KANSAS CORN STEM

Kansas Corn:

Genetically Modified Information?

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KANSAS CORN COMMISSION

Kansas Corn: Genetically Modified Information?
Grade Level: High School

Overview
Genetically Modified Organisms (GMO) are defined in a myriad of different ways, and there is much debate around the world about what the phrase actually means. During this lab, students will determine the importance of operational definitions by collaboratively coming to agreement on a class definition, making sure everyone is operating on the same page. Students will then explore the various types of conventional breeding methods, as well as those considered genetically engineered and genetically altered. By learning more about each method of alteration, students will create a graphic organizer showing similarities and differences between and among the different methods. One method of genetic modification has become especially controversial, the creation of transgenic organisms. Students will do a little speed dating by looking at different genes as they are transferred from one donor organism to another, conveying important traits along the way.

Kansas College and Career Ready Standard
Science
- **HS-LS1-1.** Construct and explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- **HS-LS3-1.** Ask questions to clarify relationship about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- **HS-LS3-2.** Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) variable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- **HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
- **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller more manageable problems.

Language Arts
- **RST.11-12.1.** Synthesize information from a range of sources (e.g., texts experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.
- **WHST.9-12.1.** Write arguments focused on discipline-specific content.

Math
- **MP.2.** Reason abstractly and qualitatively.
- **HSS-IC.B.6.** Evaluate reports based on data.

Kansas Corn: Genetically Modified Information?
Grade Level: High School

Ag Competencies: 018.Agriscience in Our World

- **1.** Define and relate agriscience to agriculture, agribusiness, and renewable natural resources. (LA)
- **2.** Connect biology, chemistry, and biochemistry to agriscience. (S)

Learning Objectives

- Students will be able to define genetically modified and explain some of the history behind the term.
- Students will be able to describe multiple practices used in the creation of new breeds of plants.
- Students will be able to distinguish the difference between genetic engineering practices and traditional breeding methods.
- Students will be able to describe the process of creating transgenic organisms.

Materials

- *Genetically Modified Information?* PowerPoint (available at kansascornstem.com)
- What is a GMO Student Sheet (pg. S1-S2, or available at kansascornstem.com)

Materials for Classroom Discussion:

- Computer and internet access to access Jimmy Kimmel video
- Jimmy Kimmel video on GMOs – *What's a GMO* (search YouTube "Jimmy Kimmel GMO")
- Large Post-it Notes, white boards, or poster paper
- Markers of various colors

Materials for GMO Graphic Organizer:

- Computer and internet access for individual research
- Breeding and Domestication Graphic Organizer Cards (1 per pair or group of students; pg. S3, or available at kansascornstem.com)
- Printed Infographic: The History of Genetic Modification in Crops (available online at Bit.ly/GMOanswers-Infographics)
- Printed Infographic: Get to Know GMOs – Seed Improvement (available online at Bit.ly/GMOanswers-Infographics)
- Printed Infographic: Lifecycle of a GMO (available online at Bit.ly/GMOanswers-Infographics)
- Printed Infographic: Are GMOs Safe? (available online at Bit.ly/GMOanswers-Infographics)
- Printed Handout: GMO Answers Informational Guide (available online at Bit.ly/GMOanswers-Infographics)
- Transgenic Speed Dating Cards (1 set; pg. S4-S23, or printable version available at kansascornstem.com)
- Overhead projector (optional)

Kansas Corn: Genetically Modified Information?
Grade Level: High School

Procedures for Instruction
Length of Time for Preparation: 5 minutes (copying and opening presentations)
Length of Time for Classroom Teaching: 2 45-minute class periods, or 1 90-minute class period

Background Information
One of the most critical parts of teaching any controversial issue is making sure you have all your facts straight the first time. Finding resources that are impartial and relevant are critically important in that process. Inevitably, students will come up with questions you do not have the answers for, and as teachers we must have trusted resources to send our students to for further research and clarification purposes. Just as we would not begin teaching a unit in cells without any prior knowledge of what a cell is, as good teachers we can not provide our students with flawed or outdated information. In a field, such as Genetic Engineering, where new innovations are constantly occurring, staying current is equally important. The following resources are great at providing background and further clarification of the processes involved in genetic modification, as well as the current and past practices being implemented in the plant breeding fields. Please review these sources **before** you begin your unit.

GMOanswers.com is a great reference source for everything from infographics to current statistics of GMOs. On their site, questions are answered by professionals in the field of genetic engineering, and the answered questions archived for future viewing. This allows you, and possibly your students, to peruse previously asked questions on the site, as well as ask further questions you both may be having. The site is easy to navigate, and it provides well-framed questions to help focus results for students in a very intuitive way. There is also a plethora of infographic PDF files that can be easily downloaded and turned into station activities as extension or background activities for your students. GMOanswers.com (Bit.ly/GMOanswers-Infographics) is a virtual one stop shop of information for both teachers and students.

Another fantastic resource is Yourgenome.org. This source has some wonderful information about the newly developing field of genome editing. Genome editing is basically a way for scientists to alter the genome of organisms without using genes from other organisms. With the advent of CRISPR-Cas9 technology and TALEN editing, it is critically important to stay up to date. As these are some of the newest forms of genetic engineering techniques, this site provides some valuable insight for both educators and students.

Kansas Corn: Genetically Modified Information?

Grade Level: High School

Classroom Discussion

"What is a GMO?"

- Watch the Jimmy Kimmel video on GMOs – *What's a GMO* (search YouTube "Jimmy Kimmel GMO")
- So what does *GMO* mean? Even if you know what the letters stand for, do you really know what it means?
- Hand out the *What is a GMO* Student Sheet (pg. S1-S2, or available at kansascornstem.com).
    - Make sure you are guiding students through this activity but not influencing their definitions. Students will want to know, "What is the right answer?", but there is no right or wrong answer. Whatever definition they come up with together is correct!
    - Have students individually define the phrase *Genetically Modified Organism*. Encourage them to also use examples to clarify their points.
    - Have students pair up or get into small groups of two or three others. Each group will need a large white board or poster-sized Post-it Note and a writing utensil.
    - Compare individual definitions; have students underline any parts of their individual definitions that the other members of their groups also have (these could be words, phrases, or even examples).
    - Ask students to examine the differences they see in their definitions (all of the non-underline parts) Ask the groups the following questions:
        - Why did feel like you needed to include these words or phrases?
        - Are these parts critically important or can they be eliminated from the definition?
- Breaking it down: What does the letters *GMO* really mean?
    - Look at the meaning of each word independently...
        - *Genetic*: referring to genes or DNA
        - *Modification*: changing from an original
        - *Organism*: any living thing including animals, plants, bacteria, fungi, etc.
    - Now add all of these definitions together: Changing a living thing's original genes or DNA.

Procedure for Lab

Students will be analyzing different methods of creating new breeds of crops, both through traditional means and through genetic engineering.

GMO or Non-GMO:

1. Place all of the Breeding and Domestication Graphic Organizer Cards (pg. S3, or available at kansascornstem.com) face up (with the name of the method) on the table. Allow five to six minutes for students to read through the cards and ask any questions of clarification if necessary before you proceed.
2. Using the operational definition for GMO, have students divide the breeding methods into two groups – GMO and Non-GMO.

3. At this point there is really no right or wrong answer, students should us the criteria in the definition to help them group the breeding methods. Teachers can provide leading questions, such as "So how is DNA changed?" or "Does it matter what changes the DNA?", to guide students.
4. Once all students are finished grouping their cards, have a student or pair share out their results. You can use an overhead projector to show how the students have grouped their cards.
5. Ask students if anyone had any different arrangements. Make any needed changes, then specifically ask the students why they feel those changes are needed.
6. Show students the PowerPoint slide (or a printed version of the slide) about the history of genetic modification in crops (Slide 8). Pay close attention to the dates and emphasize this is a timeline. Ask students the following questions:
   - When did we start the domestication of crops?
   - Which breeding method card do you think matches with domestication?

   Then have students continue to try and place all of the other cards in order on their diagram or desk.
7. Allow students to see some of the ancestral fruits that are commonly used foodstuffs today on Slide 10 of the PowerPoint. Ask students the following questions:
   - What differences do you see in these fruits in comparison to their modern day counterparts?
   - How would we have changes these fruits?
8. Ask students the following questions:
   - When did we start choosing the genes in our crops?
   - So... Would that change any of your card placements from before?

   Explain to students that all of the methods would meet our operational definition of a GMO.

Traditional vs. Genetic Engineering:

1. Use the PowerPoint to show students the difference between traditional and genetic engineering breeding practices (Slide 13).
2. Review with students that specific segments of DNA code for different proteins, known as *segments of DNA genes.*
3. Remind students the orange genes (spheres) represent the genes for the favorable traits we want to see in our crops. The green genes are those already present in the crop species.
4. Explain to students that traditional breeding includes incorporating half of the traits from the organism that has the desired trait, but not necessarily the desired trait itself. The combination of genes is completely random in sexually reproducing species. Just because you have isolated a specific gene as the one you want, does not mean it will be found in the offspring of any one cross of two individual parents. It may take thousands of crosses before the desired trait is confirmed into the organism.

Kansas Corn: Genetically Modified Information?

Grade Level: High School

5. Explain to students that on the other hand, genetic engineering isolates the one gene from the original organism that possessed a specific trait naturally. We then insert that one gene into the crop. This means only one gene is moved and only one gene will be seen in the crop organism.
6. Tell students, "Now look at the breeding method cards again, and group the methods into two groups – traditional and genetic engineering."
7. Give the students four to five minutes to analyze the cards again. Remember, at this point, there is no right or wrong answer. Provide leading questions if necessary, for example:
   - How many genes are moved in the traditional methods?
   - How does sexual reproduction figure into the mix?
8. Show the students the traditional vs. genetic engineering slide in the PowerPoint (Slide 13), or show them a grouping with Simple Selection, Selective Breeding, Interspecies Crosses, and Mutagenesis as a traditional group, and Transgenesis and Genome Editing in the Genetic Engineering group.
9. Ask students, "What is the one feature that separates these two groupings?" They should be able to isolate the difference between the number of genes being altered. Traditional is many, while genetic engineering is only one or a few.
10. Make sure to highlight that many individuals in the public often confuse the terms *genetically engineered and genetically modified*. There is a big difference, and this is the source of many individual's misconceptions about GMOs. Not every GMO has genes from other organisms, transgenic organisms do, but not those created through selective breeding or mutagenesis.
11. Apply the definitions to the infographic Get to Know GMOs (available at Bit.ly/GMOanswers-Infographics). Either by having a printed copy or by using the PowerPoint, ask students the following questions:
    - Where would you divide these groups?
    - What would be traditional and what would be genetically engineered?

Hopefully students will be able to discern that transgenesis is different than the others.

Starting January 2022, you will start to see new GMO labeling for products that are bioengineered or contain bioengineered ingredients. The National Bioengineered Food Disclosure Standard establishes the rules for disclosing which foods in the U.S. that have been or may have been bioengineered (BE) and enforced by USDA. To learn more about the labeling visit https://gmoanswers.com/USDA-Bioengineered-BE-GMO-labels

Kansas Corn: Genetically Modified Information?
Grade Level: High School

Transgenesis: Speed Dating:

1. Review the definition of *transgenesis.* Based on the criteria from before, this method is classified as genetic engineering. One gene that conveys a beneficial trait is taken from the genome of an organism and inserted into the genome of a crop.
2. Hand out one Transgenic Speed Dating Cards (pg. S4-S23, or available at kansascornstem.com) to each individual. Make sure the cards handed out will match together (e.g. donors and recipients). You can use the teacher's guide to eliminate pairs so you have exactly the correct number of cards for the number of students you have. Some cards can be paired up in groups.
3. Arrange students in your preferred mode, just make sure it involves movement!
    - Option 1: Students with donor cards sitting, and students with recipient cards standing. Recipients then move from table to table, rotating every 30-60 seconds. Recipients continue moving until they find their corresponding donor.
    - Option 2: An inside outside circle, with students who have donor cards forming the inner circle (facing outwards), while students with recipient cards form the outer circle (facing in towards those with donor cards). Students then rotate every 30-60 seconds until they have found their match. Once a match is found, have students step out of the circle with their partner and wait for further instructions.
    - Option 3 (Mixer Style): Students stand and walk looking for their possible partner or group. Have students mill around the room until they find their match. Once they have found their match, students should move to the exterior portions of the room.
4. Once students have found their pair/match have them go through the reflection questions on their own copy of the What is a GMO Student Sheet and provide answers. Then write down their specific pair/match on a large sheet of poster paper, or a large Post-it Note, to post for a gallery walk.
5. After students have completed their individual analysis, complete a gallery walk where each student views the poster of the other groups. Allow students 10-15 minutes to complete the gallery walk. Students can now finish the last two questions on their reflection sheet. Ask two to three students to share about their most surprising pairings.
6. Show students the timeline of the steps required to create a transgenic crop, Infographic: Lifecycle of a GMO (available at Bit.ly/GMOanswers-Infographics). Also show students the graphic of the transgenic crops on the market now.
7. Finally, review where genetic engineering is going in the future. In the PowerPoint, review the slide (Slide 21) about genome editing and the potential impacts on our definition of *GMO*.

Teacher Tips

Visit kansascornstem.com for videos and resources to assist with this lab.

Kansas Corn: Genetically Modified Information?

Grade Level: High School

Reflection and Conclusion

Throughout the steps of this lesson, students will have been given opportunities to explore some of the most critical terms related to the creation and clarification of GMOs. At the end of the lesson students may have more questions related to this area of discussion. In this case, please feel free to refer them to the sources listed in the background of the lab for further research. By allowing students to explore their own questions relative to GMOs, teachers can often ascertain specific gaps in the understanding of the overall process of genetic engineering. This activity is a great precursor to further laboratory work in the both of the following labs:

- *Kansas Corn: Feeding the World – DNA to the Rescue* (available at kansascornstem.com)
- *Kansas Corn: Protein Production Jackpot* (available at kansascornstem.com)

Science and Agriculture Careers

In order to meet the needs of the world's growing population, we are faced with the demand of producing higher yields on the same, if not decreasing, amounts of land. One of the most important tools in reaching this goal is genetic modification. We use genetic modification in one form or another to create better quality seeds. Almost all new seed varieties being created today have some level of biotechnology involved in their development. Basic breeding techniques, plant tissue culturing, genomic analysis, and genomic alteration, all rely on a basic understanding of the creation of new varieties of crops, including those utilized in the past and those we foresee in our future. Several different careers in agriculture are fundamental in the development of these new varieties of crops: botanists, horticulturalists, biochemists, biological engineers, climatologist, ecologists, food scientists, geneticist, microbiologists, plant pathologist, and an army of lab technicians are all involved in the development of each and every variety. Additionally, individuals who are involved in any area of agriculture: producers, seed salesmen, senators, the Secretary of Agriculture, agronomists, etc., must be versed in knowing how these new varieties are being created, tested, and grown. This is necessary in order to advocate effectively for the agricultural community and the human population as a whole.

To learn more about agriculture careers visit agexplorer.com. You can also find career profiles at kansascornstem.com.

Sources

- Stewart, C. N. (Ed.). (2016). Plant biotechnology and genetics: Principles, techniques, and applications (2nd ed.). Hoboken, NJ: Wiley.
- GMO infographics/handout – bit.ly/GMOanswers-Infographics
- *What's a GMO* (Jimmy Kimmel video on GMOs) – bit.ly/JimmyKimmelGMO
- Student research – GMOanswers.com
- Student research – Yourgenome.org

Kansas Corn: Genetically Modified Information?

Grade Level: High School

Any educator electing to perform demonstrations is expected to follow *NSTA Minimum Safety Practices and Regulations for Demonstrations, Experiments, and Workshops*, which are available at http://static.nsta.org/pdfs/MinimumSafetyPracticesAndRegulations.pdf, as well as all school policies and rules and all state and federal laws, regulations, codes and professional standards. Educators are under a duty of care to make laboratories and demonstrations in and out of the classroom as safe as possible. If in doubt, do not perform the demonstrations.

What is a GMO Student Sheet

Name: ______________________________

1. Define *Genetically Modified Organism* in your own words. (Write big, you will be marking this up later.)

2. Pair or group up! Look at your individual definitions, underline anything you have in common with your partner(s).

3. Look at the non-underlined parts of your definition. Why did you include that information? Is it critically important or can it be eliminated? If it can be eliminated, cross it out (with one single line so you can still see the words).

4. Work together as a team to create a shared definition. It must include all of the important elements you have underlined already in each individual definition. Make sure everyone can defend your definition. (You all must agree on the definition!)

5. As a class, repeat #2-4. What is your agreed upon definition?

6. The answer for #5 above represents an operational definition; meaning it's a definition all agree upon for the purposes of discussion and/or research. Why are operational definitions so important?

7. Would it be possible for you to collaborate or even discuss issues, especially controversial ones, without using operational definitions? How might your collaboration be affected?

8. In the Jimmy Kimmel video, are all of the people using the same definition? Do you think their answers might change if they were all using the same operational definition?

What is a GMO Student Sheet (Continued)

Transgenic Speed Dating Reflection:

1. What organisms are involved in your match/group?

2. Who is the donor? What are they giving in your match/group?

3. Who is the recipient in your match/group?

4. In your match/group, are these the same type of organism?

5. What problem is being addressed in your match/group? (For example: pest resistance, medical treatments, etc.)

6. Now look at all the matches/groups for the whole class. Which overall match or pair do you think is the most unusual? Why?

7. Which overall match of pair do you feel has to most potential to help people?

Breeding and Domestication Graphic Organizer Cards

MUTAGENESIS

Description: Using chemicals or radiation to change the DNA and occasionally produce a favorable trait.

Genes: 10,000 to 300,000+

SIMPLE SELECTION

Description: Choosing to plant seed from the healthiest plants available.

Genes: 10,000 to 300,000+

INTERSPECIES CROSSES/ HYBRIDIZATION

Description: Breeding techniques that permit genetic exchange between plants not crossing naturally.

Genes: 10,000 to 300,000+

SELECTIVE BREEDING

Description: Combining traits through intentional breeding, from similar and dissimilar plants by crossing into one genetic background with improved traits.

Genes: 10,000 to 300,000+

TRANSGENESIS

Description: Adding a specific well-characterized gene, from another organism into a new organism, to transfer a specific trait.

Genes: 1 or a Few

GENOME EDITING

Description: Specific changes to the DNA. An Enzyme cuts the DNA at a specific sequence; when repaired by the cell, an edit of change can be made.

Genes: 1

DONOR

NAME
Phyllomedusa Bicolor

Giant Leaf Frog

KEY GENES
DRS B1

PROPERTIES OF GENE PRODUCTS
B1dermaseptin protein kills bacteria and fungi.

GM USE
To prevent blight and bacterial diseases in potato crops.

Seed to STEM

DONOR

NAME
Bos primigenius

Cattle

KEY GENES
Cym

PROPERTIES OF GENE PRODUCTS
Chymosin is a protease enzyme that curdles milk.

GM USE
GM bacteria produces the enzyme which is purified and used to make cheese. Previously chymosin was extracted from the stomachs of calves so cheese made in this way was not acceptable to vegetarians. 80-90% of the cheese sold in Britian is made with GM bovine chymosin.

Seed to STEM

DONOR

NAME
Bacillus Thuringiensis

Species of Bacterium

KEY GENES
Cry

PROPERTIES OF GENE PRODUCTS
Crystal protein kills caterpillars, maggots and beetles that eat the protein.

GM USE
To make crops such as maize, cotton and soybean resistant to herbivorous insects.

Seed to STEM

DONOR

NAME
Agrobacterium sp

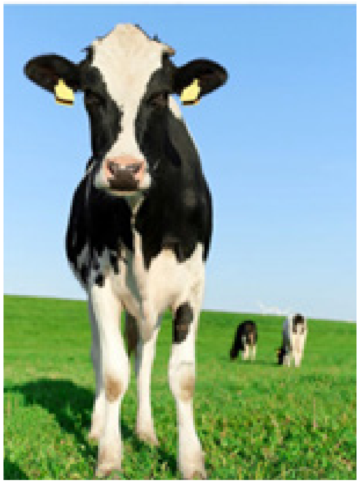
C4 Strain

KEY GENES
C4 EPSPS

PROPERTIES OF GENE PRODUCTS
EPSP synthase performs a crucial metabolic step in plant chloroplasts. The bacterial version is undamaged by glyphosate.

GM USE
To make crops resistant to glyphosate so it can be used as a weed killer without harming the maize, cotton, or soybean crops.

Seed to STEM



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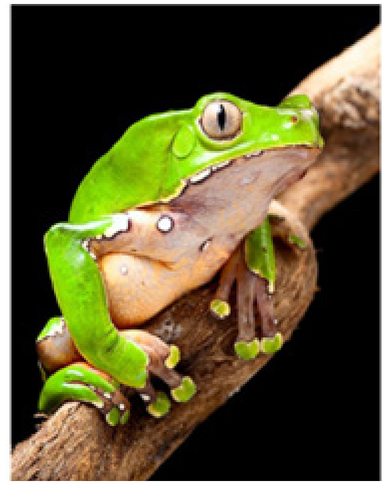

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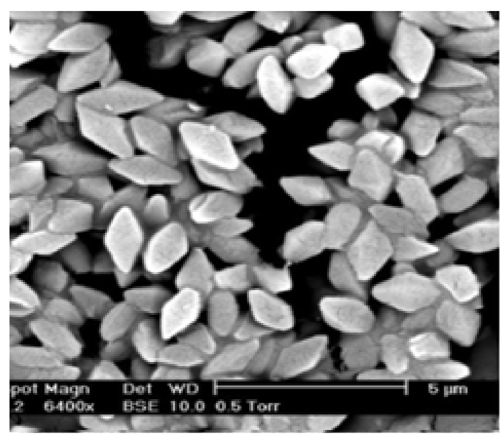


SPEED DATING

DONOR

NAME
Bacillus Subtilis

KEY GENES
cspB

PROPERTIES OF GENE PRODUCTS
Cold shock protein B helps organisms metabolize normally during abiotic stress.

GM USE
To produce higher yields for maize crops and produce a higher yield under drought conditions.

Seed to STEM

DONOR

NAME
Nephila Clavipes

Golden Orb Weaver

KEY GENES
MaSp

PROPERTIES OF GENE PRODUCTS
High-strength silk fiber for webs.

GM USE
Gene is switched on in mammary glands of GM goats to mass-produce the silk fiber for artificial tendons and ligaments and for bullet-proof vests and parachutes.

Seed to STEM

DONOR

NAME
Hepatitis B virus

KEY GENES
HBsAg

PROPERTIES OF GENE PRODUCTS
Surface antigen of virus stimulates an immune response in humans if injected or given orally.

GM USE
GM potatoes eaten raw in small quantities boost immunity to hepatitis B. This is an inexpensive and efficient way to deliver vaccines in developing countries

Seed to STEM

DONOR

NAME
Aequorea Victoria

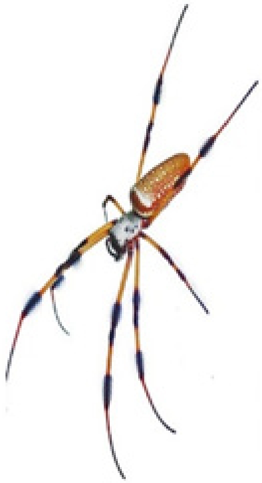
Jellyfish

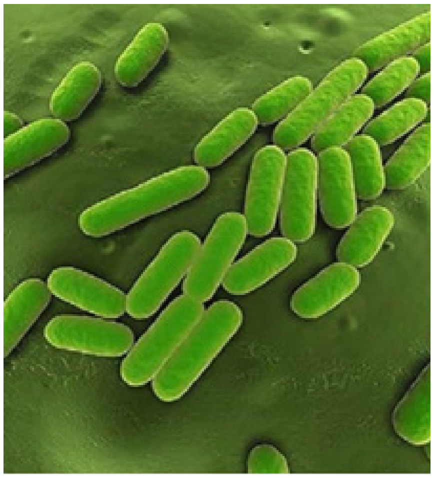
KEY GENES
GFP

PROPERTIES OF GENE PRODUCTS
Green Fluorescent Protein glows under UV light.

GM USE
The gene is extensively used as a marker to reveal which organisms have taken up a foreign gene and in which tissues in the gene is switched on. Spin-offs include Glo-FishTM) and NeonMice sold as pets in the USA.

Seed to STEM





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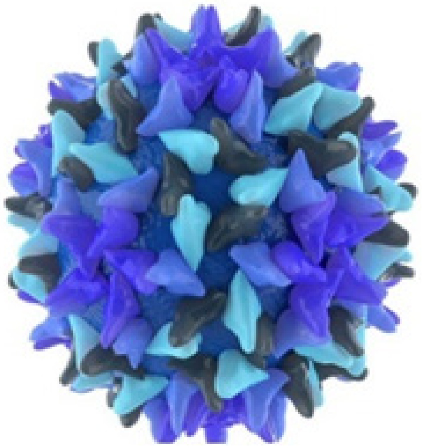

SPEED DATING

SPEED DATING

DONOR

NAME
Homo sapiens

Human

KEY GENES
Mutated version of BRCA1 and activated Ras oncogene.

PROPERTIES OF GENE PRODUCTS
Cause cancer. The products of the normal versions of the genes repair DNA mutation and suppress tumors.

GM USE
Creating cancer research models GM mice engineered to carry the mutant alleles are used to study cancer and treatments for cancer.

Seed to STEM

DONOR

NAME
Homo sapiens

Human

KEY GENES
Normal al-leles coding for insulin, lactoferrin, Factor IX, anti-thrombin III and gluco-sidase.

PROPERTIES OF GENE PRODUCTS
Insulin controls blood glucose concentration.
Lactoferrin is an antimicrobial found in colostrum and milk.
Factor IX helps blood clot.
Anti-thrombin III stops blood clotting.
Glucosidase in lysosome function.

GM USE
Pharmaceutical drugs
Insulin from GM bacteria treats diabetics.
Lactoferrin in GM rice treats diarrhea in children.
Factor IX from GM sheep's milk treats people with haemophilia B.
Anti-thrombin III from GM goats' milk is used as an anti-coagulant in surgical procedures. Glucosidase from GM carrot cells in culture treats people with Gaucher's disease.

Seed to STEM

DONOR

NAME
Homo sapiens

Human

KEY GENES
CFTR
RPE65

PROPERTIES OF GENE PRODUCTS
CFTR protein allows normal mucus production in lungs and gut.
RPE65 protein is needed in rods and cones for normal vision.

GM USE
Gene therapy
Normal CFTR allele is introduced into lung epithelial cells of cystic fibrosis patients.
RPE65 inserted into retinal cells of blind patients with Leber's Congenital Amaurosis restored sight.

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DONOR

NAME
Androctonus Austrails Hector

Species of arachnid

Scorpion

KEY GENES
AaHIT1

PROPERTIES OF GENE PRODUCTS
Toxic to insects but not harmful to mammals.

GM USE
To kill insects on GM cotton crops.

Seed to STEM

SPEED DATING

SPEED DATING

SPEED DATING

SPEED DATING

DONOR

NAME
Coat protein (CP) of Papaya Ringspot

Virus (PRSV)

KEY GENES
PRSV HA 5-1

PROPERTIES OF GENE PRODUCTS
Provide resistance to PRSV.

GM USE
Confer resistance to PRSV.

Seed to STEM

DONOR

NAME
Zoarces americanus

Ocean Pout

KEY GENES
Antifreeze glycoproteis or AFGP gene

PROPERTIES OF GENE PRODUCTS
Permit survival in subzero environments.

GM USE
The promoter for the antifreeze protein gene is used in conjunction with the growth hormone taken from a Chinook salmon, which leads to a higher concentration of the growth hormone in the blood, causing the genetically modified salmon to grow much more rapidly than it would naturally.

Seed to STEM

DONOR

NAME
Polygalacturonase (PG)

PROPERTIES OF GENE PRODUCTS
Antisense DNA keeps Polygalacturonase (PG), the major cell wall degrading enzyme of tomato fruit, from forming.

GM USE
By inhibiting the development of PG, the fruit should stay fresher longer.

Seed to STEM

DONOR

NAME
Agrobacterium tumefaciens

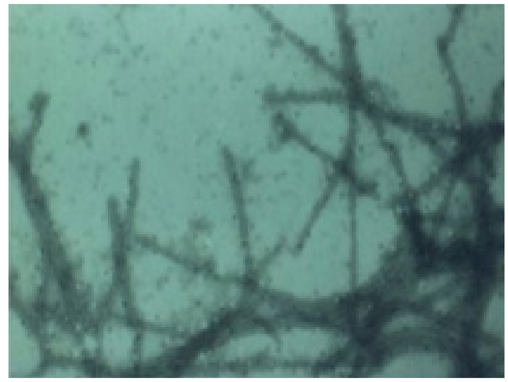
Species of Bacterium

KEY GENES
CaMV 35S

PROPERTIES OF GENE PRODUCTS
Code for coat protein (CP) encoding sequences from zucchini yellow mosaic virus (ZYMV) and the watermelon mosaic virus (WMV2).

GM USE
Provides protection against these viruses.

Seed to STEM



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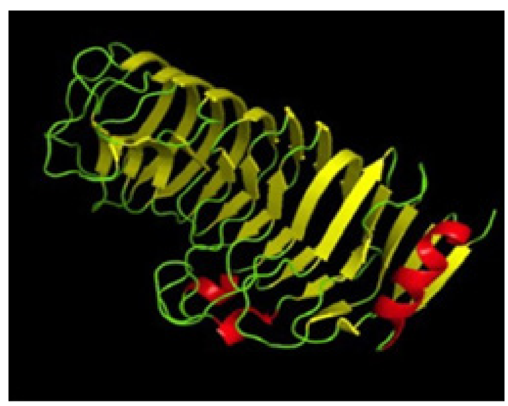

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DONOR

NAME
Agrobacterium tumefaciens

KEY GENES
CP4 EPSPS (5-enolpyruvylshikimate-3-phosphate synthase) encoding gene.

GM USE
Inhibits action of glyphosate, the key ingredient in RoundUp (Monsanto).

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DONOR

NAME
Delta-12 oleate desaturase

KEY GENES
gm-fad2-1; FAD2-1

PROPERTIES OF GENE PRODUCTS
An antisense RNA strand is created to silence the formation of the enzyme that coverts oleic acid into linoleic acid using the omega-6 desaturase encoding gene.

GM USE
Inhibits conversion of oleic acid to linoleic acid, keeps oleic acid levels high for healthier oil.

Seed to STEM

RECIPIENT

NAME
Zea mays

Maize or Sweetcorn

SUITABILITY AS A GM RECIPIENT
Major food source for animals and humans. Also a source of starch and sugars for processed food. Many insects attack the crop, its yield falls in drought conditions and the crop must be kept free of weeds.

Seed to STEM

RECIPIENT

NAME
Gossyplum hirsutum

Cotton

SUITABILITY AS A GM RECIPIENT
Important crop for textile fibers but many insect pests attack it and the crop must be kept free of weeds.

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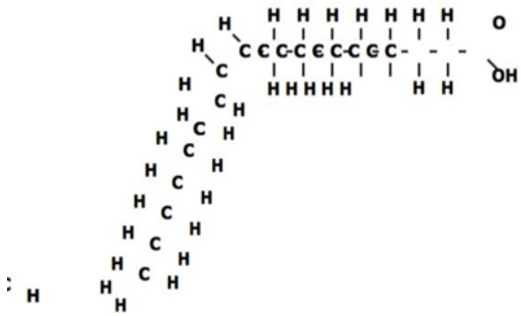

SPEED DATING

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RECIPIENT

NAME
Glycine max

Soybean

SUITABILITY AS A GM RECIPIENT
Major food source for animals and humans as a source of protein in processed food. Many insects attack the crop, and the crop must be kept free of weeds.

Seed to STEM

RECIPIENT

NAME
Solanum tuberosum

Potato

SUITABILITY AS A GM RECIPIENT
Major carbohydrate food source in Europe and America. Potatoes are easy to grow and can give high yields but suffer from many diseases such as blight, which lower yields. They can be engineered to make vaccines, but these must be grown under cover to prevent gene flow to other potatoes an to stop antigenic potatoes accidentally entering the human food chain.

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RECIPIENT

NAME
Daucus carota

Carrot

SUITABILITY AS A GM RECIPIENT
Field-grown crops generally have been found to be unsafe to use as vehicles for production of pharmaceutical drugs, but carrot cells grown in culture in bioreactors are a new 'expression platform' for human proteins that can be used as medical drugs.

Seed to STEM

RECIPIENT

NAME
Oryza sativa

Rice

SUITABILITY AS A GM RECIPIENT
Major food source in Asia and a suitable vehicle for therapies like treating children with diarrhea (rice enhanced with human lactoferrin) and preventing vitamin A deficiency (genes from maize or daffodil and a soil bacterium).

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RECIPIENT

NAME
Capra aegagrus hircus

Goat

SUITABILITY AS A GM RECIPIENT
Female goats produce plenty of milk. A gene is linked to a promoter to switch the gene on in the mammary glands, so that the protein product appears in the milk. So-called 'spider-goats' produce silk in their milk for medical and military application. Other GM goats produce a drug, human anti-thrombin III, used as an anticoagulant in surgery.

Seed to STEM

RECIPIENT

NAME
Ovis aries

Sheep

SUITABILITY AS A GM RECIPIENT
Female sheep produce plenty of milk. A gene for a pharmaceutical protein is linked to a promoter to switch the gene on in the mammary glands, so that the protein appears in the milk. Sheep have been used to make factor IX to treat sufferers of haemophila B.

Seed to STEM

RECIPIENT

NAME
Mus musculus

Mouse

SUITABILITY AS A GM RECIPIENT
It is a genetic model organism with a well-known, fully sequenced genome. As a mammal its genome is very similar to that of humans. Mice are small so are cheap to feed and house. Many GM techniques applicable to humans or farm mammals are first tried on mice. Fluorescent GM NeonMice are sold as pets in the USA.

Seed to STEM

RECIPIENT

NAME
Homo sapiens

Human

SUITABILITY AS A GM RECIPIENT
People suffering from genetic diseases caused by two recessive non-functional alleles can be treated with gene therapy. The dominant functional allele is inserted into affected somatic cells. Trials have included treatment of cystic fibrosis and Leber's congenital amaurosis. The limitation on treating a human with another human allele is whether the cells that need the foreign DNA are accessible (e.g. lung epithelium) and stable (not replaced every few days).

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RECIPIENT

NAME
Rerio danio

Zebrafish

SUITABILITY AS A GM RECIPIENT
It is a genetic model organism with a well-known, fully- sequenced genome. It is a useful, simple vertebrate for research. GM zebrafish expressing genes for fluorescent proteins are on sale in the pet trade in the USA marketed as Glo-Fish™.

Seed to STEM

RECIPIENT

NAME
Escherichia cali

SUITABILITY AS A GM RECIPIENT
GM bacteria divide rapidly in a fermenter to produce proteins like human insulin and bovine chymosin for cheese-making.

E. coli is a genetic model organism with a well-known, fully sequenced genome. Its plasmids are widely used as vectors. However, some strains of E. coli are pathogenic, and the GM process may involve inserting antibiotic resistance genes into the bacteria.

Seed to STEM

RECIPIENT

NAME
Carica papaya

Papaya

SUITABILITY AS A GM RECIPIENT
The papaya is cultivated in most tropical countries. However, it is susceptible to the Papaya Ringspot Virus (PRSV). Since 1992, PRSV has destroyed nearly all non-GMO papaya in Hawaii.

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RECIPIENT

NAME
Salma Salar

Salmon

SUITABILITY AS A GM RECIPIENT
Wild salmon disappeared from many rivers during the twentieth century due to overfishing and habitat change.

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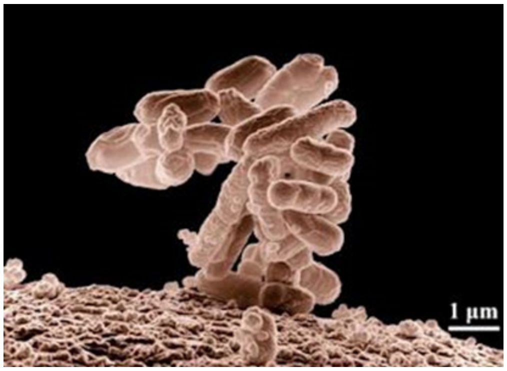

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RECIPIENT

NAME
Fragaria x ananassa

Strawberry

SUITABILITY AS A GM RECIPIENT
Strawberries grow in temperate climate regions which are capable of having low temperatures and frost.
Spring frosts cause damage to the flowers of the plant leading to poor yields and erratic fruiting. Frost on average causes millions of dollars in damages and drives up the price of the fruit for the consumer.

Seed to STEM

RECIPIENT

NAME
Solanum lycopersium

Tomato

SUITABILITY AS A GM RECIPIENT
Tomatoes are picked as green fruits and artificially ripened by ethylene treatment, which gives a ripe tomato color but not the full vine-ripened tomato flavor.

Seed to STEM

RECIPIENT

NAME
Glycine max

Soybean

SUITABILITY AS A GM RECIPIENT
Soybean oil is hydrogenated as a preservative to extend shelf life. High oleic oil does not need to be hydrogenated.

Seed to STEM

RECIPIENT

NAME
Cucurbita pepo

Summer squash

SUITABILITY AS A GM RECIPIENT
Viral diseases are a limiting factor to squash production, particularly during summer and fall months. Mosaic viruses include the cucumber mosaic cucumovirus (CMV), zucchini yellow mosaic potyvirus (ZYMV) and watermelon mosaic potyvirus (WMV2).

Seed to STEM

SPEED DATING

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RECIPIENT

NAME

SUITABILITY AS A GM RECIPIENT

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RECIPIENT

NAME

Glycine max

Soybean

SUITABILITY AS A GM RECIPIENT

Soybeans chief rivals in the field are weeds. If the plant can resist herbicide spraying, the control of weeds is much easier

Seed to STEM

RECIPIENT

NAME

SUITABILITY AS A GM RECIPIENT

Seed to STEM

RECIPIENT

NAME

SUITABILITY AS A GM RECIPIENT

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Gene donor	Recipient organism	Purpose of GMO
Bacillus thuringensis	Maize	insect resistant crop
Agrobacterium sp. C4		herbicide resistant crop
Bacillus subtilis		drought resistant crop
Bacillus thuringensis	Cotton	insect resistant crop
Agrobacterium sp. C4		herbicide resistant crop
Bacillus thuringensis	Soybean	insect resistant crop
Agrobacterium sp. C4		herbicide resistant crop
Giant leaf frog	Potato	disease resistant crop
Hepatitis B virus		vaccine production
Human	Carrot	pharmaceutical product for Gaucher's disease patients
Human	Rice	lactoferrin-containing rice treats children with diarrhea
Erwinia uredovora Maize		Golden Rice 2 with -carotene to prevent vitamin A deficiency
Golden orb weaver spider	Goat	strong silk fibres for medical and military uses
Human		pharming of anti-thrombin III
Human	Sheep	pharming of factor IX for haemophilia B sufferers
Human	Mouse	mouse cancer models
Jellyfish		NeonMice
Human	Human	gene therapy for recessive genetic disorders like cystic fibrosis and Leber's congenital amaurosis
Jellyfish	Zebrafish	Glo-Fish™
Cow	Escherichia coli	GM rennet (chymosin) for cheese-making
Human		insulin for diabetics
Scorpion	Cotton	insect-resistant crop
Papaya ringspot virus	Papaya	resistance to PRSV
Ocean pout	Salmon	antifreezing compounds
	Strawberry	
Antisense Polygalacturonase (PG) enzyme from tomato	Tomato	stops formation of enzyme that breaks down pectin; keeps fresh longer
Zucchini yellow mosaic virus (ZYMV) and watermelon mosaic virus (WMV2)	Squash	resistance to SMV
Delta-12 oleate desaturase enzyme silencing from soybean	Soybean	stops conversion of oleic acid into linoleic acid; health benefit