Family Trees
Classroom Experience
grades 4-12

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Introduction

Family Trees
for all grades

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
2. Cup of Purple Water
3. Cup of Clear Water
4. Two Empty Cups
5. Marker for Labeling
6. Flower Reproduction Story

A few things your students should already know:
1. A flower is a type of angiosperm in the plant kingdom.
2. DNA contains the genetic instructions for our characteristics and traits.
3. What reproduction is.
### Suggestions:
- Sign up for the “Family Trees” classroom experience to accompany this activity!
- Don’t forget to tour all of Phipps Conservatory!

### 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.

**Charles Darwin.**

Charles Darwin, a naturalist who studied plants, also performed experiments with self-fertilization and cross-fertilization. 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. A genome is the organism’s collection of genes. 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 natural selection.
For All Students:
“Family Trees,” in correlation with The Gallery plantings at Phipps Conservatory and Botanical Gardens, explains the basic inheritance and reproduction principles of plants.

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.

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, while cross-fertilization requires a partner of the same species. Self-fertilization is specifically 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.
For Older Students:
In addition to the content above, “Family Trees” also offers teachers and students the chance to study genetics and variation in more detail.

Mendelian Genetics.
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

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 1)
One green pod x One green pod

Offspring Generation 2:
Green and yellow pods
for all grades

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 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. Because the alleles that code for the green seed color were dominant over the recessive alleles for the yellow pod color, the first generation of offspring all had green pods. If an allele is dominant, this means that it hides the other allele. Mendel deduced that both of the original parents must have 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 lowercase letters represent recessive alleles. In this example, "A" and "B" are dominant alleles and "a" and "b" are 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 than in instances of more complicated genetics, there are exceptions to this rule. 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".

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Punnett Squares.

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,” a simple chart that is used to predict basic genetic ratios. Below is a simple Punnett square:

The genotype of each parent is listed along the top and the side of the Punnett Square.

Because each parent genotype contains two alleles, one allele is placed into each of the boxes directly below or beside it. Once these parent alleles are in place, copy the parent allele down, or across, the respective row or column.
This movement results in two alleles per box. These allele combinations are the possible genotypes for the offspring.

**What is a Punnett square and why is it so important?**

A Punnett square helps predict the ratio of genotypes of the offspring based on the genotypes of the parents. A genotype is the collection of alleles of a gene in an organism. Punnett squares are used only when predicting the outcome of traits controlled by one gene. Furthermore, the Punnett squares above assume that one trait is being influenced by only two alleles. (In reality, crosses can be done with more than simply two alleles. Dihybrid crosses would be an example.)
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:

L = Straight leaf veins
l = Wavy leaf veins
Parents: LL x Ll

Answer:

Offspring (F1):
-Genotypic Ratios-
½ LL, ½ Ll

-Phenotypic Ratios-
All straight veins (4/4)

What happened?
Even though the genotypic ratio varies (half are homozygous dominant and half are heterozygous), the phenotypes of all of the offspring will be straight veins since L is dominant over l.
for grades 8-12

Example 2

Now consider this situation.

\[ L = \text{Straight leaf veins} \]
\[ l = \text{Wavy leaf veins} \]

Parents: \( Ll \times Ll \)

**Answer:**

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<thead>
<tr>
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Offspring (F2):

- **Genotypic Ratios:**
  - \( \frac{1}{4} LL; \frac{1}{2} Ll; \frac{1}{4} ll \)
- **Phenotypic Ratio:**
  - \( \frac{3}{4} \text{straight leaf veins} \)
  - \( \frac{1}{4} \text{wavy leaf veins} \)

**What happened?**

Here, although none of the parents (F1 offspring from the previous Punnett square) phenotypically show wavy leaf veins, the wavy leaf vein phenotype has reappeared in this generation of offspring (F2 generation).
for all grades

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 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.
Family Trees for grades 8-12

Time: 40-50 minutes

Materials:
- One cup of purple water
- One cup of clear water
- Two empty cups

Note:
Before starting this activity, introduce flower reproduction using the previously designed Phipps lesson plans and the poster of the reproduction cycle from the Discovery Cart in the “Family Trees” exhibit in the Gallery Space.

Discussion
1. Ask students what they know about self-fertilization and cross-fertilization.
2. Ask students what they know about Gregor Mendel and genetics.
3. Define the following terms in the appropriate context: gene, allele, phenotype, genotype, homozygous, 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 and, in turn, discovered the laws of inheritance.
5. 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.
   - Explain that a genotype is the genetic make-up of a trait; a phenotype is the physical appearance that results from the genotype.
   - Explain that even though more factors influence the phenotype, one can speculate about the phenotype of a plant based on its genotype.

Activity
1. Set-Up:
   a. 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”.
   b. Place “Offspring of Self-Fertilization of Plant A” and “Offspring of Cross-Fertilization of Plants A and B” on the table.
2. Talk about 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 (Deoxyribose Nucleic Acid) contains all of the instructions for an organism’s development and characteristics.
   a. While talking, perform a general example:
      i. Identify two cups as “parents” – Plant A and Plant B. Pour clear water into one and yellow water into the other.
      ii. Mix a cup of yellow water and a cup of clear water into a third cup (previously empty). Explain how the “offspring” now has traits from both parents.
3. Using the poster, discuss flower reproduction. Explain to the visitors that the water represents the pollen of the plant. Genetic information is found in the nucleus of the pollen, where it is transferred during flower reproduction. In this experiment, the water acts like the pollen and therefore, “contains the genetic information.” Explain briefly that plants can reproduce with each other (sexual reproduction.
for grades 8-12

Instructions

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:
    i. Identify the “parent” cup as Plant A.
    ii. Pour 1/3 of the water from the Plant A into the empty cup labeled “Offspring of Self-Fertilization of Plant A”.
    iii. 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.)
    iv. Ask the visitors to compare the offspring to Plant A: lead the visitors to understand that the offspring looks just like Plant A because it has the same genetic material.
    v. “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.
    i. 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.
    i. Re-define inheritance as the process of passing traits from a generation to the next, from the parent passed on to the child.
    ii. In self-fertilization, the child received all characteristics from the parent, so the resulting “plant” (cup of water) looks like the parent “plant”.
    iii. Ask the students what the water stands for? (genetic information)

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

a. Demonstrate cross-fertilization:
    i. Identify the parent cups “Plant A” and “Plant B” and the offspring cup labeled “Offspring of Cross-Fertilization of Plants A and B”.
    ii. Pour 1/3 of the water from Plant A into the empty cup labeled “Offspring of Cross-Fertilization of Plants A and B”.
    iii. 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
for grades 8-12

Plant A” does. (Note: Use the Punnett squares during this segment to help explain the conclusions!)

c. Ask your visitors 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. 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!)

d. 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? 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 can lead to greater genetic variability, as there are more traits in the “gene pool” for the new offspring to “choose” from. In fact, some flowers have mechanisms to prevent self-fertilization, in order to increase their genetic variation.

a. Explain:

i. 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.

ii. Charles Darwin studied self- and cross-fertilization and hypothesized that cross-fertilization propels evolution by increasing genetic variability.

8. Darwin also knew that for evolution to occur, traits must be passed between generations, but he didn’t know how! Now you know that DNA is passed between parents and offspring.
for grades 4-7

Activity
1. Read the students a story about flower reproduction.

Discussion
1. Continue discussing flower reproduction using the previously designed Phipps lesson plans and the poster of the reproduction cycle from the Discovery Cart in the “Family Trees” exhibit in the Gallery Space.
2. Ask students what they know about self-fertilization and cross-fertilization. (They should already know these terms after completing the pre-visit lesson plan and visiting the exhibit.)
3. Explain that inheritance occurs when traits are passed from parents to offspring. Some traits are dominant over others.
4. Explain that when a plant reproduces with itself, its offspring will look exactly like that plant. This is self-fertilization. When two plants reproduce with each other, the offspring will have traits from both parents. This is cross-reproduction. The Laws of Inheritance provide this foundation.

Activity
(You could perform the above activity (with the water experiments) for these younger students depending on the type of audience present.)
1. On the chalkboard complete the following equations:
   - Yellow = ? (Yellow, Self-Fertilization)
   - White = ? (White, Self-Fertilization)
   - Yellow + Yellow = ? (Yellow, Cross-Fertilization)
   - White + White = ? (White, Cross-Fertilization)
2. Complete the “Guess The Offspring” worksheet with the class.

Discussion
1. Talk about Variation with cross-fertilization. Because there are two plants involved, there is a greater chance of genetic variability among offspring. This means that when two flowers reproduce together, there are more traits to “choose from” for the offspring.
   For example: Yellow + White = ?
   - Answer: Both outcomes are possible
     Yellow - This occurs because Purple is dominant over White (ie: YY x yy)
     White - This occurs because there are more chances for White to be inherited (ie: Yy x yy)
2. Ask the students if they know who Charles Darwin is. Explain that he was a naturalist that studied variation in plants and other organisms.
Based on your observation of “Family Trees,” what do you think happens during each situation of reproduction?

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<td>Offspring will be a <strong>White flower.</strong> (Self-fertilization)</td>
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<td><img src="image" alt="Purple flower" /> ➞ <img src="image" alt="Purple flower" /></td>
<td>Offspring will be a <strong>Purple flower.</strong> (Self-fertilization)</td>
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<td>Offspring will be a <strong>White flower.</strong></td>
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<td>4.</td>
<td><img src="image" alt="Purple flower" /> + <img src="image" alt="Purple flower" /> ➞ <img src="image" alt="Purple flower" /></td>
<td>Offspring will be a <strong>Purple flower.</strong></td>
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<td>5.</td>
<td><img src="image" alt="White flower" /> + <img src="image" alt="Purple flower" /> ➞ <img src="image" alt="Purple flower" /> or <img src="image" alt="White flower" /></td>
<td>Offspring could be a <strong>Purple flower or a White flower.</strong></td>
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Based on your observation of “Family Trees,” what do you think happens during each situation of reproduction?

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