Where GMOs Stand Today

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What I want to communicate

What is my bias?

How do we put genes into plants?

What are the major "transgenic crops" today?

What about fruit crops?

Will new technologies "replace" GMO plants?

What do we need to do next?

What is my bias?

- Use knowledge-based processes to understand potential risks and rewards of new (and old) technologies
- Protect the right for farmers to farm in different sustainable ways (and make a living), and for consumers to choose foods of their preference
- *Concern:* Over-heated rhetoric is obscuring the risks and rewards of GMOs.
  - GMOs will double yields and solve all agricultural problems!!!
  - GMOs will kill you, or at least make you sick, and besides…it's MONSANTO (buy organic) !!!

I use GMO "technology" to put genes into plants for basic research and discovery.

Flower with added Green Fluorescent protein gene

Research support: the National Science Foundation, USDA, DOE, National Institutes of Health

Major Scientific Societies Worldwide Agree that Genetic Engineering Technology is Safe

GENETIC LITERACY PROJECT

WHERE SCIENCE TRUMPS IDEOLOGY

www.geneticliteracyproject.org

1 THE AMERICAN MEDICAL ASSOCIATION

(Chicago)

"There is no scientific justification for special labeling of genetically modified foods. Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

2 THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(Washington, D.C.)

"The science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe."

3 THE NATIONAL ACADEMY OF SCIENCES

(Washington, D.C.)

"To date more than 98 million acres of genetically modified crops have been grown worldwide. No evidence of human health problems associated with the ingestion of these crops or resulting food products have been identified."

4 FOOD STANDARDS AUSTRALIA NEW ZEALAND

(Australia & New Zealand)

"Gene technology has not been shown to introduce any new or altered hazards into the food supply, therefore the potential for long term risks associated with GM foods is considered to be no different to that for conventional foods already in the food supply."

5 THE FRENCH ACADEMY OF SCIENCE

(France)

"All criticisms against GMOs can be largely rejected on strictly scientific criteria."

6 THE ROYAL SOCIETY OF MEDICINE

(United Kingdom)

"Foods derived from GM crops have been consumed by hundreds of millions of people across the world for more than 15 years, with no reported ill effects (or legal cases related to human health), despite many of the consumers coming from that most litigious of countries, the USA."

7 THE EUROPEAN COMMISSION

(Belgium)

"The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are no more risky than conventional plant breeding technologies."

8 THE UNION OF GERMAN ACADEMICS OF SCIENCES AND HUMANITIES

(Germany)

"In consuming food derived from GM plants approved in the EU and in the USA, the risk is in no way higher than in the consumption of food from conventionally grown plants. On the contrary, in some cases food from GM plants appears to be superior in respect to health."

9 SEVEN OF THE WORLD'S ACADEMIES OF SCIENCES

(Brazil, China, India, Mexico, the Third World Academy of Sciences, the Royal Society, and the National Academy of Sciences of the U.S.)

"Foods can be produced through the use of GM technology that are more nutritious, stable in storage and in principle, health promoting—bringing benefits to consumers in both industrialized and developing nations."

10 WORLD HEALTH ORGANIZATION

(Switzerland)

"No effects on human health have been shown as a result of the consumption of GM foods by the general population in the countries where they have been approved."

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Putting a GENE of choice into plants using Agrobacterium was first achieved in 1983

NATURE VOL. 303 19 MAY 1983

Expression of chimaeric genes transferred into plant cells using a Ti-plasmid-derived vector

Luis Herrera-Estrella*, Ann Depicker*, Marc Van Montagu* & Jeff Schell*†

* Laboratorium voor Genetica, Rijksuniversiteit Gent, B-9000 Gent, Belgium
† Max-Planck-Institut für Züchtungsforschung, D-5000 Köln 30, FRG

Foreign genes introduced into plant cells with Ti-plasmid vectors are not expressed. We have constructed an expression vector derived from the promoter sequence of nopaline synthase, and have inserted the coding sequences of the octopine synthase gene and a chloramphenicol acetyltransferase gene into this vector. These chimaeric genes are functionally expressed in plant cells after their transfer via a Ti-plasmid of Agrobacterium tumefaciens.

CROWN gall formation on dicotyledonous plants by *Agrobacterium tumefaciens* is the result of the transfer and covalent integration of a segment (called T-region) of the Ti-plasmid into the chromosomal DNA of plant cells (for reviews see refs 1–4). Insertion of foreign DNA sequences within the T-region of Ti-plasmids leads to their co-transfer and integration into the plant genome[5]. To date, inserts of up to 50 kilobases (kb) from pTiT37 (refs 15, 16). Although both genes are encoded by plasmids of bacterial origin, they share more characteristics with eukaryotic genes than with prokaryotic genes. Both octopine and nopaline synthase genes, designated *ocs* and *nos* respectively, have a sequence similar to the so-called 'TATA' or 'Goldberg–Hogness' box[17] in the 5′ region upstream of the start of transcription, and a sequence 'AATAA' similar to the

Proc. Natl. Acad. Sci. USA
Vol. 80, pp. 4803–4807, August 1983
Genetics

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Vol. 80, pp. 4803–4807, August 1983
Genetics

Expression of bacterial genes in plant cells

(plant protoplasts/transformation/foreign DNA/antibiotic resistance/selectable markers)

ROBERT T. FRALEY, STEPHEN G. ROGERS, ROBERT B. HORSCH, PATRICIA R. SANDERS, JEFFERY S. FLICK, STEVEN P. ADAMS, MICHAEL L. BITTNER, LESLIE A. BRAND, CYNTHIA L. FINK, JOYCE S. FRY, GERALD R. GALLUPPI, SARAH B. GOLDBERG, NANCY L. HOFFMANN, AND SHERRY C. WOO

Monsanto Company, 800 North Lindbergh Boulevard, St. Louis, Missouri 63167

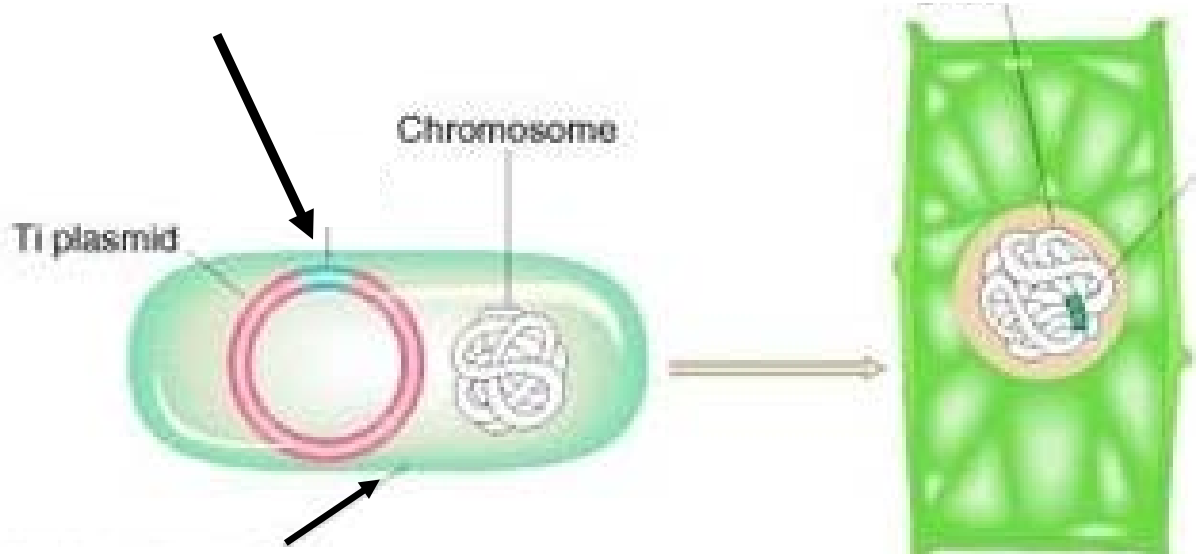
Communicated by Howard A. Schneiderman, April 25, 1983

Monsanto Company, 800 North Lindbergh Boulevard, St. Louis, Missouri 63167

Using Agrobacterium to make "Transgenic" Plants

We insert DNA with Our Favorite Gene into the bacterium

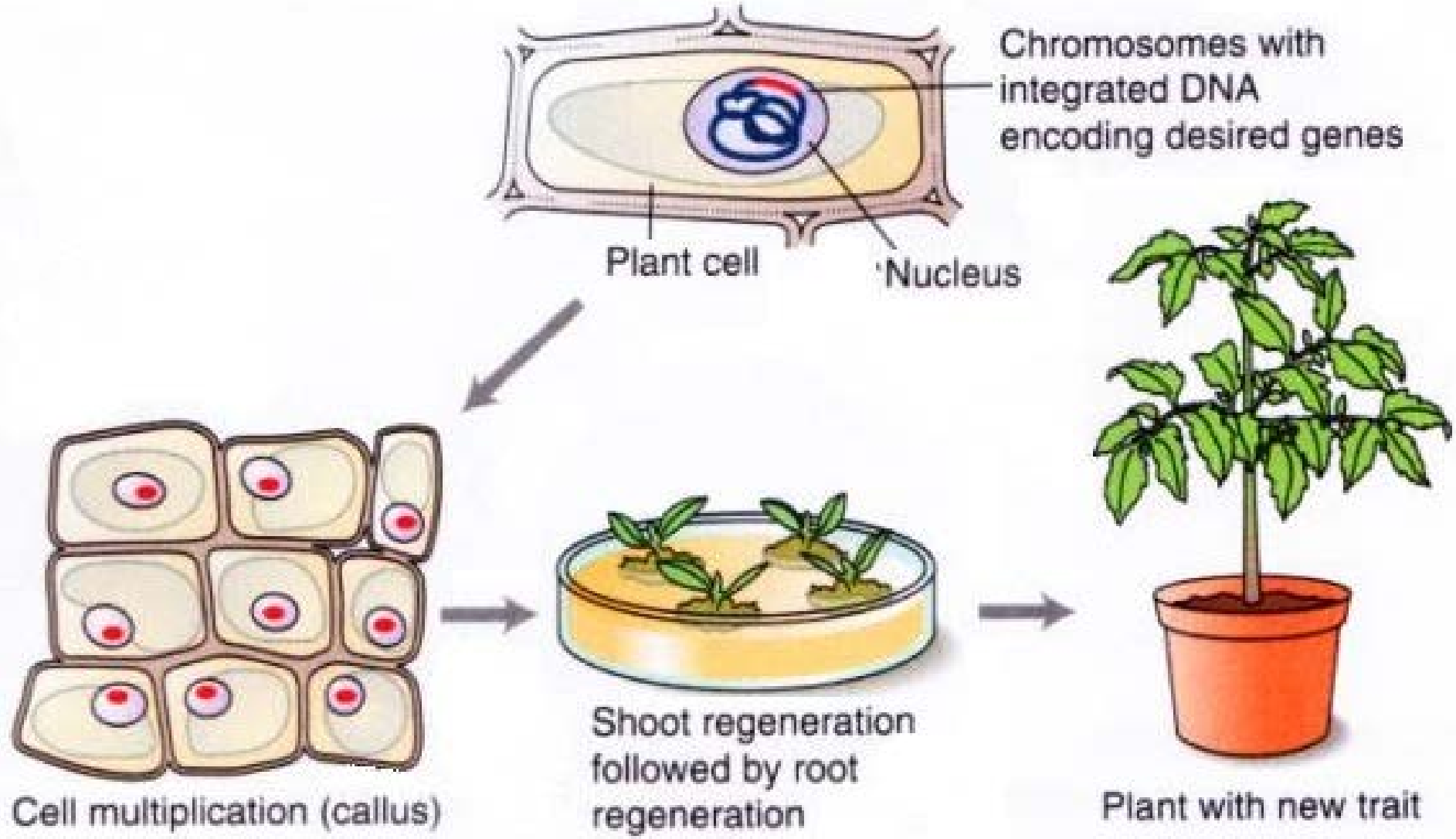
The bacterium puts it into the plant for us!



Agrobacterium

Plant Cell

We can introduce a gene into a plant cell and the "regenerate" a whole plant



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International Service for the Acquisition of Agri-biotech Applications

http://www.isaaa.org/default.asp

Center for Environmental Risk Assessment

- About Us
- GM Crop Database
- Bibliography Database
- CERA Meetings & Events
- CERA Publications
- S. Asia Biosafety Program

http://cera-gmc.org/

The Center for Environmental Risk Assessment (CERA) is dedicated to developing and applying sound science to the environmental risk assessment of agricultural biotechnologies so their contributions to the sustainable production of food, fuel and fiber may be safely realized.

"Biotech" crops currently grown

Countries listed in order of number of acres

Note: There is NO "GMO" rice, wheat, peanut

Country	
USA*	Maize, soybean, cotton, canola, sugar beet, alfalfa, papaya, squash
Brazil*	Soybean, maize, cotton
Argentina*	Soybean, maize, cotton
India*	Cotton
Canada*	Canola, maize, soybean, sugar beet
China*	Cotton, papaya, poplar, tomato, sweet pepper

Major genes currently in transgenic crops

- **Herbicide tolerance (HT):** Corn, soybean, canola, cotton, sugar beet, alfalfa

  "Roundup Ready"

  Gene: EPSP synthase

- **Insect Resistance (Bt):** Corn, Cotton

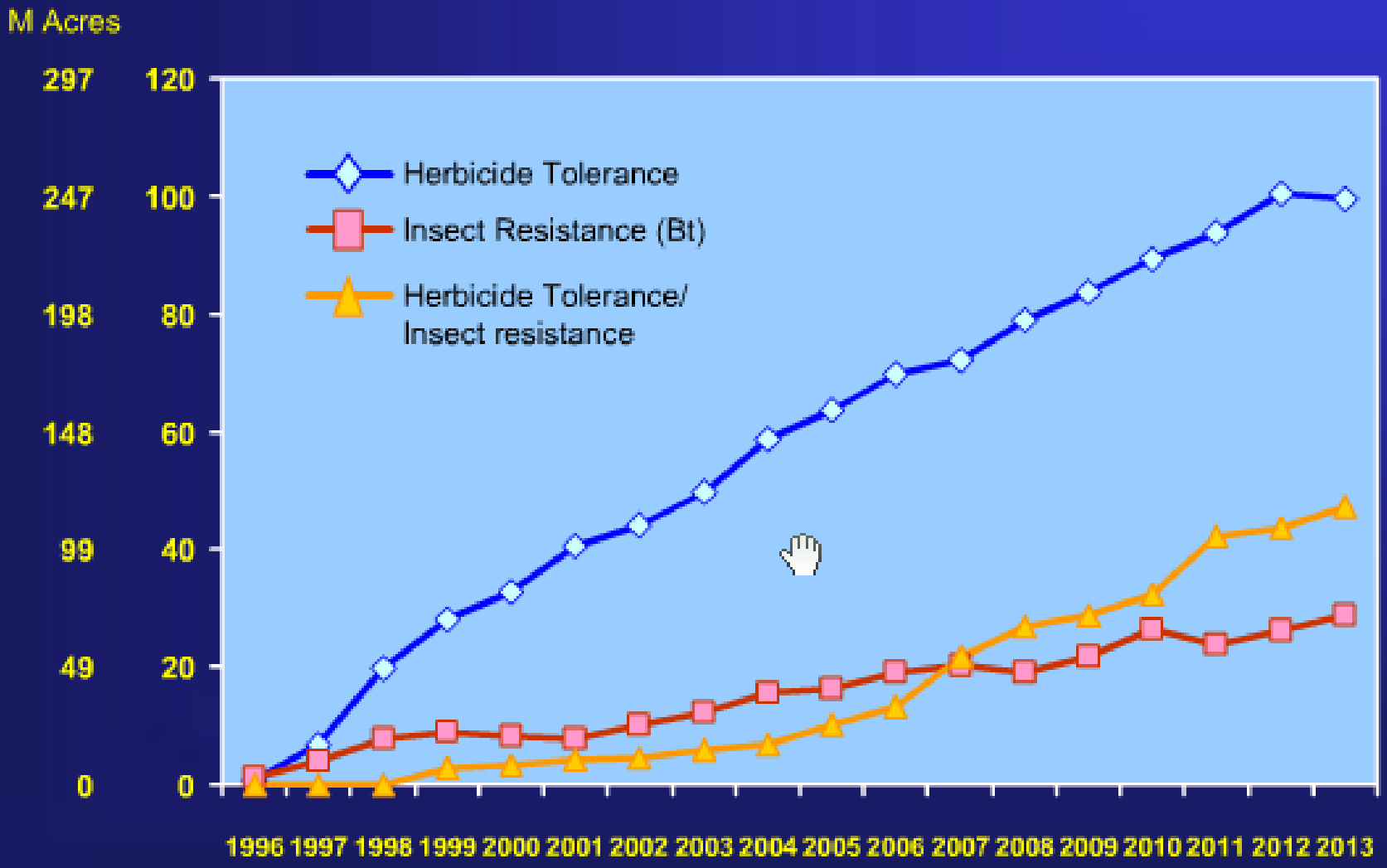
  "*Bacillus thuringensis* toxin"

  Gene: Bt toxin

- **Papaya Ring Spot Virus resistance:** Papaya

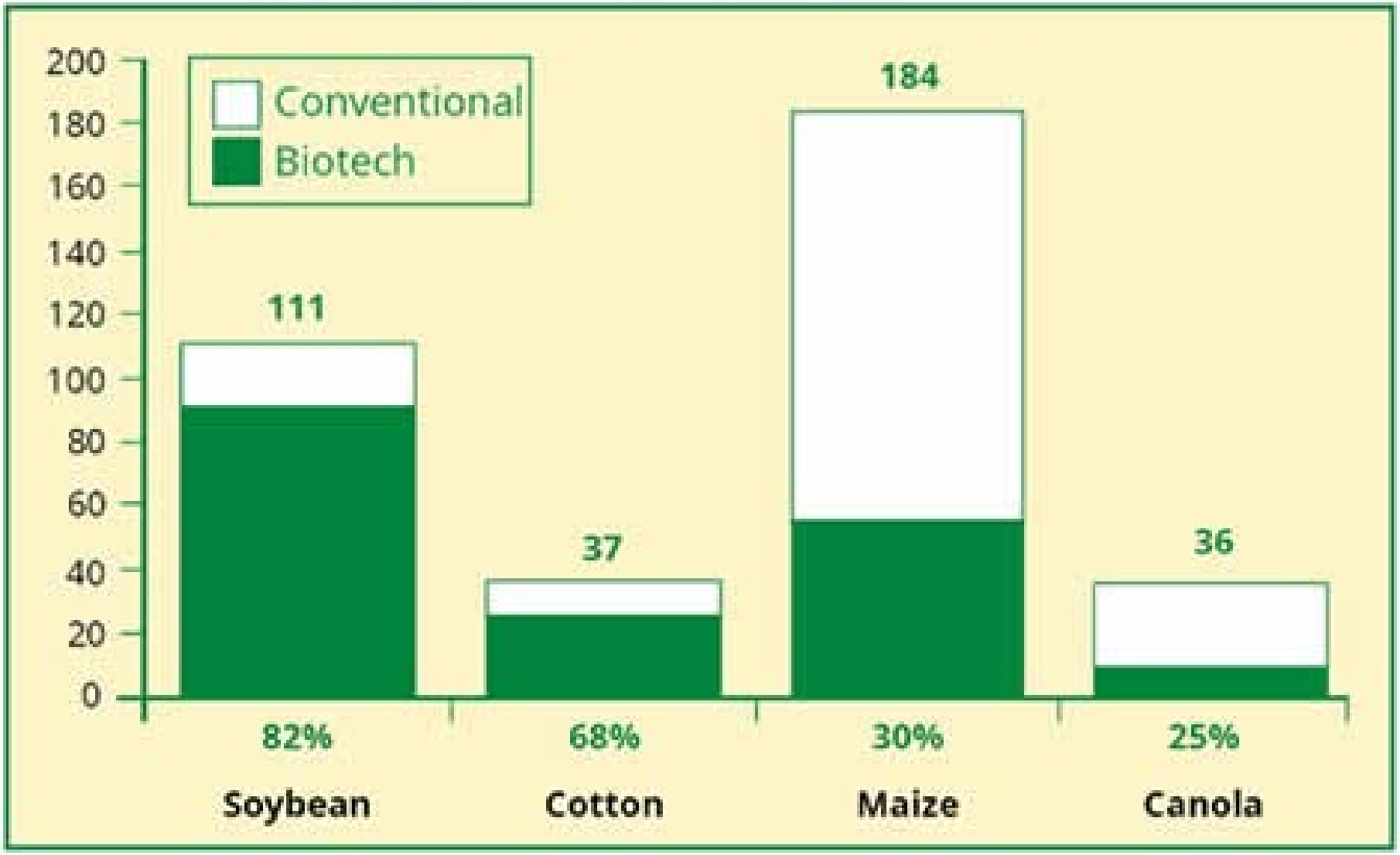
  Gene: RSV protein

Global Area of Biotech Crops, 1996 to 2013: By Trait (Million Hectares, Million Acres)



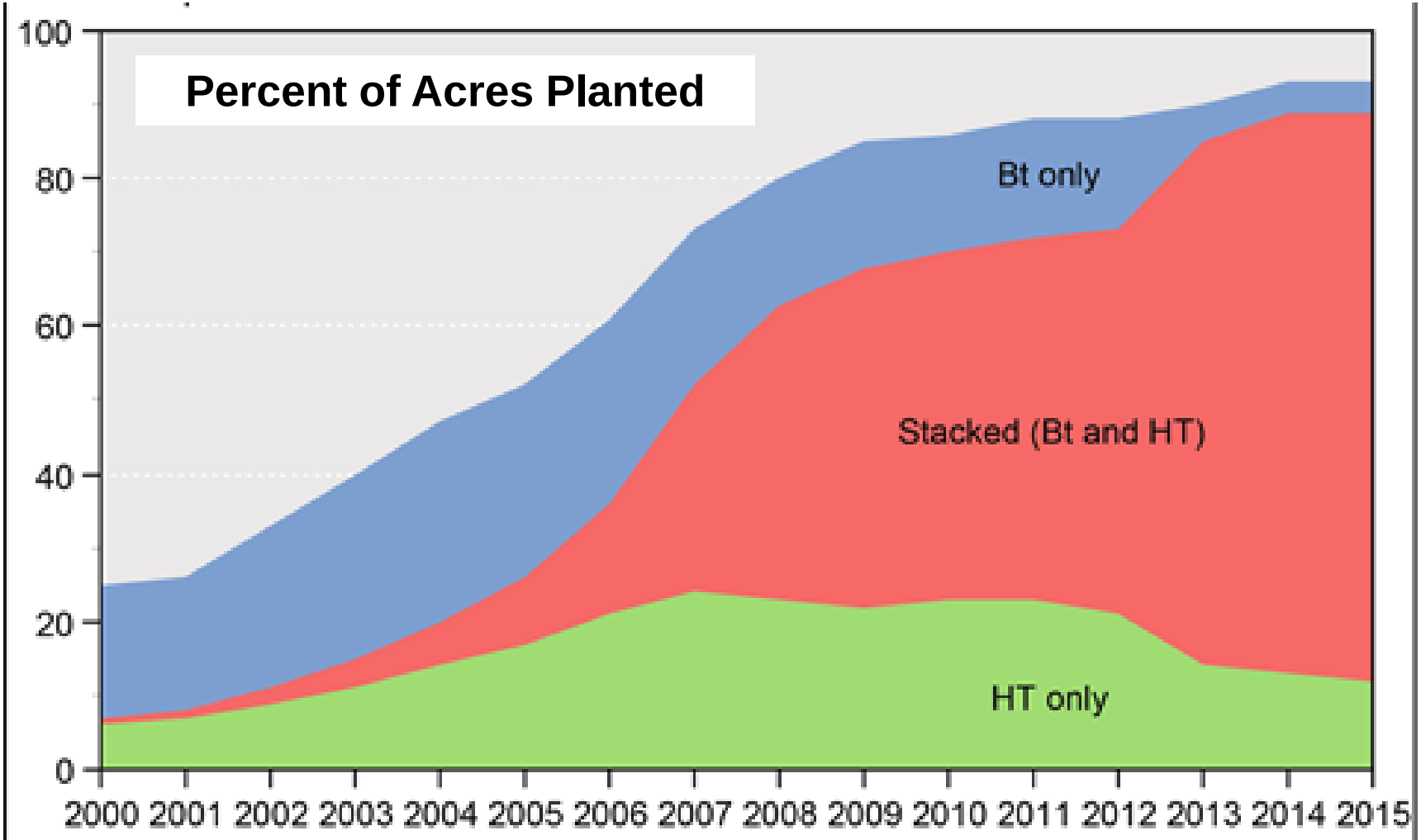
Source: Clive James, 2013

Figure 3. Biotech Crop Area as % of Global Area of Principal Crops, 2014 (Million Hectares)



Source: Clive James, 2014.

Adoption of Genetically Engineered Corn in the US



Source: USDA, Economic Research Service using data from USDA, National Agricultural Statistics Service, *June Agricultural Survey*.

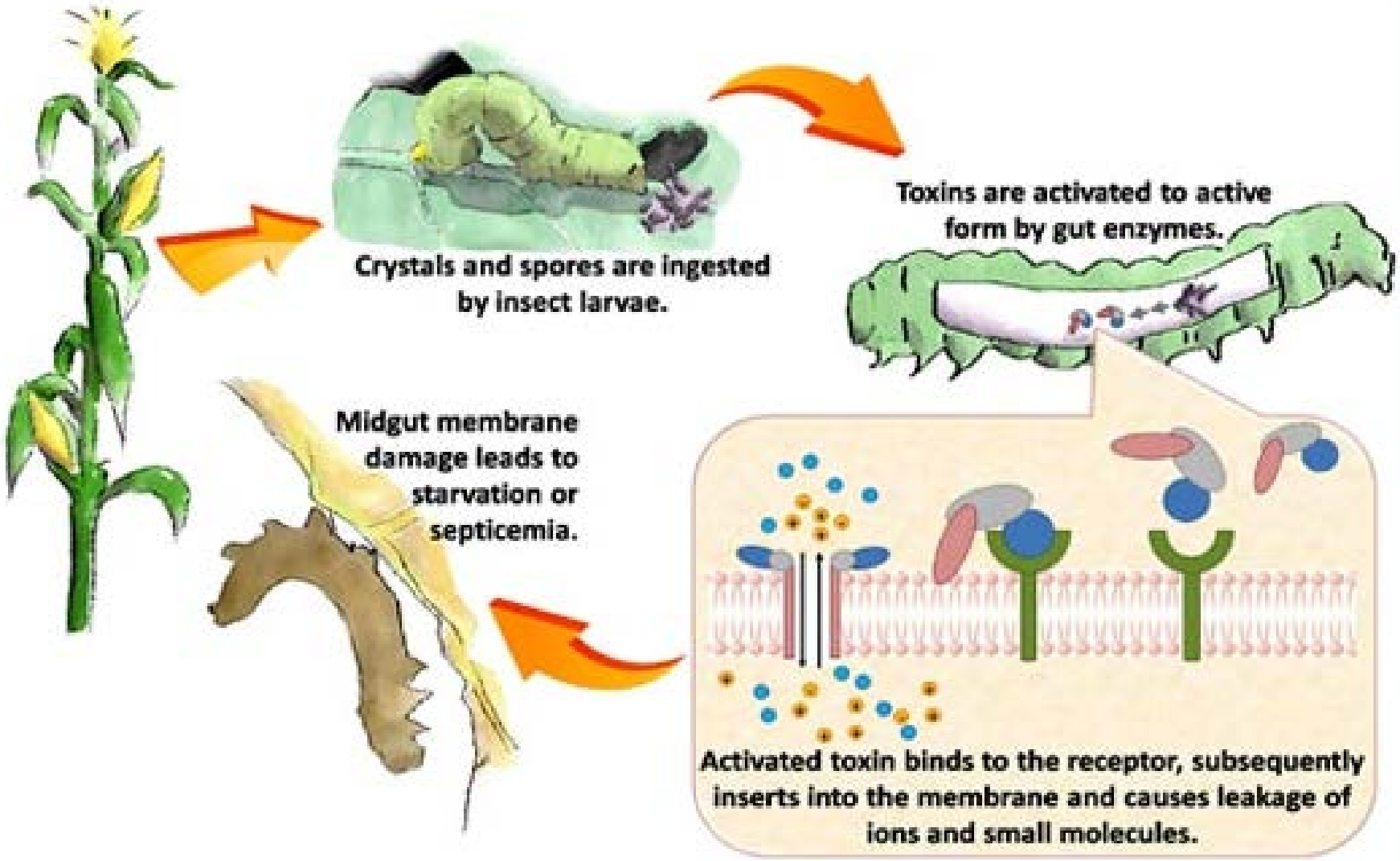
Why I am perfectly happy eating herbicide tolerant plants!

The gene used specifies a protein found in all plants. We eat it all the time!

The change that makes the protein "herbicide tolerant" involves a few amino acids – less difference than there is between two different plants.

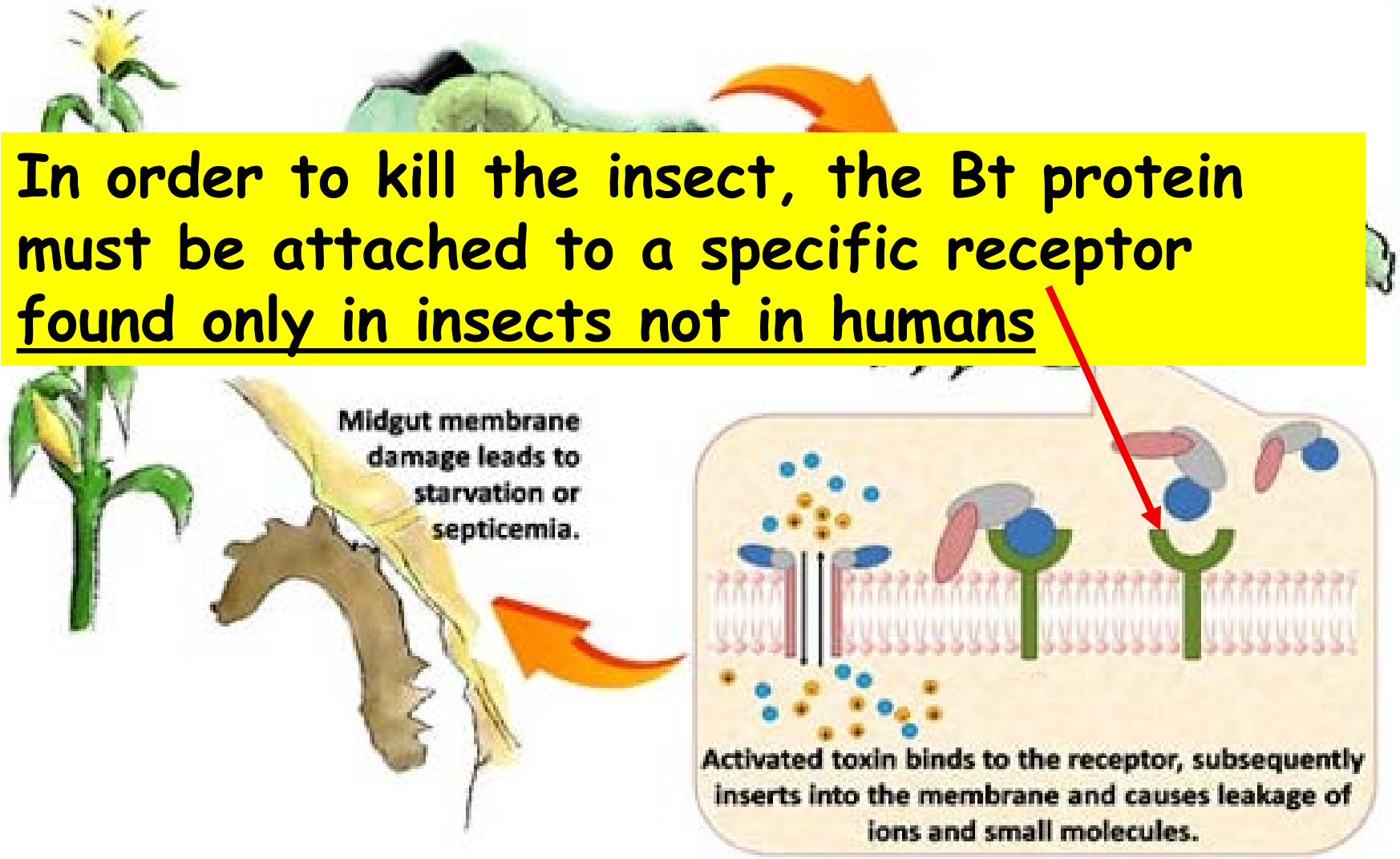
Why I am perfectly happy eating insect resistant plants!

Bt toxin is very INSECT SPECIFIC, specific types affect only certain insects



Bt toxin is very INSECT SPECIFIC, specific types affect only certain insects

In order to kill the insect, the Bt protein must be attached to a specific receptor <u>found only in insects not in humans</u>



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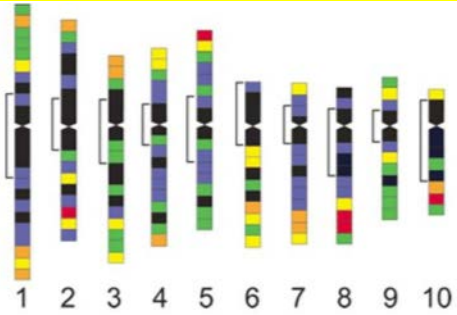
Why are GM methods used sometimes and molecular breeding others?

Molecular breeding

1. Desired trait must be present in population



2. Genetic resources must be available

3. Plant should be propagated sexually

GM

1. Gene can come from any source

2. Genetic resources not required

3. Plant can be propagated vegetatively

Photo credits: Gramene.org ETH Life International

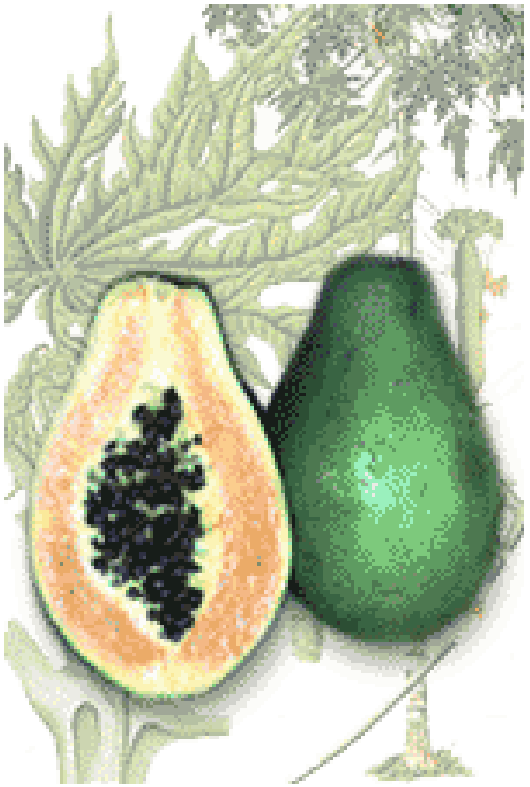
GM Disease Resistant Papaya has replaced 80% of the Hawaiian Papaya crop

GM Crop Database

Database Product Description Show abstract Print this page

UFL-X17CP-6 (X17-2)

Host Organism	*Carica papaya* L. (Papaya)
Trait	Resistance to viral infection, papaya ringspot virus (PRSV).
Trait Introduction	*Agrobacterium tumefaciens*-mediated plant transformation.
Proposed Use	Production of papaya for human consumption, either fresh or processed.
Company Information	University of Florida



http://cera-gmc.org/index.php?action=gm_crop_database

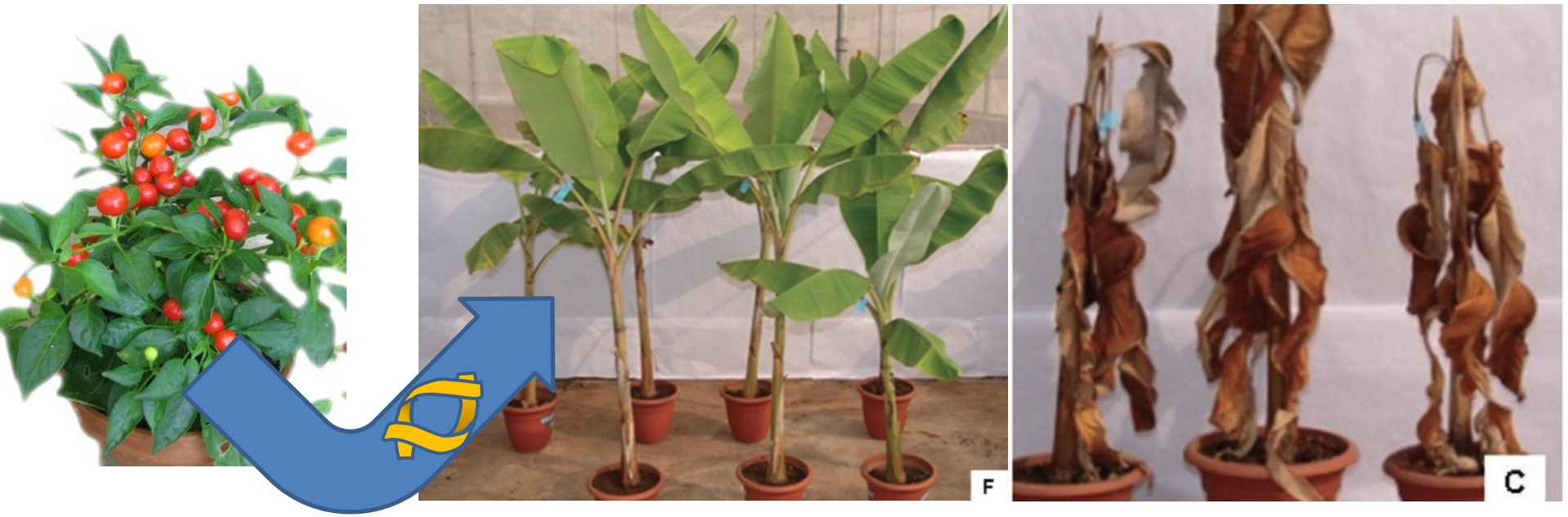
Transgenics have been successful with other diseases of fruit crops

Bananas
Bacterial wilt disease

Apples
Fire blight
Bacterial disease

Plums
Plum pox
Viral disease

GM Example: Disease resistant banana by introduction of a gene from pepper



Resistant Susceptible

Banana bacterial wilt is destroying plants in eastern Africa. Transgenic plants carrying a resistance gene from pepper are resistant to the disease

Tripathi, L., Mwaka, H., Tripathi, J.N., and Tushemereirwe, W.K. (2010). Expression of sweet pepper Hrap gene in banana enhances resistance to Xanthomonas campestris pv. musacearum. Molecular Plant Pathology 11: 721-731.

Erwinia amylovora (Apple Fireblight) Resistance from "Crab apple" Engineered into Commercial Cultivars

Engineering fire blight resistance into the apple cultivar 'Gala' using the *FB_MR5* CC-NBS-LRR resistance gene of *Malus* × *robusta* 5. Giovanni A. L. Broggini et al.

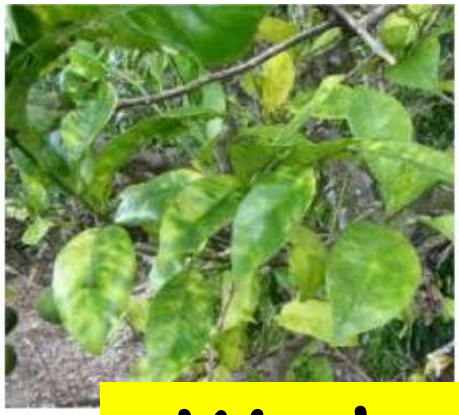
Plant Biotechnology Journal
Volume 12, Issue 6, pages 728–733, August 2014

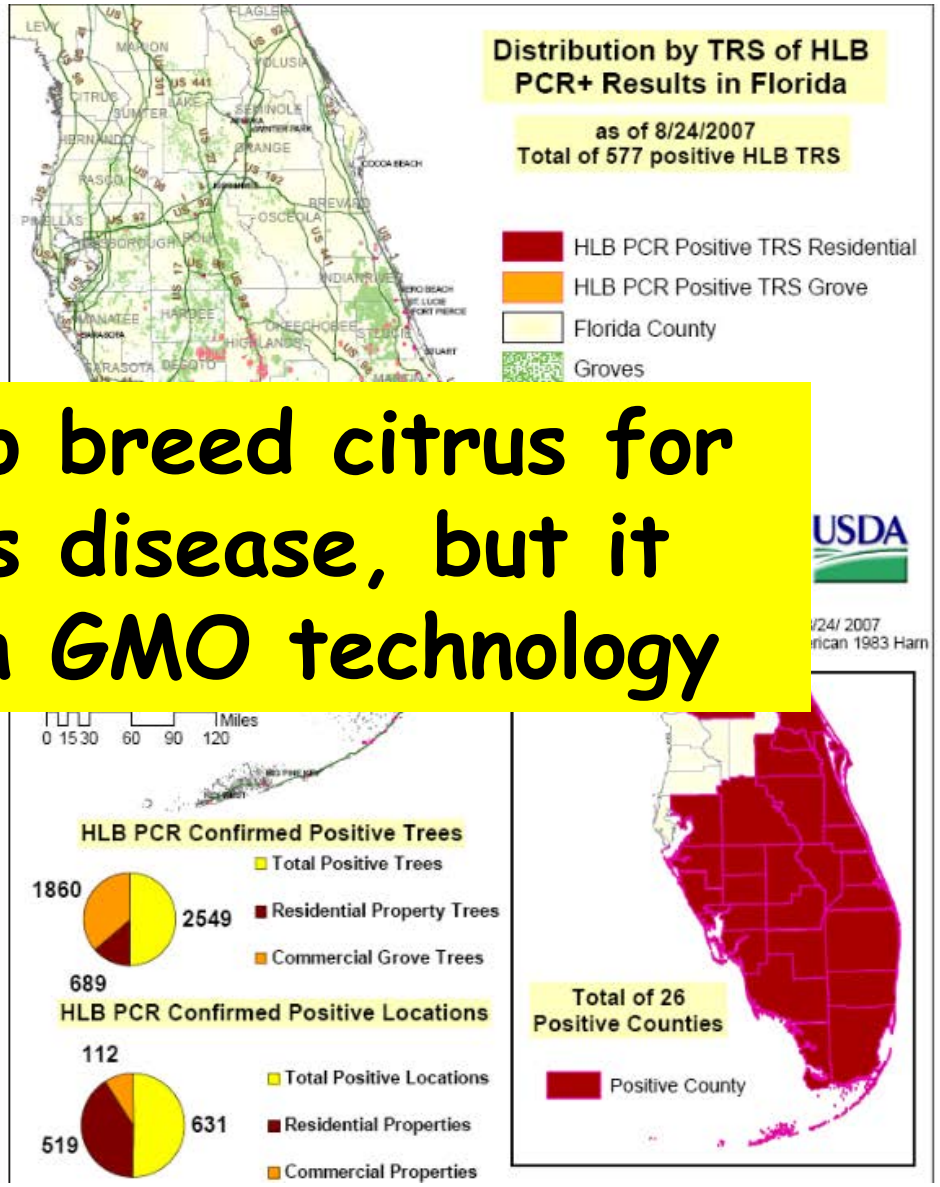
Plum Pox (viral disease) Resistance Engineered with Gene Silencing of Viral Gene

- Current treatment – Destruction of infected trees.
- Field tests of transgenics were conducted in Poland from 1996 to 2006, Spain from 1996 to 2012, Romania 1996–2006 and Czech Republic 2002–2013. Clearly demonstrated resistance to PPV infection through aphid vectors and by graft inoculation.
- Not yet in commercial production.

http://www.ars.usda.gov/is/br/plumpox/

The spread of Citrus Greening disease





We have no way to breed citrus for resistance to this disease, but it could be done with GMO technology

"Artic" Apple – Non-browning

Okanagan Specialty Fruits Inc.
PO Box 1533
Summerland, BC V0H 1Z0
Canada

Engineered to inhibit expression of the apple polyphenol oxidase gene.

Inhibits browning but not softening.

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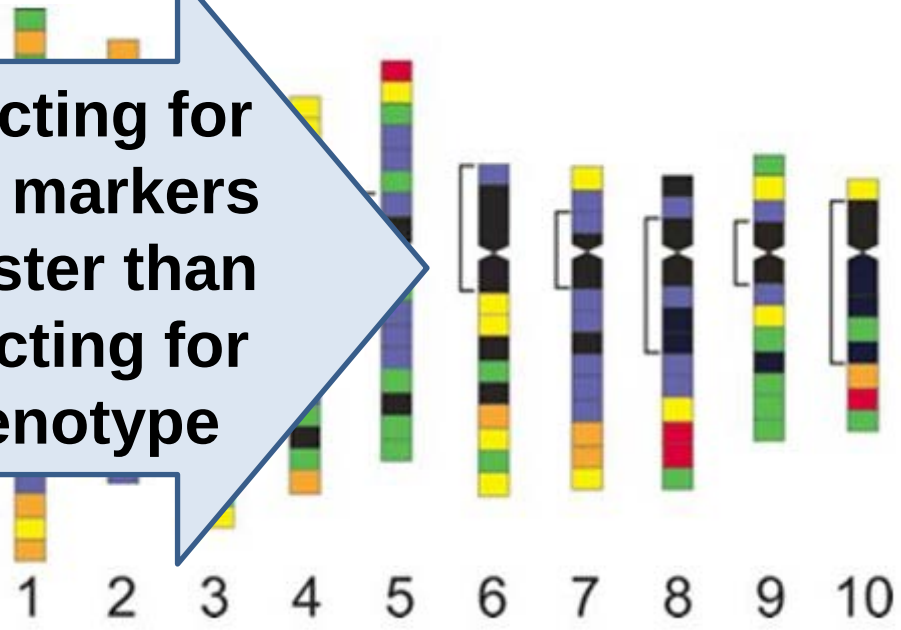
New Technologies for Crop Improvement

- Marker Assisted Selection/Breeding
- CRISPR/Cas gene editing

Marker Assisted Selection

Phenotype: physical expression of traits

Selecting for DNA markers is faster than selecting for phenotype



Genotype: sequence of all the genes in a genome

Photo credit LemnaTec; Anderson, L.K., Lai, A., Stack, S.M., Rizzon, C. and Gaut, B.S. (2006). Uneven distribution of expressed sequence tag loci on maize pachytene chromosomes. Genome Research. 16: 115-122.

MAS was used to produce of submergence tolerant rice (*Sub1*)

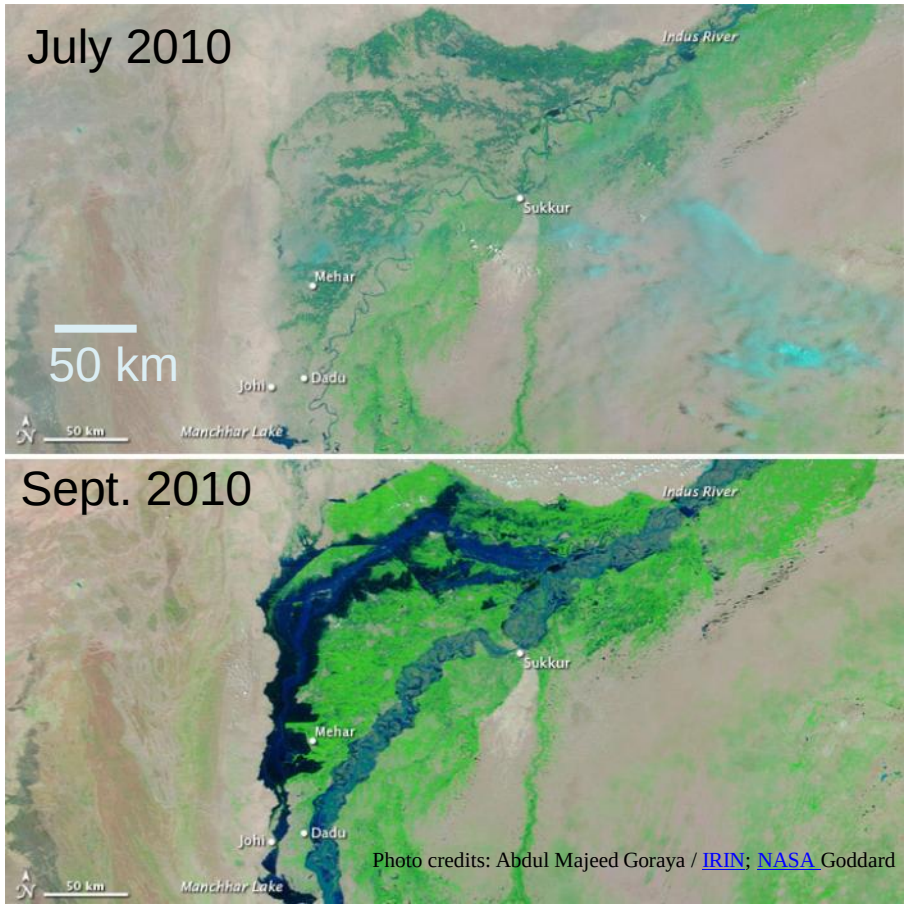


Photo credits: Abdul Majeed Goraya / IRIN; NASA Goddard

Many rice-growing regions are prone to flooding. In Pakistan a 2010 a huge flood submerged 17 million acres (69,000 km^2) and destroyed much of the harvest

CRISP/Cas

A technique for "Editing" a genome

Remove genes, change existing genes

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Worldwide, preharvest crop loss estimates:

- We need to use every tool at our disposal, including GMO technology, to solve agricultural and environmental problems to create food security and sustainability

Other losses due to stress:
drought, cold heat, salinization

Where to go from here?

- Each crop, each "trait" (modification) needs to be evaluated separately.

- We need more agricultural research
  - To understand how to combat pests and disease
  - To move away from monoculture towards sustainable practices

- Let's be passionate about the science!

Thanks to many members of my research lab over the last 30 years

Thank you for your attention!