FDE 330
FOOD BIOTECHNOLOGY

GENETICALLY MODIFIED FOODS

What are GMOs and GM foods?

- **Genetic Modification:** Genetic modification is **the alteration of the genetic makeup of an organism that can be passed on to its descendants**.

- Genetic modification is a biological technique that effects alterations in the genetic machinery of all kinds of living organisms.

- Strictly, this definition includes traditional methods of selective breeding of crops or animals for specific attributes by normal reproduction, breeding closely related species or isolating mutants, which have been practised by farmers and breeders for thousands of years.

- However, the term is now more often used to describe **«genetic engineering»** in which techniques in molecular biotechnology are used to manipulate genes, outside the normal reproductive process of a plant, animal or microorganism, to produce new physiological or physical characteristics in a food.

What are GMOs and GM foods?

- **Genetically Modified Organisms (GMOs):** GMO is defined as follows by WHO (World Health Organization): "**Organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination**"

What are GMOs and GM foods?

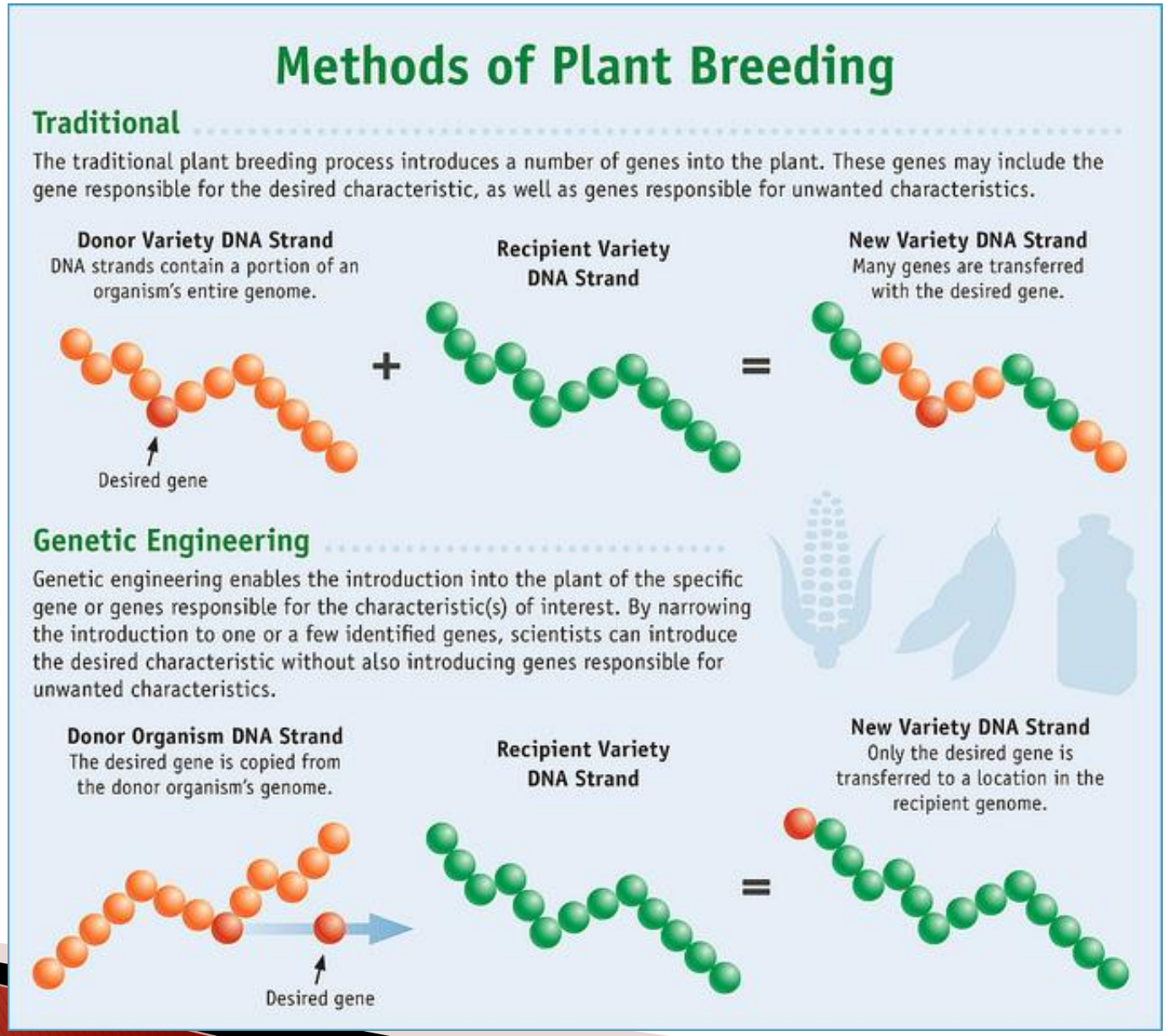
- **Genetically Modified Organisms (GMOs):** The FAO (Food and Agriculture Organization of the United Nations) and the European Commission define a GMO as a product **“not occur naturally by mating and/or natural recombination”.**

What are GMOs and GM foods?

- **Genetically Modified Food (GM Food):** **«food containing, consisting of, or produced from, a genetically modified organism»,** according to EU legislation.

- **"GM foods"** refer to **foods produced from genetically modified plants or animals**.

Genetic Engineering vs. Selective Breeding



GMO vs. Selective Breeding

GMO vs. Selective Breeding Comparison		
Characteristics	**GMO**	**Selective Breeding**
Definition	GMO is an organism which is subject to an artificial genetic modification, i.e. a modification which has not occurred under natural conditions.	Selective breeding is breeding of plants or animals in order to selectively develop particular characteristics in the offspring by selecting males and females with the desired characteristics for reproduction.
Time range	The results of the genetic engineering are detectable in the first generation.	A number of generations are necessary to obtain the desired results of the selective breeding.
Involved organisms	Via genetic engineering, genes from one species can be inserted in other, non-related one.	In selective breeding, the individuals have to be from the same species.
Combination of genes	In GMO, the scientists create new combinations of genes.	In selective breeding, genes combine on their own.
History	The first GMO was produced in 1973.	Various forms of selective breeding have been used since the dawn of human society.

GM Food Crops

- **The first commercially grown GM food crop** in 1994 was a tomato (the `FlavrSavr') that carried a gene to reduce the level of polygalacturonase and hence reduce softening and increase the shelf-life.
- A variant of this was used to produce tomato paste that was first sold in 1996.
- Since then, several transgenic crops have received FDA approvals, including "Canola" with modified oil composition, cotton and soybeans resistant to herbicides, etc.
- GM foods that are available in the market include **cotton, soybean, canola, potatoes, eggplant, strawberries, corn, tomatoes, lettuce, cantaloupe, carrots, and many more** are in pipeline.

- Currently, the majority of GM foods are aimed at endowing the altered plant two desirable properties–pest-resistance or herbicide-resistance.
- Insect-resistant crops are typically designed to express insecticidal crystal proteins (CRY), naturally produced by the soil bacterium *Bacillus thuringiensis* (Bt).
- Herbicide-tolerant crops are designed to express enzymes that protect against herbicides (primarily the glyphosate RoundupTM), often by their ability to degrade the herbicide.
- The strategy is clever: the human-applied herbicide kills the weeds, but does not harm the crop-plant.

GM Food Crops

- The most important GM crops are **soybeans**, **maize**, **rapeseed** and **cotton**, which have been widely adopted in the USA and in several developing countries (Argentina, Brazil, Canada, China, Paraguay, South Africa).

Do we need GM foods?

There are three major challenges we are facing that motivate our resort to the new technology for help.

1) *Expansion of population*
2) *Decrease in arable land*
3) *Bottleneck of conventional and modern breeding*

Public Perceptions of GM Foods

- There is substantial controversy between supporters and opponents of GM foods, focused mainly on environmental and health concerns, labelling and consumer choice.

Supporters of GM Foods

Environmental Benefits

Supporters of GM foods claim environmental benefits from reduced pesticide and herbicide use.

For example:

- ✓ GM cotton has reduced synthetic pesticide use in the USA, Australia and India, increased cotton yields by 50% as a result of reduced losses to insects, and insect protected crops can reduce exposure of farmers to synthetic insecticides.
- ✓ Insect protected GM maize can also have lower mycotoxin levels due to reduced insect damage to the crop.
- ✓ GM crops can be developed for cultivation in soils or climates where they previously could not grow, thus releasing more land for crop production and increasing crop yields per unit area of land to meet the needs of population growth, and thus contribute to sustainable food security.
- ✓ Reduced ploughing or conservation tillage associated with GM crops reduces fuel use and increases carbon sequestration in soils, thus contributing to reduced greenhouse gas emissions from agriculture.

Supporters of GM Foods

Economic Benefits

Supporters also point to economic benefits:

- ✓ Higher yields increase farm outputs and lower food prices, which benefit farmers and consumers respectively; insect-protected GM crops have greater economic benefits in developing countries because agriculture is often a large part of the economy and reduced crop losses due to insect damage and improved yields benefit large numbers of people. Higher yields of feed crops also meet demand from increased consumption of animal protein.

Benefits of GM Foods

Modification of the Chemical Composition in Food

- Some genetic modification is specifically targeted to enrich certain nutrients or substances having high therapeutic and pro- health value, including vitamins A, C, E, unsaturated fatty acids, alimentary cellulose and probiotics.
- The "Golden Rice" is a significant example. It ameliorates malnutrition in an effective and economic way.
- Similarly, using this biotechnology, researchers can also alter the amino acid composition of proteins as well as the content of carbohydrates.
- The former is exemplified by sweet lupine, of which the content of methionine is enriched.
- The generation of Amflora, a modified potato variety, is a good example for the latter scenario. Enhanced nutritional value in transgenic products has been obtained by manipulating their composition of carbohydrates. A potato, named "Amflora", where the gene responsible for the synthesis of amylose had been turned off, thus the potato is unable to synthesize the less desirable amylose. The Amflora potato is with decreased amylose, but rich in amylopectin.

Benefits of GM Foods

Improvement in Food Processing

- The GM technology can also be employed to facilitate food processing.
- A notable achievement is “Flavr Savr” tomatoes. They were produced by the California company, Calgene, in 1992. The genetic alteration consists of introduction of an anti-sense gene, which suppresses the enzyme polygalacturonase; the consequence is to slow down the ripening of tomatoes and thus allow longer shelf life for the fruits.
- The composition in potato bulbs has also been altered by gene editing. For instance, using a cyclodextrin glycosyltransferases gene from bacteria, potatoes exhibit greater stability of brightness factors and, thus, a more attractive appearance.
- Genetic modification is not limited to plants, but is also applied to animal products. Some researchers are exploring transgenic fish with a view to enhancing the generation of growth hormones to accelerate growth and body mass.
- Very recently the FDA (the US Food and Drug Administration) has approved the first genetically engineered animal, “AquAdvantagea” salmon-a fast-growing salmon - for human consumption in the United States.
- Meanwhile, quite a few attempts have been made to generate milk with decreased content of lactose or humanized bovine milk.

Opponents of GM Foods

The main concerns raised by opponents of GM foods are that they threaten unintended, undesirable or unforeseeable consequences to the environment, and create a risk to consumer health and safety.

Opponents of GM Foods

Environmental Concerns

Environmental concerns have arisen due to the following:

- The possibility that unwanted traits could be introduced along with the desired ones, or the risk of cross-contamination of GM genes to traditional crops or wild plants.
- For example, the uncontrolled spread of GM insecticidal proteins into wild plants could give a competitive advantage to those plants or disrupt the role of insects in natural ecosystems. The use of herbicides substantially reduces weed densities, which can have significant impact on wildlife that consume the weed seeds and hence reduce biodiversity.
- For example, the results of a UK farm-scale trial showed that some broadleaf weeds were less numerous in fields containing GM rapeseed and produced one-third fewer seeds for farmland birds to eat at the end of the season, compared with those in a conventional crop. Two years later, there were still fewer seeds, even though the weedkiller had not been applied again, and there were also fewer bees and butterflies in the GM crops.

Opponents of GM Foods

Long-term Health Risks

Consumer rights groups also emphasize the long-term health risks that GM foods could pose, or that the risks have not yet been adequately investigated. These include the following:

- Exposure of populations to large amounts of novel proteins could cause unpredictable problems with allergenicity that are difficult to detect because symptoms can take several years to develop. Examples include a Bt-maize, which was reported to have caused allergic responses, some life-threatening, in over 200 people and was subsequently banned, and the unintentional transfer in 1993 of a gene for an allergenic trait from the Brazil nut into GM soybeans. The intention was to increase the methionine content to improve the protein quality of soybeans for animal feed, but the methionine-rich protein was also the source of Brazil nut allergy and further development was discontinued.

- In the USA, the Food and Drug Administration (FDA) reported no evidence for adverse health effects of GM bovine somatotropin. However, there have been reports of the hormone having a negative impact on the ability of cows to conceive, and that cows often developed severe infections requiring treatment with antibiotics. As a result, some dairies have stopped using the hormone and it is banned in Europe because of health concerns.

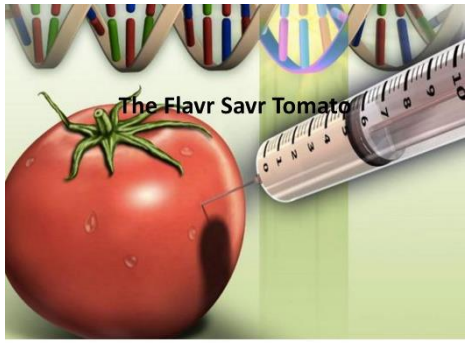
Potential Risks of GM Foods

Health Risks Associated with GM Foods

- Three major health risks potentially associated with GM foods are: **the transfer of antibiotic resistance**, **toxicity** **and** **allergenicity**.

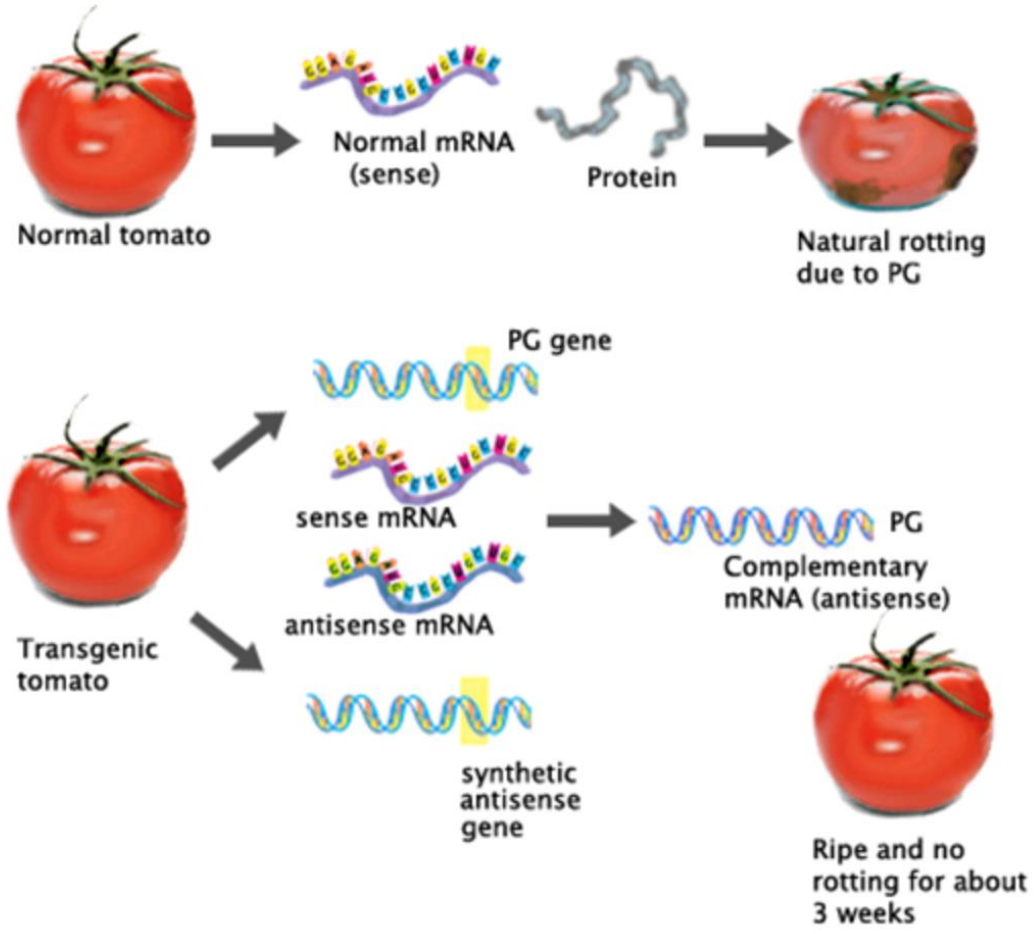
Famous Examples of Food Products Developed Through Modern Food Biotechnology

Flavor Savr Tomato (the first GM food)

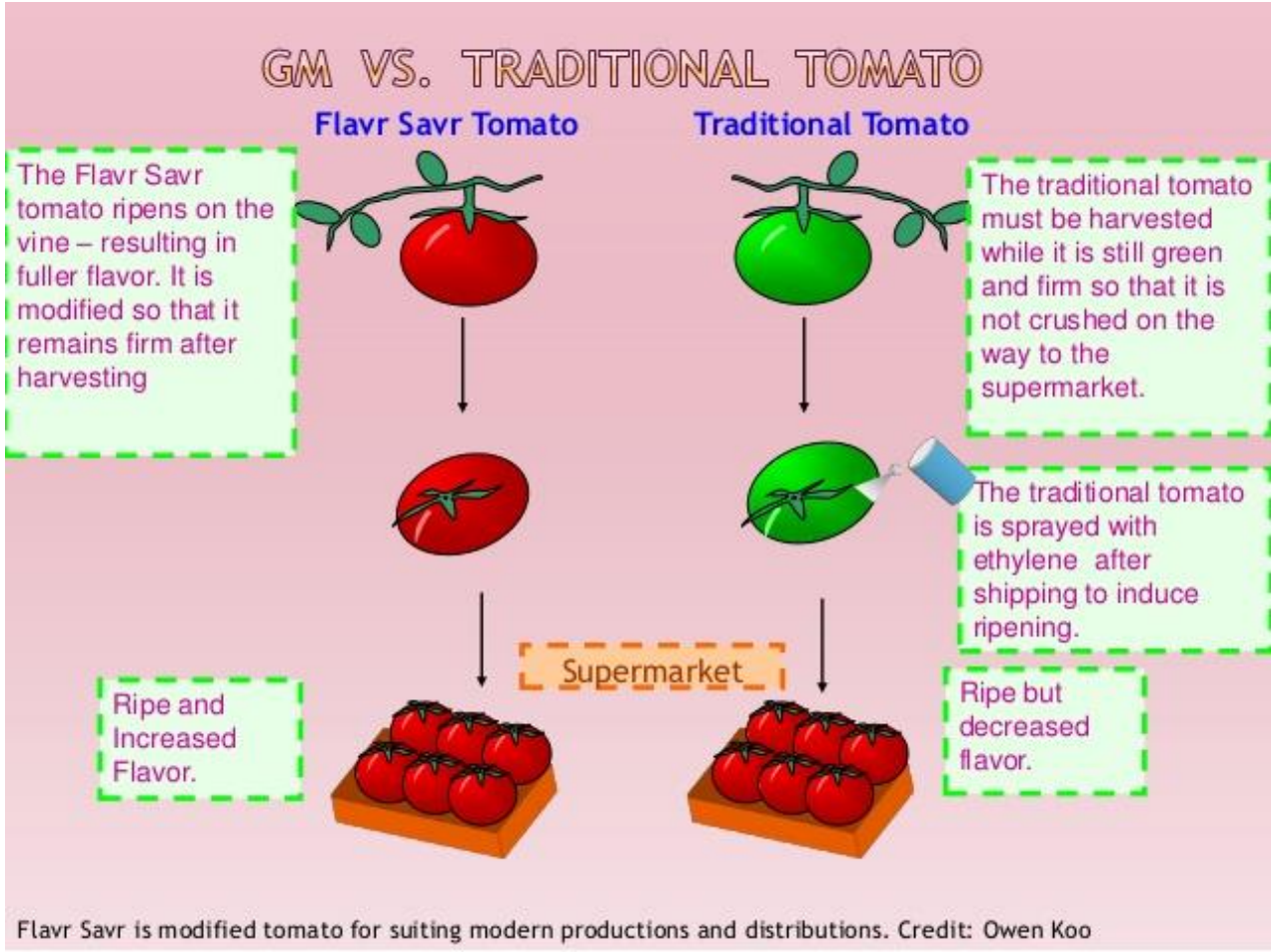


- The first FDA approved genetically modified food
- Licensed in 1994
- Ripening causes production of an enzyme Polygalacturonase in a gradual increasing level, which is responsible for softening of the tomato and which becomes the cause of rottening
- Calgene introduced a gene in plant which synthesize a complementary mRNA to PG gene and inhibiting the synthesis of PG enzyme.

Flavor Savr Tomato



Flavor Savr Tomato



Flavr Savr is modified tomato for suiting modern productions and distributions. Credit: Owen Koo

Golden Rice

- *Golden rice*, a recombinant variety of rice that has been engineered to express the enzymes responsible for ß-carotene (Vitamin A precursor) biosynthesis.

- Golden rice was created by transforming rice with only two ß-carotene biosynthesis genes: *psy* (phytoene synthase) from daffodil (*Narcissus pseudonarcissus* and *crtI* (carotene desaturase) from the soil bacterium *Erwinia uredovora*.

- ß-Carotene derived from Golden Rice was effectively converted to vitamin A in humans.

- Golden Rice could supply 50% of the Recommended Dietary Allowance (RDA) of vitamin A from a very modest amount if consumed daily. Thus, Golden Rice containing provitamin A could possibly solve the problem of malnutrition in millions and save thousands of children from blindness in the developing countries.

Bt Cotton

- **Bt cotton** is a genetically modified organism (GMO) or genetically modified pest resistant plant cotton variety, which produces an insecticide to combat bollworm.
- Strains of the bacterium *Bacillus thuringiensis* produce over 200 different Bt toxins, each harmful to different insects. Most notably, Bt toxins are insecticidal to the larvae of moths and butterflies, beetles, cotton bollworms and flies but are harmless to other forms of life.
- Bt cotton was first approved for field trials in the United States in 1993, and first approved for commercial use in the United States in 1995.

AquAdvantage salmon

- **AquAdvantage salmon** is a genetically engineered (GE) Atlantic salmon developed by AquaBounty Technologies in 1989.
- The typical growth hormone-regulating gene in the Atlantic salmon was replaced with the growth hormone-regulating gene from Pacific Chinook salmon.
- This gene enables the GM salmon to grow year-round instead of only during spring and summer.
- In 2015, the Food and Drug Administration (FDA) approved **genetically engineered AquAdvantage® Salmon** for human consumption.