Understanding Genetics: Punnett Squares

- How do Punnett Squares help us understand dominant and recessive traits and the probability of specific genetic outcomes?
- How does the knowledge of genetics come into play in selective breeding of food crops?

Science & Math Connections

Common Core Standards

CCSS.Math.Content.7.SP.C.8 Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation.

CCSS.Math.Content.7.SP.C.8c Design and use a simulation to generate frequencies for compound events.

Next Generation Science Standards

Understanding about the Nature of Science

Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Science carefully considers and evaluates anomalies in data and evidence.

Biological Evolution: Unity and Diversity

MS-LS4-6. Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Life Science

LS3.A Inheritance of traits
LS3.B Variation of traits
In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring.

Can We Accurately Predict Inherited Genetic Traits? Can They Be Controlled?

Humans have been selectively breeding various plants and animals for centuries. The goal is to maximize desired traits and minimize or eliminate undesirable traits. But how does selective breeding work? Can scientists and breeders really predict genetic outcomes or are they simply making a lucky guess?

Let's learn some of the basics of genetics, including important vocabulary and how to use a Punnett Square. What connections can we make to the selective breeding of plants to generate hybrid seeds for food crops?

Watch the following animated lesson from TED-Ed to get a head start:

http://ed.ted.com/lessons/how-mendel-s-pea-plants-helped-us-understand-genetics-hortensia-jimenez-diaz#watch

Images: Jennifer Sheffield

A Short History of Mendelian Genetics

Gregor Johann Mendel (July 20, 1822 – January 6, 1884) was a friar who gained posthumous fame as the founder of the science of genetics. Mendel demonstrated that the inheritance of certain traits in pea plants follows particular patterns, now referred to as the laws of Mendelian inheritance. The profound significance of Mendel's work was not recognized until the turn of the 20th century when the independent rediscovery of these laws initiated the modern science of genetics.

In the 1850s and 60s, in a monastery garden, Mendel was cultivating peas. He began separating the wrinkly peas from the shiny peas and studying and recording which characteristics were passed on when the next crop of peas were grown. In this slow and systematic way, Gregor Mendel worked out the basic law of heredity and stumbled upon what was later to be described as the fundamental unit of life itself…the gene.

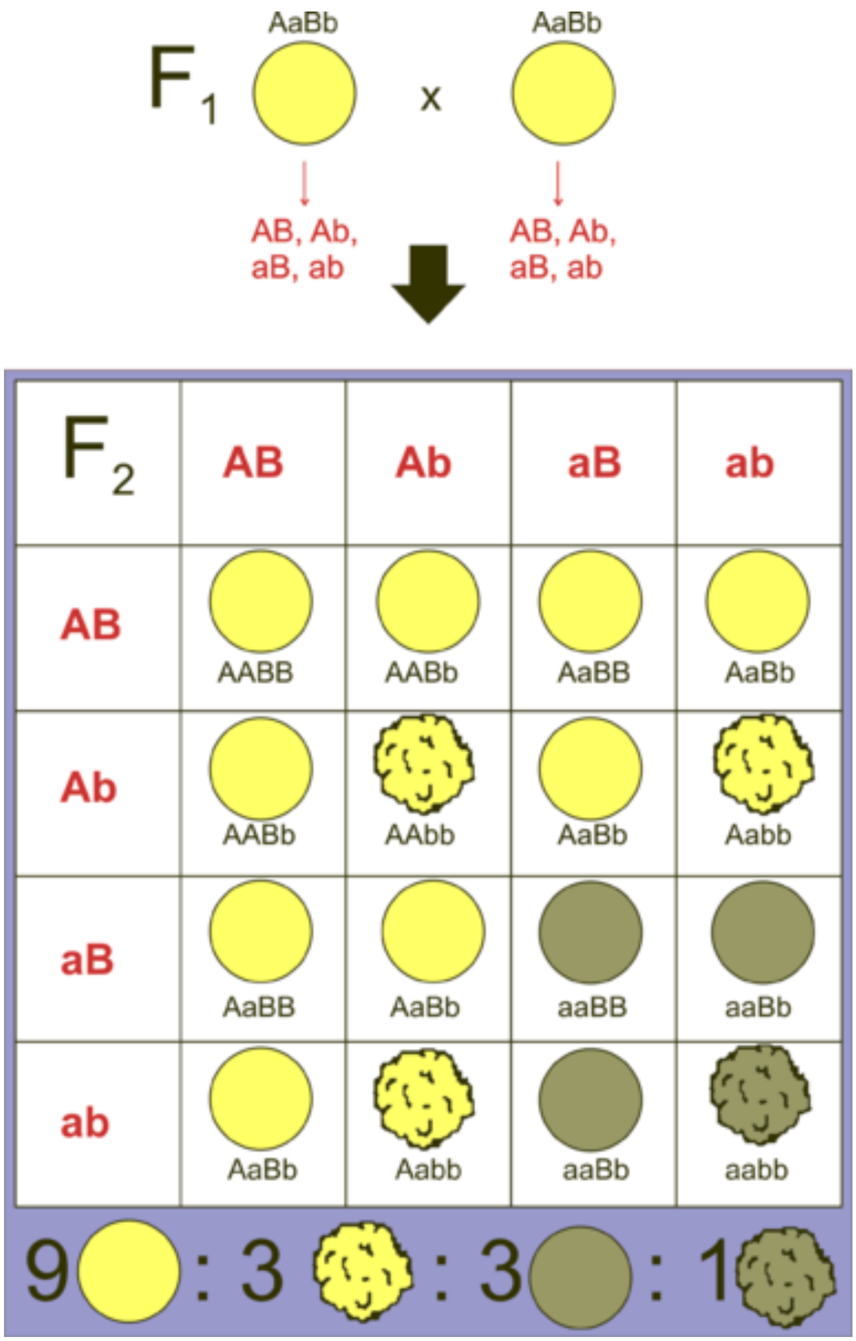
The **Punnett square** is a diagram that is used to predict an outcome of a particular cross or breeding experiment. It is named after Reginald C. Punnett, who devised the approach to determine the probability of an offspring's having a particular **genotype** (combination of alleles).

Mendel made careful observations and kept systematic records…

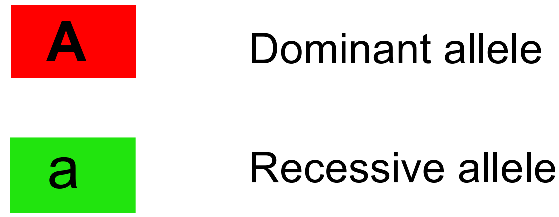
Dominance in genetics is a relationship between alleles of a gene, in which one allele masks the expression (**phenotype**) of another allele.

A **recessive gene** is an allele that causes a visible or detectable characteristic that is only seen in a **homozygous** genotype (when an organism that has two copies of the same allele) and never in **a heterozygous** genotype (when an organism that has two different alleles – one dominant and one recessive.)
An organism will always express the phenotype of the dominant allele. The only way a recessive trait is expressed is if *both* alleles in the gene are recessive. A heterozygous genotype can pass on a recessive allele to its offspring, even though it only displays the dominant phenotype. In other words, it can have both dominant and recessive genes, but not necessarily look like it does from the outside!

An Example from Mendel's Study of Peas



A Punnett Square is used to represent all of the possible combinations of genes that could be inherited by the offspring of two parents. Each parent contributes one gene to the **genotype**, or gene combination, of the offspring. If a genotype contains two of the dominant **alleles**, or single genes, the organism will exhibit the dominant trait. If both alleles in the genotype are recessive, the organism will display the recessive trait. If both a dominant and recessive allele are present, the exhibited trait, or **phenotype**, will present as the dominant trait.



Parent 1: Aa genotype

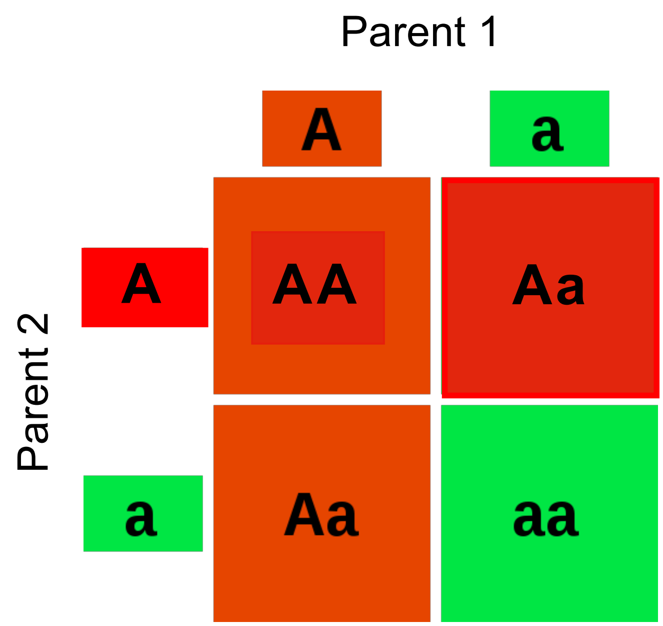
Both parents carry one dominant and one recessive gene. Both parents will exhibit the dominant trait, or phenotype.

There are three (3) possible outcomes of genotype combinations for the offspring:

25% - both genes are dominant

50% - one gene is dominant, one is recessive

25% - both genes are recessive



Parent 1: Aa genotype

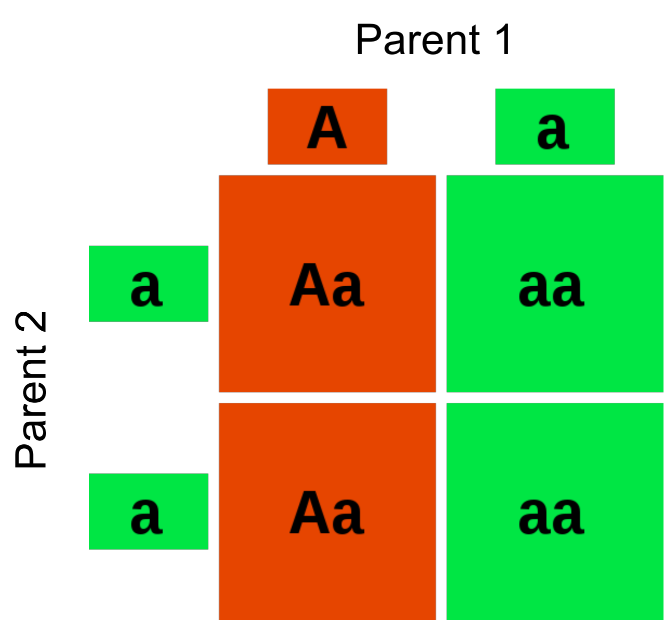
Parent 2: aa genotype

Parent 1 carries one dominant and one recessive gene. Parent 2 carries two recessive genes. Parent 1 will exhibit the dominant trait, or phenotype. Parent 2 will exhibit the recessive.

There are two (2) possible outcomes of genotype combinations for the offspring:

50% - one gene is dominant, one is recessive

50% - both genes are recessive



Punnett Squares

Name: ______________________________

Fill in the following Punnett Squares with the genotype information given for both parents. (Either parent's information can go on the top or the left side.) Dominant genes are always capital letters and are listed first. Recessive genes are always lowercase letters. Can you correctly fill out the array for gene combinations, or genotypes, for their offspring? What is the probability of each outcome? What phenotype, or evidence of a dominant or recessive trait, will each combination have?

Parent 1: Freckles dominant FF
Parent 2: Freckles dominant Ff

Possible genotypes of outcomes and percentage of probability:

Which genotype(s) will display the dominant trait?

Which genotype(s) will display the recessive trait?

Parent 1: Freckles dominant Ff
Parent 2: Freckles recessive ff

Possible genotypes of outcomes and percentage of probability:

Which genotype(s) will display the dominant trait?

Which genotype(s) will display the recessive trait?

Name: ______________________________________

Ready for a little Punnett Square Challenge? C'mon, you know you are!!! Let's see what happens when we consider **two** different sets of dominant and recessive traits. Let's say we are working with rabbits. Rabbits will either have spotted coats (S), which is dominant, or solid coats (s), which is recessive. The rabbits will have ears that stand up (E), which is dominant, or lop-ears (e), ears that lay down, which is recessive. REMEMBER: each parent will only pass on ONE of each gene allele!

Parent 1: ssEe
Solid coat (ss)
Stand up ears (Ee)

Parent 2: Ssee
Spotted coat (Ss)
Lop ears (ee)

	___	___	**se**	**se**
sE				
se				
sE				
se				

1. List out all of the different genotypes possible from the combination of parents above, and how many times each combination occurs in your Punnett Square.

2. What are the probabilities of each genotype occurring?

3. Draw another 16-square Punnett Square on a blank sheet of paper. Create a simple visual representation of each of the phenotypes that correspond with the genotypes for each square from your Punnett Square above.

Punnett Square Challenge Extensions

1. Have students change the genotypes of one the parent rabbits to all dominant genes (SSEE) and construct and complete a new Punnett Square matrix.

2. Have students extend the Punnett Square to include all of the possible combinations for 2nd generation "grand-rabbits" from the parent pair from Extension 1, using a set of new parents possible from the 1st generation of their offspring, and analyze their results.

3. Can students detect a mathematical pattern to the Punnett Square system? Can they express this pattern in an equation, or a series of equations?

4. Have students research albinism (a defect of melanin production that results in little or no pigment in the skin, hair, and eyes) and create a product to present their results.

Technology Resources

GEMS Academy Genetics Glog

http://gemsacademy1.edu.glogster.com/genetics/

This link will take you to a Glog we created for use at GEMS Academy. It contains active links that students can explore to genetics interactives, interviews with experts about the pros/cons of GMO's, and BrainPOP videos (you will need your own BrainPOP login to watch the videos on genetics and DNA.)

Education Development Center: Punnett Square Interactive Tutorial

http://www2.edc.org/weblabs/Punnett/punnettsquares.html

Students can actively participate in this fun and informative animated interactive on the use of Punnett Squares to predict outcomes when considering dominant and recessive gene combinations from two parents. Includes an interactive tutorial and a student task that can be repeated without penalty until the desired results are obtained.

The Khan Academy Biology: Genetics and Heredity

http://www.khanacademy.org/science/biology/heredity-and-genetics

A series of very detailed, higher level tutorials about various principles of genetics and heredity.

BrainPOP

http://www.brainpop.com/science/cellularlifeandgenetics/heredity/

A very basic animated introduction to principles of heredity. This particular video is free!

Strawberry DNA Extraction Lesson Plan

This lesson plan is for the extraction of DNA from strawberries. Strawberries are an exceptional fruit to use for this lesson because each individual student is able to complete the process and strawberries yield more DNA than any other fruit (i.e. banana, kiwi, etc.). Strawberries are octoploid, meaning that they have eight copies of each type of chromosome.

Primary Learning Outcomes
Students will observe first hand that DNA is in the food that they eat. Students will learn the simple method to extract DNA and why each step is necessary due to the complex organization of DNA in cells. Students will learn why it is important for scientist to extract DNA from organisms.

Background:
Strawberries are soft and easy to pulverize. Strawberries have large genomes; they are octoploid, which means they have eight of each type of chromosome in each cell. Thus, strawberries are an exceptional fruit to use in DNA extraction labs.

The soap helps to dissolve the phospholipid bilayers of the cell membrane and organelles. The salt is used to break up protein chains that bind around the nucleic acids. DNA is not soluble in ethanol. The colder the ethanol, the less soluble the DNA will be in it. Thus make sure to keep the ethanol in the freezer or on ice.

Procedures/Activities
Teacher may choose prior to class to prepare the DNA extraction buffer. In a container add 900mL water, then 50mL dishwashing detergent (or 100mL shampoo), and finally 2 teaspoons salt. Slowly invert the bottle to mix the extraction buffer.

Lab procedures should be conducted as stated in the *DNA Extraction: Strawberry* lab at the end of this document. Modifications can be made based on the needs of the students. Some classes may decide for each student to add individual components of the extraction buffer to the Ziploc bag (roughly 2 tsp water, 1 tsp soap, 1 pinch salt), while other classes may choose to use the teacher prepared extraction buffer (from Step 1).

When the students add ethanol to their strawberry extract, they will see the fine white strands of DNA precipitate. The DNA will form cotton like fibers that will spool onto the stirring rod/inoculating loop/popsicle stick.

Total Duration
10 minutes teacher prep before class 40-60 minutes in class

Materials and Equipment

For each student:

- heavy duty Ziploc bag (freezer or storage bag)
- 1 strawberry
- DNA extraction buffer (900mL water, 50mL dishwashing detergent, 2 teaspoons salt)
- small plastic cup to hold extraction buffer
- cheesecloth to fit in small funnel (4" X 4" should be appropriate)
- small funnel
- 50mL vial / test tube
- glass rod or popsicle stick
- cold ethanol
- ice

Assessment

Lab report and/or discussion questions. Discuss questions as a class to assess the students understanding and ability to communicate scientific concepts. Discuss why each step was needed and how this relates to the organization of genetic material.

Name____ Date_______________

DNA Extraction: Strawberry

Background:

The long, thick fibers of DNA store the information for the functioning of the chemistry of life. DNA is present in every cell of plants and animals. The DNA found in strawberry cells can be extracted using common, everyday materials. We will use an extraction buffer containing salt, to break up protein chains that bind around the nucleic acids, and dish soap to dissolve the lipid (fat) part of the strawberry cell wall and nuclear membrane. This extraction buffer will help provide us access to the DNA inside the cells.

Pre-lab questions:

1. What do you think the DNA will look like?

2. Where is DNA found?

Materials:

heavy duty ziploc bag
1 strawberry
10 mL DNA extraction buffer (soapy, salty water) cheesecloth
funnel
50mL vial / test tube
glass rod, inoculating loop, or popsicle stick
20 mL ethanol

Procedure:

1. Place one strawberry in a Ziploc bag.
2. Smash/grind up the strawberry using your fist and fingers for 2 minutes. *Careful not to break the bag!!*
3. Add the provided 10mL of extraction buffer (salt and soap solution) to the bag.
4. Knead/mush the strawberry in the bag again for 1 minute.
5. Assemble your filtration apparatus as shown to the right.
6. Pour the strawberry slurry into the filtration apparatus and let it drip directly into your test tube.
7. Slowly pour cold ethanol into the tube. OBSERVE
8. Dip the loop or glass rod into the tube where the strawberry extract and ethanol layers come into contact with each other. OBSERVE

Conclusions and Analysis

1. It is important that you understand the steps in the extraction procedure and why each step was necessary. Each step in the procedure aided in isolating the DNA from other cellular materials. Match the procedure with its function:

PROCEDURE FUNCTION

A. Filter strawberry slurry through cheesecloth

B. Mush strawberry with salty/soapy solution

C. Initial smashing and grinding of strawberry

D. Addition of ethanol to filtered extract

___ To precipitate DNA from solution

___ Separate components of the cell

___ Break open the cells

___ Break up proteins and dissolve cell membranes

2. What did the DNA look like? Relate what you know about the chemical structure of DNA to what you observed today.

3. Explain what happened in the final step when you added ethanol to your strawberry extract. (*Hint*: *DNA is soluble in water, but not in ethanol*)

4. A person cannot see a single cotton thread 100 feet away, but if you wound thousands of threads together into a rope, it would be visible much further away. How does this statement relate to our DNA extraction? Explain.

5. Why is it important for scientists to be able to remove DNA from an organism? List two reasons.

6. Is there DNA in your food? ________ How do you know?

REMEMBER: Students may place either parent's genotype on the top or side rows of their Punnett Square. This key represents only one way that a properly completed matrix may look. Both variations should render the same percentages of genotypes for the offspring, however.

Parent 1: ssEe
Solid coat (ss)
Stand up ears (Ee)

Parent 2: Ssee
Spotted coat (Ss)
Lop ears (ee)

	___	___	**se**	**se**
sE				
se				
sE				**ssEe**
se				

Key

1. List out all of the different genotypes possible from the combination of parents above, and how many times each combination occurs in your Punnett Square.

SsEe - 4

ssEe - 4

Ssee - 4

ssee - 4

2. What are the probabilities of each genotype occurring?

25% change for each genotype equally

3. Draw another 16-square Punnett Square on a blank sheet of paper. Create a simple visual representation of each of the phenotypes that correspond with the genotypes for each square from your Punnett Square above.

SsEe = Spotted coat, upright ears

ssee = Solid coat, lop ears

Ssee = Spotted coat, lop ears

ssEe = solid coat, upright ears