Food Biotechnology:

Agustin K Wardani

- Biotechnology helps to meet our basic needs.
- Food, clothing, shelter, health and safety

What is Food Biotechnology?

Food biotechnology is the **evolution** of **traditional** agricultural techniques such as crossbreeding and fermentation.

Food biotechnology employs the tools of modern genetics to enhance beneficial traits of plants, animals and microorganisms for food production. It involves adding or extracting select genes to achieve desired traits.

Food Biotechnology Applications

- **Biotechnology methods are currently used to improve many foods.**
- **Food biotechnology has had a profound positive impact on farming and food security.**
- **At least twelve industrialized and four developing countries currently use some form of food biotechnology**

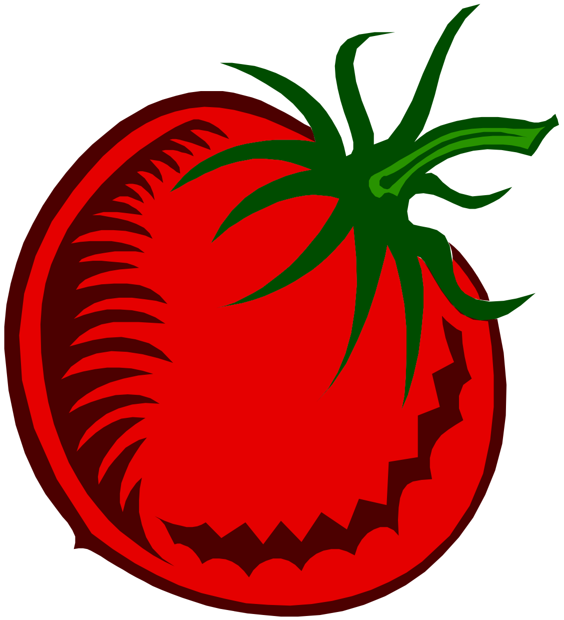
Gene and Our Foods:

- **Taste and Quality**
  - Delayed ripening allows fruits and vegetables to remain fresh longer

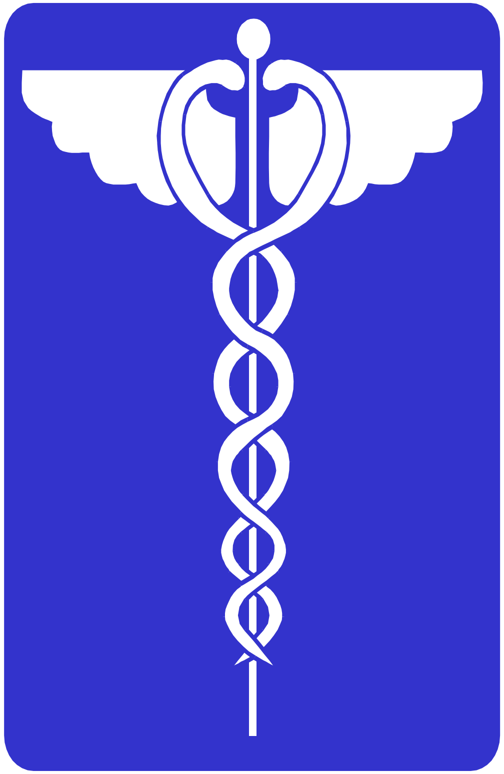
  Flavorsavar®.

  - Increased solids give foods superior taste

  and less water to remove for sauces.



- **Health**
  - Some foods have enhanced nutritional profiles.
  - Biotechnology allows for the production of foods to help protect against diseases.
  - Enhanced foods will soon offer higher levels of antioxidant vitamins to reduce risk of cancer. Now being commercialized at Rutgers! (black tea extract).



- **Nutrition**
  - Some oils are lower in saturated fat and higher in oleic acid, making them more stable for frying without further processing.

- potatoes with greater solids that absorb less oil and yield lower fat french fries
- peanuts containing less of the proteins that cause allergies.

What are Genetically Modified Food or GM crops?

These are plants with particular genes inserted into these plants to improve their characteristics in a very specific way, as compared to their conventional counterparts.

Beginning of GMOs

In 1976, the company called Monsanto introduced its signature product, Roundup®, an herbicide widely used in farming.

By 1981, Monsanto scientists had come up with the first genetically modified plant: tobacco with a gene coding for resistance to the antibiotic kanamycin.

First in the Field

In 1986: The first field test of a genetically modified organism. Frostban → It contained genetically altered bacteria that were designed to stop the growth of other bacteria that enhance ice formation → allow the plants sprayed with Frostban to survive in temperatures much lower than.

There are several advantages that genetically modified crops could offer us.

- Foods can be modified to **enhance their flavor,**
- **higher amounts of certain vitamins** or other molecules that are essential to our diets
- Overall **yields could be increased** when GM crops with pesticide or cold weather resistance are grown
- a solution to the world hunger dilemma.

Some Examples of GMOs

http://cgi.wn.com/?t=worldphotos/viewphoto.txt&action=display&article=35443823

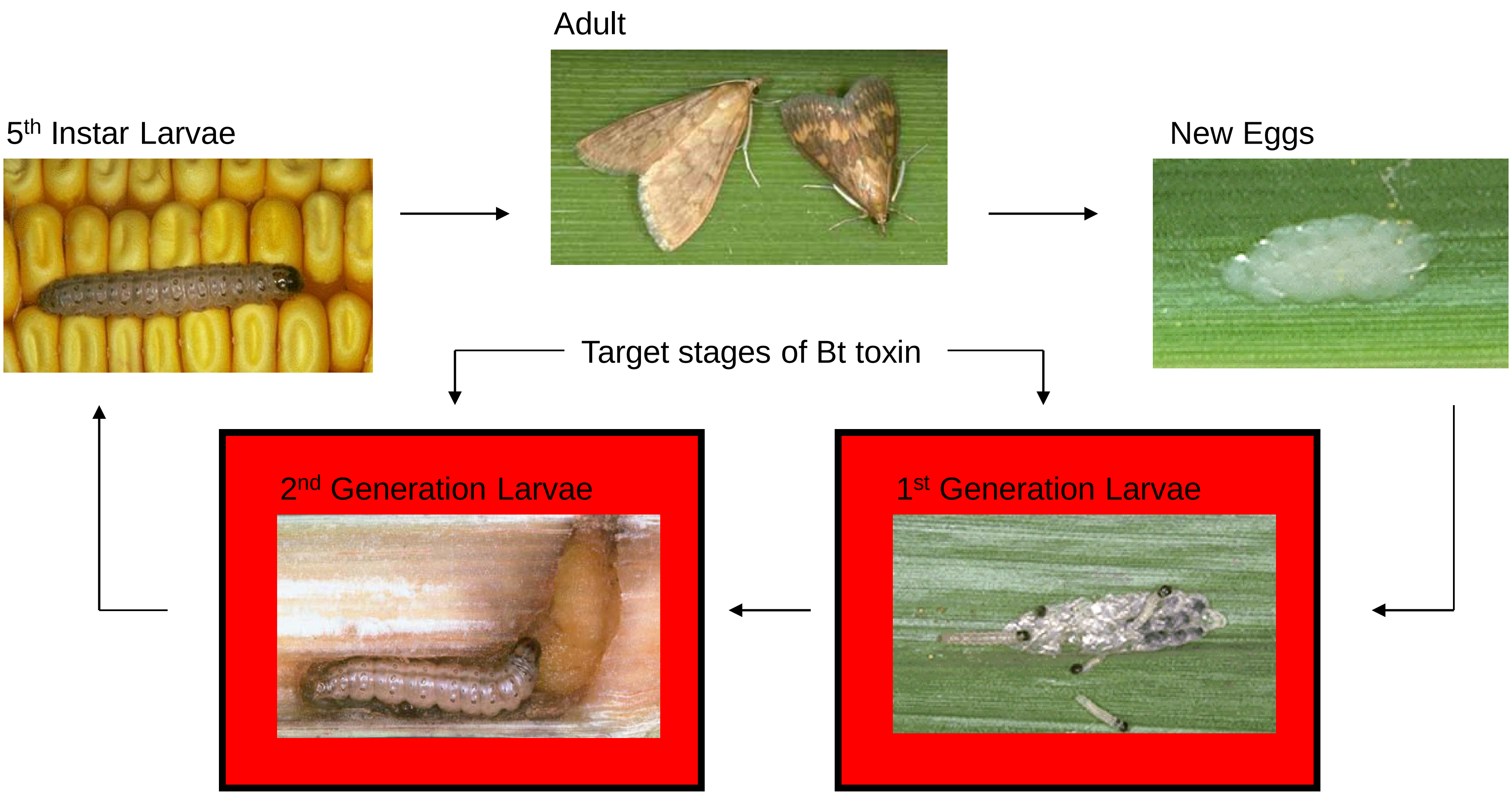
- Bt corn – US, 1996
- Roundup® Ready Soybeans – US, 1996
- Flavr Savr® tomatoes – US, 1994
- "Golden Rice" – Switzerland, 1999

I. Bt Corn: What is it?

The **transgenic corn hybrid Bt corn** was first made available to growers in the U.S. in 1996 by Ciba Seeds and Mycogen Seeds.

The **genetically modified corn seed produces an insecticide protein that comes from the bacterium Bacillus thuringiensis (Bt**). The protein is particularly **toxic to the larvae of the corn borer**.

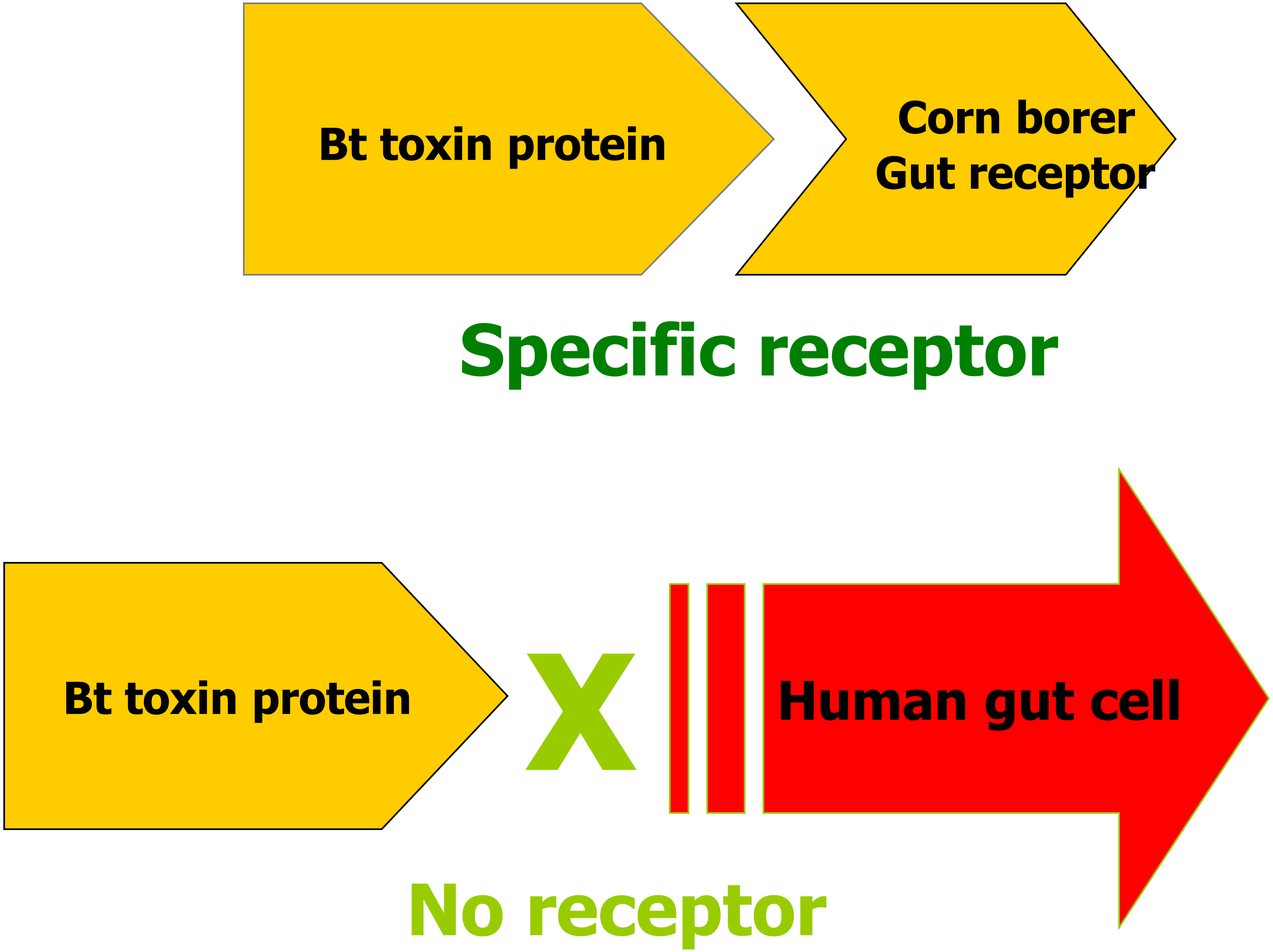
Life Cycle of European Corn Borer



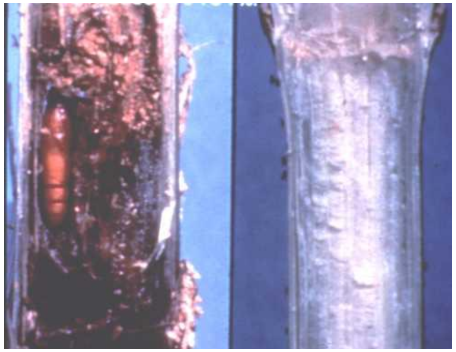
Bt

Bacillus thuringiensis → common soiborne bacterium
Produces crystal protein → kill certain group of insect

-Stomach toxins, must be ingested
-Protein bind the receptor in intestines →insects stop eating
-Used as granular or liquid as pesticide (30 years)
-Many different cry proteins (>60) →effective against different insects


Bt toxin protein
Corn borer
Gut receptor
Specific receptor
Bt toxin protein
X
Human gut cell
No receptor

Insect resistant cotton – Bt toxin kills the cotton boll worm
• ***transgene = Bt protein***



Normal **Transgenic**

Insect resistant corn – Bt toxin kills the European corn borer
• ***transgene = Bt protein***

Damage Report

- http://www.extension.umn.edu/distribution/cropsystems/DC7055.html

II. Roundup® Ready Soybeans

developed by the Monsanto company in 1996.

These plants have been genetically altered to be resistant to the herbicide Roundup®, This resistance would allow fields to be sprayed with large doses of the weed killer without causing damage to the soybeans being grown.

The sale of these soybeans would bring the company enormous profits as farmers who plant the seeds switch to the herbicide Roundup®.

- http://www.monsanto.com/monsanto/content/media/pubs/rrsoybean_ffsafety.pdf

Roundup Sensitive Plants

Shikimic acid + Phosphoenol pyruvate

+ Glyphosate

Plant EPSP synthase

3-Enolpyruvyl shikimic acid-5-phosphate (EPSP)

Without amino acids, plant dies

Aromatic amino acids

Roundup Resistant Plants

Shikimic acid + Phosphoenol pyruvate

+ Glyphosate

Bacterial EPSP synthase

RoundUp has no effect; enzyme is resistant to herbicide

3-enolpyruvyl shikimic acid-5-phosphate (EPSP)

With amino acids, plant lives

Aromatic amino acids

Herbicide Resistance

Non-transgenics

Transgenics

Final Test of the Transgenic

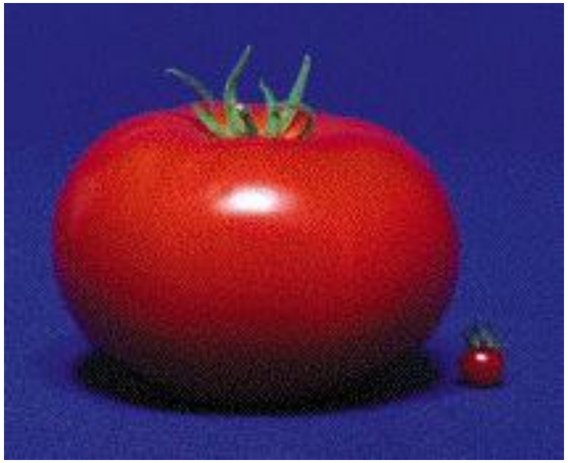
RoundUp Ready Corn

Before **After**

III. Flavr Savr® Tomatoes

Calgene, Inc. in 1994 developed The Flavr Savr® tomato has an antisense PG gene for the enzyme polygalacturonase (PG),

The PG enzyme is responsible for the breakdown of pectin within the cell walls of plants, which causes fruits to become soft as they ripen. By **incorporating the antisense PG gene**, the **expression of PG in ripening fruit is decreased**. The result of this genetic alteration is tougher skin.



IV. Golden Rice

- "Golden Rice" is a genetically modified crop that was developed by Swiss and German scientists in 1999.
- This breed of rice was engineered to produce **higher levels** of **beta-carotene**, the precursor of Vitamin A in the human body. Increased levels of this substance give the rice its characteristic "golden" color.

β-Carotene Pathway in Plants

IPP (Isopentenyl diphosphate)

↓

Geranylgeranyl diphosphate

↓ **Phytoene synthase**

Phytoene

↓ **Phytoene desaturase**

↓ **β-carotene desaturase**

Lycopene

↓ **Lycopene-beta-cyclase**

β -carotene
(vitamin A precursor)

<u>Problem:</u>
Rice lacks these enzymes

Normal Vitamin A "Deficient" Rice

The Golden Rice Solution

β-Carotene Pathway Genes Added

IPP (Isopentenyl diphosphate)

↓

Geranylgeranyl diphosphate

↓ Daffodil gene — Phytoene synthase

Phytoene

↓ Phytoene desaturase

Single bacterial gene; performs both functions

↓ carotene desaturase

Lycopene

↓ Daffodil gene — Lycopene-beta-cyclase

β -carotene
(vitamin A precursor)

Vitamin A Pathway is complete and functional

Golden Rice

Golden Rice have been this obtained that accumulate of to 37 µg/g carotenoid of which 31 µg/g is ß-carotene (as compared to the first generation where only 1.6 µg/g were obtained in the greenhouse and 6 µg/g in average in a field trial).

IV. Drought / Salinity Resistance

Trehalose is a protectant against many environmental stresses; freezing, osmotic pressure (salinity), heat and dessication.

Trehalose (1-α-D-glucopyranosyl-glucopyranoside) is synthesised in a two-step process in yeast.

Zygosaccharomyces rouxii is one of the most highly osmo-tolerant yeasts – especially to salt

Kwon, S.J., Hwang, E.W. & Kwon, H.B. (2004). Genetic engineering of drought resistant potato plants by co-introduction of genes encoding trehalose-6-phosphate synthase and trehalose-6-phosphate phosphatase of *Zygosaccharomyces rouxii*. *Korean J. Genet.* 26, 199-206.

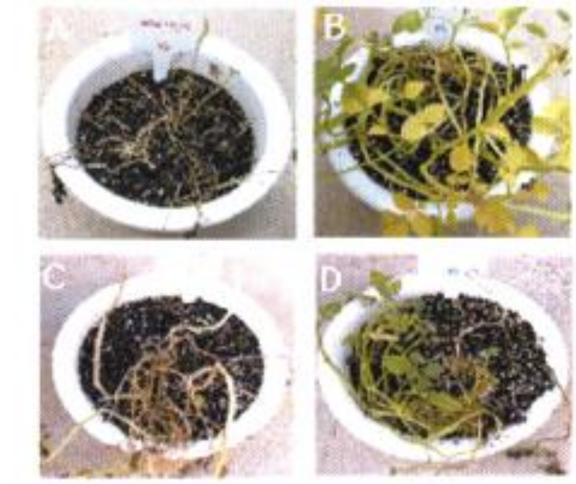
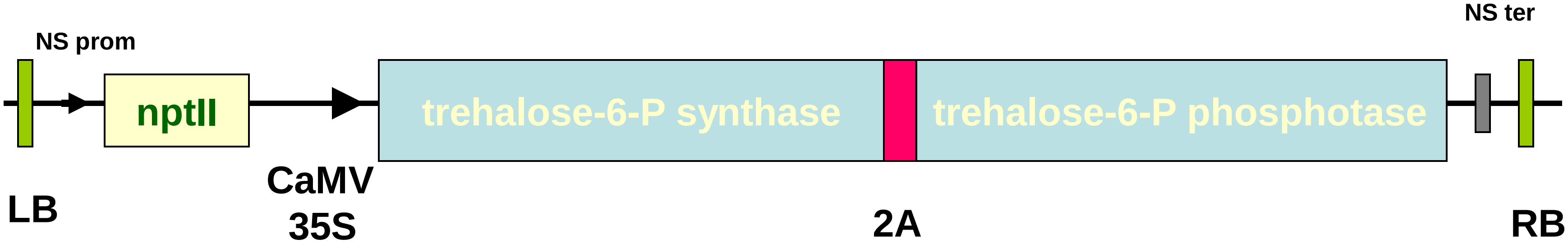


Figure 4. Drought stress tolerance of ZrTPS2-2A-ZrTPS1 transgenic plants. One month old plants rooted in the soil mixture were not watered for 3 weeks. (A) is the empty vector transgenic control plant, and (B~D) are ZrTPS2-2A-ZrTPS1 transgenic lines.

Transgenic potatoes morphologically identical to parents.



Edible Vaccines – A Biopharming Dream

Biotech Plants Serving Human Health Needs

- A pathogen protein gene is cloned
- Gene is inserted into the DNA of plant (potato, banana, tomato)
- Humans eat the plant
- The body produces antibodies against pathogen protein
- Human are ***"immunized"*** against the pathogen
- Examples:
  - ✓Diarrhea
  - ✓Hepatitis B
  - ✓Measles

Is Genetic Engineering Different from Traditional Breeding?

- No!
  - Traditional breeding also involves gene transfer but thousands of genes, good and bad, are moved

Cross Breeding

Is Genetic Engineering Different from Traditional Breeding?

- Yes!
  - Specific gene/s from “**any**” source can be introduced and is faster

Conclusions

Advantages

- **increased crop yields** due to decreased damage by pests and herbicides,
- could **provide an additional food** source for malnourished populations around the world.
- **Enhanced nutrition and flavor** of GM foods provide benefits for all consumers.
- Genetically altered foods hold many possibilities for the future. For example, **foods containing vaccines** are being developed. Applications of this that are currently under study include genes that will produce HIV-transmission blockers, antibodies for rabies, and antibodies for Hepatitis B.

Disadvantages

- One of the gravest concerns is the potential **allergenicity** of these products.
- the development of a “superior” breed of an organism could lead to a **loss of biodiversity**, which could throw off balance the entire world’s ecosystem.

How are Transgenic Plants Produced?

Commonly Used Methods:

- ***Agrobacterium tumefaciens***
- **Gene Gun / Biolistics**
- **Electroporation**

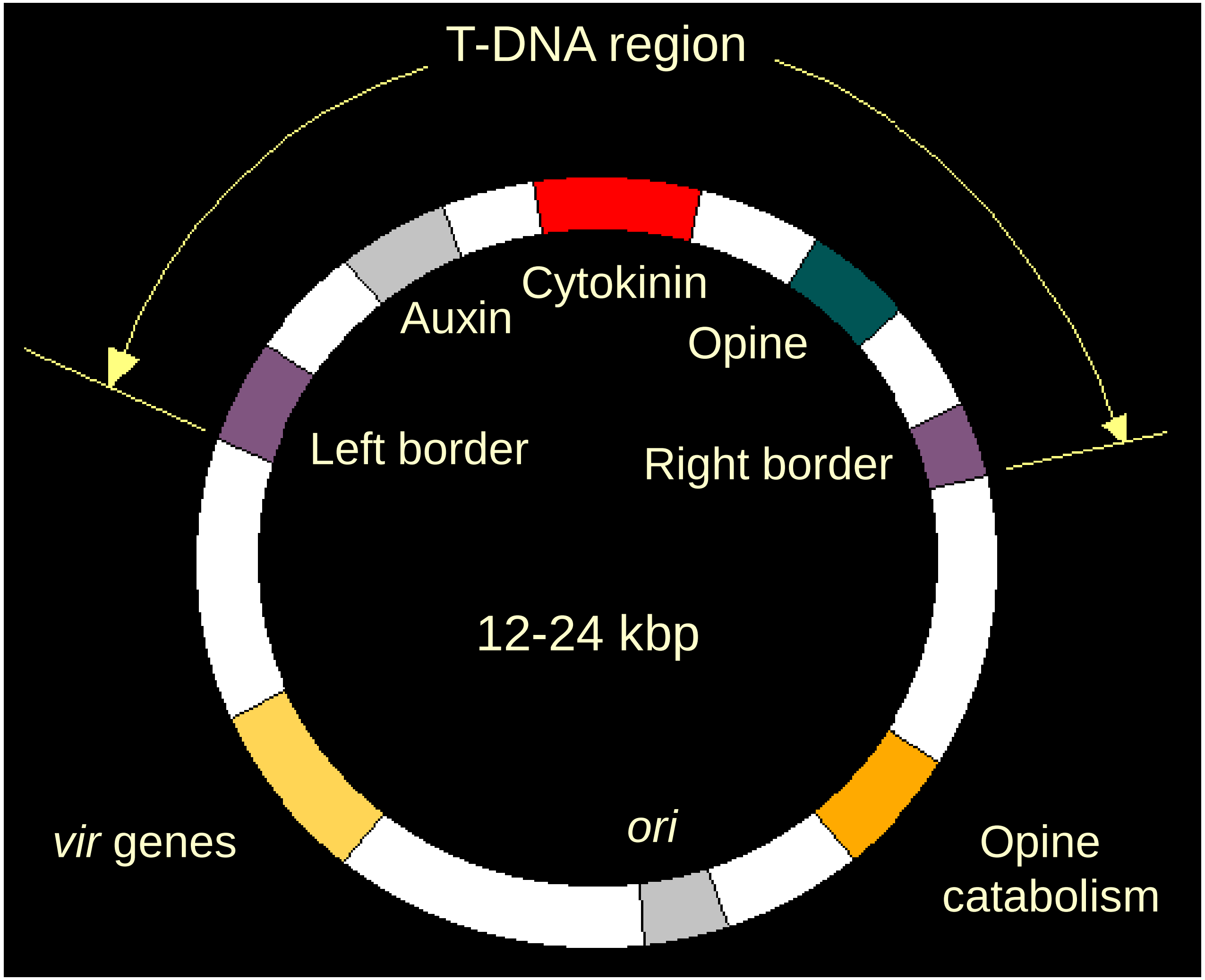
Agrobacterium tumefaciens - a soil bacterium that causes crown gall disease on plants

contains large Ti plasmid (Tumor-inducing plasmid)

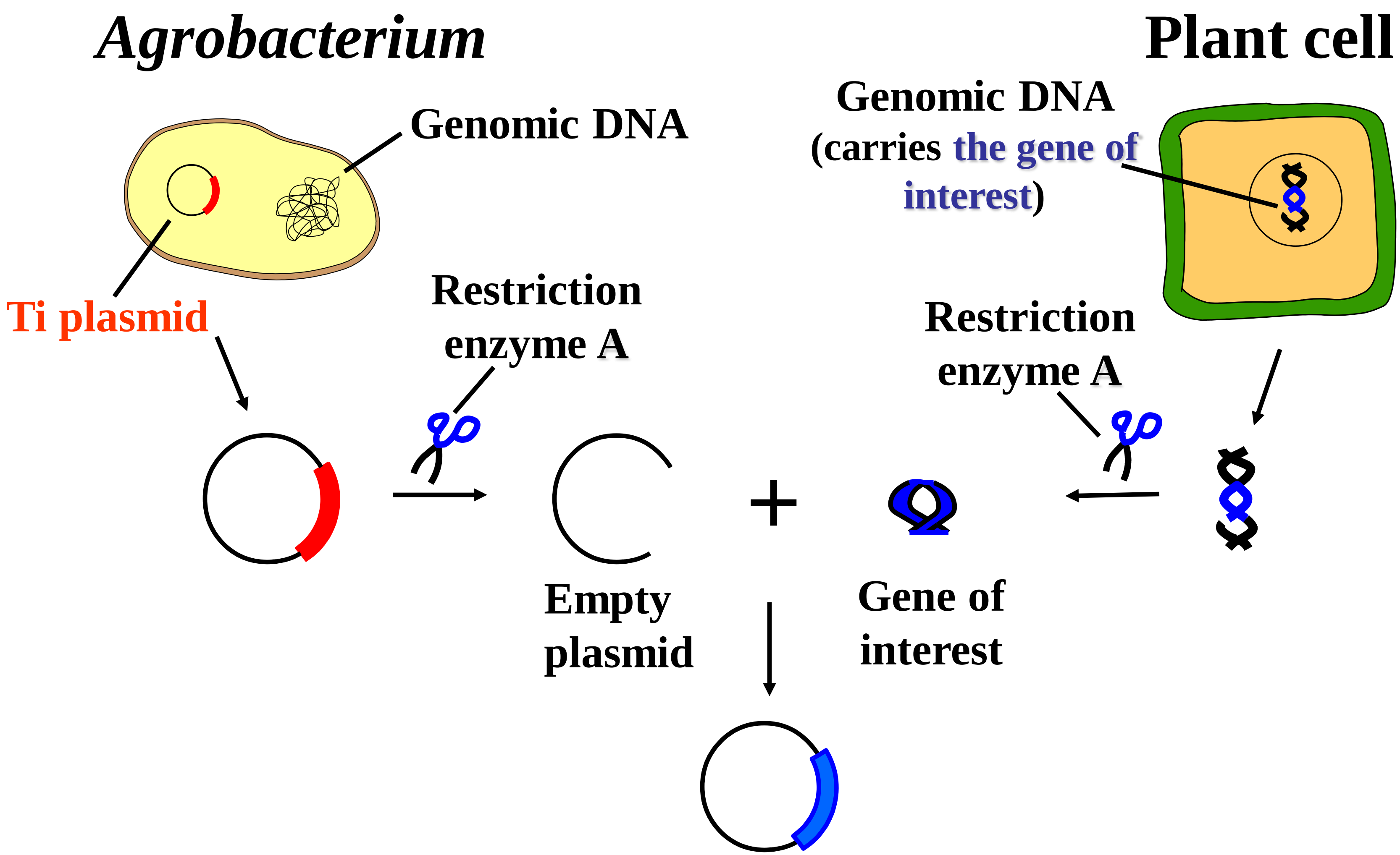
Ti plasmid has region of DNA, the T-DNA (Transferred DNA), that is incorporated into the plant's nuclear DNA on infection

Genes could be integrated into the plant chromosomes when the T-DNA is transferred

Ti Plasmid

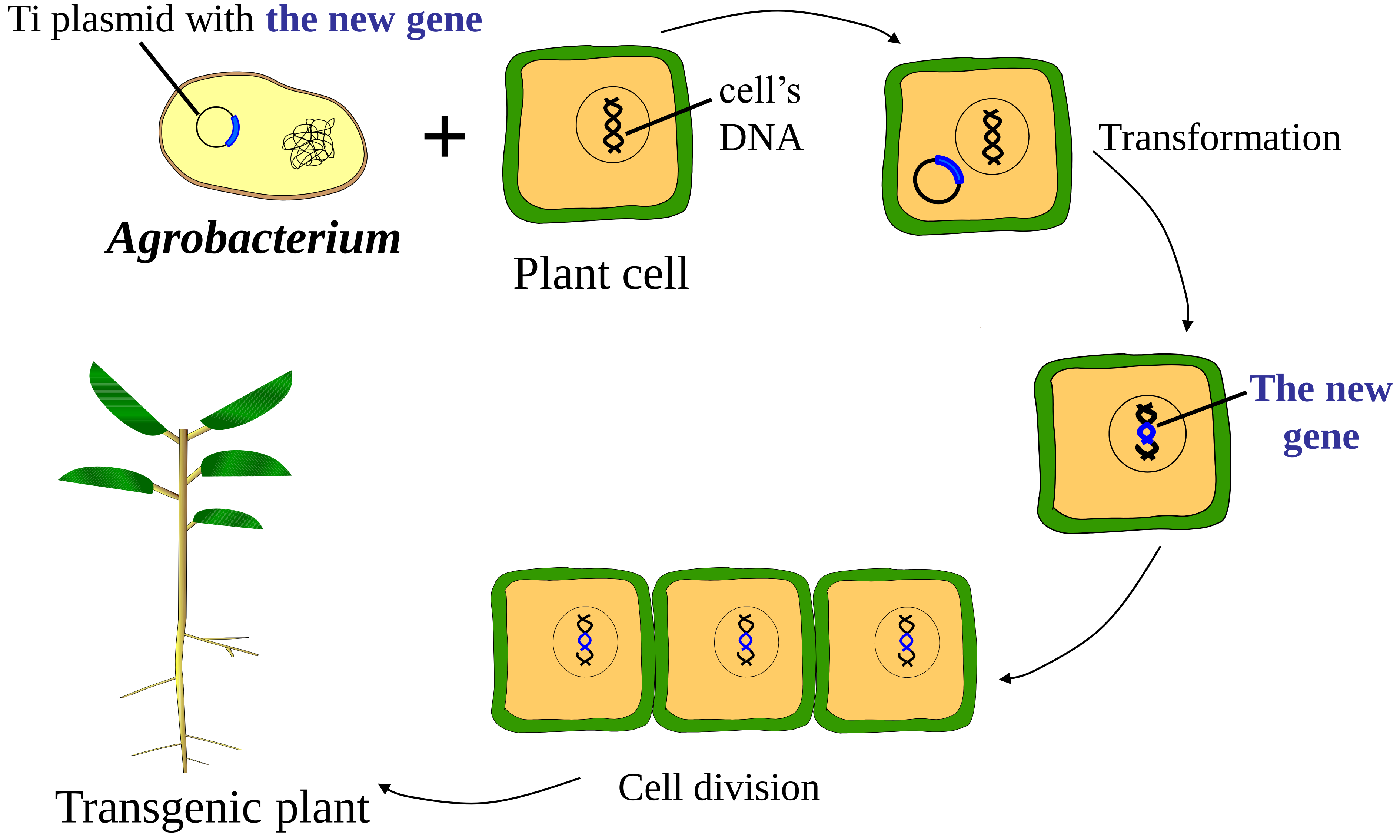

T-DNA region
Cytokinin
Auxin
Opine
Left border
Right border
12-24 kbp
ori
vir genes
Opine
catabolism

Agrobacterium tumefaciens

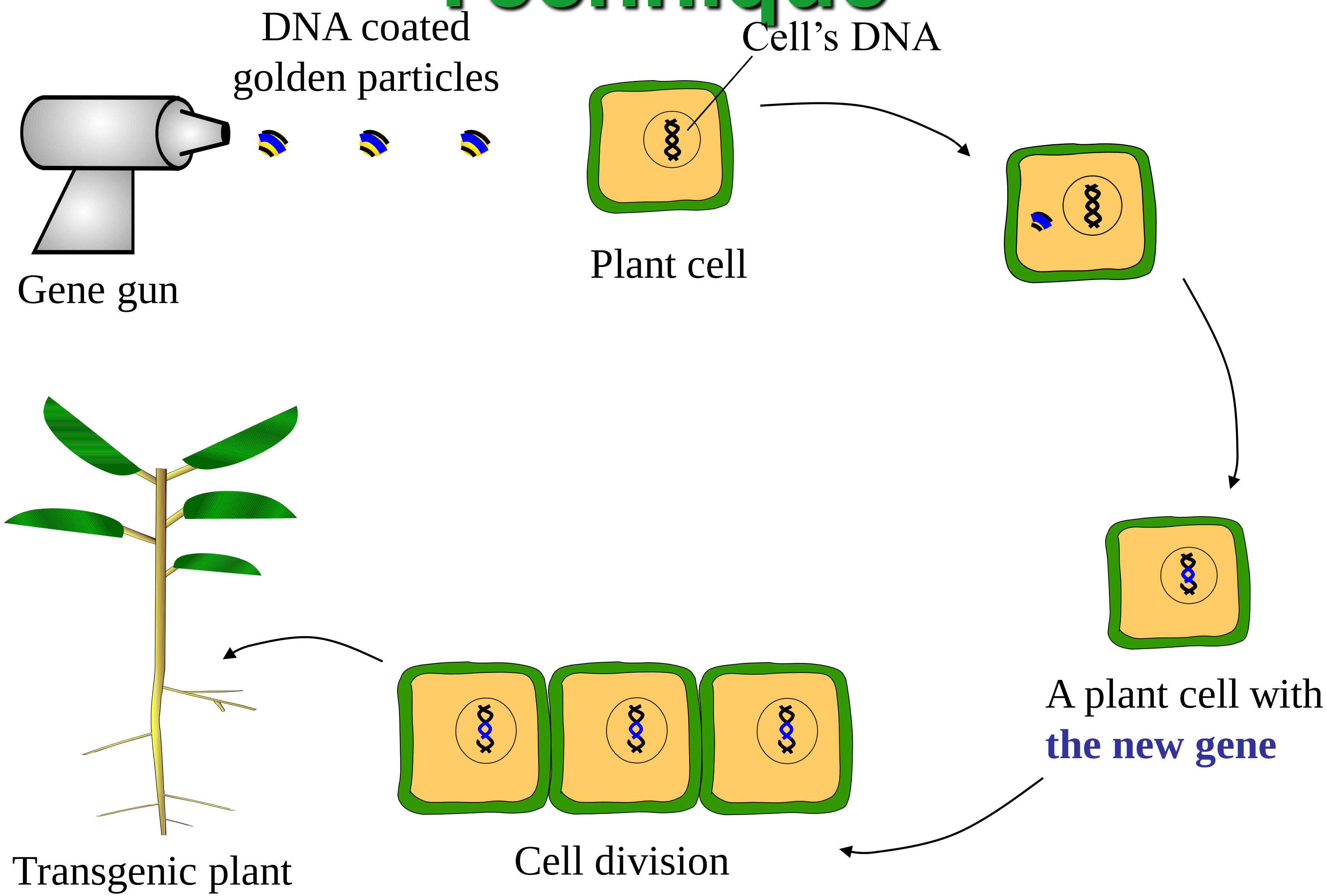


Ti plasmid with the gene of interest

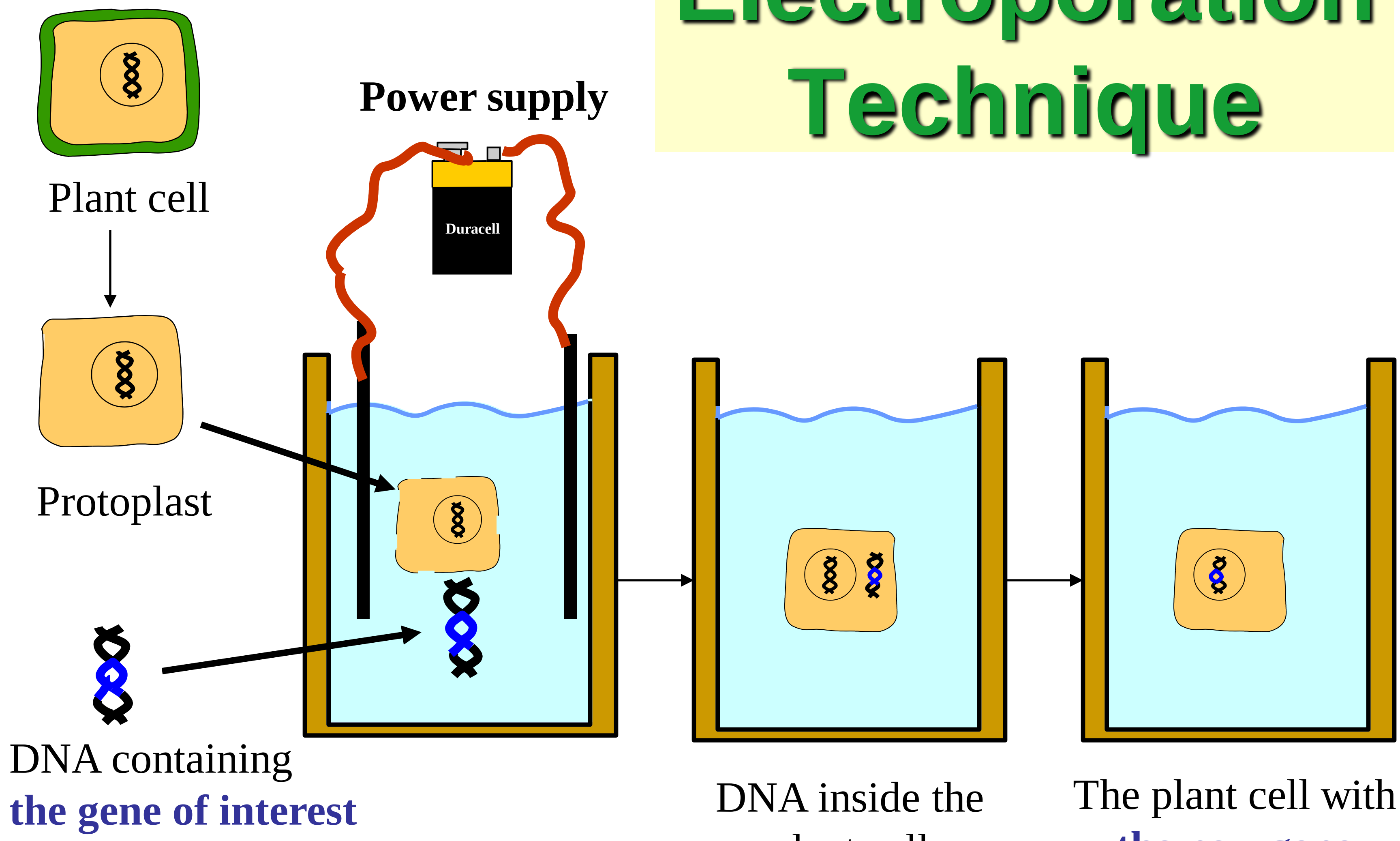
Agrobacterium tumefaciens



"Gene Gun" Technique



Electroporation Technique



DNA with desired gene and antibiotic resistance is coated onto the surface of gold particles.

Calli are placed
in vacuum chamber,
Helium pressure
shot DNA into cells

Calli remain
on the high osmotic media
for 20 hours
following shooting.

[plantsciences.montana.edu/ .../transform1.htm]()

Closer look on (“gene gun”)

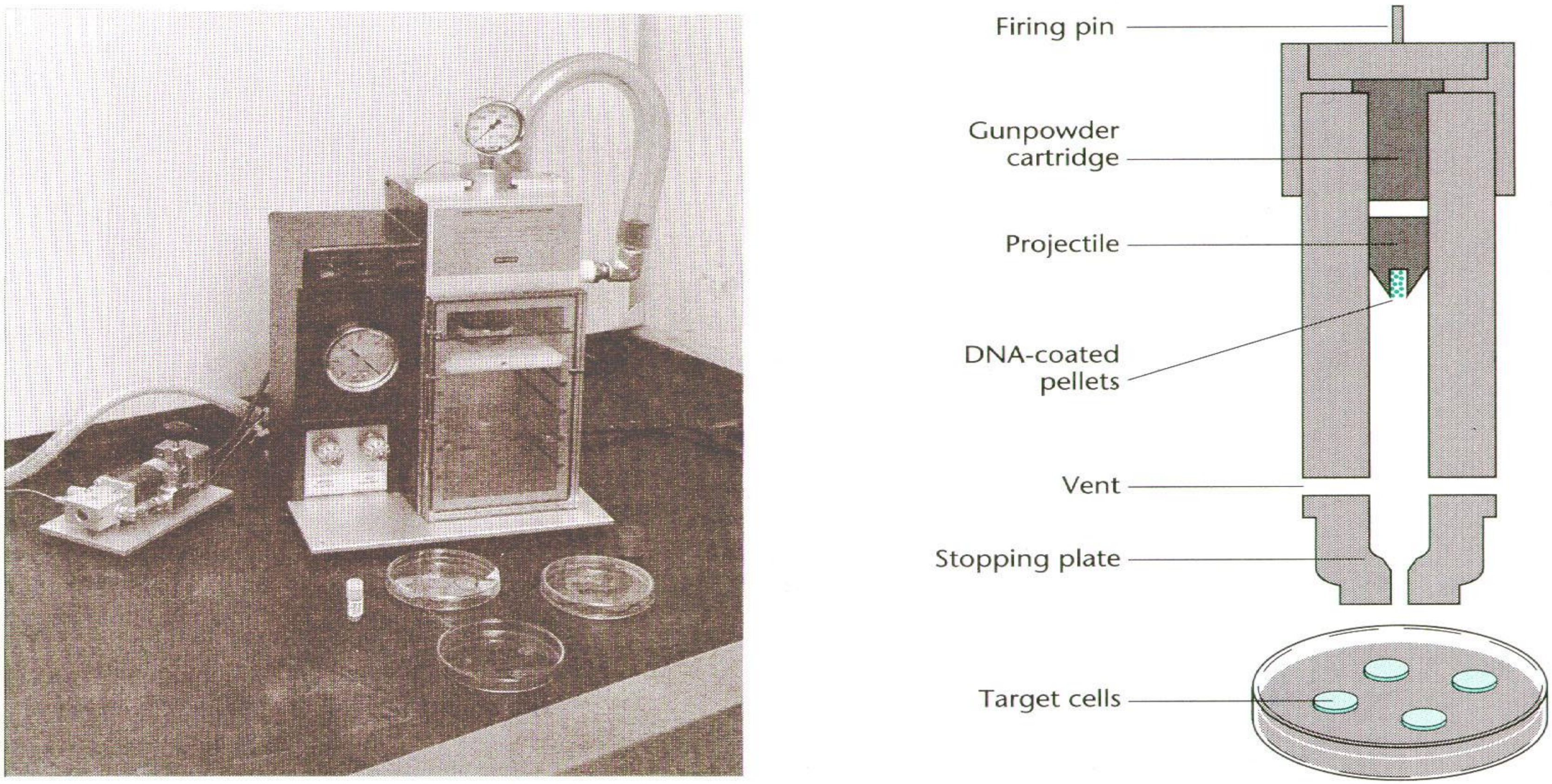


Figure 15.3

DNA Particle Gun. *The DNA particle gun, developed by John C. Sanford of Cornell University, fires tungsten pellets coated with DNA into plant cells. The pellets are held by a plastic microprojectile, which is accelerated by a gunpowder charge. The plate stops the microprojectile; momentum sends the DNA-coated pellets into the target. The instrument shown is the Biolistic® system from Bio-Rad, but other instruments using variations of this basic principle have been developed.*

FDA

USDA

AMA

IFT

FAO/WHO

ADA

Food Biotechnology Is Safe ?

- **Food biotechnology is one of the most extensively reviewed agricultural advancements to date.**
- **Studies to date have shown no evidence of any harmful effects.**

GMO Pro-Contra