: dominance. In Mendel's laws of inheritance, he explains that each parent plant passes on a "factor" to their offspring. Mendel discovered that there are two "factors," called alleles, which correspond with each trait. Alleles are alternate forms of a gene. So every plant would have two alleles for the gene that determines their color. In reproduction, each parent plant passes on one of its alleles, so the offspring receives one allele from each parent, totalling two.

The offspring received a green and a yellow allele - so why did it have only a green color? Mendel discovered that the allele that codes for the green seed color was dominant over the allele for the yellow color, so the first generation of offspring all had green pods. If an allele is **dominant**, this means that it hides the other allele - the **recessive** allele.

In the second crossing, the new green plants produced both green and yellow pods! This let Mendel confirm that both of the new green pods had at least one recessive allele, which was passed to the later generation and reappeared.

Genotypes

Combinations, or sets, of alleles are called genotypes. "Aa" and "Bb" are examples of genotypes where "A", "a", "B", and "b" are the alleles. In most cases, capital letters represent dominant alleles, while lower-case letters represent recessive alleles. In this example, "A" and "B" are dominant alleles and "a" and "b" are the respective recessive alleles. Genotypes are **homozygous** if both alleles present are the same: "AA" or "aa." When two dominant alleles are present, the trait will be influenced by the dominant allele; when two recessive alleles are present, the trait will be influenced by the recessive allele only. Genotypes are **heterozygous** if each allele is different: "Aa" or "Bb." Heterozygous genotypes contain one dominant and one recessive allele. In this case, the dominant allele will have the influence over the trait, while the recessive allele is "masked" or "hidden."

It is important to note that most traits are determined by multiple genes working together and by the environment. Those examples will not be discussed here.

Phenotypes

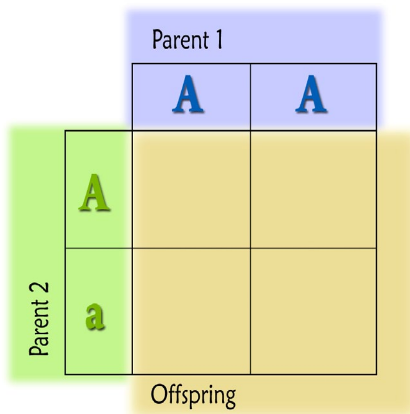
Genotypes can be used to speculate about the physical appearance of the individual. A phenotype is the physical appearance of the trait. For example, if the dominant allele "A" indicates "straight plant stems" and the recessive allele "a" indicates "curly plant stems" one possible genotype could be "Aa." Remember that "Aa" is heterozygous. One could assume that from this genotype, the phenotype would be a straight stem since "A" is dominant over "a." This means that the dominant allele "A" has masked the recessive allele "a." If the genotype is homozygous recessive ("aa"), the phenotype would be a curly stem, because no dominant allele is present to mask the recessive allele "a."

for grades 8-12

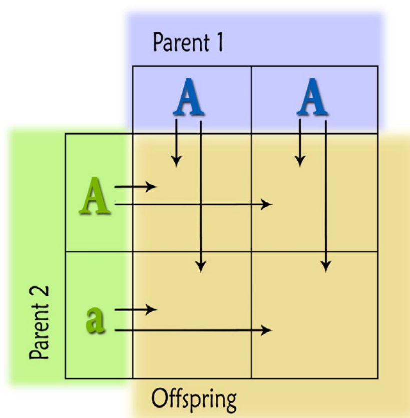
Punnett Square

As previously mentioned, Gregor Mendel studied the inheritance of traits between parent pea plants and their offspring. While Mendel made his own charts when performing his experiments, Reginald Punnett created the Punnett square. What is a Punnet square and why is it so important? The Punnet square helps predict the ratio of genotypes of the offspring based on the genotypes of the parents. Below is a simple Punnett square:

1. The genotype of each parent is listed along the top and the side of the Punnett square.
2. Because each parent genotype contains two alleles, one allele is placed into each of the boxes directly below or beside it.

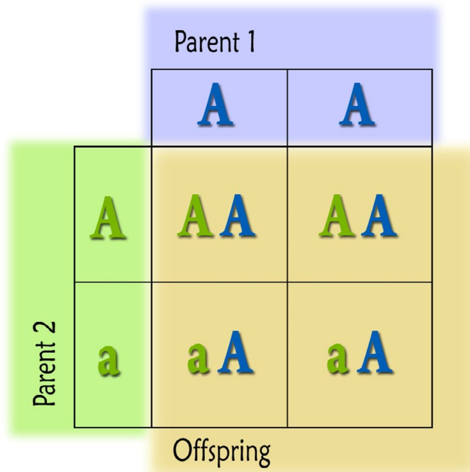


3. Copy the parent allele down, or across, the respective row or column.



for grades 8-12

4. This movement results in two alleles per box. These allele combinations are the possible genotypes for the offspring.



But, remember that Punnet squares do not predict physical traits. We can speculate on the associated phenotypes - but most traits are actually determined by many genes working together and by environmental conditions.

for grades 8-12

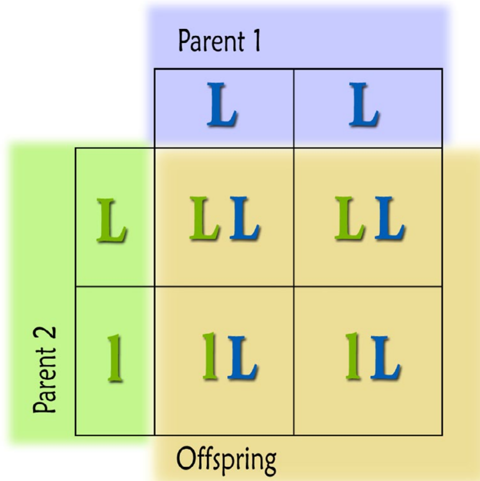
Example 1

Punnett squares are used to predict the genotypes of the offspring. From these genotypic ratios, the phenotypic ratios of the offspring can be speculated. Consider the following situation:

Parents: LL x Ll

L = Straight leaf veins, l = Wavy leaf veins

Answer:



Offspring (F1):

Genotypic Ratios: ½ LL, ½ Ll

Phenotypic Ratios: All straight veins (4/4)

What happened?

Even though the genotypes of the offspring vary (half are homozygous dominant and half are heterozygous), the phenotypes of all of the offspring are likely to all have straight veins since L is dominant over l.

for grades 8-12

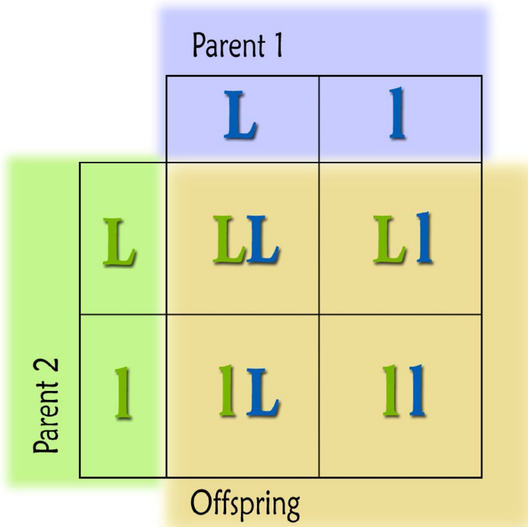
Example 2

Consider this situation:

Parents: LL x Ll

L = Straight leaf veins, l = Wavy leaf veins

Answer:



Offspring (F2):

Genotypic Ratios: ¼ LL; ½ Ll; ¼ ll

Phenotypic Ratio: ¾ straight leaf veins, ¼ wavy leaf veins

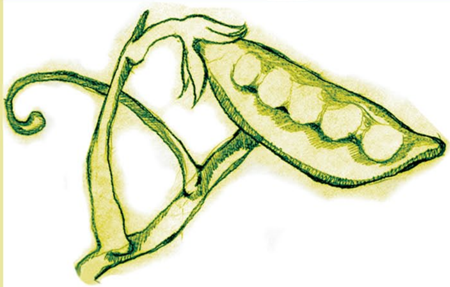
What happened?

Here, although none of the parents (F1 offspring from the previous Punnett square) have wavy leaf veins, the wavy leaf vein phenotype has reappeared in this generation of offspring (F2 generation). This is likely to happen 1/4 of the time when the offspring receives a recessive allele from each parent.

for grades 8-12

More Vocabulary

1. **Dominance**- Dominance is observed when an organism displays one trait (ie. brown fur) but has the genetic information for more than one trait (ie. also has genetic information for white fur). The dominant allele or phenotype masks the recessive allele or phenotype. Only the dominant trait is expressed.
2. **Recessive**- An organism will only express the trait of a recessive allele when it possesses two copies of the recessive allele. When the organism has a dominant allele and a recessive allele, the latter is hidden, and is therefore not expressed.
3. **Genotype**- The combination of alleles in an organism, usually used in reference to a specific gene or trait.
4. **Phenotypes**- The physical appearance of a trait in an organism. The phenotype results from a combination of factors, including the genotype and the environment.
5. **Gene**- Functional unit of inheritance which controls the physical appearance of a trait. Usually several genes contribute to defining a trait in an organism.
6. **Allele**- Every diploid organism has two forms, or alleles, for each gene- one inherited from each parent or, in the case of self-replicating plants, both inherited from the same parent. An allele can be dominant or recessive.
7. **Homozygous**- When an organism has two or more identical alleles in a gene that represent the same trait. In Biology, this is denoted by two of the same characters such as AA.
8. **Heterozygous**- When an organism has two or more different alleles in a gene that represent different traits. In Biology, this is denoted by two different characters, such as Aa.
9. **Punnett square**- Invented by Reginald Punnett, a chart used to predict the ratio of possible genotypes (allele combinations) for an offspring, based on the genotypes of the parents.
10. **Genome**- Made up of the various combinations of alleles, a genome contains an organism's heredity information (DNA).
11. **DNA**- Deoxyribonucleic Acid; DNA contains the instructions for an organism's development and characteristics.



Introduction
Family Trees
for all grades

Time: 40-50 minutes

Materials:

- diagram of flowering plant

Discussion

1. Ask your students what they know about flowers and how they reproduce.
2. Ask about the role of seeds. Ask about the role of fruit.
3. Tell students that they will be learning about two different ways that flowers reproduce.

Lecture

1. Use the diagram on page 4 to show students the parts of a flowered plant.
2. Define fertilization, self-fertilization, and cross-fertilization. Use the diagram to better explain these terms.
3. Explain that when organisms (plants, animals, humans, etc.) reproduce, traits are passed from the parents to their children.
4. This is called the "Law of Inheritance" and was established by a scientist named Gregor Mendel. Gregor Mendel worked with pea plant reproduction and inheritance of traits.

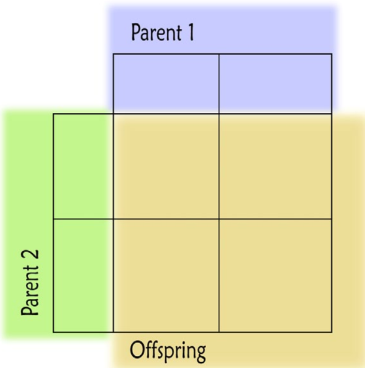
Discussion

1. Ask the students if they have ever heard of Charles Darwin. Explain that he was a naturalist, or someone who draws conclusions based on his observations of the world around him.
2. Tell students that later in the lesson plan and activity, they will become naturalists, like Charles Darwin. They will be able to observe what the offspring, or children, of parent plants will look like after undergoing both self fertilization and cross-fertilization.
3. Explain to the students that Charles Darwin studied self- and cross-fertilization of plants. He discovered that cross-fertilization leads to greater genetic variability. Explain that this means that cross-fertilization creates different combinations of traits in the offspring because DNA from two parents is passed along.

for grades 8-12

Note:

Punnett squares use the genotype of the parents to predict the genotype of the offspring.



Lecture for Advanced Students

1. Tell the students that Gregor Mendel lived around the same time as Charles Darwin and studied genetics and heredity using pea plants.
2. Ask the students what they already know about genetics and the inheritance of traits.
3. Define the following terms: gene, allele, phenotype, genotype, homozygous and heterozygous.
4. Explain that Mendel made hereditary charts to experiment with self- and cross-fertilization across many generations of pea plants. He tracked the traits of the offspring in each generation and discovered the Laws of Inheritance.
5. Mendel experimented with crossing a green and a yellow plant. What do students think the offspring would look like? (Potential answers: green and yellow, or a blending of the two). Mendel expected the latter, but the offspring were all green. Ask your students to explain why.
6. After crossing multiple generations of green pea plant pods, Mendel eventually saw another yellow pea plant pod. Ask your students why. Draw or show example 2 from page 7 and explain the concept of recessive genes.
7. Explain to the students that Reginald Punnett developed the "Punnett Square" based on Mendel's Laws of Inheritance. These squares predict the genotypes of offspring based on the genotypes of the parents. These genotypes can then be used to predict possible phenotypes.
8. Explain that a genotype is the genetic make-up of a trait; a phenotype is the physical appearance that results from the genotype. Note that most traits are actually determined by many genes working together and by the environment in which the organism lives.
9. Explain that even though more factors influence the phenotype, one can speculate about the phenotype of a plant based on its genotype.

   Examples

   1. If "AA" is the genotype for homozygous dominant, where the allele "A" means straight hair, we can speculate that the phenotype is straight hair.
   2. If "Aa" is the genotype for heterozygous, where "A" means straight hair and "a" means curly hair, we can speculate that the resulting phenotype is straight hair. This is due to the dominance of "A" over "a."

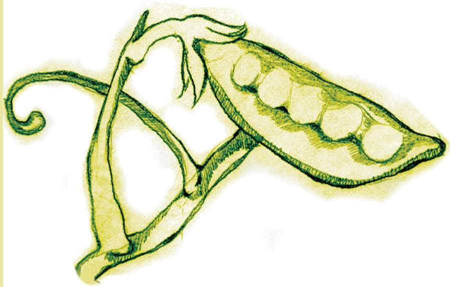
Activity

1. Show the students a simple Punnett square and ask them to predict the genotypes and phenotypes of the offspring.
2. Perform sample Punnett square examples with the class.

for grades 8-12

Reflection

Tell the students that later in this lesson and activity, they will be using a combination of Darwin's studies about plant reproduction and Mendel's methods for genetics to observe and predict what the offspring of various plant parents will look like.



Activities
Family Trees

Food Coloring Activity for all grades

Time: 30 minutes

Materials:

- see "Materials, Resources, and Preparation" on page 2

Set-up

1. Prepare one pitcher of water dyed yellow.
2. Prepare one pitcher of clear water (un-dyed).
3. Label 2 cups "Plant A."
4. Label 2 cups "Plant B."
5. Label 1 cup "Offspring from Self-Fertilization of Plant A."
6. Label 1 cup "Offspring from Self-Fertilization of Plant B."
7. Label 2 cups "Offspring from Cross-Fertilization of Plants A and B"
8. Place print out of "SelfCrossFert.pdf" - use this mat as you do examples of self- or cross-fertilization below.
9. Place two cups of water on the table. Cup 1, previously labeled as Plant A, has yellow water; Cup 2, previously labeled as Plant B, has clean water and is considered "white."
10. Place "Offspring of Self-Fertilization of Plant A" and "Offspring of Cross-Fertilization of Plants A and B" on the table.

Activity

1. Begin by asking the student: "In what ways do you look like your parents?" "Do you know why you share this characteristic?"
   a. Explain **inheritance**; Inheritance occurs when traits are passed from parents to offspring. Some traits are dominant over others, which can explain why you look more like one of your parents than the other! Traits are essentially made up of DNA; DNA (Deoxyribonucleic Acid) contains all of the instructions for an organism's development and characteristics.
   b. While talking, perform a general example:
      - Identify two cups as "parents" – Plant A and Plant B. Pour clear water into one and yellow water into the other.
      - Mix a cup of yellow water and a cup of clear water into a third cup (previously empty). Explain how the "offspring" now has DNA from both parents.
2. Ask if the students know how plants reproduce. Explain that there are some similarities and differences between plant reproduction and human reproductions.
   - How is the reproduction of plants and humans similar? *Plants, like people, also have parents.*

Food Coloring Activity for all grades (cont.)

- Ask "How do you think they are different?" *Plants have many methods of reproduction – for example, they can either have one parent or two parents.*

3. Using the image on page 4, discuss flower reproduction in more detail. Explain to the students that genetic information is found in the pollen. In this experiment, the water represents the pollen and therefore, "contains the genetic information."

   Explain briefly that plants can reproduce with each other (sexual reproduction and cross-fertilization) or by themselves (asexual reproduction and self-fertilization).

4. What do you think will happen when a plant reproduces with itself? *This is self-fertilization. Self-fertilization is when the pollen from a flower is transferred to the stigma of the same flower.*

   a. **Demonstrate self-fertilization:** (or ask for a volunteer to help you)

      - Identify the "parent" cup as Plant A.
      - Pour 1/3 of the water from the Plant A cup into the empty cup labeled "Offspring of Self-Fertilization of Plant A"
      - Pour 1/3 of the water from the cup labeled Plant A into the same cup. This means that you will essentially be pouring 2/3 of the water from the Plant A cup.
      - Ask the students to compare the offspring to Plant A: lead the students to understand that the offspring looks just like Plant A because it has the same genetic material.
      - "Offspring of Self-fertilization" will be now be yellow to show that the offspring of a flower that undergoes self-fertilization has the same phenotypes as its one parent.

   b. **Repeat this experiment** with the water in the white cup, labeled Plant B, in order to compare the offspring of self-fertilization from Plant A with Plant B.

      - Pour 1/3 of the water from the Plant B cup into the empty cup labeled "Offspring of Self-Fertilization of Plant B." Pour 1/3 of the water from the Plant B cup into the same cup. "Offspring of Self-Fertilization of Plant B" will now be clear.

   c. **Discuss** what happened in each situation.

      - Redefine inheritance as the process of passing traits from a generation to the next, from the parent passed on to the child.
      - In self-fertilization, the child received all DNA from the parent, so the resulting "plant" (cup of water) looks like the parent "plant."
      - Ask the students what the water stands for? *Genetic information or DNA.*

Food Coloring Activity for all grades (cont.)

Note:

For older students, use the Punnett squares during this segment to help explain the conclusions!

5. Cross-fertilization is when the pollen from a flower is transferred to the stigma of a different flower. These offspring will therefore have DNA from both parents and often exhibit traits from both.

   a. Demonstrate cross-fertilization: (or ask for a volunteer to help you)

      - Ask "what do you think the offspring of **both** of these parents will look like?" *The student will most likely assume that the colors will blend together to produce a lighter yellow color. Since the importance of this exercise is to show that one trait (yellow) is dominant over another trait (white), the yellow drop of food coloring already placed in the bottom of the cup will help the students to understand that these traits do NOT blend. The extra food coloring will help the "offspring" to show more yellow than white. Additionally, you could pour more of the yellow parent into the offspring cup, to achieve a more yellow color.*
      - Identify the parent cups "Plant A" and "Plant B" and the offspring cup labeled "Offspring of Cross-Fertilization of Plants A and B."
      - Pour 1/3 of the water from Plant A into the empty cup labeled "Offspring of Cross-Fertilization of Plants A and B."
      - Pour 1/3 of the water from Plant B into the same cup labeled "Offspring of Cross-Fertilization of Plants A and B."

   b. "Offspring of Cross-Fertilization of Plants A and B" will now contain yellow water, just as the "Offspring of Self-Fertilization of Plant A" does.

   c. ***What happened?*** *Inheritance has occurred here: the offspring has received characteristics from both parents.*

      How is this different from self-fertilization? *Plant received genetic material from both parents.*

      Why is the offspring plant yellow? *Only the characteristics from one parent can be seen; this is called dominance. Here, blending did not occur. In cases of dominance, some traits are dominant over others - this helps to explain why you look more like one of your parents than the other!*

      Does the offspring plant have genetic information for the clear color? *Yes, and it can be passed on to the next generation. It is just hidden.*

6. **Discuss:** What do you think would be the offspring of two plants where one is white and short, and the other is tall and yellow? *The offspring could be white and tall or short and yellow, etc.*

   Conclude that in sexual reproduction, the traits of the parents are combined in new ways.

7. Ask your students if they can think of any advantage of using sexual reproduction instead of asexual? *Cross-fertilization leads to greater genetic variability, by introducing more genes into the gene pool. The offspring will have a new combination of their parents' genes. In fact,*

Food Coloring Activity for all grades (cont.)

some flowers have mechanisms to prevent self-fertilization, in order to increase their genetic variation.

9. **Explain:**

- Charles Darwin was a naturalist that studied plants. He was amazed at the variation he found within species and between species. This was one of the clues that led him to propose the principle of evolution. In his time, no one actually knew the methods of flower reproduction. Gregor Mendel finally figured out the Laws of Inheritance, which were observed today.
- Charles Darwin studied self- and cross-fertilization and realized that cross-fertilization allows the creation of new combinations of traits which may make the new individuals more fit to their environment. A fitter plant will reproduce more, propagating its DNA to the next generation - over time then, cross-fertilization propels evolution!
- Darwin also knew that for evolution to occur, traits were passed between generations, but he didn't know how! Now we know that DNA is passed between parents and offspring and that DNA determines physical characteristics or traits.

Plant Pyramids Activity for grades 4-7

Time: 30 minutes

Materials:

- 12 potted flowering plants of two distinct colors (can be live or fake)
- diagram of plant reproduction *(page 6)*
- copies of "Darwin, Mendel and Punnett.doc" *(separate document)*
- print out "SelfCrossFert.pdf" *(separate document, preferably laminated)*

Suggestions for creating Plant Pyramids

- Plant two different colors of flowers in the pattern explained above.

- Teach the students about plant-care and allow them to help you plant these flowers.

- Buy artificial flowers and place them in small plastic cups or vases.

- Make flowers out of tissue paper and place them in small plastic cups or vases.

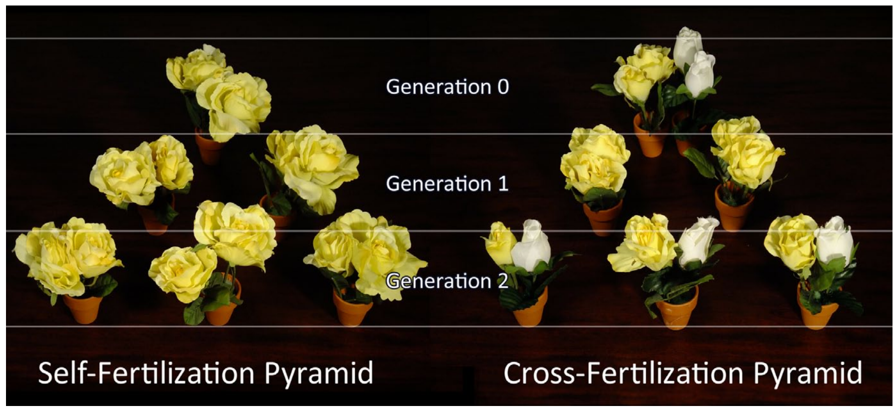
- Make a drawing or diagram of these pyramids and hang them on the chalkboard or wall.

Requirements for Plant Pyramids

- The top tier represents the "original parents," the second tier represents the offspring of the first, and the third represent the offspring of the second.
- Remember to represent at least four flowers on tier 2 and 3, to maintain genetic ratios.
- On the cross-fertilization pyramid, you will need at least one white and one purple flower on the top tier, multiples of four purple flowers on the second, and multiples of a set of three purple flowers and one white flower for the third.

Set-Up

1. To prepare for this activity, at least two Plant Pyramids must be used. Each pyramid will illustrate self- and cross-fertilization. See image below for what they should look like. See side bar for suggestions on creating them.
2. Any colored flowers can be used. Be sure to choose two colors and adjust the lesson plan for the colors used.



You will need at least two pyramids. The examples above represent a "pyramid" of generations of flowers where self-fertilization occurs (left), and where cross-fertilization occurs (right). Optionally, create also a third pyramid with all white flowers to represent self-fertilization of white flowers.

Discussion

1. Show the students the plant pyramids.
2. Tell them to observe the two or three plant pyramid displays and that two types of reproduction are represented. Help students understand that each level of the pyramid represents a generation. The plants on the top are the parents of the plants in the middle, who are the parents of the plants on the bottom.
3. Encourage students to pretend they are naturalists and scientists like Darwin and Mendel.
4. Review plant reproduction, using the appropriate signs (see Materials, on the left).
5. Ask the students:
   - Which pyramid shows self-fertilization?
   - Which pyramid shows cross-fertilization?
   - In these pyramids, what characteristics are shared by offspring and their parents?

Plant Pyramids Activity for grades 4-7 (cont.)

6. Reiterate that inheritance is the passing of characteristics, or traits, from parents to their offspring.
7. In case the students are confused, explain:
   - Pyramid 1: Shows self-fertilization; the offspring all look like the parent.
   - Pyramid 2: Shows cross-fertilization; white and purple flowers reproduce creating only purple flowers. But this generation of purple flowers can produce purple and white flowers.
8. Ask the students to identify which pyramid causes more variation in the offspring generations. Encourage your students to speculate why there is more variation in cross-fertilization than self-fertilization.

   Cross-fertilization; In self-fertilization, the offspring will inherit all of its traits from the parent, so all offspring are very similar. In cross-fertilization, the offspring combine traits from the two parents, resulting in more varied plants.
9. Ask: Why does cross-fertilization of purple and white flowers create only purple flowers? Explain that there is no blending, but some traits are dominant over other traits. Here, the purple color is dominant over the white color. This explains why a cross between a white and a purple parent produces all purple offspring in the first generation.
10. Explain that Charles Darwin was a naturalist who studied plant fertilization. He concluded that variation, caused by cross-fertilization, is important for evolution.
11. Go through the “Guess the Offspring” (page 26) worksheet. Answer Key is on page 27.

Punnett Squares Activity for grades 8-12

Time: 30 minutes

Materials:

- flowering plants of two distinct colors
- space for planting (see “Suggestions for planting” below)

Suggestions for planting:

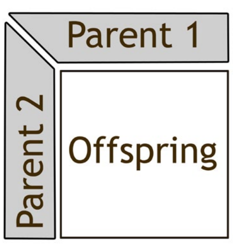
- Plant these flowers in a school-wide garden or greenhouse. Your students can help and learn about ecology and plant-care!

- Plant these flowers in small trays in your own classroom. Again, your student can help you!

- Use artificial flowers and “plant” them into Styrofoam blocks.

- Make paper flowers out of tissue paper and straws and “plant” them into Styrofoam blocks.

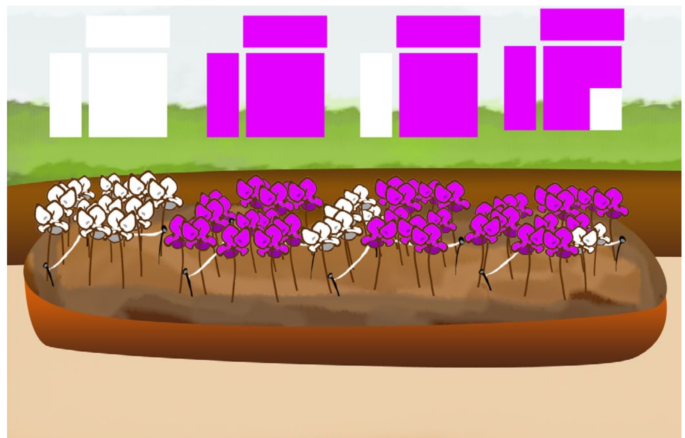
- Make a drawing or diagram of the Punnett Squares and hang it on the chalkboard for the students to see.



In this simplified Punnett square, we indicate only where the parents and the offspring of the particular cross can be found.

Set-Up

1. For this activity, you will need a Genetic Garden. Your garden should look like the image below indicates: a series of four Punnett squares, the first two representing self-fertilization of white and purple flowers, respectively, the third representing cross-fertilization between white and purple flowers, and the fourth representing self-fertilization of the offspring of the third square.
2. Any colored flowers can be used. Be sure to choose two colors and adjust the lesson plan for the colors used. In this representation, purple will be the dominant trait.



Although physically represented by flowers under “Parent 1,” “Parent 2” and “Offspring,” each section of the Punnett square actually represents the allele(s).

Genetic Garden in Phipps Conservatory in Pittsburgh, PA.

Punnett Squares Activity for grades 8-12

Activity

1. Remind the students that **alleles** and **genes** are fundamental pieces of inheritance. **Genotypes** are actual allele combinations that code for the genetic make-up of the **phenotype**.
2. Genotypes lead to phenotypes, or the physical appearance of the alleles. Keep in mind that other factors, in addition to the genotype, help make up the phenotype.
3. Reiterate that some alleles are **dominant** and some are **recessive**. The dominant allele is always expressed. The recessive allele is expressed when there are two homozygous recessive alleles, but it is masked, or "invisible," if paired with a dominant allele (heterozygous). This means that it is possible for the phenotype of a recessive allele to appear in later generations.
4. Tell students to study the flowers planted in the Punnett squares on the ground. The students should understand that the plants in the Punnett Squares actually represent the alleles that make up the genes of the plants. They are colored to show the phenotypes that these genes code for.
5. Ask students to explain what is happening in each Punnett square.

   1: White Parent + White Parent = All White Offspring

   2: Yellow Parent + Yellow Parent = All Yellow Offspring

   3: Yellow Parent + White Parent = All Yellow Offspring

   4: Yellow Parent + Yellow Parent = Some Yellow Offspring and Some White Offspring
6. Ask:
   - If the color of these flowers is controlled by only one gene and two alleles, where yellow is dominant, what are the possible combinations of alleles that produce a purple flower? (Yy or YY)
   - If the color of these flowers is controlled by only one gene and two alleles, where white is recessive, what are be the combination of alleles that produce a white flower? (ww)
7. Help the students create a Punnett square that represents the planted squares. Use the situations in the Genetic Garden working from left to right.
   - What are the possible genotypes for the parents of each Punnett square? What are the possible genotypes for the offspring plants?

     1: yy x yy = all yy - shows inheritance (white pyramid)

     2: YYx YY = all YY - shows inheritance

     3: YY x yy = all Yy - shows dominance

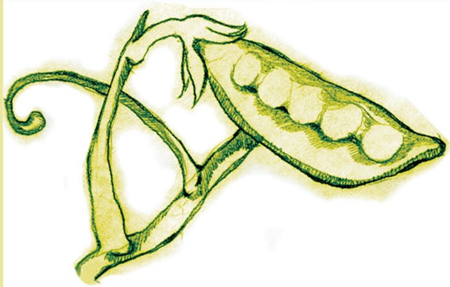
     4: Yy x Yy = ¼ YY, ½ Yy, ¼ yy - shows recessiveness vs. dominance
   - Encourage the students to explore other combinations:

     yy x yy

     Yy x YY

Punnett Squares Activity for grades 8-12 (cont.)

8. Ask the students to predict the phenotypes of the offspring.
9. Discuss the limitations of Punnett Squares:
   - These types of Punnett squares can only be used for predicting the genotypes and phenotypes of traits coded for by only two alleles and one gene. Most traits are more complex than two alleles.
   - Punnett squares do not account for mutations, crossing-over, etc. in the genome.
   - Environmental factors and other factors can affect the phenotype – it is not only determined by the genotype.



Post-Activity

Family Trees

for all grades

Time: 40-50 minutes

Materials

- Four uncolored flowers per student. Students can make their own or print out the file “flower.jpg” (page 28).

Discussion

1. Ask your students what they thought about this lesson.
2. Ask the students to define these terms in their own words: fertilization, self-fertilization, and cross-fertilization.
3. Ask students what they learned about Darwin.

Activity

Part 1

1. Pass out a picture of a flower to each student. The flowers should look exactly the same, except that they should be different colors - some repetition is ok.
2. Ask the students to look at their flower and draw what the offspring of this flower would be in the case of self-fertilization.
   - The offspring should look exactly like the parent (same color).

Part 2

1. Randomly group the students into pairs with another classmate.
2. Ask the students to compare the color of their flower with their partner’s. Ask them to draw what the offspring of these flowers would be in the case of cross-fertilization. Because blending does not occur, the students will have to choose one of their colors to be the dominant trait.
   - If the students have the same colored parent flowers, their offspring will look like both of their parents; the results should look like the case of self-fertilization.
   - If the students have different colored parent flowers, the students should make up their own rules of dominance for color. The offspring will look like the more dominant parent. In some cases, there might be more than one possible phenotype for the offspring, and the students should prepare as many flowers as needed.
   - **Optional:** If you provide four flowers per group of two students, students can display their results by making their own Genetic Garden. They will create four offspring flowers in the expected phenotypic ratio.
3. Have students present their offspring and explain how they made their decision.

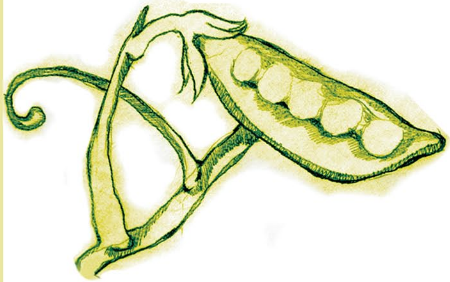
for grades 8-12

Additional Section

1. The groups of two students will work together to create a Punnett square for their pairing.
   - What is the genotypic ratio of the offspring?
   - What is the phenotypic ratio of the offspring?
   - Does the drawing make sense in connection with the Punnett square?

2. Ask the students to switch the dominant characteristic. They should make a different Punnett square that reflects this change.
   - What is the genotypic ratio of the offspring?
   - What is the phenotypic ratio of the offspring?

3. **Optional:** Tell the students to find another partner in the room and repeat this entire activity with another colored flower.



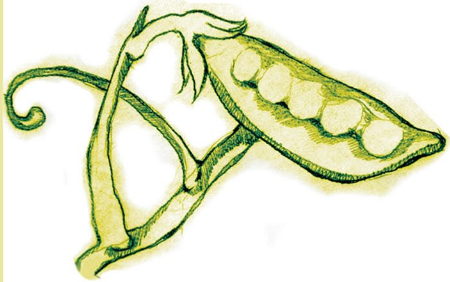
Worksheet

Family Trees

Name: ________________

Based on your observation of "Family Trees," what do you think happens during each situation of reproduction?

1.	 White			→	
2.	 Purple			→	
3.	 White	+	 White	→	
4.	 Purple	+	 Purple	→	
5.	 White	+	 Purple	→	



Answer Key
Family Trees

Based on your observation of “Family Trees,” what do you think happens during each situation of reproduction?

1.	White		→	Offspring will be a White flower. (Self-fertilization)
2.	Purple		→	Offspring will be a Purple flower. (Self-fertilization)
3.	White	+ White	→	Offspring will be a White flower.
4.	Purple	+ Purple	→	Offspring will be a Purple flower.
5.	White	+ Purple	→	OR Offspring could be a Purple flower or a White flower.

Family Trees