

Tomato Genetics and GMOs Teaching Script

Your name _____ Lab partner's name _____ cell # _____

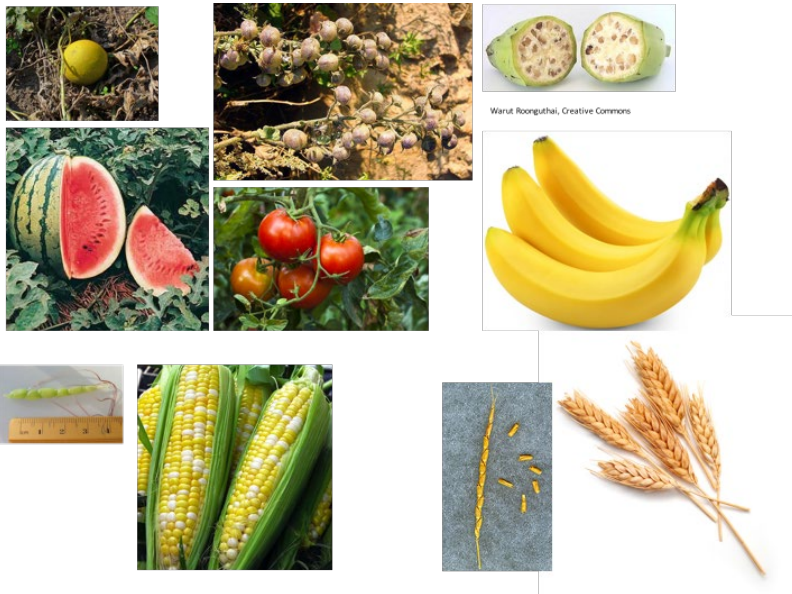
KEY TO SCRIPT: **bold & highlighted = directions for Instructors**; underline = questions to pose to high school students; *italics = answers to questions*; regular text = information to convey to students

Have students write names on nametags.

Pass out word bank handout

Part 1: Plants and mutations

Pass out mixed-up cards of modern crops and their wild ancestors (Figure 1).



Q: Here are some cards of crops plants and their wild ancestors they were derived from. Can you match the wild ancestor plant with the modern crop plant?

All fruits, vegetables, and grains we eat today have been derived from a wild ancestor, and have been modified by a combination of breeding and selection for desirable features.

Q: Looking at the pairs of cards, what are some of the changes that you notice between the ancestor and the modern plant?

A: size, color, shape, more or fewer seeds.

Q: What are some of the advantages of the modern crops compared to the wild ancestors?

A: larger fruits, more seeds (in grains), reduced seeds (e.g. banana). Other advantages not apparent from the photos: sweeter/better tasting, uniform size, less bitter taste, resistant to diseases, uniform ripening time...

Show picture of evolution of teosinte to modern corn (Figure 2).

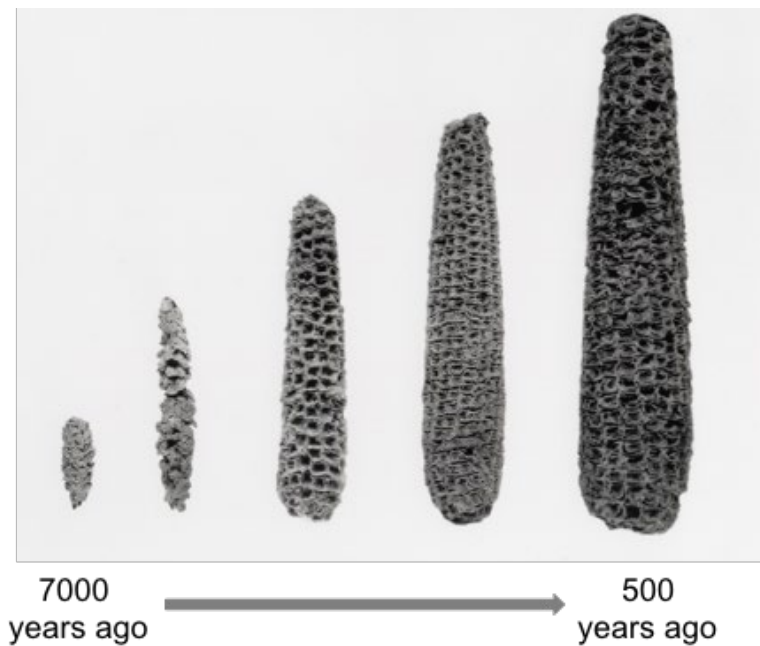


Photo © Robert S. Peabody Museum of Archaeology, Phillips Academy, Andover, Massachusetts. All Rights Reserved.

This photo shows cobs of corn, from 7000 to 500 years of age, with intermediate stages of ancient corn in the middle. We don't have pictures for the other crops, but they also changed gradually into their modern forms, through selection of desirable features and careful breeding.

Q: Corn was domesticated in Central America about 7000 years ago. Which desirable features did the ancient native Central Americans choose to develop modern maize?

A: Larger kernels, larger ears, seeds that stayed on the cob when mature, larger plants.

Q: Do we still improve crops today?

A: Yes. Plant breeders and scientists work to improve crops all the time. New, improved varieties are always coming on the market.

Show photos of wild type (Red Heinz) and mutant (Purple Heinz) tomato fruits. (Figure 3).

Red Heinz

Purple Heinz



- You are a tomato farmer, growing processing tomatoes to be made into ketchup. You grow a variety of tomato called Red Heinz.
- **You discover a plant in your field that produces purple fruits, rather than the normal red.**
- The one on the left is the normal Red Heinz and you call the new plant 'Purple Heinz'.

Q: What might cause a tomato plant to have purple fruits instead of red?

Answers may include water, fertilizer, sunlight, etc. Keep asking until someone mentions genes or genetics. If needed, lead them to the answer by giving an example of inheritance. Gene: formal definition = unit of inheritance. You may want to formally define gene.

Q: There might be a difference in genes in these two tomato fruits. What is it called when there is a change in a gene?

Answer: We are looking for students to say mutation! (Hint: X-men)

Q: What is a mutation?

A change in the information content of a gene. Note: this question might be redundant, or you could ask it if students are not getting the answer to the above question.

Q: Are all mutations bad or harmful to the plant? Explain why or why not?

Answer: NO! Mutations can have beneficial, harmful, or neutral effects on a plant. Are purple tomatoes harmful, helpful, or neutral?

Q: Look back on the cards of the wild ancestors and the modern crop plants, and on the teosinte-to-corn transition. What type of mutations were these—helpful or harmful?

A: All helpful in terms of improving the crop for human use.

Let's look at an example of another helpful mutation.

Show photos of tomato plants with and without wilting (Figure 4)



Red Heinz plant



Purple Heinz plant

Q: You notice in your tomato field that on very hot days, most of the red-fruited plants are wilted. You also notice that the Purple Heinz plant is hardly wilted, even on hot days when you have not watered. It seems to thrive and grow under hot, dry conditions.

Q: What causes plants to wilt?

A: When they don't get enough water.

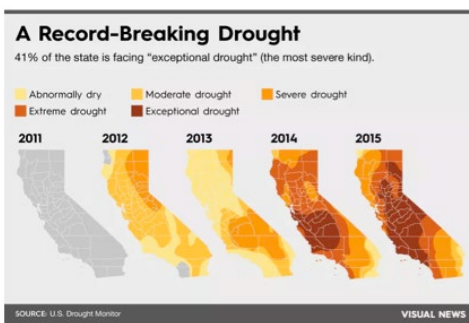
Q: When or under what conditions do crop plants not get enough water?

A: In between infrequent rain storms, during a drought (when it doesn't rain enough for an extended period of time), and when farmers don't have access to irrigation (watering systems).

Q: Has drought recently been a problem in the US? If so, where?

A: Yes, drought is increasing problem in the US. Answers may include California, the Midwest, the Southeastern US. In 2012 most of the US experienced drought conditions.

Show graphic of drought in CA over the past 4 years. (Figure 5)



California was in a drought for 5 years, from 2011-2016. The areas that grow tomatoes experienced exceptional drought for 5 years, and will definitely experience drought in the future. In 2014 California lost \$1.4 billion in agricultural revenue, mainly from planting fewer acres of land because there was not enough water.

Show figure of fruit/vegetable/tree nut production (Figure 6)



Q: How did the drought in California affect tomato availability across the US?

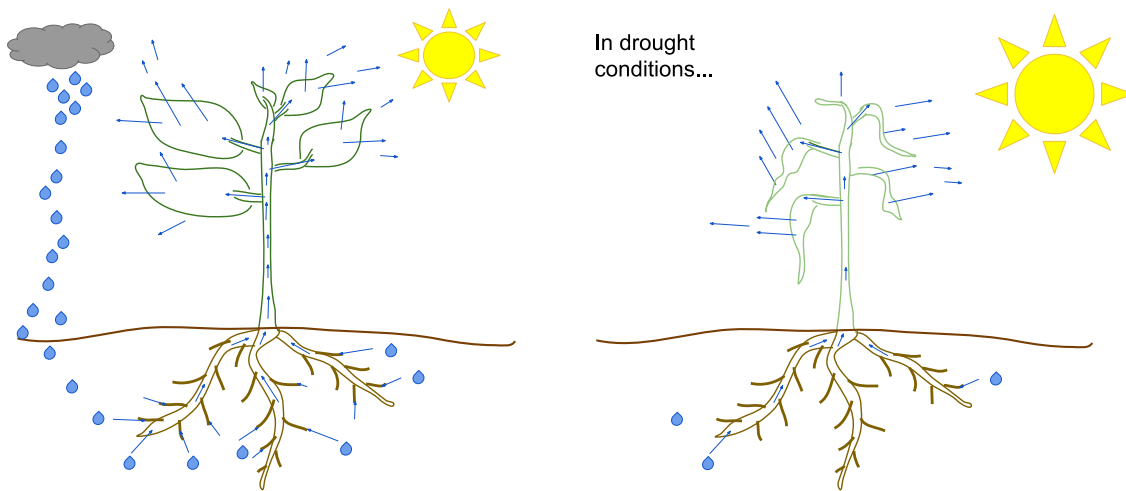
A: Most of the tomatoes sold and eaten in the US are grown in California. Drought in California could cause an increase in the cost of tomatoes in the rest of the US, or could cause a shortage of tomatoes in the rest of the US.

Notice that the areas where these important crops are grown are also the same areas that are experiencing severe drought conditions. Only a few of the crops produced in CA are shown here.

Q: What part of the plant is responsible for taking up water?

A: The roots.

Show cartoon of transpiration in normal and drought conditions. (Figure 7.)



Q: What do these cartoons show about the differences in a plant under normal conditions and under drought conditions?

A: Water from rain enters soil and is taken up into plants through roots. The water moves up the plant's stem and into the leaves. Then it moves out of the leaves into the air. Under drought conditions, there is less water to be taken up by the roots, but water still moves out of the leaves. There is not enough water in the leaves, so they wilt.

Q: Why might the Purple Heinz tomato mutant grow better than Red Heinz in the drought conditions?

A: Allow students to guess and to be wrong. Students may get sidetracked on the purple fruit trait, so lead them to think about other parts of the plant. Answers might include purple plants don't need as much water, get water better than the red plants, have thicker leaves, have better roots.



Show pictures of seedlings of the normal red fruited variety (Red Heinz) that is drought sensitive and a purple fruited plant that grew better in drought conditions (Purple Heinz). (Figure 8) Don't tell the students which seedling is which.

Q: Examine this picture of two tomato seedlings. One is a red-fruited drought sensitive plant and one is a purple-fruited drought resistant plant.

Q: What differences can you see between the two varieties?

A: Seedling on right has more roots, has more red color in stem. Students may name other differences, but those are the most important.

Q. Why would the Purple Heinz mutant be more successful in drought conditions?

A: Because it has more roots to take up more water.

Q. Which seedling is the Purple Heinz mutant? Support your answer with what you know about the mutant.

A: The one on the left, because it has more roots.

Some students may say that the seedling on the right is Purple Heinz, and it has fewer roots because it needs less water. Show the transpiration cartoons to explain why more roots would make a plant more drought tolerant.

Part 2. Genetics

Now let's talk about testing our hypothesis that mutations could be responsible for changes in fruit color and root branching in the Purple Heinz plant.

Q: We've talked about the unique fruit color & root structure of the Purple Heinz mutant. These physical features of tomatoes that are called TRAITS. What are some other traits that you can think of?

A: There is an infinite number of answers: Students may name traits of humans—eye color, height, hair color—or of plants—fruit size, fruit shape, leaf shape, flower color, plant height, etc.

Q: How are traits passed onto the next generation?

A: Through reproduction

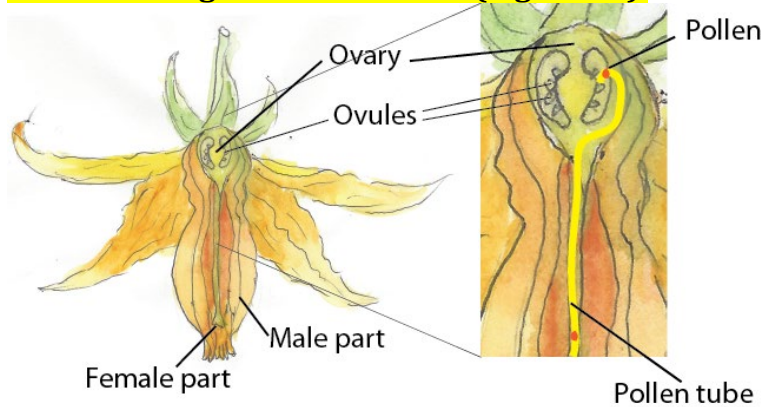
Let's learn now about how plants reproduce.

Pass out plant reproduction cards for card sort. (Figure 9). Ask students to place the cards in a circle in the correct order.



If students have cards in the wrong order, ask them why they think the (incorrect) card goes at that position. Ask them if there are other positions that would make sense. (Only share Figure 9 after students are done.)

Show drawing of tomato flower (Figure 10).



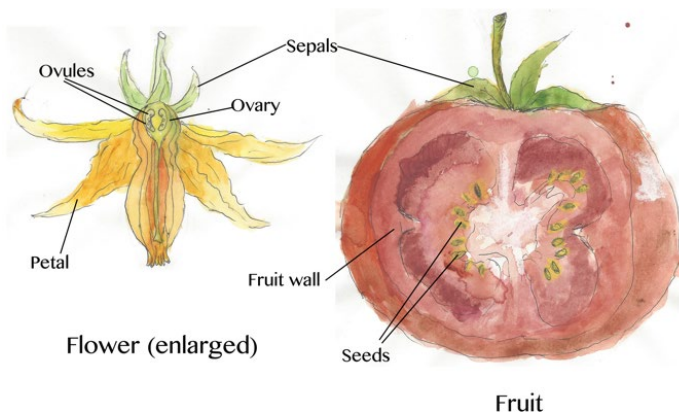
Q: What is the bee doing in the card sort photo?

A: Gathering nectar, and also bringing pollen from one flower and pollinating another flower.

Q: What happens when the flower becomes pollinated?

A: It becomes fertilized and creates fruit and seeds. Pollen from the male part of the flower (stamen) lands on the female part (stigma). The pollen moves down through the style and into the ovary, where it fuses with egg cells in the ovules. The next generation of plant is created.

Show drawing of flower and fruit (Figure 11).



Q: Look at this picture that shows the flower and the fruit. The fruit and seeds develop from the flower structures. Can you identify the part within the flower that gives rise to the fruit and seeds?

A: The ovary becomes the fruit and the fertilized egg cells in the ovules develop into the seeds.

Q. How do farmers control plant reproduction?

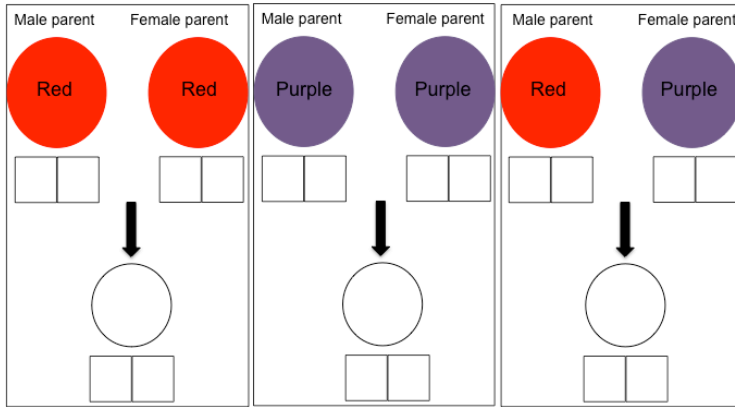
A. They take pollen from one specific plant and place it on the female reproductive structure of another specific plant.

This is called a CROSS.

Q: What is the physical substance, contained in the pollen and the eggs, which contains the information about traits, and which is inherited?

A: DNA or genes. Genes control traits. Genes/DNA are the physical substance that control traits and are passed down from generation to generation.

Show Figure 12a. Now let's consider the inheritance of the two traits, fruit color and root structure.



Q: We are going to look at how traits are inherited from parents. We will start with two red-fruited parents. Another term used to describe the physical appearance of an organism is *PHENOTYPE*. So if we cross two parents with the red-fruit phenotype, what color fruit will the offspring have?

A: The phenotype would be red. NOTE: REPEAT VOCABULARY WORDS (FOUND IN WORD BANK) AS MUCH AS POSSIBLE.

Color in the bottom circle to represent the color of the fruit of the offspring. Ignore the boxes for now. 'Crossing' means taking the pollen from the male parent and putting it on the stigma/flower of the female parent, as we just saw in the card sort.

Q: What fruit color phenotype would be produced if the two parents had purple fruits?

A: The phenotype would be purple.

Q: What fruit color phenotype would be produced in the offspring if one parent was red and one was purple?

A: Expect and encourage lots of different answers: red, purple, brown, striped. Then tell the student that the answer is red (in this case, for this exercise)

Q: In this example you get the red fruit phenotype when you cross the red and purple varieties. Why?

A: Because the red form of the gene is DOMINANT over the purple form of the gene, which is RECESSIVE. Dominant gene forms always show up as the phenotype, whether there are 1 or 2 copies of that gene in the individual. Recessive gene forms require 2 copies for the phenotype to show up. Therefore, the purple form is recessive. NOTE: Make sure that all students in your group understand this concept before moving on.

Q: How many copies of gene does an individual have?

A: Each individual has two copies, because there are two copies of each chromosome. Those genes could be the same, or the individual could have two different forms of the gene.

In the Red Heinz plant, the fruit color genes specify *red* fruit. In the Purple Heinz plant, the fruit color genes specify *purple* fruit. Likewise, the root structure genes specify branched roots in the Red Heinz plant and extra-branched roots in the Purple Heinz plant.

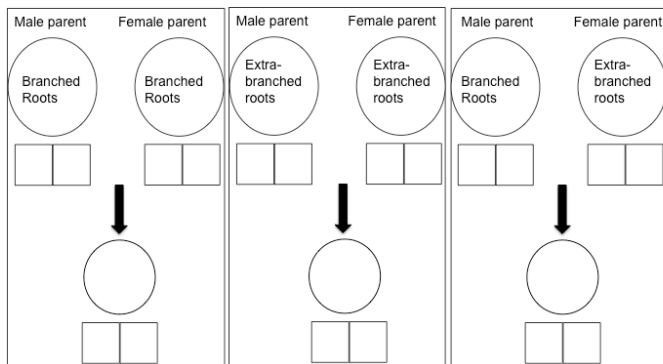
Q: We need a simple way to designate dominant and recessive genes using a single letter for the traits. Do you know which type of letters we use for dominant and recessive genes?

A: Capital letters for dominant genes, lower case letters for recessive genes.

Fill in the genotype in the boxes for the individual plants. Put one letter in each box. Use capital R for the red form of the gene and lower case r for the purple form of the gene. When an individual has two copies of the same form of the gene, they are HOMOZYGOUS; if they have two different forms of the gene, they are HETEROZYGOUS.

For this example, each parent is a HOMOZYGOTE. We call the combination of genes the GENOTYPE.

Show Figure 12b. Now we are going to do the same thing with the **root phenotype**. Write the root phenotype that you think will result from each of the following crosses. NOTE: IF STUDENTS GRASP CONCEPT EASILY, GO DIRECTLY TO THIRD CROSS.



Q: What will the root structure phenotype be in the offspring of a cross between a Red Heinz and a Purple Heinz?

A: Normal branched roots

Q: If a cross between a branched root plant and an extra-branched root plant gives branched roots, then is the gene that specifies extra-branched roots dominant or recessive?

A: recessive

Now determine the genotypes of the crosses: Fill in the boxes using the letters capital B for the branched root gene and lower case b for the extra branched roots gene.

Now we will use a more simplified diagram, the Punnett square, to look at the outcome of the crosses. **Hold up diagram of Punnett square on laminated sheet (Figure 13A). Refer students to blank Punnett squares in handout.**

	R	R
r		
r		

A Punnett square lets us predict the percentage of each of the possible GENOTYPES in the offspring.

Some general rules for doing Punnett squares are:

- Capital letters are used for the dominant trait, and lower case for the recessive trait
- One parent's gene form are listed on top, one down the side (beside each box), keeping dominant letters first
- Write the offspring genotype in the large boxes: combine the gene form above and the gene form to the left of each box to get the genotype of the offspring.

Work through Punnett square of the Red Heinz x Purple Heinz cross on the laminated sheet to show students how it is done. Have students put gene abbreviations in the squares and color squares to match fruit phenotype.

Q: What percentage of the offspring would have the red-fruited phenotype? What % purple? (Remember, capital R is dominant, red fruit; lower case r is recessive.)

A: 100% red, 0% purple or 4/4 red

Q: What percentage of the offspring would have a homozygous genotype? What percentage would have a heterozygous genotype?

A: 0% homozygous (either RR or rr), 100% heterozygous Rr

Show the next Punnett square (Figure 13b); refer students to next blank square.

	R	r
R		
r		

Phenotype: 75% red, 25% purple,
or 3:1 red:purple
Genotype: 25% RR, 50% Rr, 25%
rr, or 1:2:1 RR:Rr:rr

Q: Now complete a Punnett square of a cross between the offspring of the above cross, i.e. the offspring of Red Heinz and Purple Heinz.

A. Make sure that all students understand that the gene forms are R & r.

Q: What are the genotypes of the offspring?

A: 25% RR, 50% Rr, 25% rr

Q: What percentage of the progeny will be purple?

A: 25%.

Refer students to the next two blank Punnett squares.

	B	B
b		
b		

Phenotype: 100% Branched roots

Genotype: 100% Bb

	B	b
B		
b		

Phenotype: 75% branched, 25% extra branched, or 3:1 branched: extra branched

Genotype: 25% BB, 50% Bb, 25% bb, or 1:2:1 BB:Bb:bb

Q: Now let's do the same two crosses, but consider the root phenotype instead of the fruit color phenotype. Let's first cross a homozygous dominant parent (BB) with a homozygous recessive parent (bb). NOTE: IF STUDENTS STRUGGLE, WORK THROUGH BOTH PUNNETT SQUARES. IF NOT, HAVE STUDENTS DO ON THEIR OWN, OR JUST HAVE THEM GIVE THE ANSWERS FOR THE PHENOTYPE RATIOS AND GENOTYPE RATIOS FOR EACH CROSS.

Q: What would be the percentage of offspring with the normal branched root phenotype? With the extra branched root phenotype?

A for first cross (BB X bb): 100%, 0%

A for second cross (Bb x Bb): 75%, 25%

Q: What are the genotypes of the offspring?

A for first cross: 0%, 100%

A for second cross: 25% BB, 25% bb; 50% Bb

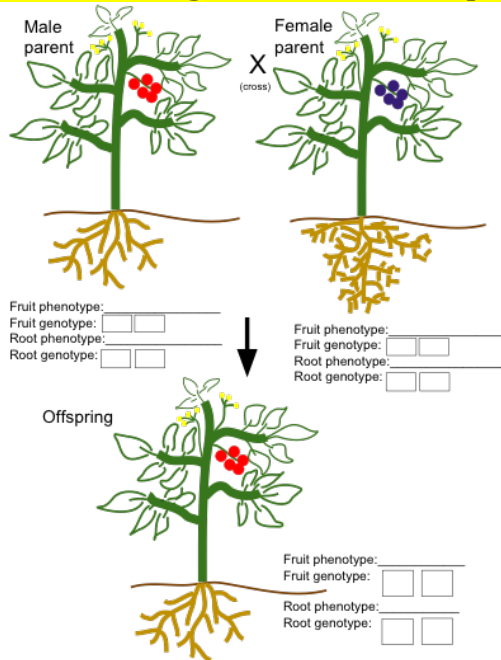
Q: What do Punnett squares help us to figure out?

A: They help us predict the possible gene form combinations, genotypes, and phenotypes of the offspring/progeny.

Let's go back to our scenario: you are a tomato farmer growing processing tomatoes that are bought by the Heinz corporation to make ketchup. You are very excited about the fact that the Purple Heinz plant might grow better in drought conditions because of its increased roots. However, Heinz only wants to buy red tomatoes. They will not buy tomatoes of any other color.

Q: Is it possible to get offspring that have red fruits but extra branched roots, so that they are drought tolerant but have red fruits? Let's look at a cross between the two different Heinz plants and see if we can get offspring with red fruits and extra branched roots.

Show drawing of HOMOZYGOUS parent plants (Figure 14).



Q: Write down the fruit and root phenotypes of each parent on the diagram. What are the forms of the gene that are found in each parent that make up the genotype? Write them in the boxes.

A: Red Heinz parent: Red fruit, $R R$; Branched roots, $B B$. Purple Heinz parent: purple fruit $r r$; extra branched roots, $b b$.

Q: What are the fruit and root phenotypes of the offspring? What are the fruit and root genotypes? Write them in the boxes.

A: Red fruit, $R r$; Branched roots, $B b$. NOTE: even though the phenotype looks the same as the male parent, the genotype is not the same. Also note that if the Purple Heinz plant were the male and the Red Heinz were the female in the cross, the offspring would also have the Red fruit, branched root phenotype and the Rr, Bb genotype.

So with a cross between a Red Heinz parent and a purple Heinz parent, the offspring will all have red fruit and normal branched roots. We want plants with red fruit and extra branched roots.

Q: Let's see what the next generation of offspring will look like if we cross two of the offspring from the first cross. For this cross we need a bigger Punnett square. How big should the Punnett square be? How many boxes will it have in it?

A: 4×4 with 16 boxes.

Q: This is called a dihybrid cross. What are the 4 possible gene combinations that we can put in our Punnett square if we cross two plants with the genotype $RrBb$?

A: $RB, Rb, rB, \text{ and } rb$.

Show dihybrid Punnett square (Figure 15)

	RB	Rb	rB	rb
RB				
Rb				
rB				
rb				

Do one row together then show the answer.

Show filled in dihybrid Punnett square (Figure 16)

	RB	Rb	rB	rb
RB	RRBB Red fruit, branched roots	RRBb Red fruit, branched roots	RrBB Red fruit, branched roots	RrBb Red fruit, branched roots
Rb	RRBb Red fruit, branched roots	RRbb Red fruit, extra- branched roots	RrBb Red fruit, branched roots	Rrbb Red fruit, extra- branched roots
rB	RrBB Red fruit, branched roots	RrBb Red fruit, branched roots	rrBB Purple fruit, branched roots	rrBb Purple fruit, branched roots
rb	RrBb Red fruit, branched roots	Rrbb Red fruit, extra- branched roots	rrBb Purple fruit, branched roots	rrbb Purple fruit, extra- branched roots

Q: How many purple fruits will you get? What is the fraction of the total?

A. You will get 4 purple fruits out of 16 (1/4).

Q: How many extra branched roots will you get?

A. You will get 4 extra branched roots (1/4).

Q. Do all red-fruited plants also have regular roots? Do all purple-fruited plants also have extra branched roots?

A: No

Q. How many plants will have both purple fruits and extra branched roots?

A. One plant (1/16)

Q: Which genotype you would choose to grow to get plants that always have red-fruited plants that also have extra branched roots?

A: They should come to the conclusion that the best genotype would be RRbb because this plant is homozygous for each trait, so it will always produce offspring with the same phenotype.

So now that you have seen how genes are passed onto the next generation of plants, we need to think about the physical structure of genes.

Q: What biological molecule contains genes?

A: DNA

Q: Do you think the DNA of a red tomato and the DNA of a purple tomato will look the same?

A: Let's do the experiment!!

DNA EXTRACTION PROCEDURE:

1. Add the DNA Extraction Solution (large tube) to the plastic bag with tomato fruit in it and knead for 1-2 min.

You are breaking cells open in the fruit by mashing them. The DNA Extraction Solution contains salt, water and detergent (like soap) that also break up the layer of phospholipids (fats) that make up the membrane of the cell and of the nucleus, since we need to get the DNA out of the nucleus.

2. Assemble the filter, funnel and the empty large tube. Dump plastic bag contents into filter, collect 7-10 mL into the tube.

We are separating all the cell parts from the solution that has DNA dissolved in it. DNA can dissolve in water, so we can't see it yet.

3. Add ethanol (in the small tube) by pouring it carefully down the side of the tube held at a slant, and allow it to separate into two distinct layers.

4. DO NOT SHAKE!!!

Q: What do you see in your tubes?

A: DNA can't dissolve in ethanol (just like oil and water don't mix), so the whitish, 'snotty-looking' material at the interface of the two layers is DNA.

Q: Does the DNA from the red tomato look the same as from the purple tomato? If so, why?

A: At this level of resolution, the DNA from both types of tomatoes looks identical. We can only see the bulk structure of the tangled chromosomes—a mixture of DNA and proteins—at this resolution.

Q: What would we need to do to see any differences between the DNA from the red tomato and the DNA from the purple tomato?

A: We would need to sequence the DNA and determine the order of the nucleotide base pairs.

Part 3: Tools for crop plant improvement

Heinz was not interested in the purple fruited tomatoes. But plant biologists at several universities are interested in them, and they call you up, asking you to save the seeds from the plant for future research.

Q: Why would anyone want a purple tomato?

A: The purple color is a natural chemical that also gives blueberries, cranberries, eggplant, and grapes the same purple color, and it has been shown to have health benefits. It is an antioxidant (called anthocyanin).

Plant scientists, farmers, and breeders have several tools for improving crops.

Show students photo of 3 purple tomatoes: Purple Heinz, Indigo Rose, and NPS Indigo (Figure 16)

Purple
Heinz



Produced by spontaneous mutation in an agricultural variety.

Indigo
Rose



Produced by conventional breeding: crossing an agricultural variety with a wild relative with purple fruits.

NPS
Indigo



GMO: Produced by genetic modification using a gene from snapdragon plants

Q: What do you notice that is the same about all these plants?

A: They all produce purple tomatoes.

Q: What is different about these 3 plants?

A: They were created by 3 different methods:

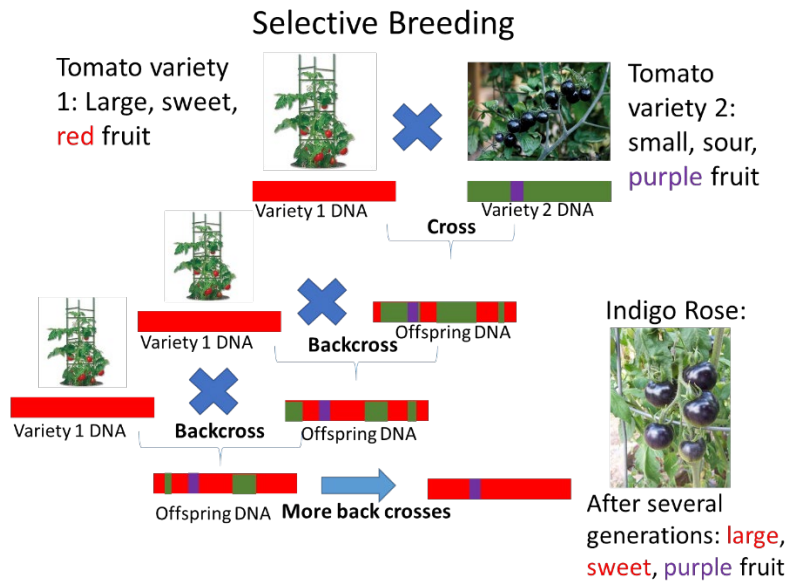
Purple Heinz arose in nature—mutations spontaneously occurred in an individual plant. Remember—not all mutations are harmful, and many are helpful.

Indigo Rose was created by selective plant breeding—crossing together multiple varieties of tomatoes that had different desirable traits, starting with a wild tomato that had purple fruits and another cultivated tomato.

NPS Indigo was created by genetic modification, using a gene from snapdragon that makes the purple color.

Plant scientists have many tools to help create plant with desirable traits. Two are indicated in this picture of the purple tomatoes: selective plant breeding and genetic modification. First let's talk about selective breeding. For hundreds of years, farmers have been selecting desirable traits that arose through SPONTANEOUS MUTATION, and crossing the plants with those desirable traits. to produce plants with the phenotype they want.

Show the diagram (Figure 17) of selective breeding and explain:



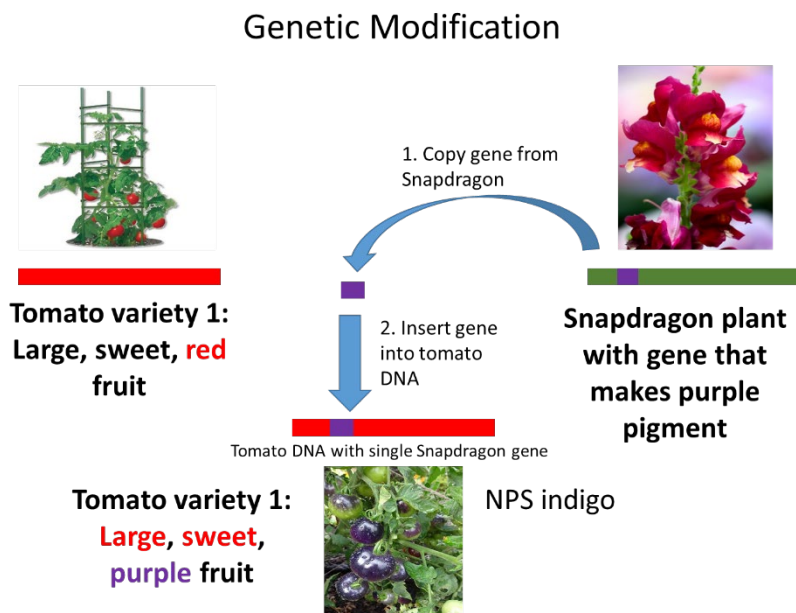
Indigo Rose was created by selective breeding. You cross two varieties of tomato, one commonly grown, with other desirable traits (#1), and one with the trait of interest (#2, purple fruit). In the case of Indigo Rose, the purple fruit trait came from a wild relative of tomato. Remember, a cross is taking the pollen from one plant and putting it on the flower of another plant. The offspring of the first cross is then crossed back to variety #1 to remove the unwanted traits of variety 2, by selecting offspring that have all the desired traits, including the new trait. Crossing back to the original parent has to be done for **many generations** to get a plant that only has the desired traits.

Q: Have any of you heard of Genetically Modified Organisms or GMOs? Do you know what a GMO is?

A: Students may have heard of GMOs and may take guesses about what they are.

Let's learn now how a GMO plant is made.

Show the diagram (Figure 18) of genetic modification and explain:



Here is how NPS indigo was created, through genetic modification. A gene from snapdragon was inserted into the DNA of a tomato with other desirable traits. **The resulting plants had large, sweet, purple fruits after 1 generation!** This method creates a genetically modified organism, or GMO. Although it is possible to insert a tomato gene, it does not have to come from the same species as the recipient plant.

Q: Do plant scientists have to choose between these two techniques—selective breeding and GM technology—to improve crops?

A: *NO! Both techniques are used by plant scientists to improve crops. Both techniques are necessary. It depends on where the gene comes from—another species or the same species or close relative.*

Q: Now that you know how a GMO is made, what have you heard about them? Are they harmful? Healthful?

Let's take a break and get some fuel for our brains. Let's do a corn chip taste test. **Pass out bowls of chips and let students try them, then vote on which ones are their favorites.** Use organic blue corn chips, organic yellow corn, and nonorganic yellow corn chips.

Q: Have you ever eaten a GMO? Could the corn chips be GMOs?

A: The organic yellow and blue corn chips were not made with GMO corn, but the other corn chips were most likely made with GMO corn.

Show chart of GMO crops (FIGURE 19). (Also in Handout) As of 2016 there are 8 commercially grown GMO crops in the US. Note: no GMO tomatoes yet. All these GMO crops contain extra genes that make them resistant to insect pests, viruses, or herbicides.

As of 2016, 8 GMO crops are currently grown in the US

Crop	% GMO of total grown	Main Uses	Extra trait added by genetic modification
Corn	90%	corn oil, corn syrup, corn meal, corn starch; all also used in processed foods	Insect resistance, herbicide resistance
Soybeans	95%	soybean oil, soy lecithin, soy protein; all also used in processed foods	Herbicide resistance
Cotton	95%	cottonseed oil, also used in processed foods	Insect resistance, herbicide resistance
Canola	90%	canola oil, also used in processed foods	Herbicide resistance
Sugar beets	90%	sugar, also used in processed foods	Herbicide resistance
Alfalfa	32%	animal feed	Herbicide resistance
Papaya	75%	eaten fresh	Virus resistance
Squash	12%	eaten fresh	Virus resistance

Show photo collage of types of processed foods containing GMOs (Figure 20)

Many processed foods contain ingredients from GMO crops.



Which do you like to eat?

Q: What ingredients from GMOs are contained in these foods?

A: Soybean oil, corn oil, corn starch, corn meal, high fructose corn syrup, cottonseed oil, soy lecithin, beet sugar. Use chart to help students Get students to realize that they eat ingredients from GMO crops on a regular basis, and that they are safe to eat. Note: many processed foods contain soybean oil, soy lecithin, and corn starch, even though those are not the main ingredients of the food (e.g. chicken tenders, lean cuisine, pizza rolls, peanut butter, Nutella, ice cream). Also, **NONE OF THESE FOODS CONTAIN THE EXTRA GENE NOR THE PROTEIN THAT MAKES THE CROP GMO.**

Q: The GM traits in currently-grown GMO crops help farmers by making it easier to control insects, viruses, and weeds. What other types of traits might help improve crop plants?

A:

1. Traits that help crops grow well with environmental challenges (e.g. drought, heat, polluted soils, increased pests)
2. Traits that increase the yield of crops (e.g. increase size, increased number of fruits or grains per plant)
2. Traits that increase the nutritional value of food (e.g. increased vitamins, decreased allergens)
3. Traits that benefit food processors and packagers (e.g. apples that don't turn brown when cut, fruits with uniform size, shape, and ripening time, tomatoes with thick skins and square sides)
4. Traits that turn plants into factories (e.g. plants that can produce medicines or industrial products)

Q: What new traits will we find in crop plants or in food in 50 years? Use your imagination!

If you have time left:

TOMATO TRIVIA:

- 293,000 acres of processing tomatoes were harvested in CA in 2015—tomatoes used to make soup, tomato sauce, ketchup, etc. (That doesn't include the acres of fresh tomatoes).
- Over 14 BILLION tons of tomatoes were harvested (approximately 48,000 tons per acre)
- Approximately 200 BILLION gallons of water were used to irrigate the tomatoes
- Farmers were paid \$83 per ton of processing tomatoes (approximately \$1.2 trillion)

