We talked about GMO's and their use in farming and in research with 4th-5th grade students at Marguerrite Montgomery Elementary School in Davis on May 8th 2015. We showed the students a picture of an organic Hawaiian papaya infected with the ring-spot virus and brought along a healthy genetically modified papaya that is resistant to the virus. We also showed the students some Arabidopsis plants that we genetically modified in our labs at UC Davis. The Arabidopsis plants contain the β-glucuronidase gene from bacteria that encodes a protein that converts the colorless substrate 5-bromo-4-chloro-3-indoyl "X-gluc" into a blue pigment and the colorless substrate 4-methylumbelliferyl-beta-D-glucuronide, "MUG" into a fluorophore, generating blue plants or glowing plants respectively. Here are some questions left in our question box by students and teachers:

What are GMO's?

GMO stands for genetically modified organism. GMO's are often made by taking a gene (a small part of DNA that controls a trait) that produces a useful trait from one organism and inserting it into the genome (the DNA) of a different organism. This technology is also called "transgenic". Transgenic technology has been used in agriculture to make crops that are resistant to pests or survive floods. Transgenic technology also has uses outside of agriculture. For example, genetically modified bacteria are used to produce enzymes used for making cheese and to make the insulin used to treat patients with diabetes. In the future, GMO's might even be used to produce biofuels, or clean up toxic spills!

How do plants get diseases?

Plants get diseases much like people do. Bacteria, viruses and fungi can all make a plant sick just as they can humans. And just like humans these microbes infect plants in a variety of ways. One example is through bugs that munch on the leaves of plants. Bacteria in the bug's mouth can infect the plant when the bug is eating the leaf. The bacteria can then travel through the plant in the xylem and phloem (water and nutrient conducting cells...like veins!). Viruses can also be transmitted by bugs. Plants can also get sick if these microbes are in the soil they are growing in, the water they are taking up from their roots or even from tools that a farmer uses on the plants!

How do the infections (ring spot virus) get to the papaya?

Like many plant diseases, the ring spot virus is spread from a sick plant to a healthy plant by insects that feed on the plants or by tools used by farmers to prune and harvest the plants.

Why don't you just make plants have an antidote (to diseases)?

That's a great idea! An antidote for plant diseases would be really cool! The nice thing about developing resistant varieties is that you can prevent the plants from every getting sick rather than having to treat each sick plant.

Can plants die from the disease (ring spot virus)?

Yes, plants can die from many diseases just like humans. It's important to protect our crop plants from diseases, because even if they don't die, the fruit can become small and damaged and not desirable for consumers.

How do you know if the food has the (ring spot) virus?

Ring spot virus only infects papayas and you can tell if they have it by the appearance of green, ring-like spots. The farmer will also notice yellowing and spots in the leaves and trunk of the plant. There are lots of other viruses that can infect different types of crops. Plants infected with viruses typically have yellow or white spots and crinkled leaves.

Can plants spread diseases to people?

In most cases, no. The diseases that hurt plants generally don't work the same in humans. Some bacteria for example infect the plant by digesting part of the cell wall but humans don't have a cell wall so those bacteria can't harm us. There are a few examples of fungi or some bacteria that can infect both plants and animals but they are only able to infect people or plants with a lowered immune system. Also if you can obviously tell that a fruit or a vegetable is sick (looks brown or black, splotchy, has fuzzy fungus growing on it) you generally wouldn't want to eat it anyway. When you get sick from eating plants it's usually from something like eating a rotting plant (the bacteria and fungus growing on the rotting plant can produce toxins that are harmful) or from some outside contamination with bacteria dangerous to humans.

So why can some plants fight off bacteria?

All plants can fight off bacteria. Plants have an immune system just like we do! But just like us, sometimes the infection outwits the immune system and the plant gets sick. Some plants are better at fending off certain bacteria than others. Maybe because they have a long history with dealing with that particular bacteria. Scientists can take advantage of those plants with a better immune system by taking the genes that make up that plant's immune system and putting it into another more susceptible plant. Now a plant that would normally get sick by that bacteria will be able to fight it off.

Are there GMO bananas?

Yes! Since 2001 a disease called bacterial wilt has been wiping out bananas in central and east Africa where people are very dependent on bananas for food and income. A gene was found in peppers that causes resistance to the bacteria. When bananas are genetically modified to express the pepper gene they are resistant too! These bananas are not yet on the market or available to African farmers, because GMO's are very heavily regulated in these countries, and they're waiting on approval. Other GMO's currently on shelves or coming soon in the US include corn, soybean, cotton, potato, papaya, squash, canola, alfalfa, apples, and sugarbeets.

How can fruits change by breeding?

There are lots of ways fruits can change by breeding! Name a characteristic you'd like a fruit to have or not have. It can probably be accomplished by breeding. Do you want a sweeter

fruit? Bigger, more juicy fruit? Do you want an apple that tastes like a grape? Seedless fruits? More nutritious fruits? Drought tolerant plants? All of these things can and have been accomplished by plant breeding. One example of how much a fruit can change by breeding is corn. If you look at teosinte (the wild ancestor of modern day corn) it doesn't look all that appetizing. It's small with few kernels and not very juicy but corn as we know it today was bred from that very plant. Every generation the farmer would collect the seeds from the plants with juicy, big ears and would cross (or mate) them with other plants that had good ears until she/he got to the big, yellow, juicy ears of corn that we have today.

Why doesn't the plant (Arabidopsis with the β-glucuronidase "GUS" gene from bacteria) glow without the chemical (4-methylumbelliferyl-beta-D-glucuronide, "MUG")?
The plant produces an enzyme (a molecule that makes reactions happen) called GUS. But in order for the reaction to occur, we have to introduce another ingredient in the chemical reaction called "MUG."

How are glowing plants (Arabidopsis with the β-glucuronidase "GUS" gene from bacteria) made?
The glowing plants are made by taking a gene from bacteria and inserting it into the genome of the plant. These bacteria glow naturally when they are introduced to the "MUG" chemical.

If you put alive plants in the glowing stuff what would happen?
The plants were alive when we put them into the "MUG" solution. They died from soaking in there for hours with none of the nutrients plants need to stay alive. If we sprayed the mug solution on live plants instead they might glow while they're alive!

Can our class have some blue plants?
We would LOVE to give you blue plants for your classroom. Unfortunately, since these plants are genetically modified (or transgenic) they are regulated and must be approved by the FDA before they can be distributed to the public.