BIOTECHNOLOGY (HS)

GMO speed dating

Focus question	What do you know about GMOs?
Learning target	Students try to find a match to their card and learn about the various genetic modifications that have occurred.
Vocabulary	Donor, recipient, AFGP gene, antigen, anti-thrombin, blight, CP4 EPSPS, chymosin, cucumber mosaic cucumovirus, cystic fibrosis, EPSP synthase, glucosidase, glyphosate, lactoferrin, Leber's congenital amaurosis, papaya ringspot virus, polygalacturonase (PG), protease, watermelon mosaic (poty)virus, zucchini yellow mosaic (poty)virus , transgenesis

LS3: Heredity: Inheritance and Variation of Traits

Performance expectation HS-LS3-2	**Classroom connection:** Students are given a card with either a donor or recipient organism. Students read about the organism, then try to find a match for themselves.

Science and engineering practices

Engaging in Argument from Evidence	**Classroom connection:** Students *make a claim and defend it based on evidence* provided on the cards or based on their own research.

Disciplinary core ideas

LS3.B: Variation of Traits	**Classroom connection:** In this case, the environmental factors are genetic modifications made by humans.

Cross-cutting concepts

Cause and Effect	**Classroom connection:** Donors and recipients match up, then students discuss the benefits and risks of genetic modification.

Background

Genetic modification is a confounding topic to many people. In reality, humans have been genetically modifying plants and animals for thousands of years. Selective breeding and selective mutagenesis have resulted in many of the different crops and breeds of animals we take for granted today. Teosinte is the most closely related plant to what we call corn or maize today; it is a tall grass that has wide branching lateral leaves and an ear with only 5–12 kernels tightly sealed in a hard casing. This plant still grows in southern Mexico.

There are many methods of genetic modification and more are being utilized every day. They include: selective breeding and hybridization, stacked traits, mutagenesis, transgenesis (transfer of a gene from one to another of a different species), TALEN, gene silencing and CRISPR. The most common method of genetic modification up to now, has been transgenesis. Donor genes have given recipient organisms new traits to add beneficial traits, or protection from disease, pests, drought, or flood. This activity is a review of some of those transgenic matches.

This activity came from the United Kingdom and has been adapted for this use. Some of the pairings are for human medical treatment, while some are for animals and crops.

Several of these pairings have been discussed, but not completed (i.e.strawberries with flounder genes to resist frost have not been released due to consumer perception that the strawberries may taste “fishy”; tomatoes with PG were the first GMO available to consumers, but are no longer available; carrots are not GMO in the U.S.; although bananas and potatoes have been suggested as a method for developing countries to grow and deliver vaccines, that has not become a reality yet.) On the other hand, fast-growing salmon (AquaBounty) were just approved in 2018 to be grown at indoor facilities, golden rice was finally approved for use in Bangladesh in 2019.

Materials

- Donor cards
- Recipient cards

Prior knowledge

Students need to know vocabulary related to the donors and recipients (see list below):

- protease
- lactoferrin
- cystic fibrosis
- Leber’s congenital amaurosis
- papaya ringspot virus
- watermelon mosaic (poty)virus
- chymosin
- glucosidase
- glyphosate
- EPSP synthase
- CP4 EPSPS
- Polygalacturonase (PG)
- zucchini yellow mosaic (poty)virus
- cucumber mosaic cucumovirus
- anti-thrombin
- blight
- antigen
- AFGP gene

Students need to be creative. All donors do have matches, however, some may be matched with more than one. Students should read the information on the backs of their cards, and be willing to make a match that they think makes sense. Whether correct or not, the match students make should be justified by evidence or benefit of the potential match, even if it has not been done in reality.

Teacher preparation

Copy the cards on cardstock front to back and cut them apart. Each student receives one card, either a donor or recipient card. If there are extra cards for your classroom, you can remove them so that all students have a match. The answer key is below.

Procedure

1. Each participant gets one card. The donor card holders sit around the room. The recipient card holders rotate around the room spending 30–60 seconds with each donor card holder.
2. After 30–60 seconds, the recipient card holders move to a new donor card holder. Repeat until each recipient has found their match (and they step out of the rotation) or all recipients have spoken with all donors.
3. Remaining unmatched participants choose a match. Each matched pair stands and shares their match with the large group.
4. Have students discuss the benefits of the match and describe any risks.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may ask a local farmer which, if any, genetically modified crops she/he uses and why. If a local farmer is not available, contact the county extension service, the state corn or soybean check-off program or the state department of agriculture for more information about the local use of GM crops.
- **Students with special needs (language/reading/auditory/visual):** The cards for the activity have supportive photos on one side and the details on the other. Students could pair up with one card to determine the most likely match with two other students.
- **Extra support:** If students are struggling, they may research one of the modifications to learn more about it.
- **Extensions:** Students may research the story of one or more of the failed attempts at genetic modification and determine how they might have been more successful (i.e. Flavr Savr Tomato, freeze protected strawberries with flounder gene, etc)

Assessments

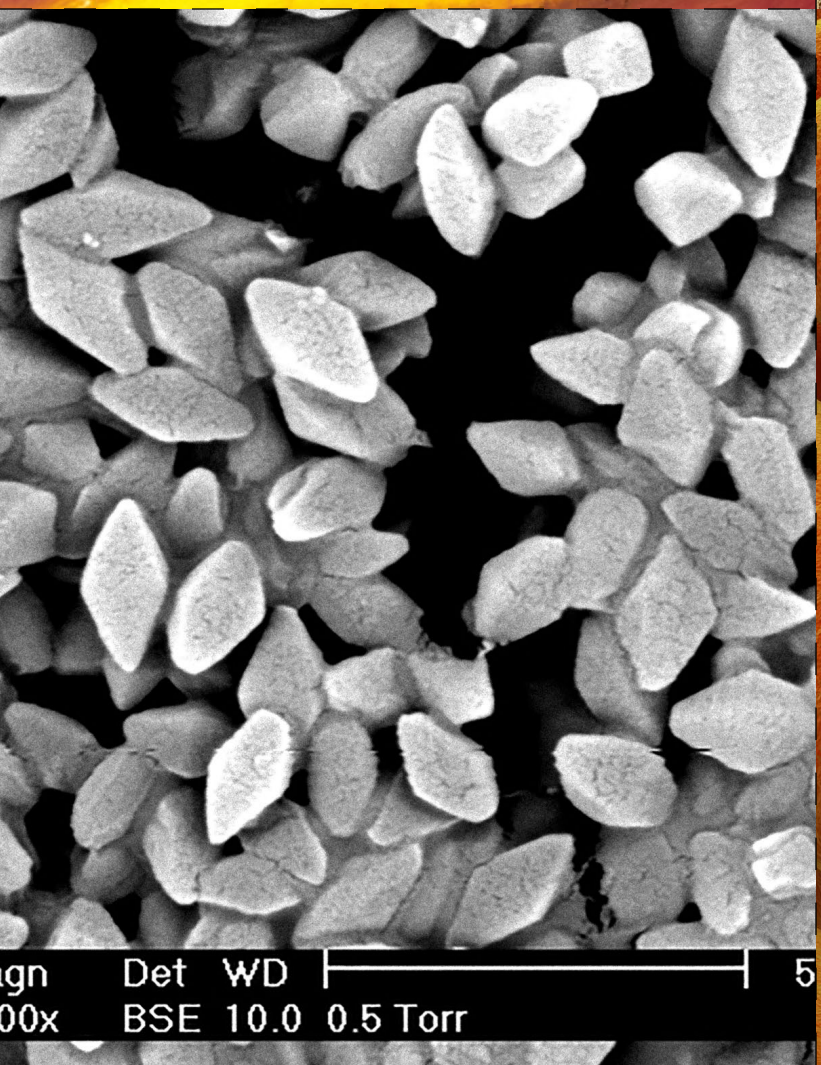
Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Make and defend a claim based on evidence that inheritable genetic variations may result from: … mutations caused by environmental factors.	Student found a match but the claim that the match was possible did not contain evidence.	Student found a match and the claim that the match was possible contained evidence to support the match.	Student found a match and the claim that the match was possible contained evidence to support the match and the evidence was discussed in terms of benefits and risks.

Rubric for self-assessment

Skill	Yes	No	Unsure
I found a match and made a claim about the possibility of the match.			
I provided evidence to back up the claim.			
I was able to discuss the benefits and risks of the match.			

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 diarrhoea
Erwinia uredovora Maize		Golden Rice 2 with β-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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DONOR

Name
Bos primigenius
Cattle

Key gene
Cym

Properties of gene product
Chymosin is a protease enzyme that curdles milk

GM use
GM bacteria produce 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 Britain is made with GM bovine chymosin.

DONOR

Name
Phyllomedusa bicolor
Giant leaf frog

Key gene
DRS B1

Properties of gene product
B1dermaseptin protein kills bacteria and fungi.

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

DONOR

Name
Agrobacterium sp
C4 strain

Key gene
C4 EPSPS

Properties of gene product
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 soya bean crops.

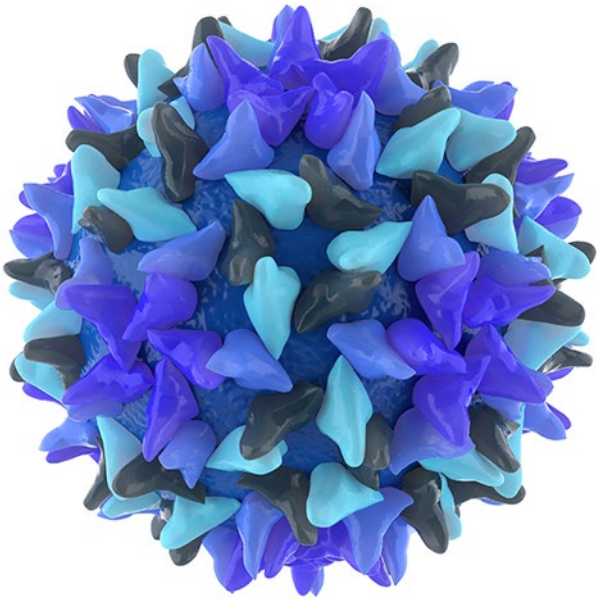
DONOR

Name
Bacillus thuringensis

Key gene
Cry

Properties of gene product
Crystal protein kills caterpillars, maggots and beetles that eat the protein.

GM use
To make crops such as maize, cotton and soya bean resistant to herbivorous insects.



DONOR

Name
Nephila clavipes
Golden orb weaver

Key gene
MaSp

Properties of gene product
High-strength silk fibre for webs.

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

DONOR

Name
Bacillus subtilis

Key gene
cspB

Properties of gene products
Cold shock protein B helps organisms metabolise normally during abiotic stress.

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

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 the gene is switched on. Spin-offs include Glo-Fish™ and NeonMice sold as pets in the USA.

DONOR

Name
Hepatitis B virus

Key gene
HBsAg

Properties of gene product
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.

DONOR

Name
Homo sapiens
Human

Key genes
Normal alleles coding for insulin, lactoferrin, Factor IX, anti-thrombin III and glucosidase.

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 diarrhoea 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.

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 mutations and suppress tumours.

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

DONOR

Name
v
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.

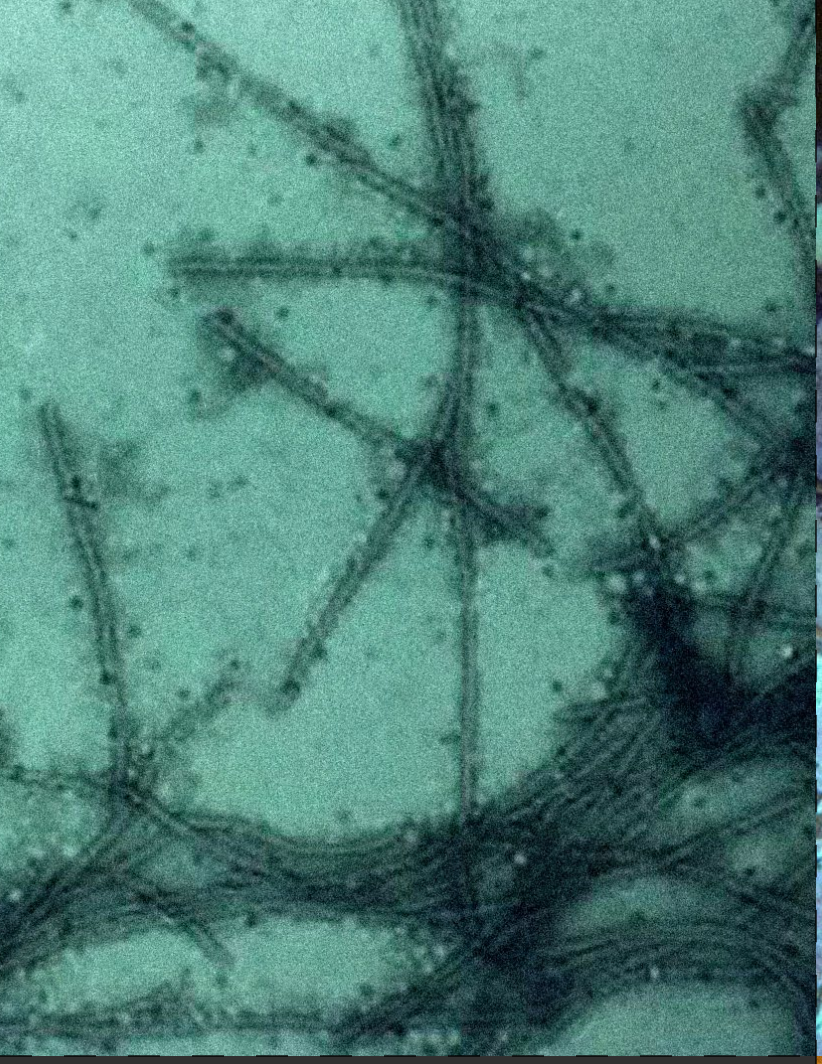
DONOR

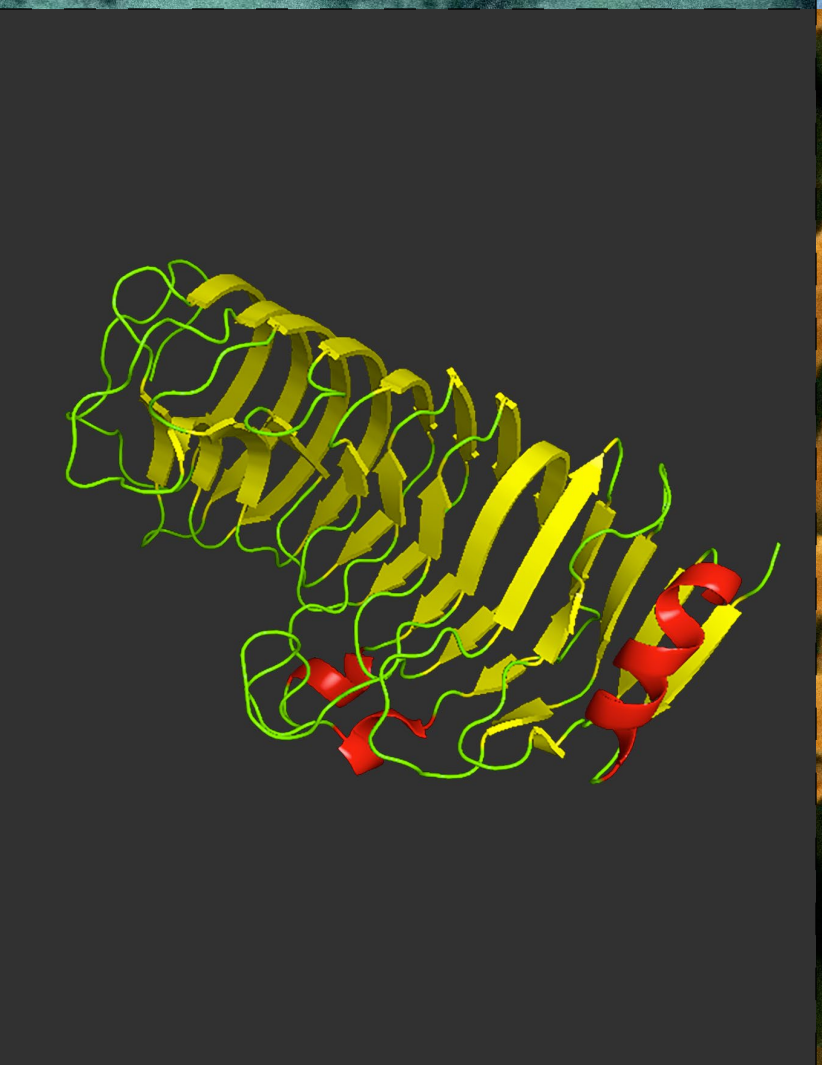
Name
Homo sapiens
Human

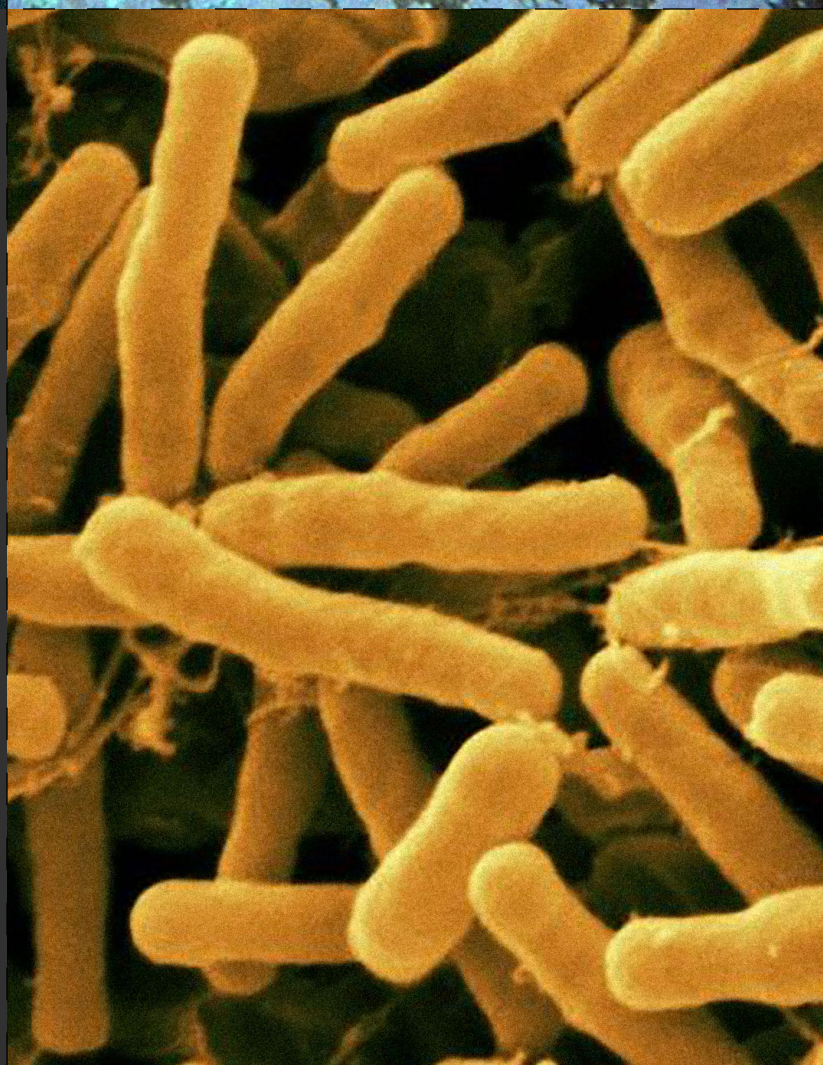
Key genes
CFTR
RPE65

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.







DONOR

Name
Zoarces americanus
Ocean Pout

Key genes
Antifreeze glycoproteins 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.

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

DONOR

Name
Agrobacterium tumefaciens

Key genes
CaMV 35S

Properties of gene products
Code for the coat protein (CP) encoding sequences from zucchini yellow mosaic virus (ZYMV) and the watermelon mosaic virus (WMV2).

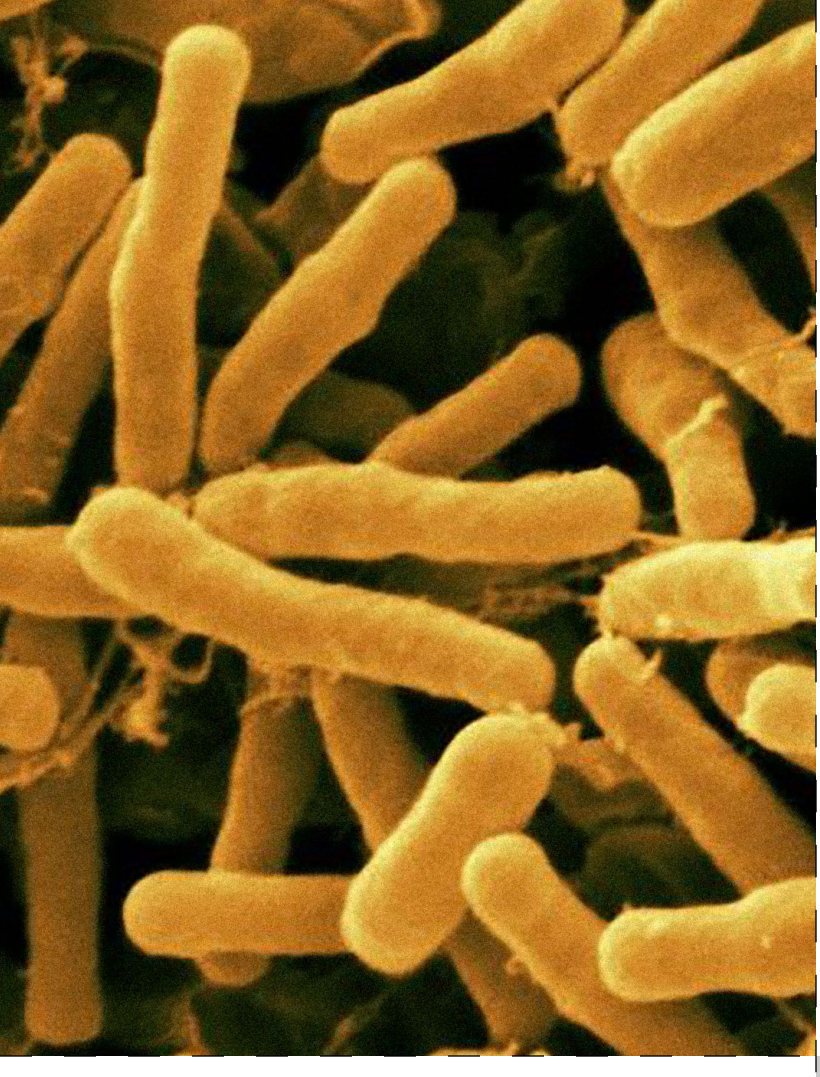
GM use
Provides protection against these viruses.

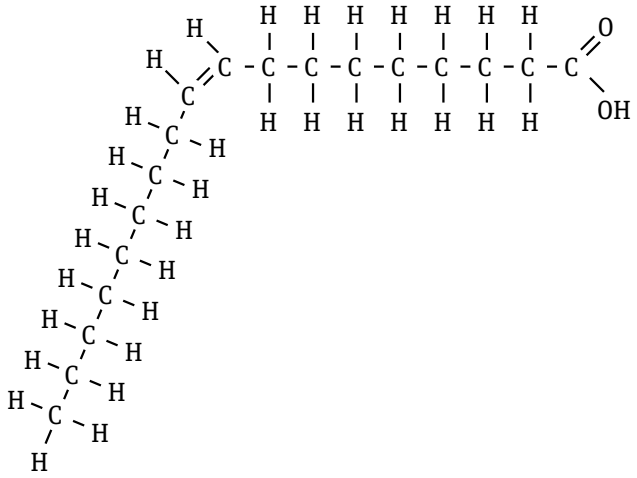
DONOR

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.





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 converts 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.

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).

RECIPIENT

Name
Gossypium hirsutum
Cotton

Suitability as a GM recipient
Important crop for textile fibres but many insect pests attack it and the crop must be kept free of weeds.

RECIPIENT

Name
Zea mays
Maize or sweet corn

Suitability as a GM recipient
Major food source for animals and humans and as 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.

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 and to stop antigenic potatoes accidentally entering the human food chain.

RECIPIENT

Name
Glycine max
Soybean

Suitability as a GM recipient
Major food source for animals and for humans as a source of protein in processed food. Many insects attack the crop and the crop must be kept free of weeds.

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).

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.

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 haemophilia B.

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 applications. Other GM goats produce a drug, human anti-thrombin III, used as an anticoagulant in surgery.

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).

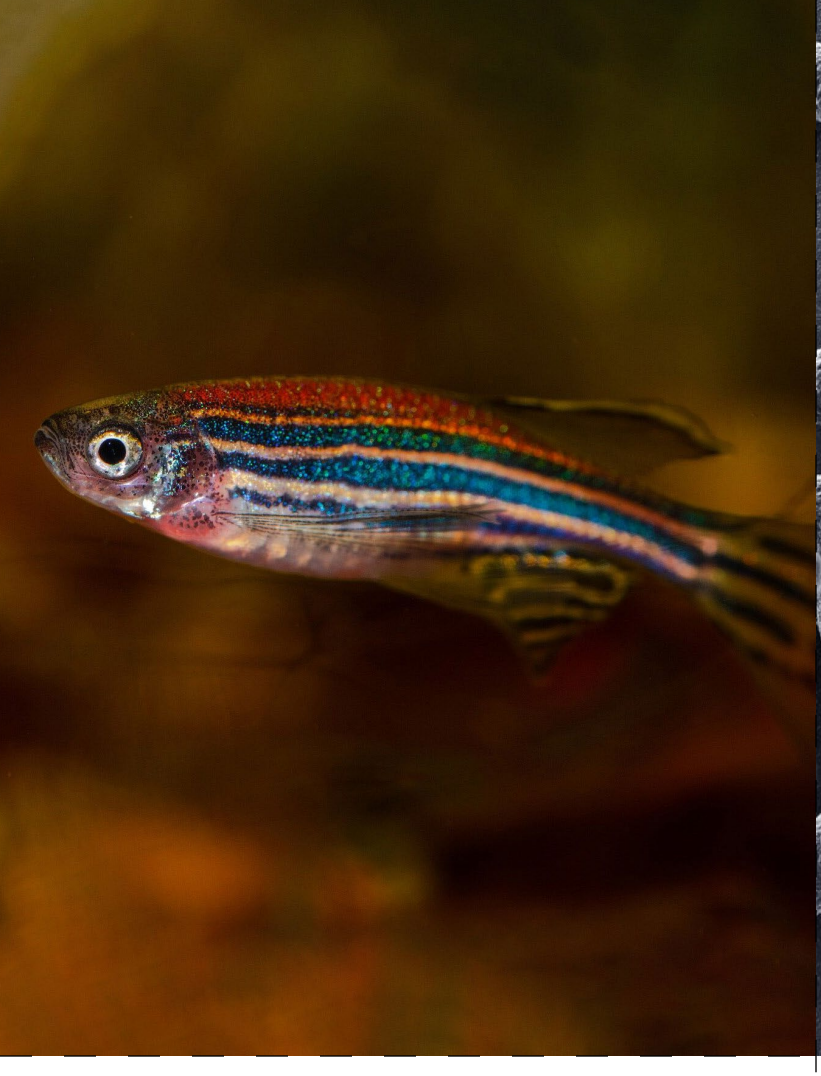
RECIPIENT

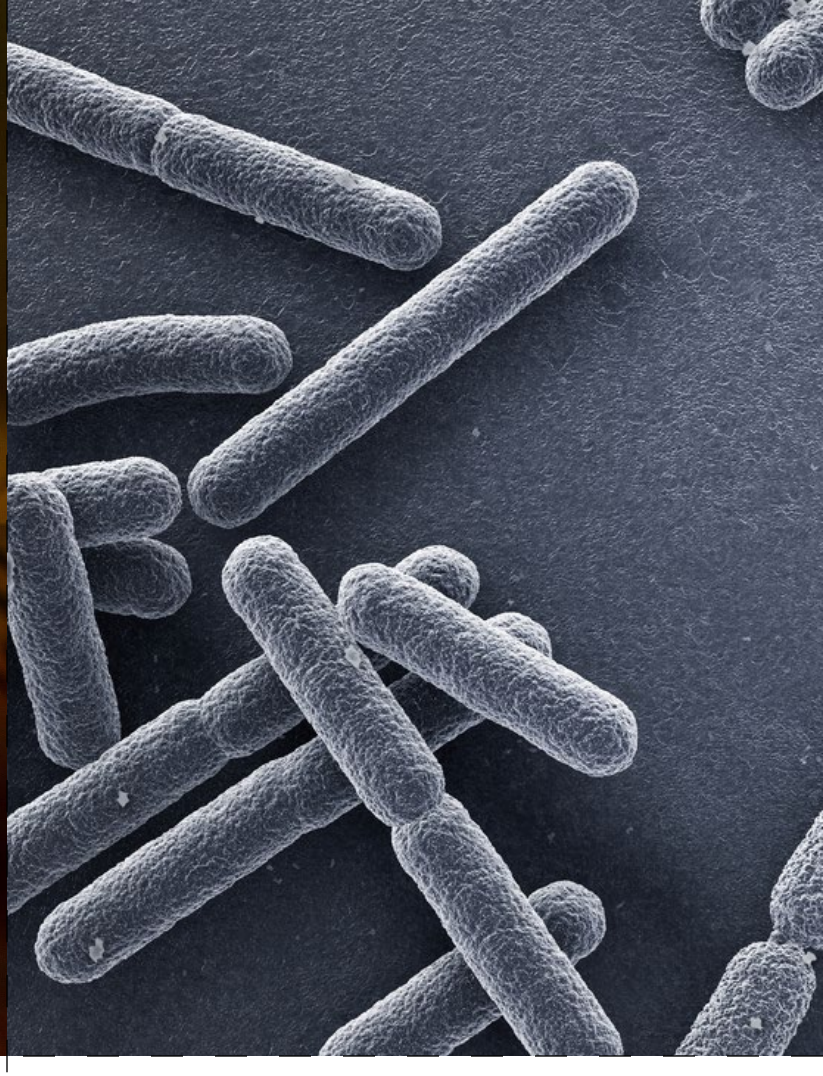
Name

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.





RECIPIENT

Name
Escherichia coli

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.

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 zecubrafish expressing genes for fluorescent proteins are on sale in the pet trade in the USA marketed as Glo-Fish™.

RECIPIENT

Name
Salmo salar
Salmon

Suitability as a GM recipient
Wild salmon disappeared from many rivers during the twentieth century due to overfishing and habitat change.

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.

RECIPIENT

Name
Solanum lycopersicum
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.

RECIPIENT

Name
Fragaria × 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.

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.

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).

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.