Berkeley Engineers and Mentors

A Concrete Taste of Genetics

Lesson Type: Module
Target Grade: Elementary School
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Semester: Fall 2016

Brief Overview

Genetics is typically not introduced until late middle school or high school. This lesson will change that! This lesson will begin by introducing students to the idea of genetics through observable phenotypes. By the end of the lesson, there will be a connection from this to the idea that this information is stored as genetic data in all living things through DNA.

Teaching Goals

At the core, the purpose of this lesson is to communicate that:

- Physical attributes differ from person to person—these are known as phenotypes.
- Many phenotypes will have a 3:1 expression ratio, due to dominance; some pieces of genetic data are present but are not expressed.
- All living things contain inside of them a stringy substance called DNA, which stores this genetic data and is responsible for these observed characteristics.

Agenda

- Module 1: Find Someone Who… (10-20 min)
- Module 1.5: Be Punnett-y or Be Square (10 min) – *[Optional: For advanced students]*
- Module 2: Taste Test Strips (10 min)
- Module 3: Strawberry DNA Extraction (30 min)

For younger students, spend more time on Module 1 and proceed to Modules 2 and 3.
For advanced students, spend less time on Module 1 and follow with Module 1.5 before proceeding to Modules 2 and 3.

Module 1: Find Someone Who…

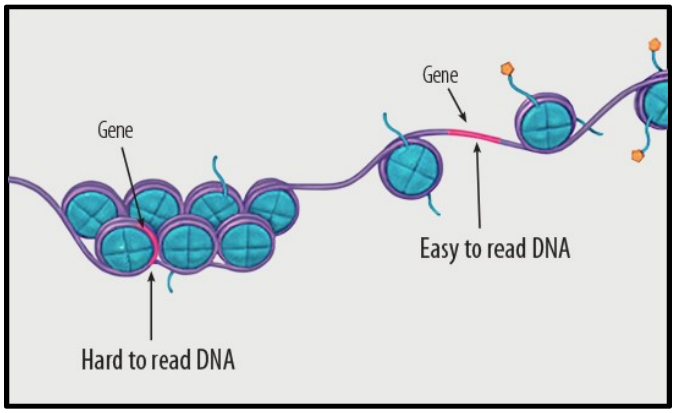
Introduction
Students will play the "Find Someone Who…" Bingo game to begin observing physical features that may differ from person to person.

Materials (per student)
- 1 "Find Someone Who…" Bingo sheet
- 1 writing utensil

Background/Notes for Mentors
Most, if not all, observable features of humans and any living organism are under genetic control. These observable physical features are known as phenotypes (in contrast, genotypes refer to the actual genetic code that compose these features). Therefore if, for example, a student has detached earlobes, which is the dominant phenotype, then according to Mendelian inheritance, he or she must have inherited a dominant gene from at least one of his or her parents. In other words, at least one of his or her parents must also have detached earlobes.

Further, each child receives one allele from each parent for any given trait. For every allele, there is generally a dominant form and a recessive form. Since each child has two such alleles, there can be the combinations of two dominant alleles (homozygous dominant), two recessive alleles (homozygous recessive), and one of each (heterozygous). When at least one of the alleles is dominant, then the dominant phenotype takes priority and is expressed. Additionally, these combinations have statistical likelihoods to occur 25%, 25%, and 50% of the time, respectively. Therefore, the dominant phenotype will be expressed 3 out of 4 times, ideally.

Still, this is an oversimplification. Today, we know that many of these observed traits are in fact determined by a large handful of genes. And through epigenetics, the current understanding is that gene expression can change over time without mutation to the raw genetic data since certain genes can become either activated or withdrawn. In fact, there are a myriad of diseases that are inherited genetically but only become expressed in later stages of life when epigenetic changes become increasingly frequent such as heart disease, various cancers, etc.



(Photo Credit: PBS)

Material to Teach

Students will begin to observe features that differ from student to student. These traits are phenotypic expressions of genetic influence. Some traits seem to be more popular than their alternatives because of dominance.

Warning

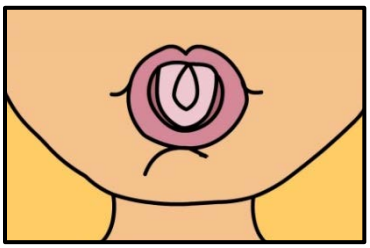
This module has students observing physical features of one another. While the traits listed on the bingo sheets should be relatively benign, be prepared to handle comments students may make about other students and their appearances.

Procedure

1. Distribute a Bingo Sheet and writing utensil to each student.
2. Have students begin roaming around the classroom to find other students who have traits that fulfill what is listed on the Bingo squares. When a student finds someone who does have a feature listed on an empty Bingo square, then he or she should write that person's name in the corresponding square. Each name can only be used once on a board. A student may write his or her own name down on his or her board, but can only do that once. Mentors should circulate the room during this time to help students identify these traits and to explain any traits that they are unfamiliar with. (See below for pictures demonstrating the less obvious traits.)
3. Continue playing until a few students have achieved five-in-a-row, column, or diagonal. If this was achieved too quickly, then the game can be extended so that the goal is to achieve blackout (racing to fill all spaces on the board).
    a. **Pro tip.** Games are only fun until they are not (duh!) so stop the game while the students are still having fun before they lose interest!
4. **Bridging the Concept.** After the game ends, debrief by asking, counting, and recording on the whiteboard how many students fell under each of the sides of several of the following categories (the supposedly dominant phenotype is listed first) (choose 3 categories where you would expect many students to fall under one side and a few falling on the other):
    a. Right Handed — Left Handed
    b. Can Roll Tongue — Can't Roll Tongue
    c. Dark Hair — Light Hair
    d. Curly Hair — Straight Hair
    e. Brown Eyes — Other Colors of Eyes
    f. Detached Earlobes — Attached Earlobes
    g. Has Freckles — No Freckles
    h. Widow's Peak — No Widow's Peak
    i. Cleft Chin — No Cleft Chin
    j. Cheek Dimples — No Cheek Dimples

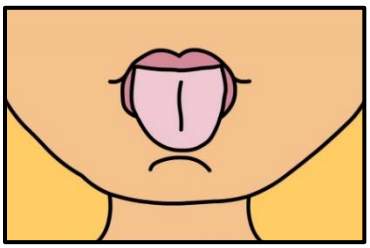
    In most cases, it should then become clear that one of the traits is more popular than the other. How close do these counts come to being in the expected 3:1 ratio that is derived from the influence of allele dominance?

Can Roll Their Tongue

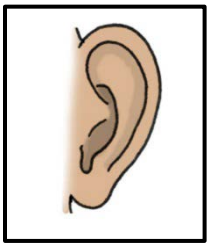


(Photo Credit: Quia)

Cannot Roll Their Tongue

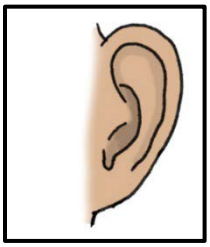


Has Attached Earlobes

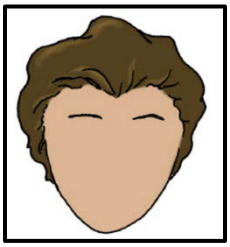


(Photo Credit: Gale Group Science in Context)

Has Detached Earlobes

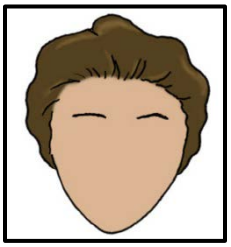


Has a Widow's Peak



(Photo Credit: Gale Group Science in Context)

Does Not Have a Widow's Peak



Has a Cleft Chin

(Photo Credit: Quia)

Has a Chin Without Cleft

Has Cheek Dimples

(Photo Credit: Seongwoo Choi, Prezi)

Does Not Have Cheek Dimples

Module 1.5: Be Punnett-y or Be Square

(Optional: For advanced students)

Introduction

Advanced students will flip coins to determine outcomes that will be recorded on the board and that will be used to demonstrate Punnett Squares.

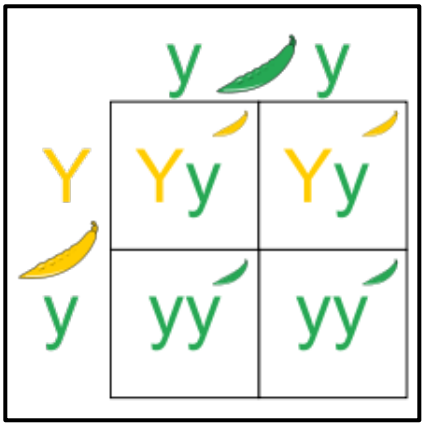
Materials (per student)

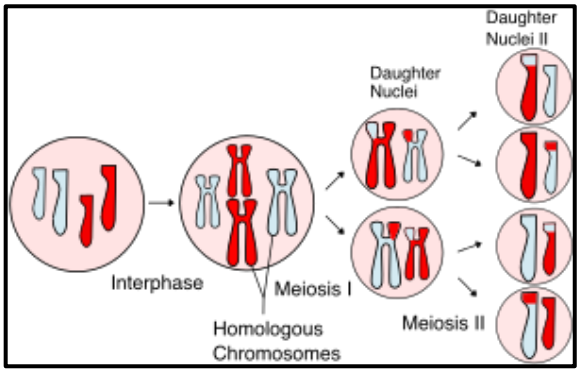
- 2 coins

Background/Notes for Mentors

The Punnett Square (shown below) was first devised by Reginald C. Punnett and is used to determine the possible genotypic outcomes (and by extension, phenotypic expression) when two pairs of alleles are crossed. Any particular offspring of these parents will inherit one allele from each parent (for each parent, either allele theoretically has an equal chance of being selected for inheritance). Thus, with large numbers of offspring, there will be a proportional number of offspring carrying each of the possible combinations/outcomes.

Below (left), one parent pea (the one on the left edge) possess one dominant allele and one recessive allele while the other parent (the one on the upper edge) possesses two recessive alleles. Each of the boxes in the grid represent a possible combination/outcome. In this case, half the offspring will be heterozygous while the other half will be homozygous recessive. In terms of phenotypic expression, this means that half the offspring will be yellow, as that is the dominant trait (takes precedence in the heterozygous case) and the other half will be green.





(Photo Credit, left and right: Wikipedia)

In reality, multiple alleles may play a role in determining phenotypic expression. A Punnett Square can be expanded to accommodate this with the addition of extra rows and columns so that all the combinations/outcomes can be represented.

On a scientific level, this “random selection” of one allele from each of the parents is done through the process of meiosis. Meiosis is a form of cell division that produces four gametes from one parent cell. Specifically, as shown above (right) in Meiosis II, each of the cells split to yield two haploid cells each (half the number of chromosomes of a typical parent cell). Later, a gamete from the mother and father will fuse with fertilization to complete the chromosomal contents of the offspring.

Material to Teach

Students will collect a larger amount of data and will be guided in analysis of the data. Students will learn to use Punnett Squares and the statistical distribution it represents.

Procedure

1. **Experiment.** Distribute 2 coins to each student.
2. Have each student flip both of the coins to generate a random outcome through each.
3. Ask for and record how many students received each of the following outcomes: Heads/Heads, Heads/Tails, Tails/Tails.
4. If the sample size was small or the distribution is not close to 1:2:1 (respectively), then repeat steps 2 – 3 to collect more data points.
5. **Data Analysis.** Once the distribution is clear, explain how this distribution arose statistically by drawing a Punnett Square on the board with Heads/Tails and Heads/Tails as the “parents” and filling in the outcomes (as shown below). Include as much or as little information additional information as described in this module’s Background for Mentors section as desired.
6. Collect back all the coins!

	H	**t**
H	**HH**	**Ht**
t	**Ht**	**tt**

Module 2: Taste Test Strips

Introduction
In this module, students will put a special taste test strip into their mouths. Due to genetic control, different students will experience different tastes. Students will likely welcome the idea of mentors (finally) allowing them to put something into their mouths and they likely will also react animatedly to what they taste and the fact that other classmates are experiencing radically different tastes.

Materials (per student)
- 1 Sodium Benzoate Taste Test Paper Strip

Background/Notes for Mentors
You may recall that there is a similar taste test strip called PTC. From it, some people taste extreme bitterness while others taste nothing at all. In this module, we will be using a similar taste test strip that has a larger variety of possible tastes.

Material to Teach
Students will make the connection between phenotypes (Module 1) and genotypes (Module 3). We can infer that there must be some sort of genetic data that causes certain versions of traits to be more popular than their alternative expressions.

Procedure
1. **Introduction.** Before handing out the strips, begin by connecting from the previous module—that there are traits that different from person to person which are controlled by genetics and that it seems that certain phenotypic expressions are dominant over the alternative. Explain that in this module, we will be observing possible differences in taste by placing a taste test strip into our mouths. The possible tastes are bitter, salty, sweet, and no taste.
2. **Experiment.** Distribute one strip per student and have them place it into their mouths.
3. **Bridging the Concept.**
    a. Take a count of how many students experienced each of the possible tastes and add these counts to the whiteboard. (A dominant allele will yield one of the tastes while homozygous recessive will result in no taste.)
    b. Did anybody taste a mix of these categories? Ask students from each category to describe the taste. Does the taste remind them of any foods in particular? For students that taste bitter, ask if they enjoy eating foods that are bitter (broccoli for example). For students that tasted sweet, ask if they especially enjoy eating sweets. Etc.
    c. Explain that we can now see that most expressed traits are not as simple as a simple binary between a single dominant expression and a single recessive expression. Here, the dominant trait was indicated by bitter, salty, and sweet tastes. Therefore, there must be many, many pieces of genetic information that factor into determining the phenotypes that we observed in Module 1. (If Module

1.5 was covered, then we now realize that our Punnett square would need many, many more rows and columns to manage the complexity of genetic variation!) What do these pieces of genetic information look like? Is it real and tangible or is it just a figment of a scientific imagination? We'll find out in Module 3!

Module 3: Strawberry DNA Extraction

Introduction
In this module, we will be extracting the DNA out of a strawberry! This will give students the opportunity to perform some basic chemical procedures and in the end, they will see and touch real DNA. Follow the steps in this protocol as closely as possible to maximize success!

Materials (per student)

- 1 Small Re-sealable Zip-Lock Plastic Bag
- 2 tsp Lysis Solution
    - To be prepared in bulk beforehand by Logistics Committee; preparation instructions are listed below Summary Materials Table.
- 1 Coffee Stirrer
- 1 Coffee Filters
- 1 Disposable Cup
- Appx 1 fl oz Rubbing Alcohol (Keep cool: room temperature or below)
- Newspapers (to lay across working surface)
- Intertwined rope/yarn (a few snippets per site)

Background/Notes for Mentors
There are tidbits of background within the protocol if you or your students are curious as to the purpose behind each step.

Material to Teach
Through a successful DNA extraction, students will be able to touch DNA and will remember that all living things, even strawberries, contain DNA. They will learn that these strands of DNA are like very skinny ropes. Each of these strands is a long string of genetic information which contains a myriad of factors that determine phenotypic expression, in terms of introducing variety beyond a simple binary option and for influencing a distribution where certain phenotypes appear more frequently than others. In the process, students will learn to perform basic laboratory techniques that are regularly used by chemists and bioengineers.

Warnings
No eating or tasting should be permitted in this module (duh!).

Procedure
Below, sections marked as Background should be explained to students while sections marked as Additional Background are primarily intended for mentors.

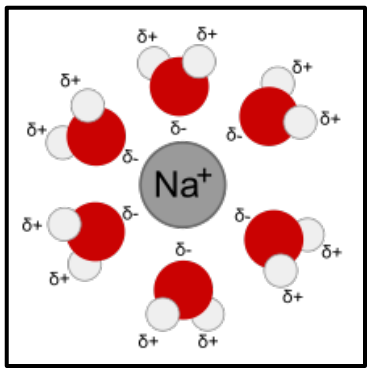
1. **Introduction/Bridging the Concept.**
    a. From Module 2, we concluded that there are many, many genetic variables at play. Organisms need a systematic method for recording all this information—some sort of a library of information about itself or a recipe with a list of ingredients needed to produce new cells. It turns out, organisms do indeed maintain such an instruction set in the form of what looks like very skinny ropes. Show the students the intertwined rope/yarn as a crude model of what DNA looks like on a structural level. Explain how just like our "model," real DNA are mindboggling in length and are composed of two complementary threads of genetic data intertwined together (in a double helix). Collectively, this genotypic information play a role in determining the variety and distribution of phenotypic expression. Today, we will expose the tiny ropes from within these strawberries!
    b. We will do this by performing basic chemical procedures. Ask the students if any of their parents are chemists or bioengineers. Where else have they seen scientists working in a laboratory? In movies? Bill Nye the Science Guy? Today we will learn some techniques that are regularly used by these scientists.
2. Distribute newspapers to lay across the working surface to reduce messiness.
3. **Physical Breakdown.** Place 2 strawberries (after removing the green leaves) into the zip-lock bag. Push out any air and seal. Mash the strawberries through the bag using your hands (or pound with your fists if you so desire).
4. **Lysis Solution.** Open the plastic bag and add about 2 tsp of the lysis solution. Re-seal the bag and mix gently. Try to avoid making bubbles.

    a. **Pro-tip.** You can estimate one teaspoon as approximately the same as from the tip to the first joint of your index finger.
    b. **Background.** You may (or may not) hear popping sounds. That is because to lyse, means to break open. This step is important because since DNA lives within the cells of an organism, we must break open these cells (similar to popping a bunch of tiny water balloons) in order to release the DNA into the solution from where we can isolate it.
    c. **Additional Background.** Specifically, the dishwashing soap in the lysis solution dissolves the lipid bilayer cell membranes, and the salt in the lysis solution separates proteins from the DNA.
5. **Filtration.** Place a coffee filter into an empty cup. Open the zip-lock bag and pour the contents into the cup through the coffee filter. Pick-up the coffee filter, twist, and gently squeeze to ensure as much of the juice falls into the cup as possible. The pulp in the coffee filter can be discarded, as the DNA is in the filtered liquid inside the cup.
6. **Precipitation.** Pour down the side of the cup rubbing alcohol such that there is a layer of rubbing alcohol above the filtered strawberry solution. DO NOT STIR**!** You will observe a cloud of white strands gradually appearing in the upper alcohol layer. Use the coffee stirrer to remove this DNA! Show the intertwined rope/yarn model again to remind

students of how the DNA they just extracted relates to what we learned in the previous modules.

a. **Background.** This step is called precipitation because just like how rain precipitates and falls from clouds, the alcohol makes the DNA fall out of solution and appear as a solid state.

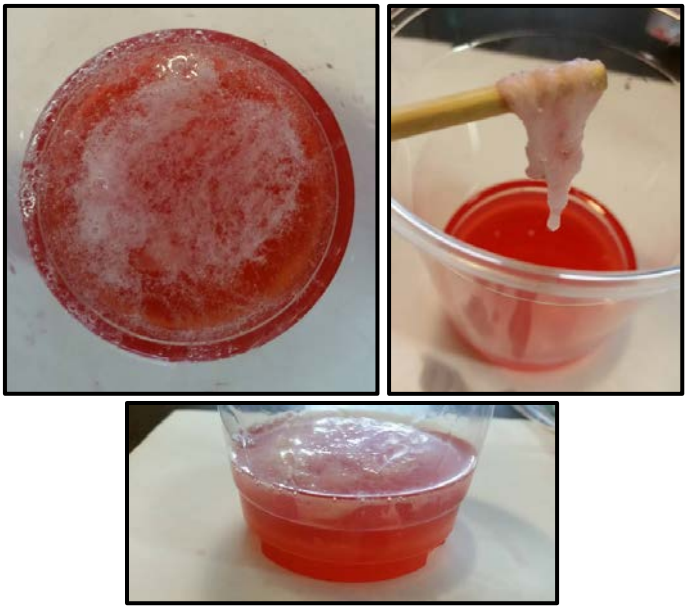
b. **Additional Background.** In the solid form, salt (Na+ -Cl) is held together by ionic bonds. When it is dissolved in water however, the ions separate. This is because water is polar and its negative dipole will be attracted to the positive Na+ ions. Effectively, as shown to the left, this results in solvation, the formation of a shield of water molecules around the positive ion. The shell hinders the negative Cl- ions ability to be attracted to the positive Na+ ions and makes it more difficult for ionic bonds to form, thus keeping it out of the solid phase.



(Photo Credit: Wikipedia)

Here, we are trying to achieve the reverse; we want to avoid solvation and encourage the formation of ionic bonds so that precipitation can occur. Recall that the solution in this experiment contains Na+ ions because of the salt added with the lysis solution, and currently has solvation because of the water that was also added with the lysis solution. But in our situation, the negative ion of interest is the DNA, which has a negatively charged phosphate backbone. So the question remains, how do we disable water's solvation effects? We add ethanol. Ethanol is significantly less polar than water and will dilute the solution enough such that the effects of solvation are weakened, ionic bonds can be formed, and the DNA will solidify and precipitate.

7. Save any unused reagents and unused materials. Dispose of the rest and clean-up!



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- Diane Sweeney, DNA Isolation from Strawberries, University of Washington Genome Sciences. (http://www.gs.washington.edu/outreach/dhillon_dnaprocedure.pdf)
- Ethanol precipitation, Wikipedia. (https://en.wikipedia.org/wiki/Ethanol_precipitation)

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
"Find Someone Who…" Bingo Sheets	1 per student	N/A	Attached as the last page of this document.
Writing Utensils	1 per student	N/A	N/A
Coins (Needed for advanced students only)	2 per student		

Sodium Benzoate Taste Test Paper Strips	1 strip per student	$1.85/vial of 100 strips (+ shipping)	Flinn Scientific (http://www.flinnsci.com/store/Scripts/prodView.asp?idproduct=16873)
Intertwined rope/yarn	A few snippets per site		Find rope or yarn that already has two strands intertwining or assemble it by twisting together two individual strands. This will be used as a crude model to help students visualize what DNA looks like structurally.
Strawberries	2 strawberries per student	(?)	(?)
Small Re-sealable Zip-Lock Plastic Bags	1 per student	$13/count of 280	https://www.amazon.com/Ziploc-Sandwich-Bags-Pack-5-875-Inch/dp/B00HG1GGUY/ref=sr_1_3?s=kitchen&ie=UTF8&qid=1472430361&sr=1-3&keywords=ziplock%2Bbag
Lysis Solution (Dish Detergent and Salt)	2 tsp per student	Dish Detergent: $3/bottle (1 bottle is enough for all sites) Salt: $1/container 26 oz (1 container is enough for all sites)	See Below for Preparation Instructions
Coffee Stirrers	1 per student	$6/count of 1000	https://www.amazon.com/Royal-Count-Coffee-Beverage-Stirrers/dp/B001FVPAOE/ref=sr_1_5?s=kitchen&ie=UTF8&qid=1472430232&sr=1-

			5&keywords=coffee+stirrers
Coffee Filters	1 per student	$9/count of 700	https://www.amazon.com/ROCKLINE-BASKET-COFFEE-FILTERS-Filters/dp/B001UBNRH6/ref=sr_1_3_a_it?ie=UTF8&qid=1472430904&sr=8-3&keywords=coffee%2Bfilter
Clear Disposable Cups	1 per student	$17/count of 330	https://www.amazon.com/Daily-Chef-Translucent-Cups-Count/dp/B001KNQ3IY/ref=sr_1_9_a_it?ie=UTF8&qid=1472430792&sr=8-9&keywords=Clear+Disposable+Cups
Isopropyl Rubbing Alcohol (91% works best)	Appx 1 fl oz per student	$4.50/bottle 32 fl oz	CVS
Newspapers	A couple sheets per site		

Lysis Solution Preparation. Make in bulk to save reagents ($$). Mix together the following (scaling up proportionally as needed):

- 2 tsp Dish Detergent
- 1 tsp Salt
- ½ cup Water

Try to avoid making bubbles.

Berkeley Engineers and Mentors

"Find Someone Who…" Bingo Sheet

Is Left Handed	Can Roll Their Tongue	Has Detached Earlobes	Has Straight Hair	Has Brown Eyes
Has Blonde Hair	Loves BEAM!	Is Shorter Than You	Has Cheek Dimples	Has a Cleft Chin
Is Taller Than You	Has a Chin Without Cleft	**FREE SPACE**	Has Brown Hair	Has Attached Earlobes
Has Curly Hair	Does Not Have Cheek Dimples	Does Not Have Freckles	Is Right Handed	Has a Widow's Peak
Does Not Have a Widow's Peak	Has Freckles	Cannot Roll Their Tongue	Has Blue Eyes	Has Black Hair