GENETICALL MODIFIED FOOD

GM FOOD

Introduction

- Advances in plant biotechnology have made it possible to identify and modify genes controlling specific characteristics
- Nowadays, scientists can transfer genes from one organism to another unrelated organism, producing what is now known as “genetically modified organism” or “transgenic animal/ plant”
- Any food produced this way is called Genetically modified food i.e. foods obtained by added or deleted gene sequence
- More technically, genetically engineered (GE) food are defined as foods produced from plants, animals and microbes that have had their genetic code modified by the selective introduction of specific DNA segments

- **This process allows the organism to acquire a desirable trait such as pest protection, herbicide resistance or improved nutritional qualities.**
- **The enhancement of desired traits has traditionally been undertaken through breeding, but conventional plant breeding methods can be very time consuming and are often not very accurate**

GM Food

Peculiar features which could define GM foods are:

- **Food that contain an added gene sequence**
- **Food that have a deleted gene sequence**
- **Animal products from animals fed GM Feed**
- **Products produced by GM organisms**

History of GM Foods

- In the 1960s, a lot of breakthroughs were recorded in the field of genetics and proven that this new knowledge had the potential to revolutionize food production, thus creating huge benefits for the world (Hammer, 2003)
- By 1972, another scientific breakthrough was recorded by Paul Berg, who joined together DNA from two different organisms, to create the first recombinant DNA molecule (Griffiths, 2006)
- This breakthrough was followed by a pioneer study in which Stanley Cohen and Robert Boyer inserted DNA from an African clawed toad into the Escherichia coli bacterium
- Shortly, after then, some companies realized that this fledging technology could open up new highly profitable markets

Some Revolutionary Period

- 1960-1970 Isolation of restriction enzymes and their use to analyse DNA structure
- 1981-1982 First transgenic animals (mice) produced
- 1983-1985 First transgenic plants produced
- 1990-1992 First transgenic cereal plants (maize and wheat)
- 1992-1993 Regulations for deliberate release of genetically engineered organisms
- 1994 Genetically engineered tomato marketed in USA

Types of GM Foods

1. **First-generation crops:**

- They have enhanced input traits, such as herbicide tolerance, better insect resistance and better tolerance to environmental stress
- The ensuing crops are not significantly different from the traditionally grown crops in terms of appearance, taste and nutrition

Examples: Herbicide resistant soybean, insect- resistant maize, and herbicide and insect-resistant potato

2. Second-generation crops:

- They have new traits to increase their benefits to consumers, such as increased levels of protein, modified or healthier fats, modified carbohydrates, increased flavor or increased micronutrients

Examples: Rice with a higher level of beta- carotene, tomatoes with higher levels of carotenoids, maize with increased vitamin C, soybean with improved amino acid composition, and potatoes with higher calcium content

3. Third Generation crops:

- These GM foods are in the research pipeline
- These may have increased ability to resist abiotic stress such as drought, increased temperature or saline soils
- Another objective may be to create “pharmaplants” to help produce active pharmaceutical products
- In February 2009, the U.S. Food and Drug Administration (FDA) approved the license for a recombinant anti-thrombin for prevention of blood clots in patients with hereditary anti-thrombin deficiency
- Recombinant anti-thrombin is the first human biologic drug derived from the milk of goats that have been genetically engineered to produce human anti-thrombin in their milk through bioreactor technique

GM Food Techniques

There are 3 main types of GM food technique:

1. **Inserting genes (Gene Shifting):**

- **Genes are determined by different DNA sequences, when the isolated gene is inserted into a plant, it becomes part of the plant's gene and works with its own function**
- **This method can increase or improve the plant such as resistance to insects, which increases the yield of food afterwards**

2. Removing genes (Gene Silencing):

- The function is reduced or stopped through genetic modification

Ex. the function of virus which causes dried and spot of tomato is reduced by removing parts of the gene, thus the virus cannot be reproduced and tomato can grow healthily

3. Changing the process of catabolism (Gene splicing):

- Food can be enhanced by changing the process of catabolism

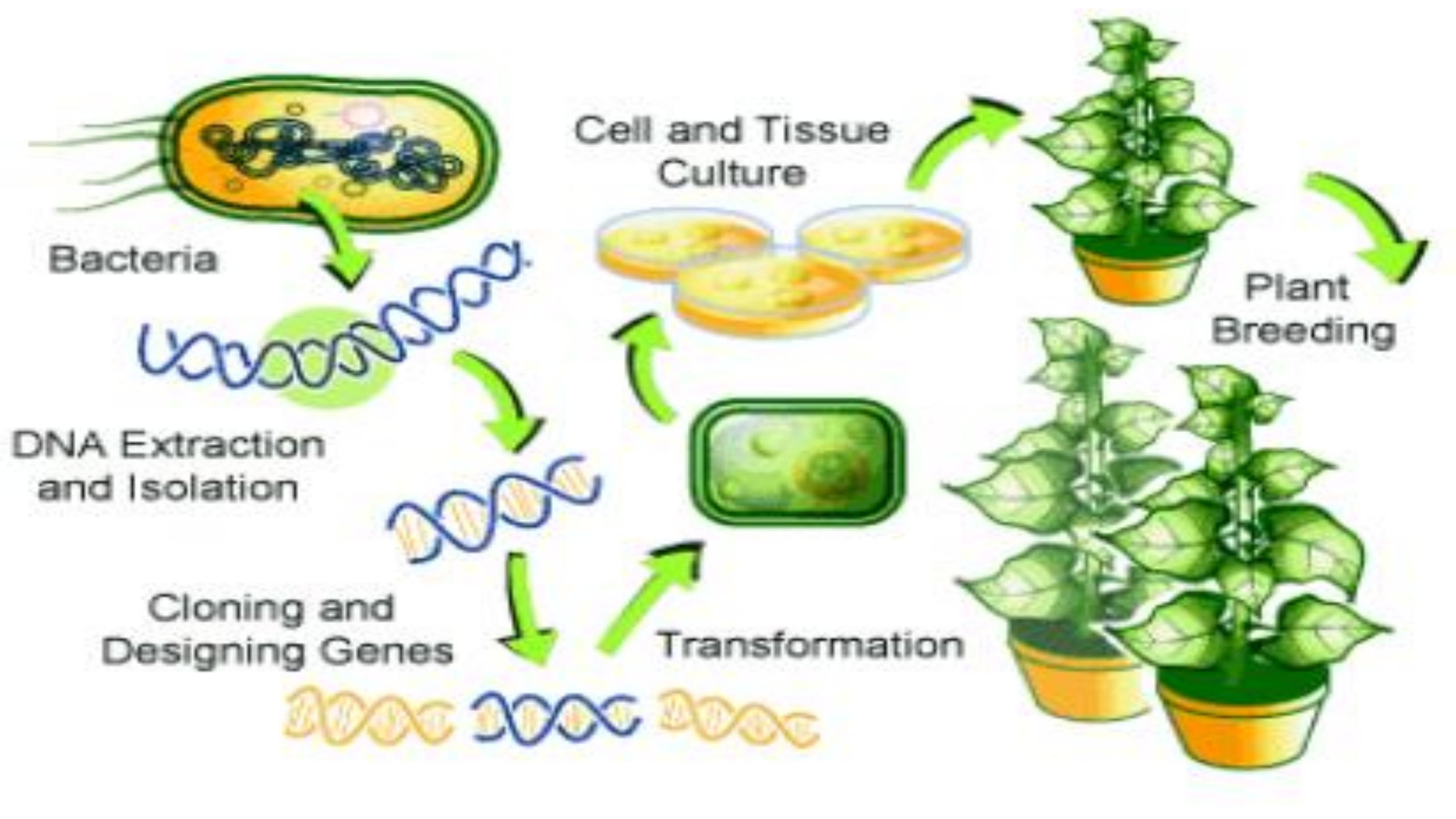
Ex. Controlling the percentage of starch of glutinous rice, controlling the taste, mass, colour, and usefulness of food

General Process of GM Food

The Process for GM has 8 steps and begins with:

1. **Isolation of the gene(s) of interest- A chromosome is used to identify the gene(s) responsible for the desired trait in the organism**
2. **Insertion of the gene(s) into a transfer vector- The desired trait is put into the plasmid**
3. **Plant transformation- The plasmid contained inside Agrobacterium tumefaciens cells transfers the plasmids and new gene into the plants chromosomes**
4. **Selection of the modified plant cells- Selectable marker genes are used to favor the growth of the cells containing the trait as apposed to the non- transformed cells**

5. Regeneration into whole plants via tissue culture- Explants (plants/cells) transferred onto media containing nutrients for development of cells to form plantlets
6. Verification of transformation and characterization of the inserted DNA fragment- Tests are done to determine the number of copies, if intact, and doesn’t interfere with other genes. These tests are done to see if the gene is functional.
7. Testing of the plant performance- The resulted plant grown in a greenhouse has acquired the favored traits and if it has any unwanted characteristics
8. Safety assessment- More test carried out to see plants performance, environmental safety assessments and other safety assessments


Bacteria
DNA Extraction
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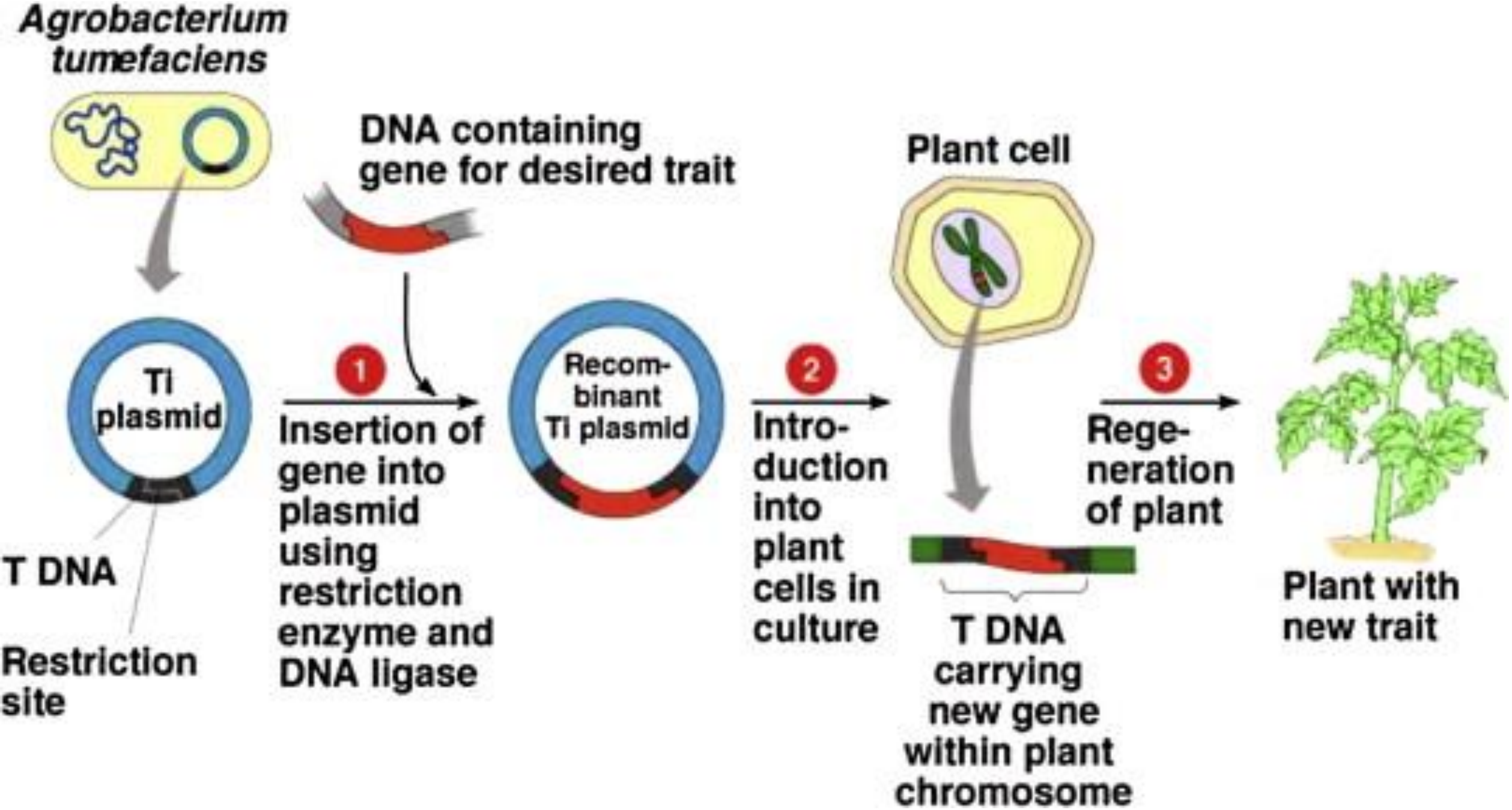
Transformation
Cell and Tissue
Culture
Plant
Breeding


Agrobacterium tumefaciens
DNA containing gene for desired trait
Plant cell
Ti plasmid
T DNA
Restriction site
1
Insertion of gene into plasmid using restriction enzyme and DNA ligase
Recom-binant Ti plasmid
2
Intro-duction into plant cells in culture
3
Rege-neration of plant
Plant with new trait
T DNA carrying new gene within plant chromosome

Common genetically modified foods

- Soybean, Corn & sugar-beet: resistant to glyphosate by inserting herbicide resistant gene
- Cottonseed oil: by inserting pest resistant Bt crystal protein gene
- Tomato: by removing the gene that codes for polygalacturonase, responsible for softening of fruits after harvesting
- Potatoes: Amylopectin rich variety by switching off of GBSS (granule bound starch synthase) gene, responsible for amylose production
- Rapeseed (canola): with high oleic acid content by adding new gene
- Rice: with high Vitamin A by inserting gene from daffodils

Specific examples of GM foods

1) Golden rice:

- It was created by Ingo Potrykus. Golden rice is a variety of rice produced through genetic modification to biosynthesize the precursors of beta-carotene (pro-vitamin A) in the edible parts of rice (endosperm)
- Golden rice has the potential to help prevent the 1 to 2 million deaths each year caused by a deficiency of vitamin A

Golden rice was created by incorporating rice with two beta carotene biosynthesis genes:

Psy (Phytoene synthase) Lyc (Lycopene cyclase)

2. Cold tolerant tomatoes:

- Scientists have created a frost resistant tomato plant by adding an antifreeze gene from a cold water fish to it
- The antifreeze genes come from the cold water flounder, a fish that can survive in very cold conditions
- The hybrid DNA, which is a combination of DNA from two different sources, is known as recombinant DNA

3. Vitamin rich tomatoes:

- The Agrobacterium naturally infects plants by causing various diseases. By replacing that gene with desirable ones, results into the new genetic makeup with advantageous traits.
- The bright orange color of carrots comes from beta-carotene, which works as the precursor for the synthesis of vitamin A in our body
- Inserting this color gene into the tomato, enhance its appearance as well as its vitamin A level to the desired level

4) Protein enriched potatoes for NASA:

- Potato is a non-cereal food crop limited in the amount of lysine, tyrosine, methionine and cysteine
- A tuber-specific protein amaranth seed albumin (AmA1) has been used to transform potatoes
- The AmA1 protein has a well-balanced amino acid profile
- This protein was used due to its non-allergenicity in its purified form
- When the AmA1 gene was inserted into a potato, 2.5 to 4 fold increases in lysine, tyrosine, methionine and cysteine content and 35 to 45% increases in total protein content was reported in transgenic tubers

5) Bt Soyabean:

- **The two target insects for insect-resistant, transgenic soybeans are the velvet bean caterpillar and the soybean looper**
- **These pests feed on the leaves of the soybean plant and can severely limit yield.**
- **Scientist have incorporated *Bacillus thuringiensis*, a ubiquitous soil bacterium, gene into soybean which has insecticidal protein that maintains the yield of the crop**

6) Genetically modified corn:

- **Corn has been deliberately genetically modified (GM) to have agronomically desirable traits**
- **Traits that have been engineered into corn include resistance to herbicides and resistance to insect pests, the latter being achieved by incorporation of a gene that codes for the *Bacillus thuringiensis* (Bt) toxin.**
- **Corn varieties resistant to glyphosate herbicides (Liberty and Roundup) have been produced**
- **Pioneer Hi-Bred has marketed corn hybrids with tolerance to imidazoline herbicides under the trademark "Clearfield"**

7) Roundup Ready Soyabean:

- The Roundup Ready soybean is a transgenic soybean that has been immunized to the Roundup herbicide
- The soybean’s natural trypsin inhibitors provide protection against pests, the only major problem in soybean farming was weeds
- The glyphosate in the herbicide would inhibit the soybean plant’s ESPSP gene, which is involved in the maintenance of the “biosynthesis of aromatic metabolites,” and cause the plant to die along with the weeds for which the herbicide was meant
- A plasmid which was transferred to the soybean cells through the cauliflower mosaic virus was soon developed to provide immunity to glyphosate-containing herbicides, the Roundup Ready soybean was first used in the US market in 1996

8. Canola oil:

- Rapeseed oil had a distinctive taste and a disagreeable greenish color due to the presence of chlorophyll
- It also contains a high concentration of erucic acid
- Experiments on animals have pointed to the possibility that erucic acid, consumed in large quantities, may cause heart damage
- GM canola oil was developed with less erucic acid contents

9. Papaya:

- Papaya cultivation is threatened by papaya ring spot virus, a disease that sharply lowers the fruit yield
- The University of Hawaii developed a ring spot virus disease resistant papaya through certain viral genes encoding capsid proteins were transferred to the papaya genome
- These viral capsid proteins elicit something similar to an “immune response” from the papaya plant
- The first resistant papaya varieties were grown commercially in 1999 in Hawaii
- These genetically modified papayas are approved for consumption both in US and in Canada

Health and Safety Concerns of GM Foods for Human Consumption

The WHO has identified the following issues of concern for human health with respect to genetically modified foods:

1)Allergenicity:

- **GM foods have the potential to cause allergic reactions in general; this risk is comparable to the risks associated with traditionally grown foods**
- **To prevent such allergenicity, the transfer of genes from commonly allergenic foods is discouraged unless it can be proven that the protein produced by the introduced gene will not be allergenic (WHO, 2013)**
- **Another potential risk is the introduction of an entirely new protein that did not previously exist in the food chain**

2) Gene Transfer:

- Another potential concern arising from GE foods is the transfer of genetic material from GE foods to the cells of the human body or the bacteria in the intestinal tract
- DNA from ingested food is not completely degraded by digestion and small fragments of DNA from GM foods, have been found in different parts of the gastrointestinal tract
- This could result in horizontal gene transfer due to absorption of DNA fragments by gut microflora or somatic cells lining the intestinal cells
- Scientists however, have postulated that uptake of GM DNA into the cells of the gastrointestinal tract will not have any biological consequences because this DNA will be degraded in the cells

3) Increase in Anti-nutrients:

- Anti-nutrients are substances that interfere with the utilization of nutrients
- The insertion of a new gene may lead to an increase in the existing levels of anti-nutrients

Example: glyphosate resistant Roundup Ready soybean has been shown to increase anti-nutrients

In sheep and cattle, heat-stable anti-nutrients such as phytoestrogens, glucinins, and phytic acid have been found to cause infertility, allergic reactions, and decreased availability of phosphorus and zinc, respectively

4) Use of Viral DNA in Plants:

- Most GM crops utilize the Cauliflower Mosaic Virus 35S promoter (CaMV35S) to switch on the introduced gene
- There is controversy as to whether CaMV35S could be horizontally transferred and cause disease via carcinogenesis, mutagenesis, reactivation of dormant viruses, or generation of new viruses
- Some scientists believe that CaMV found in foods is not infectious and cannot be absorbed by mammals
- Some scientists also point out that humans have been ingesting CaMV and its 35S promoter in high amounts and it has never caused any disease or recombined with other viruses

Governments and GM Foods

- Europe: Anti-GM protests (Austria, France, Hungary)
- Japan: GM testing is mandatory. Customers for organic
- USA: FDA , GM foods are substantially equivalent to natural food, so not subject to FDA regulations, GRAS Generally Recognized As Safe
- India: No policy yet for GM
- Brazil: Some states have banned GM crops Smuggle to compete with grain-exporting countries
- Africa: EU opposes the use of GM in Africa S. Africa, Sudan, Zimbabwe have GM laws; Kenya Act 2009
- Argentina: Very pro-GM
- New Zealand: NO GM Foods grown here!

Current Status of GM Food in India

- Bt Cotton is the only GM crop grown in India
- Cultivation of Bt Cotton was allowed in 2002
- India has become a net exporter of Cotton in the last one decade.
- 90% of total cotton cultivation area is covered by Bt Cotton
- Yield is more than 80% compared to non-Bt Cotton
- More than 600 hybrid seeds are in circulation now

Why Produce GM Food?

- Traditionally, combining the desirable genes in one plant is a tough task that utilizes longer time and so much attention, involving crossing one plant to another plant of the same species or related species
- From economical and agricultural standpoints, it is advantageous to grow crops that have higher yield or improved quality, pest or disease resistance, or tolerance to heat, cold and drought
- Desirable genes may provide means for plants to combat these conditions
- The development of transgenic technology allows useful genes from various living sources to be brought together in a relatively simple manner

Critics of GM Foods

1. Environmental hazards:

- Unintended harm to other organism • Difficult to design toxin to kills crop-damaging pests, not other insects
- Reduced effectiveness of pesticides • Develops resistance to DDT
- Gene transfer to non-target species • Cross-breeding • Transfer of herbicide resistance from crops to weeds
- The “superweeds” will then have herbicide tolerance as well

2. Human health risks:

- Allergenicity
- Unknown effects on human health

3. Economic concerns:

- Lengthy and costly process
- May be patented • Monsanto, Novartis, Dow, DuPont hold patents for GM crops • Make substantial profit by exporting it to Ems’
- Farmers from developing countries/EM cannot afford. More gap between rich and poor

4. Other invention:

- Discouraged/stopped
- Suicide gene technology
- Only one growing per season
- Next time would produce sterile seeds that do not germinate.

Future of GM Foods

- GM advocates are confident that the next generation of GM foods will show even more promising prospects and may also address many of the problems
- Australian scientists are adding genes to bananas that will not only provide resistance to Panama disease, and also increase the levels of beta-carotene and other nutrients, including iron
- New techniques are being devised that will allow genes to be inserted into precise locations in the genome, avoiding some of the potential unknown effects of disrupting a plant's normal genome with random integrations

- **In the future, GM foods will likely include additional GM animals e.g. a transgenic Atlantic salmon variety is likely to receive marketing approval in the near future.**
- **In another project, scientists have introduced a DNA sequence into chickens that protects the birds from spreading avian influenza**