

Crop Biotechnology



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Domestication: The Original Crop Biotechnology

Humans have made dramatic changes in plants during the process of domestication that have resulted in the crops that we rely on today.

The majority of these changes had already occurred before scientific breeding began.



Photo courtesy of Monsanto

Teosinte and early progenitors of corn



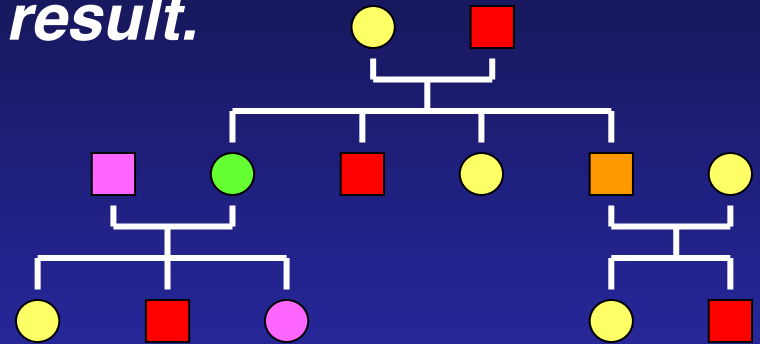
Early corn



Modern corn

Plant Breeding Is Genetic Modification

Through the application of genetics, plant breeders have directed changes in the genetic characteristics of crops to achieve a desired result.

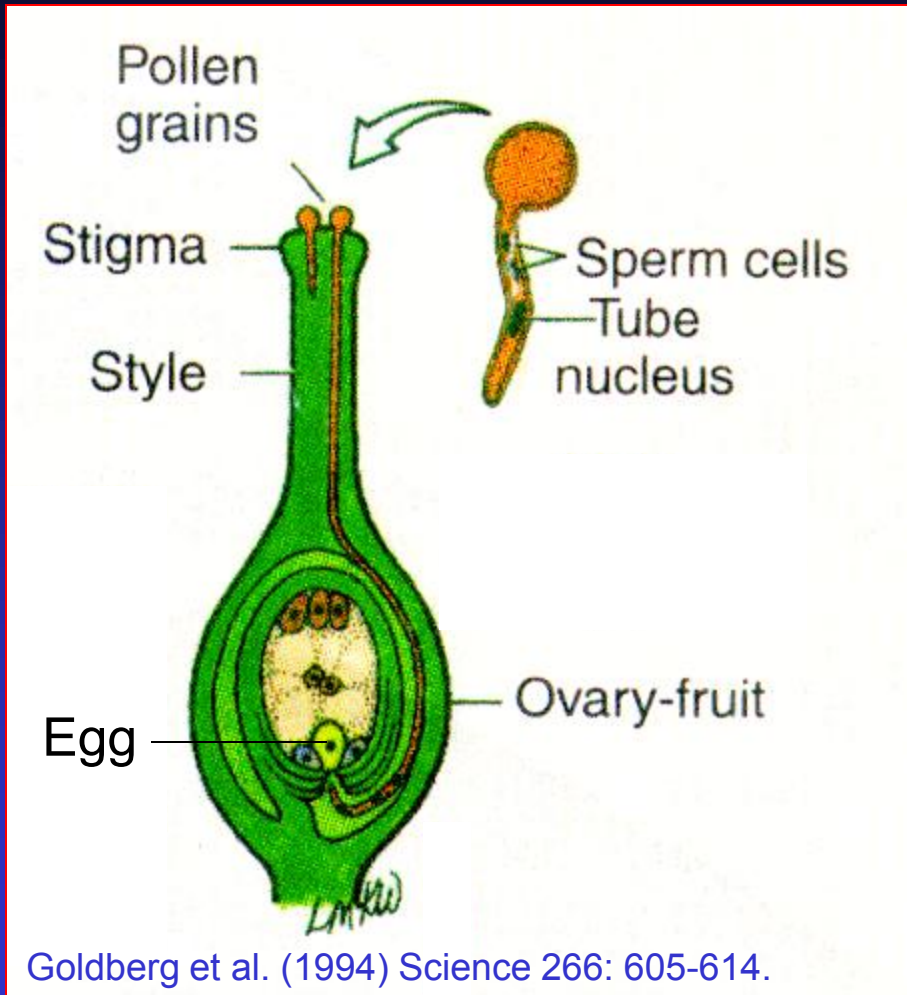


Crop Genetic Improvement

- Characteristics improved by plant breeding:
 - *Yield*
 - *Resistance to pests*
 - *Seed composition*
 - *Tolerance to environmental stresses*
 - *Adaptability to mechanization*
 - *Photoperiod response*
 - *Appearance, taste, nutritional quality*
 - *Aesthetic appeal*
- Virtually all of these improvements have involved introduction of genes from related species or races of the crop plant.

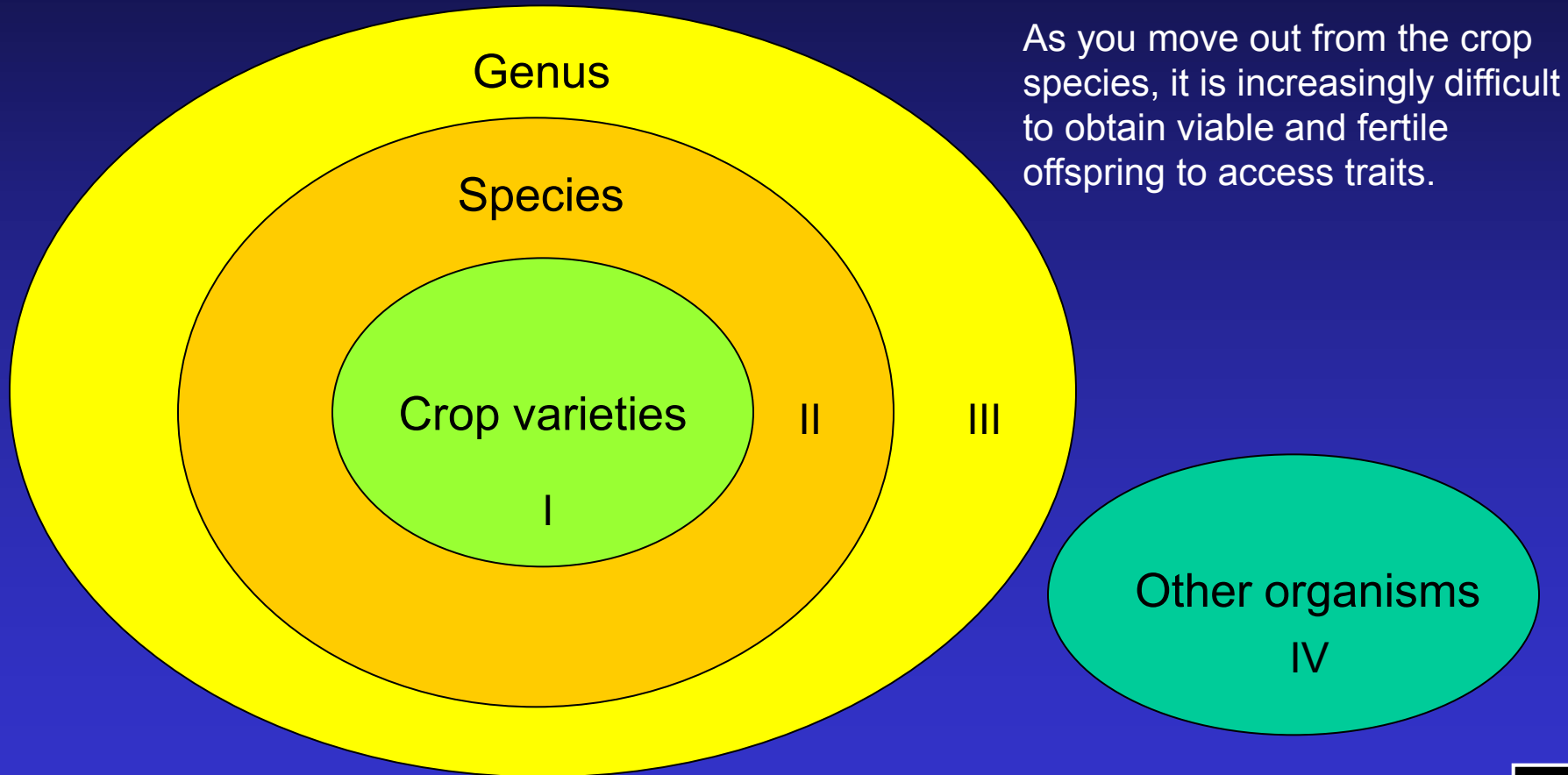


Traditional Breeding Depends Upon Sexual Crosses



Gene Pool Concept

The Gene Pool Concept – ease with which fertile, viable progeny can be obtained from crosses between different plants.



Gepts P, in MJ Chrispeels and DE Sadava (2002) Plants, Genes and Crop Biotechnology. Jones and Bartlett Publishers.



Sources of Traits for Crop Improvement

Domesticated tomato

Related wild species



Solanum lycopersicum

Solanum peruvianum

Varieties Derived from Induced Mutations



Calrose 76 semi-dwarf rice

Over 2000 crop varieties derived from mutagenesis have been commercialized.

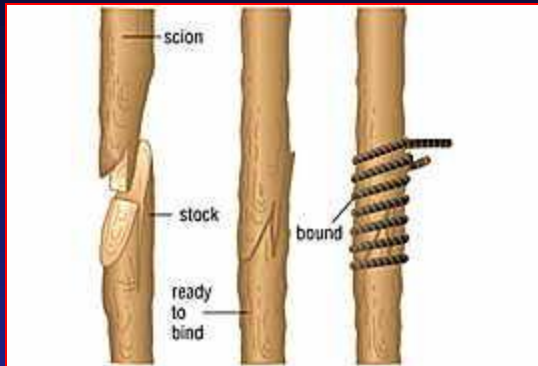


High oleic sunflower



Rio Red grapefruit

Species Are Combined by Grafting



DNA in the Chromosomes Carries Biological Information

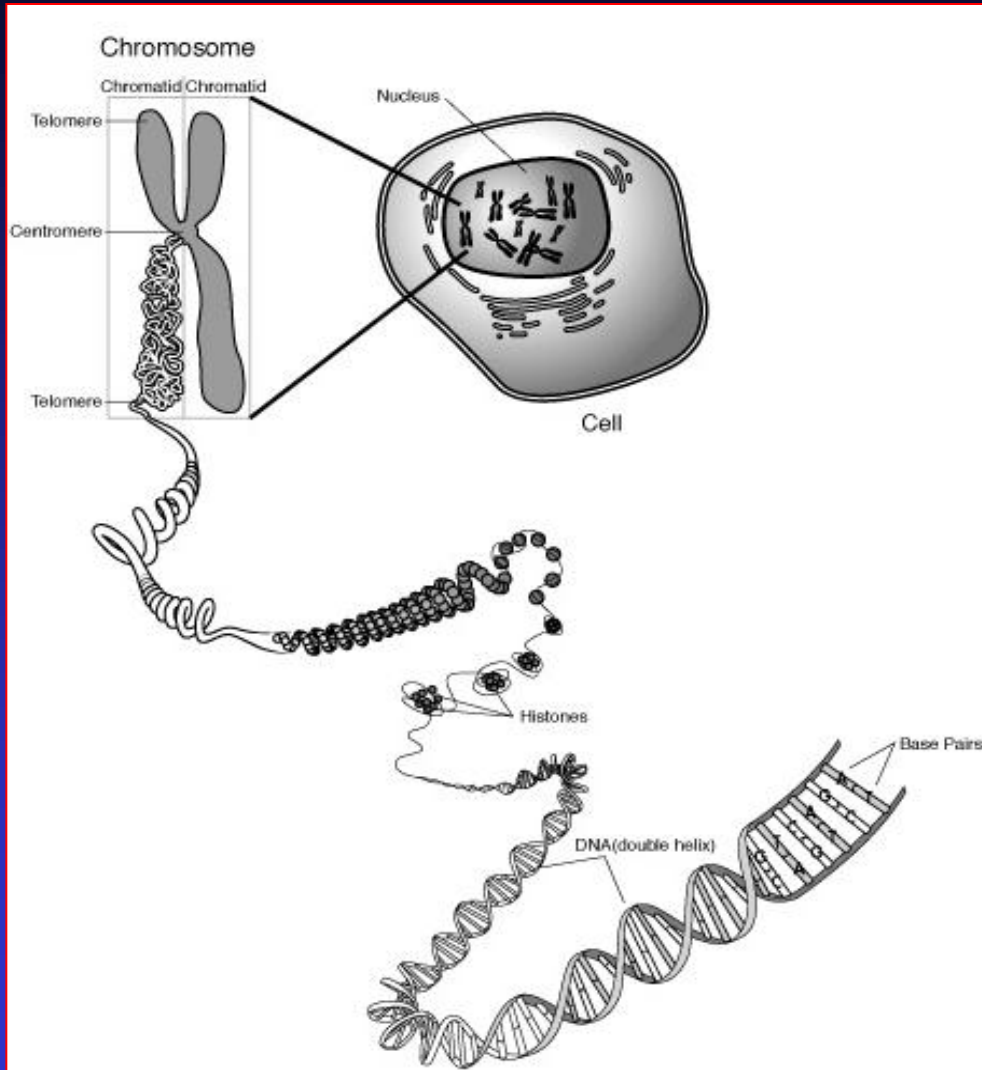
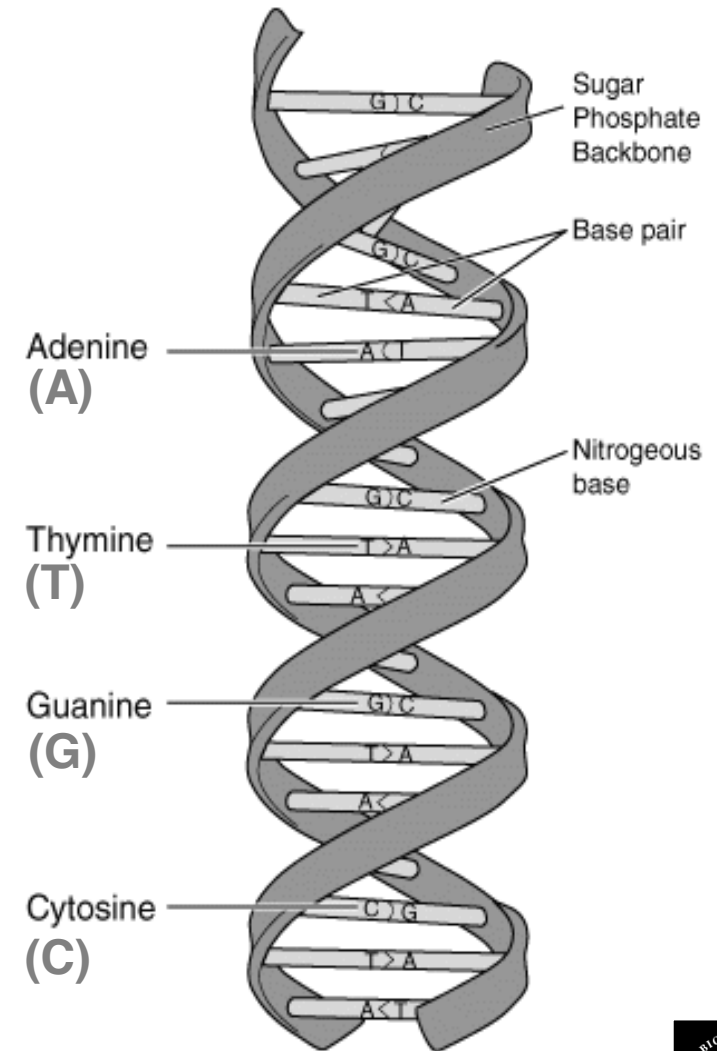
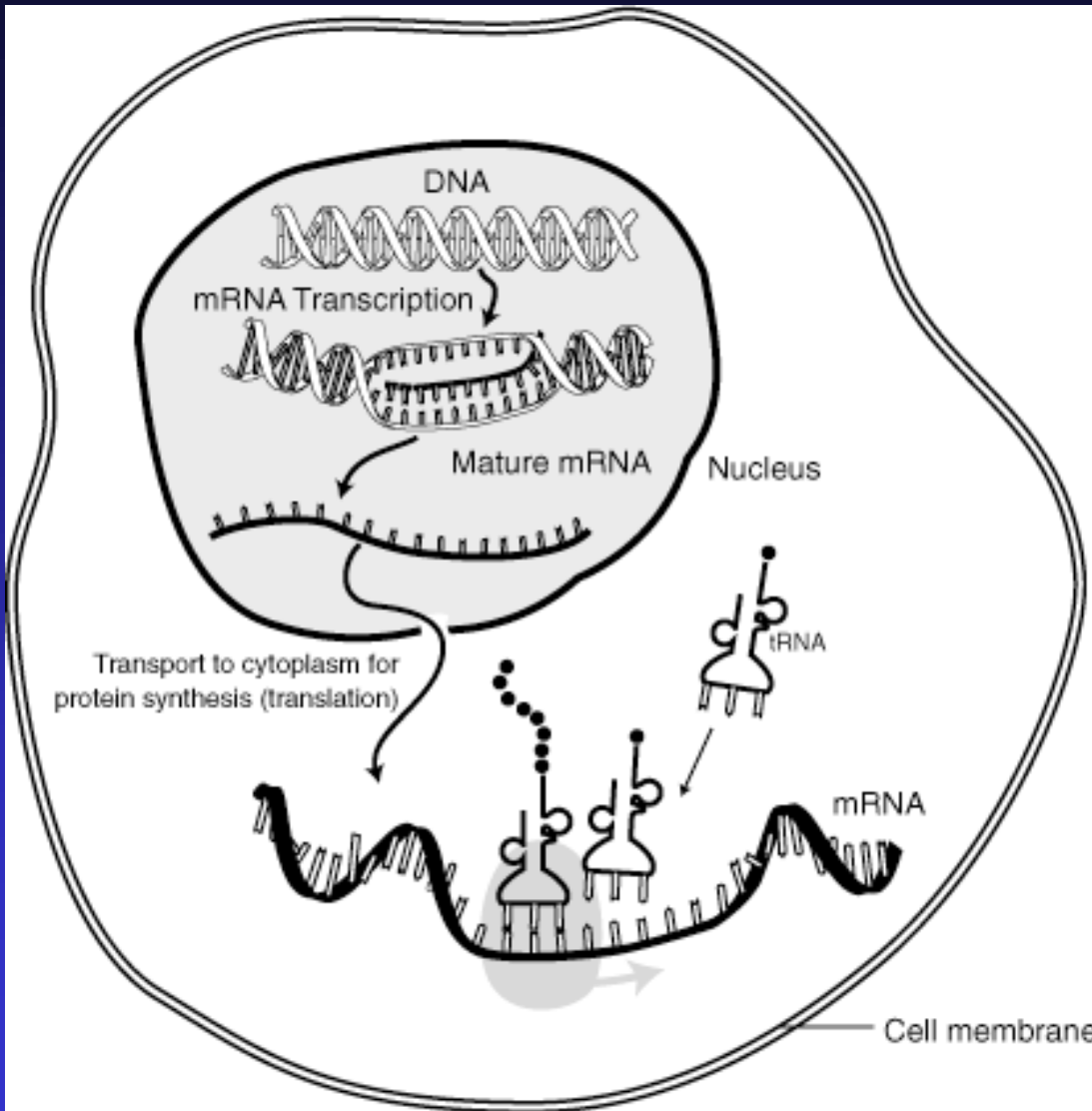


Image from National Human Genome Research Institute



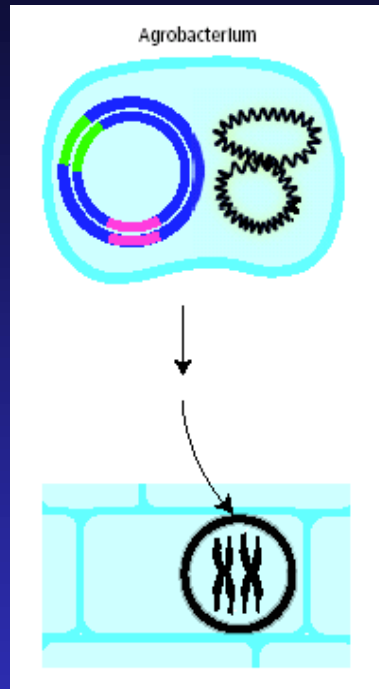
DNA ⇒ RNA ⇒ Protein



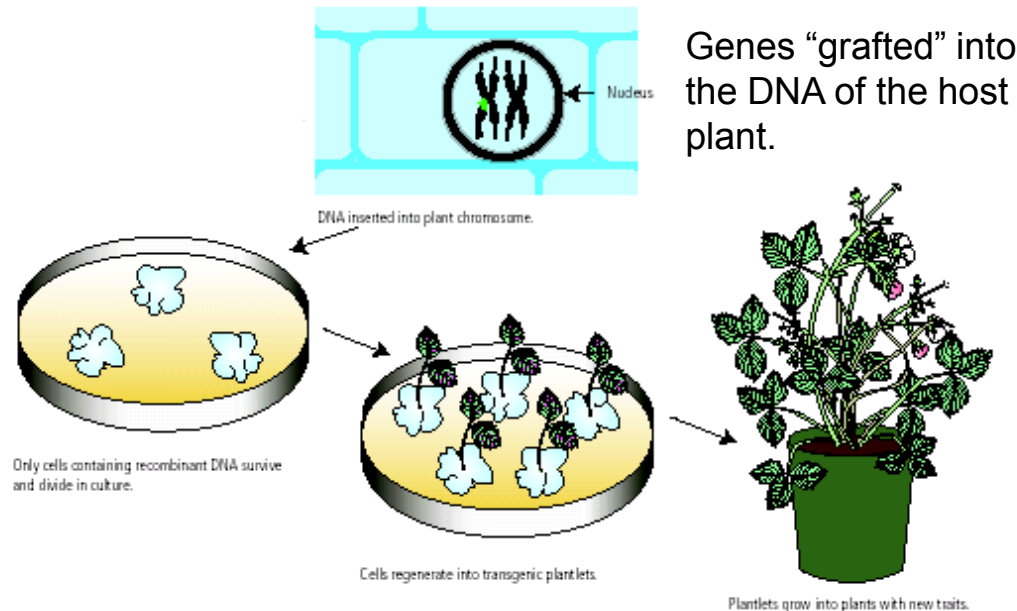
The “Central Dogma” of molecular biology is that the information in the DNA sequence is **transcribed** into mRNA, which is then **translated** into proteins.

Proteins are large molecules that are the enzymes and structural components of living cells.

Genes Can be Transferred by Recombinant DNA



Recombinant DNA techniques can now be used to transfer specific genes among organisms. Crop plants, for example, can be “transformed” by transferring a desired gene into the plant cells and then regenerating those cells into an entire plant. Essentially, individual genes can be “grafted” into the chromosomes of another plant.



Why Use Biotechnology in Crop Improvement?

- Traditional breeding is limited to the traits (genes) that occur within an interbreeding (sexually compatible) population. Specific desired traits may not exist within this population.
- Traits to enhance production, yield, or quality may exist in other species that could be transferred to crops.
- Novel characteristics can be introduced into crops to produce new or improved end products.
- Biotechnology can enable environmentally beneficial agricultural practices.



Herbicide-Tolerant Crops Improve Crop Establishment



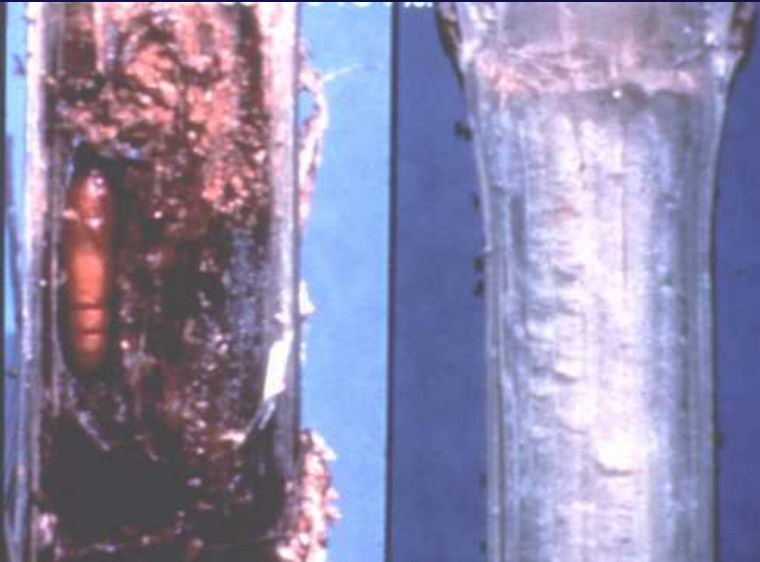
Herbicide-tolerant alfalfa allows the establishment of weed-free crops, which result in higher yield and better forage quality.



Van Deynze et al. 2004. ANR
Publication 8153
<http://anrcatalog.ucdavis.edu>



Insect-resistant Bt Corn and Cotton



Regular maize

Bt maize

Corn borer



Regular cotton

Bt cotton

Council for Biotechnology Information

Bollworm



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Virus-resistant Crops

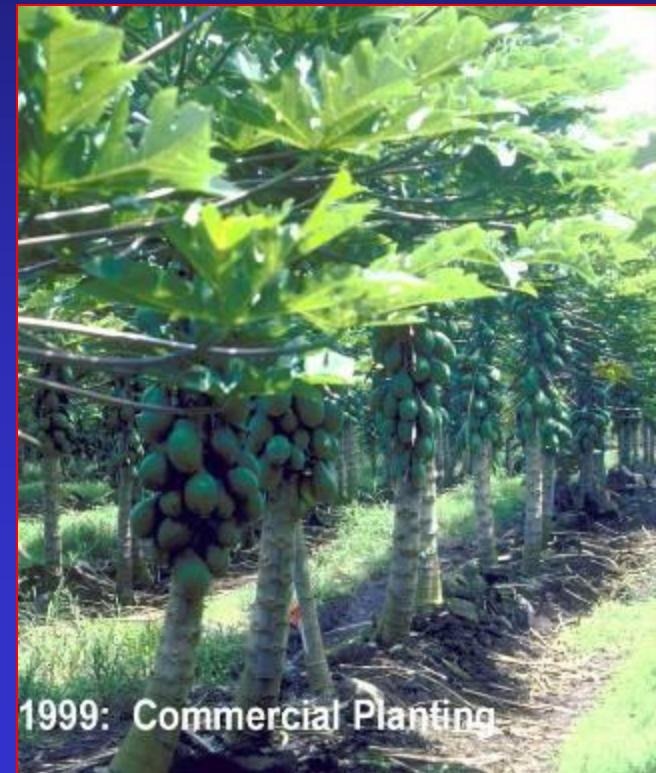


By 1995, Papaya ringspot virus had devastated the Hawaiian papaya industry.



Virus resistance introduced via rDNA techniques has re-established the industry in Hawaii.

Photos by D. Gonsalves



Impact of Biotech Crops

ANALYTICAL REPORT

GM Crops and Food: Biotechnology in Agriculture and the Food Chain 3:2, 129–137; April/May/June 2012; © 2012 Landes Bioscience

Global impact of biotech crops Environmental effects, 1996–2010

Graham Brookes* and Peter Barfoot

- 443 million kg less pesticide active ingredient used (9.1% reduction)
- 17.9% reduction in overall environmental impact
- 642 million liters less fuel used
- 17 billion kg reduction in greenhouse gas emissions, equivalent to taking 8.6 million cars off the road



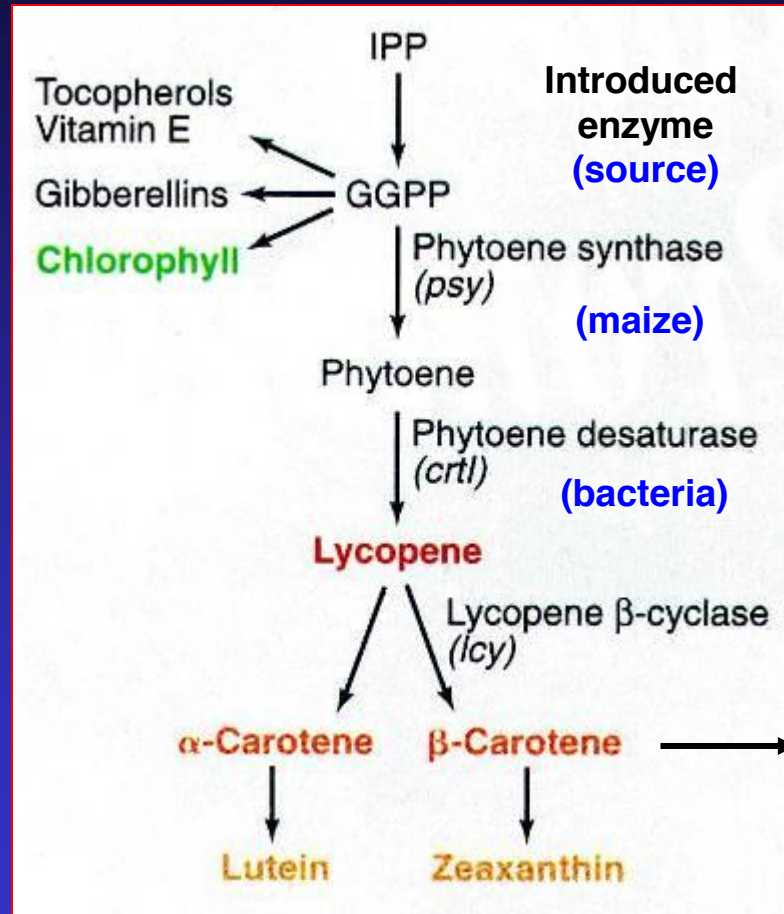
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Increased β -Carotene in Rice Grains

Over 120 million children worldwide are deficient in vitamin A. Rice has been engineered to accumulate β -carotene, which is converted to vitamin A in the body.

Widespread distribution of Golden Rice could prevent 1 to 2 million deaths each year (or ~3000 per day).

Its release is being delayed due to regulatory demands and anti-GM groups.



Normal rice



"GoldenRice 2™"

Ye et al. (2000) Science 287: 303-305.

Paine et al. (2005) Nature Biotech 23: 482-487.



Safety of rDNA Techniques

Numerous scientific reviews by organizations around the world have concluded that genetic modification by recombinant DNA techniques presents no greater dangers than genetic changes introduced by other methods.

It is the product that should be evaluated, not the method by which it is produced.



Three Agencies Regulate Biotech Crops



The US Dept. of Agriculture determines whether the crop is safe to grow. For example, is it a threat to become a weed; what are its growth and flowering characteristics?



The Food and Drug Administration determines whether the crop is safe to eat. Is it substantially equivalent to other crops with respect to composition, nutrition, allergenicity, digestibility, etc.?



The Environmental Protection Agency regulates crops that have pesticidal properties. Are they safe for humans, for non-target organisms, and for the environment?



Safety Data Requirements for Registration of Biotech Crops

Product description (7 items)
Molecular characterization (17 items)
Toxicity studies (as necessary) (5 items)
Antibiotic resistance marker genes (4 items)
Nutritional content (7+ items)
Substantial equivalence with parent variety
Literature review and background
Allergenicity potential
Similarity to natural toxicants
Anti-nutritional effects
Protein digestibility
Environmental aspects (5 items)
Germination, growth, flowering studies (8 items)
Ecological impact (5 items)



**None of this is required for traditionally bred crops.
No health issues have been confirmed for any biotech food.**



Why Agricultural Biotechnology?

Because agricultural biotechnology:

- extends a proven biological method (crop genetic improvement) that has been remarkably successful in increasing crop productivity and quality;
- can reduce pesticide use and help conserve soils;
- solves problems for which we have no other solutions (e.g., plant viruses);
- can improve nutritional content and improve health;
- can make food production more efficient so that land can be preserved for wildlife and biodiversity.



For More Information

<http://www.ucbiotech.org> -- University of California Biotechnology Education

<http://sbc.ucdavis.edu> -- Seed Biotechnology Center, UC Davis

<http://biofortified.org> -- Biology Fortified, Inc.

<http://gmoanswers.com> – Council for Biotechnology Information

