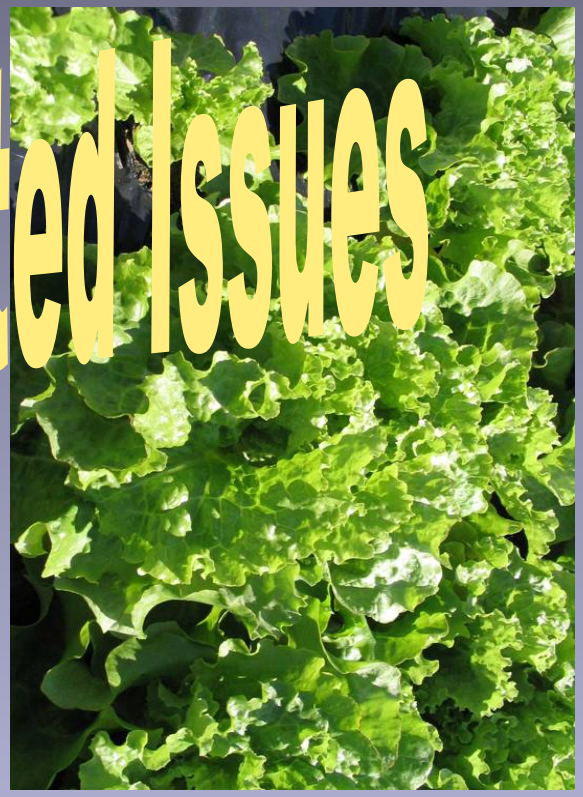


The Science of GMOs and Related Issues

Peggy G. Lemaux
University of California, Berkeley
http:/ucbiotech.org
http://pmb.berkeley.edu/!lemaux

Want to ask questions? Follow these easy steps in Biotech information section of ucbiotech.org

ucbiotech.org – Issues and Responses

ucbiotech.org – Issues and Res...

ucbiotech.org/search4.php

Google

Go to Issues and Responses section on drop-down menu from Biotechnology Information section. Chose a category to see what issues are there or type your question in "search by phrase". Hit search.

CES

ABOUT US | IN THE NEWS | BIOTECHNOLOGY INFORMATION | RESOURCES | LINKS | GLOSSARY | SEARCH

ISSUES & RESPONSES

Common issues and responses, related to topics like agriculture, foods, food safety, bioenergy, agricultural practices and biotechnology, are covered and include scientific references. Content and choice of literature is the sole responsibility of Dr. Peggy G. Lemaux. Some issues are updated from two Annual Review of Plant Biology articles Part I | Part II. Note our policy regarding outside links.

Search by Phrase

Enter a keyword such as "food".
You can also search by combination of words such as "water and food".

bt corn safe to eat?

SEARCH

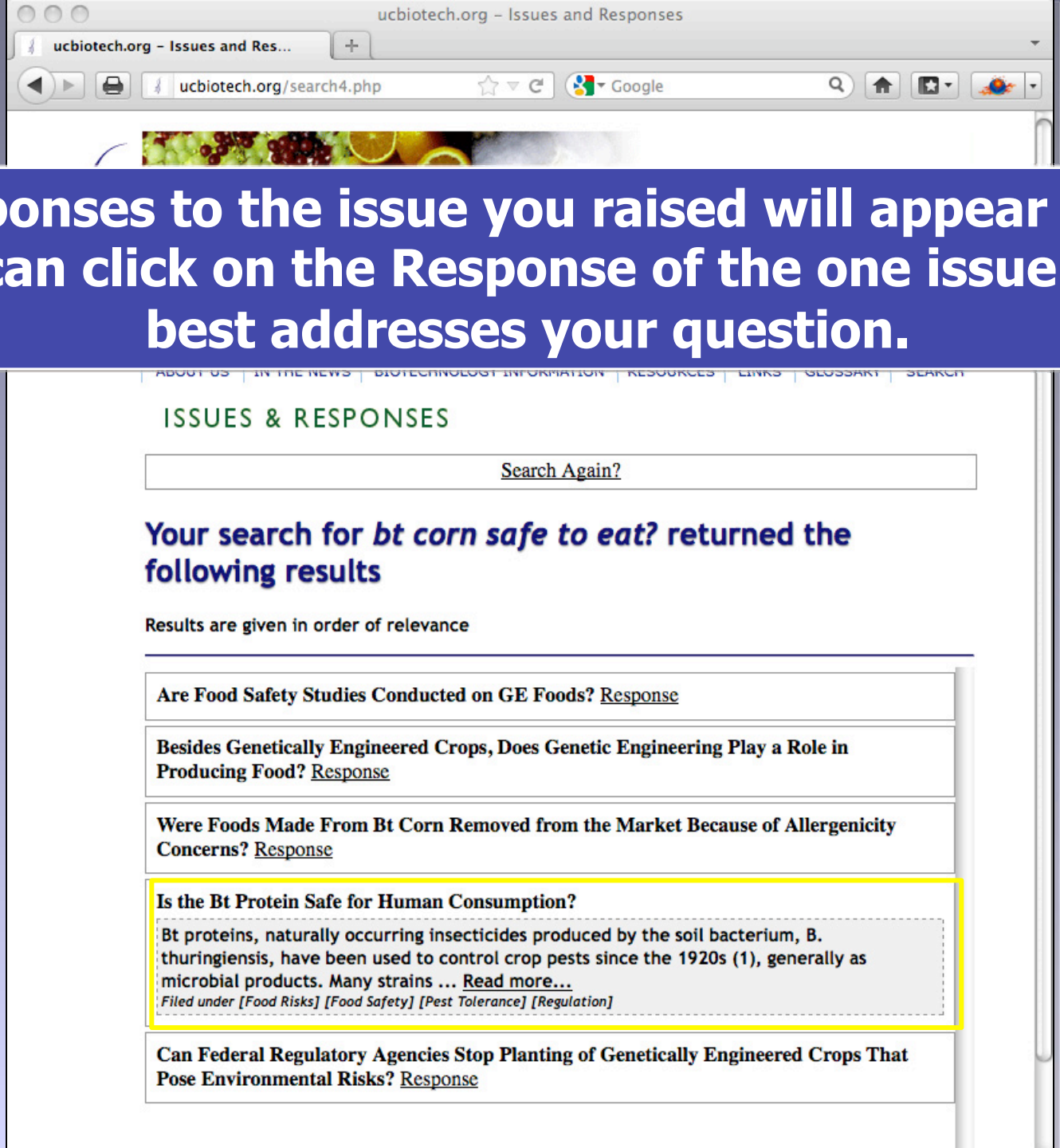
List all by Category

Alternatively, you may list all of the questions related to a category.
Select a category, and click "Display."

Agriculture

DISPLAY

Responses to the issue you raised will appear and you can click on the Response of the one issue that best addresses your question.



Is the Bt Protein Safe for Human Consumption?

Is the Bt Protein Safe for Human...

ucbiotech.org/answer.php?question=3

Google

Response to the issue you raised will appear with links to the scientific literature. If that doesn't answer your question, go back to the responses and choose another.

Is the Bt Protein Safe for Human Consumption?

Response:

Bt proteins, naturally occurring insecticides produced by the soil bacterium, *B. thuringiensis*, have been used to control crop pests since the 1920s (1), generally as microbial products. Many strains of *B. thuringiensis* exist that produce different Bt proteins varying in the insects they target, e.g., larvae of butterflies and moths, beetles, and mosquitoes. The insecticidal Bt proteins form crystalline protein bodies inside the bacterium, hence the name Cry proteins. Full-sized Cry proteins are inactive until eaten by target insect larva, and inside the midgut they are cleaved and become active. The smaller, active peptides bind to specialized receptors, creating holes in the gut membrane that cause contents to leak and kill the larvae. The precision of different Bt proteins for their targets resides in the specificity of their tight binding to companion receptors in the insect gut (2).

Bt microbial products have a long history of safe use (~40 years) with only two reports prior to 1995 of possible adverse human effects, neither of which was due to exposure to Cry proteins (3). In a 1991 study that focused on exposure via inhalation of Bt sprays, results showed immune responses and skin sensitization to Bt in 2 of 123 farm workers (4). In a 2006 article, the Organic Consumers Association linked this observation to possible impacts of Bt in GE foods, warning that "Bt crops threaten public health" (5). But the respiratory sensitization observed in the farm workers does not provide validation that oral exposure to Bt would result in allergic responses.

In recent years a variety of safety studies were conducted specifically on native Bt proteins to show that they do not have characteristics of food allergens or toxins (See 6, 2, and 7 for reviews). In its review of Bt proteins, the EPA stated that, "several types of data are required for Bt plant pesticides to provide a reasonable certainty that no harm will result from the aggregate exposure of these proteins." The data must show that Bt proteins "behave as would be expected of a dietary protein, are not structurally related to any known food allergen or protein toxin, and do not display any oral toxicity when administered at high doses" (6).

The EPA does not require long-term studies because the protein's instability in digestive fluids makes such studies meaningless in terms of consumer health (8). In vitro digestion assays were used to confirm degradation characteristics of Bt proteins, whereas murine feeding studies were used to assess acute oral

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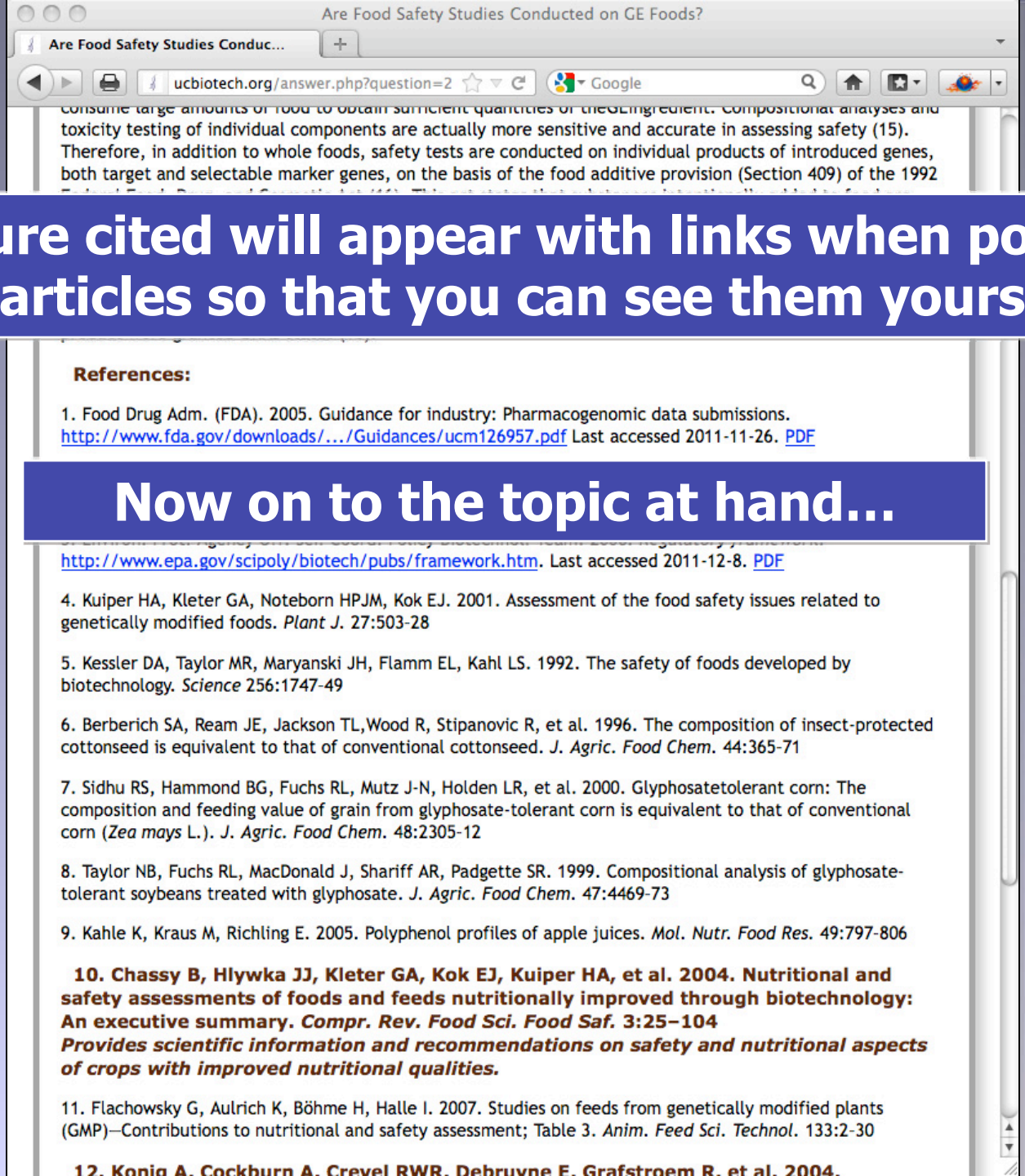

Literature cited will appear with links when possible to the articles so that you can see them yourselves.

Now on to the topic at hand…

What will be covered?

1. Background on genes, genetics, genetic engineering
2. What GE crops are commercialized? In the pipeline?
3. What is the regulatory structure for GE crops?
4. What are food safety issues with GE foods?
5. What are environmental issues with GE crops?

Tour d'Onion

Or what makes an onion, an onion?

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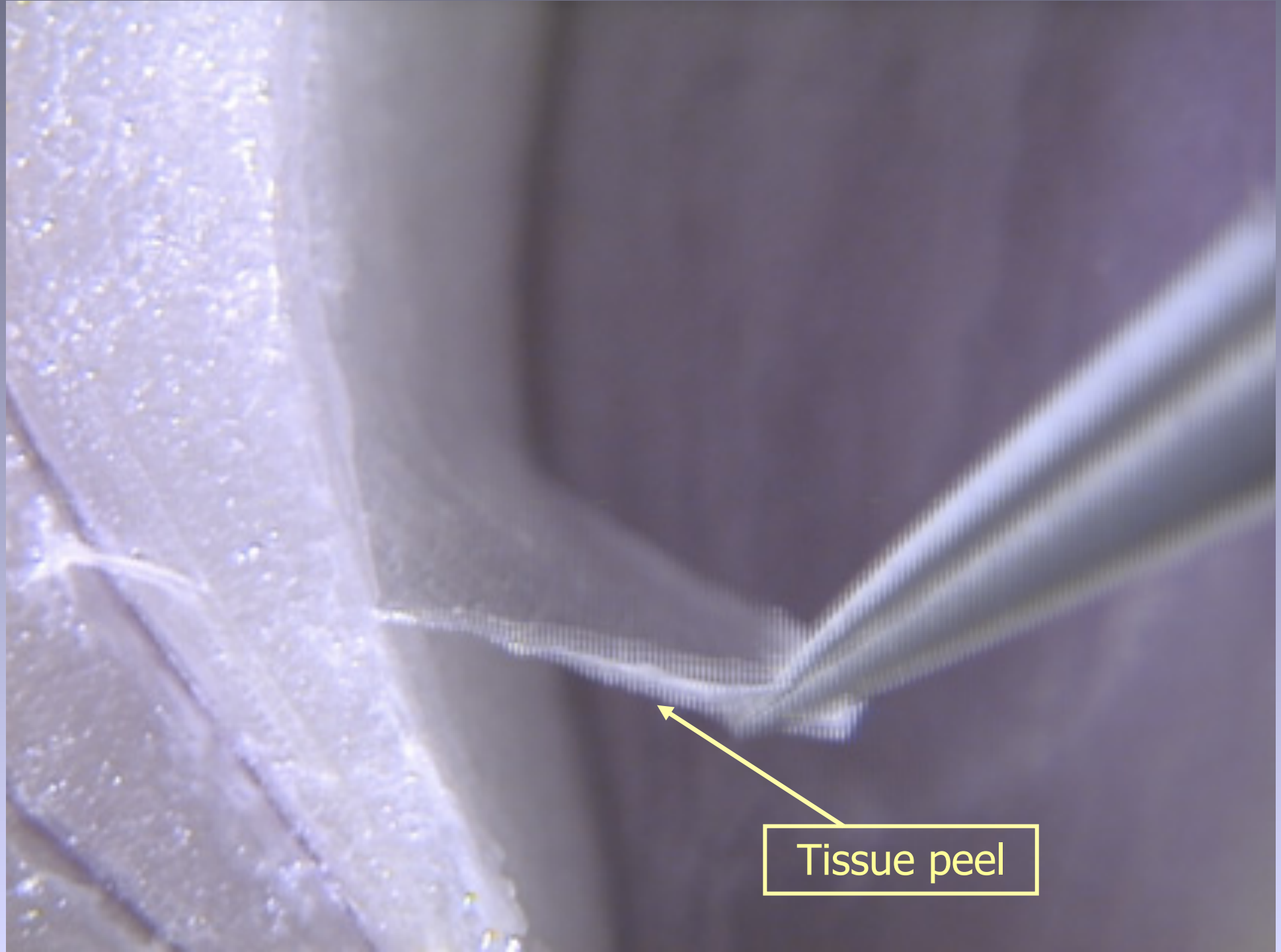
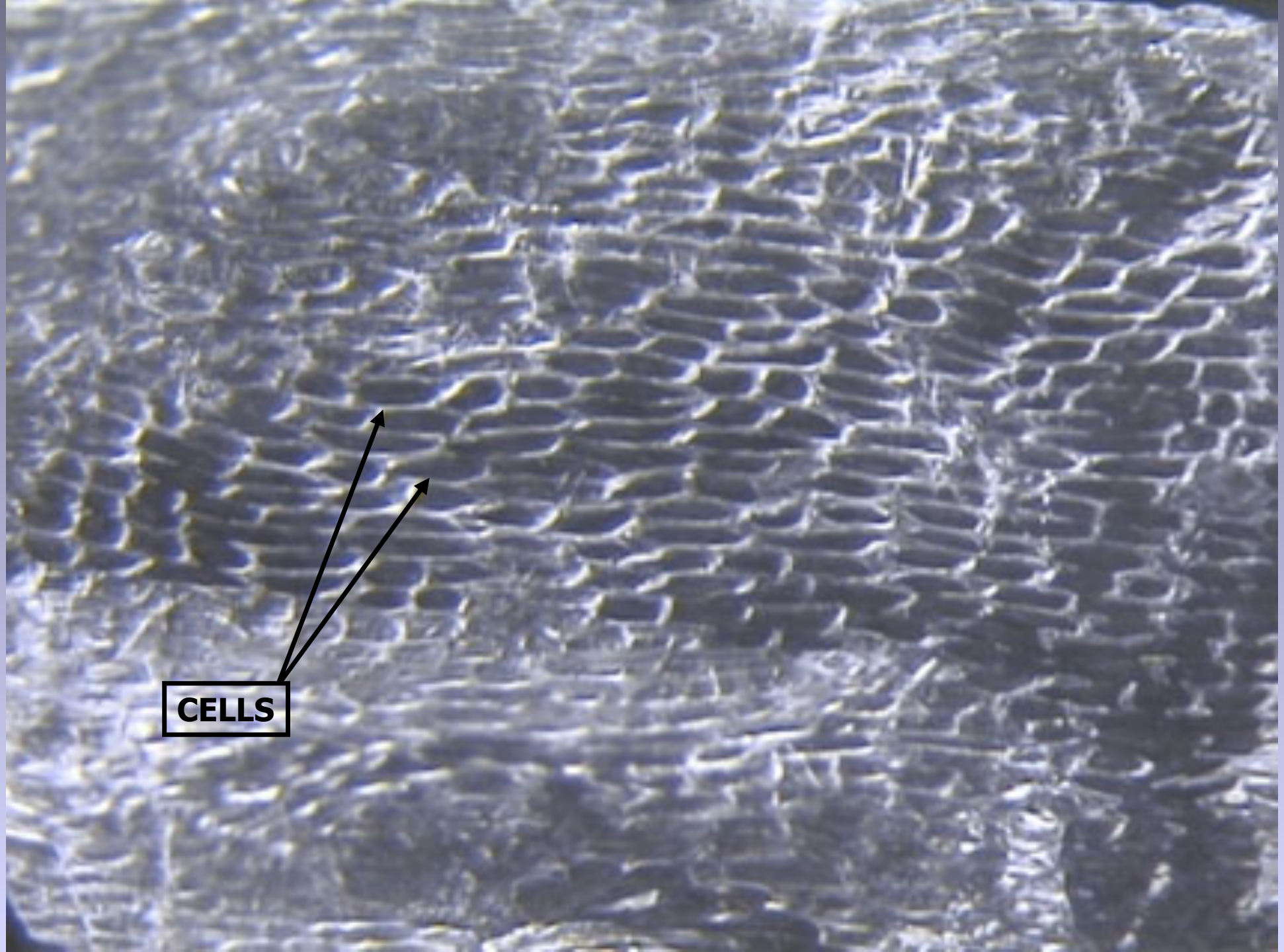
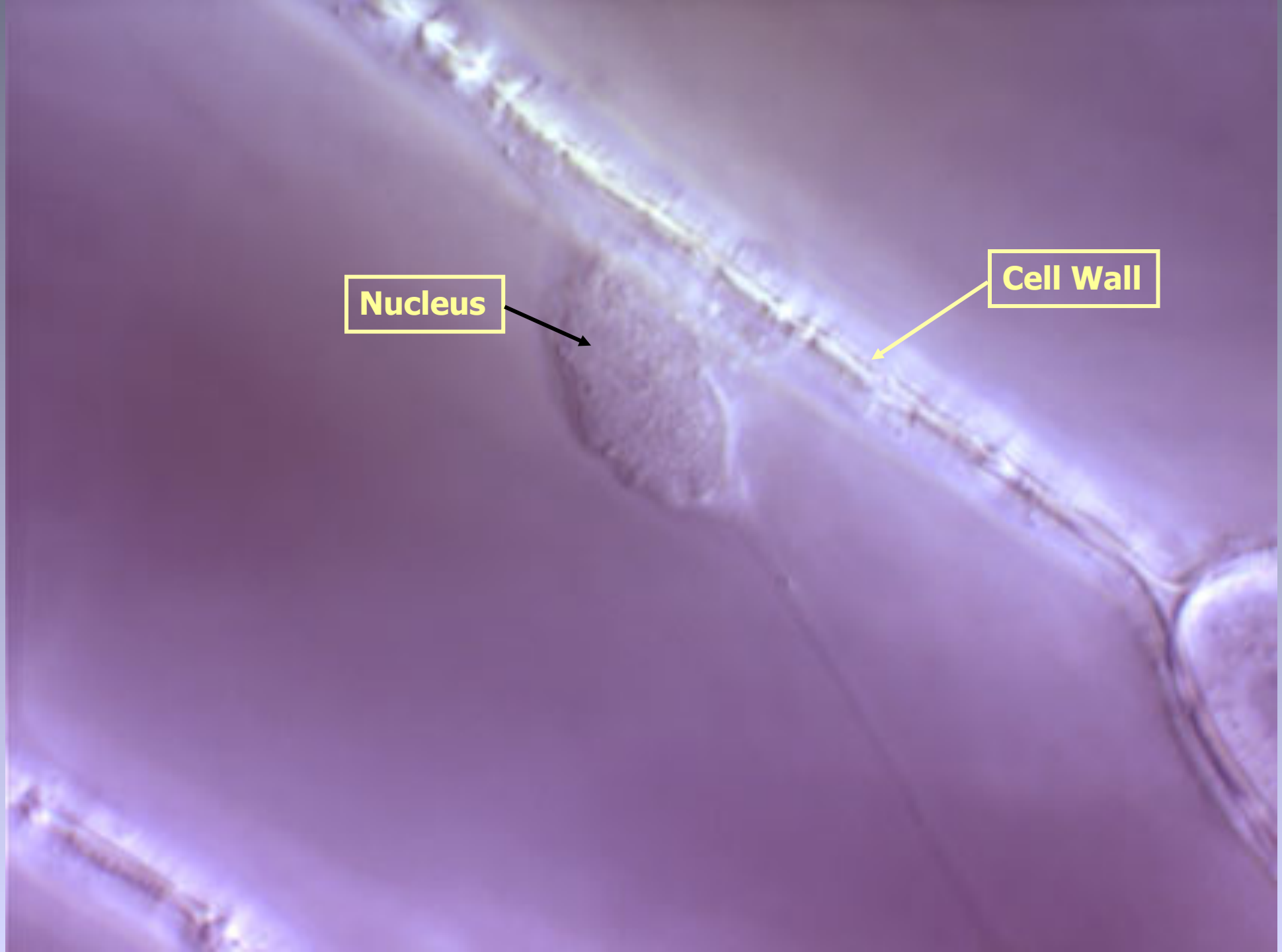
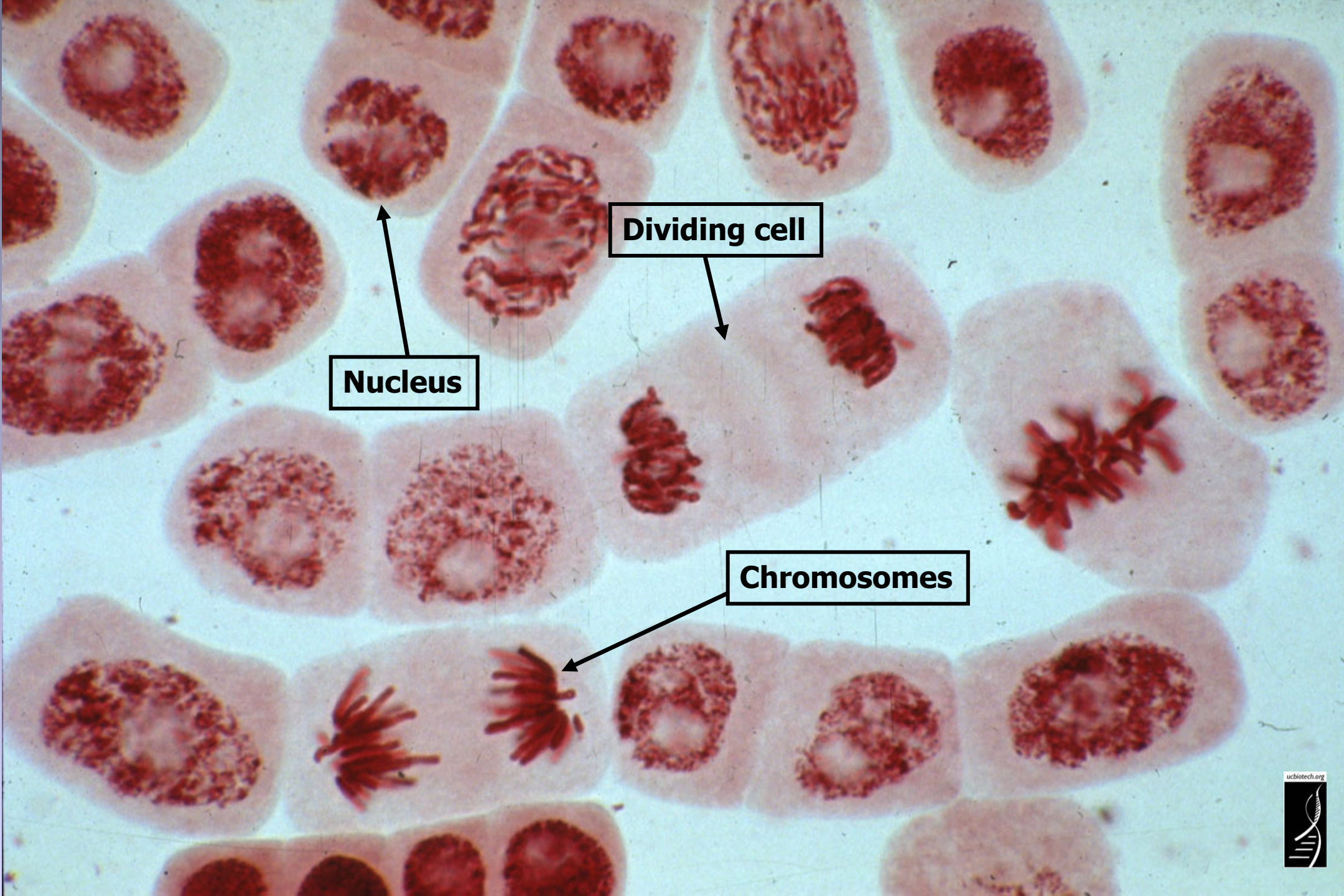
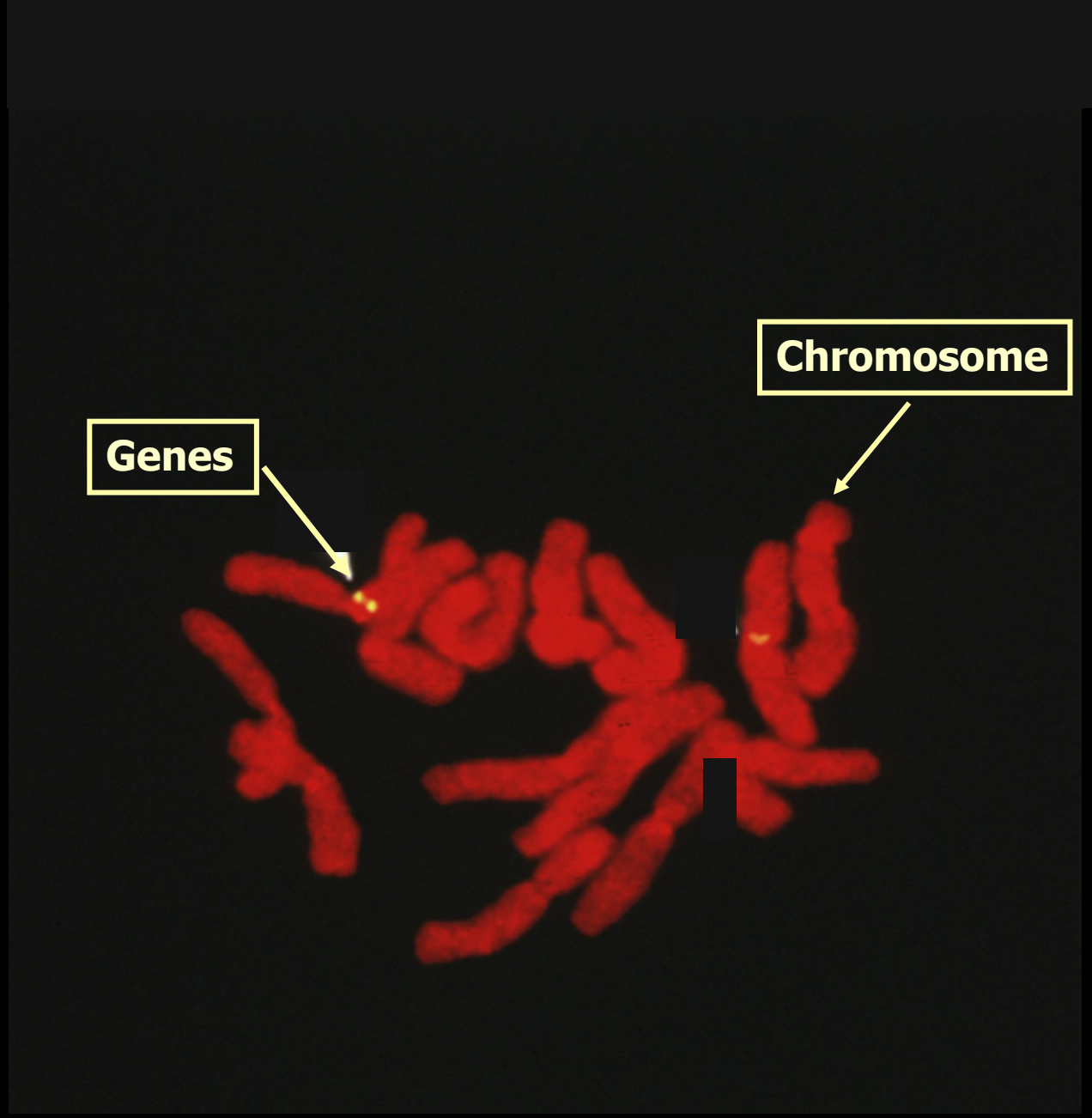

Tissue peel


CELLS


Nucleus
Cell Wall


Dividing cell
Nucleus
Chromosomes


Chromosome
Genes

How are the genes and chromosomes manipulated to create a new plant variety by classical breeding?

Triticum monococcum

Ancient variety

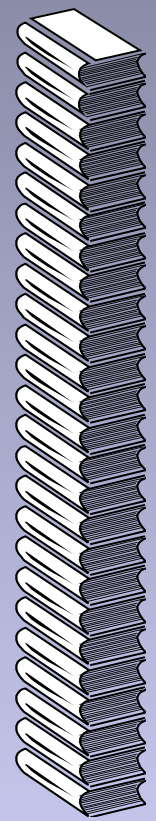
Triticum aestivum

Modern bread variety

Information in the wheat genome

Chemical units represented by alphabetic letters

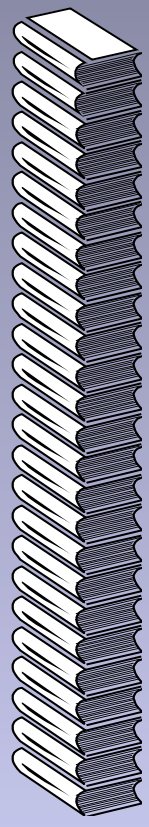
...CTGACCTAATGCCGTA...



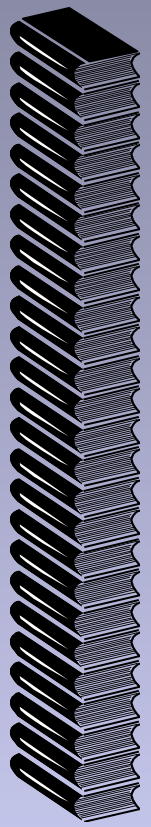
1700 books
1000 pages each

1700 books
(or 1.7 million pages)

Hybridization or cross breeding of wheat



X

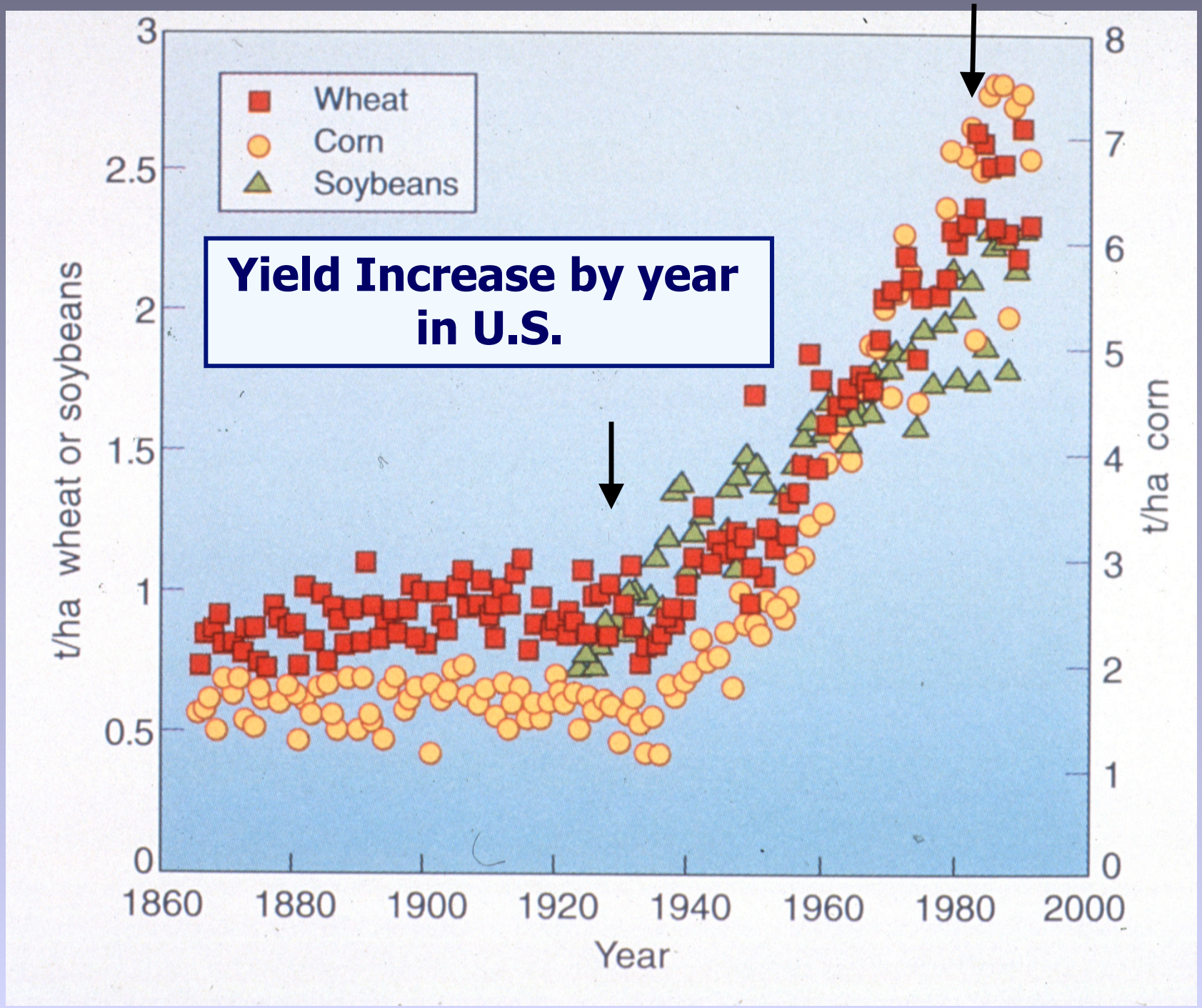


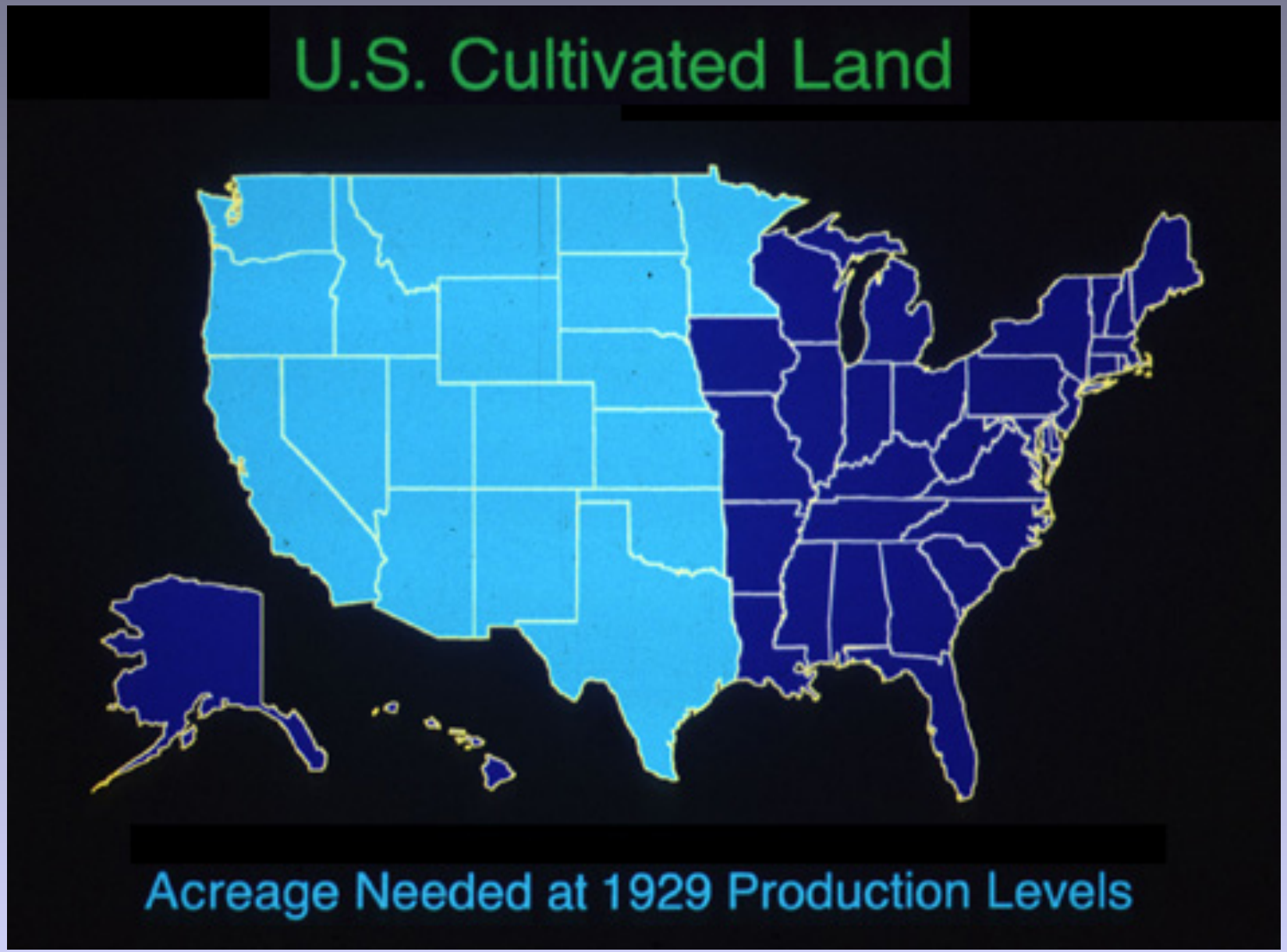
Random retention of information from each parent

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)


Wheat
Corn
Soybeans
Yield Increase by year in U.S.
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000



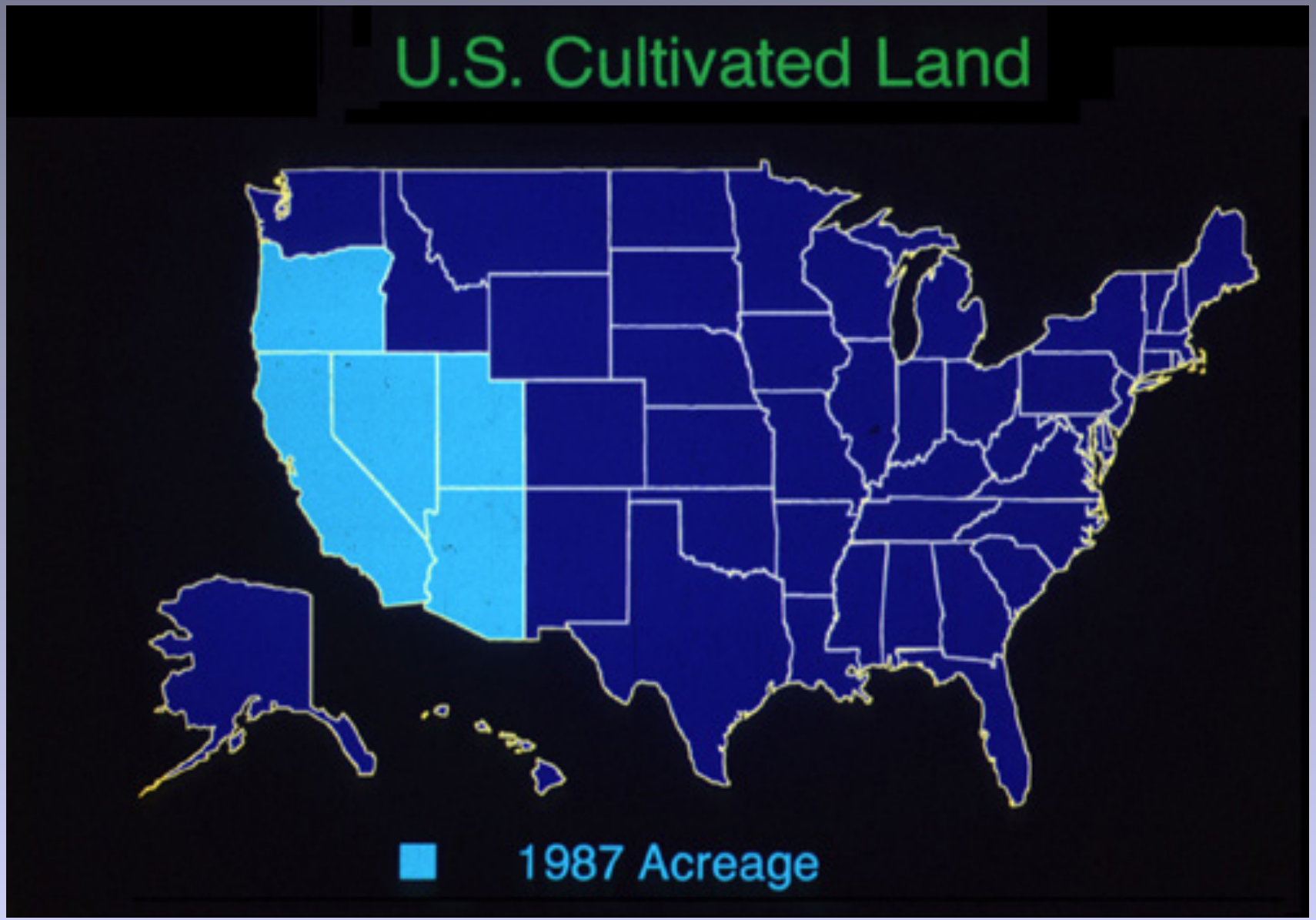
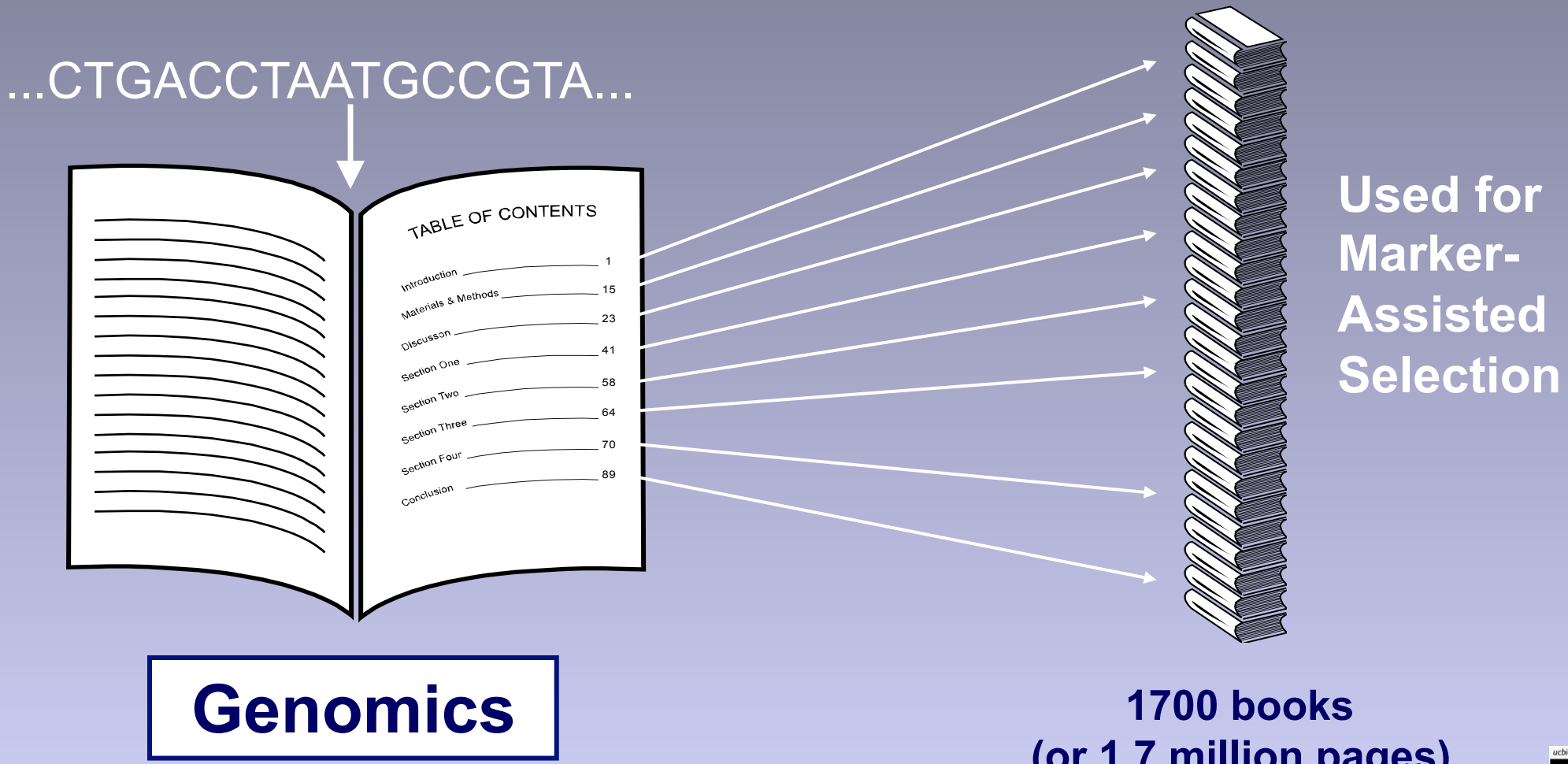


Table of contents for genes in wheat



Marker-assisted selection used to protect rice against bacterial blight and blast disease

Marker-assisted selection used to protect potatoes against wireworms, but…

Protection limited to diversity in crop and compatible relatives

SOURCE: "New Potatoes Withstand Destructive Wireworms", Agricultural Research Service, 9/20/11. http://www.ars.usda.gov/is/AR/archive/sep11/wireworms0911.htm


But there are other ways to create new varieties using the modern tools of genetics
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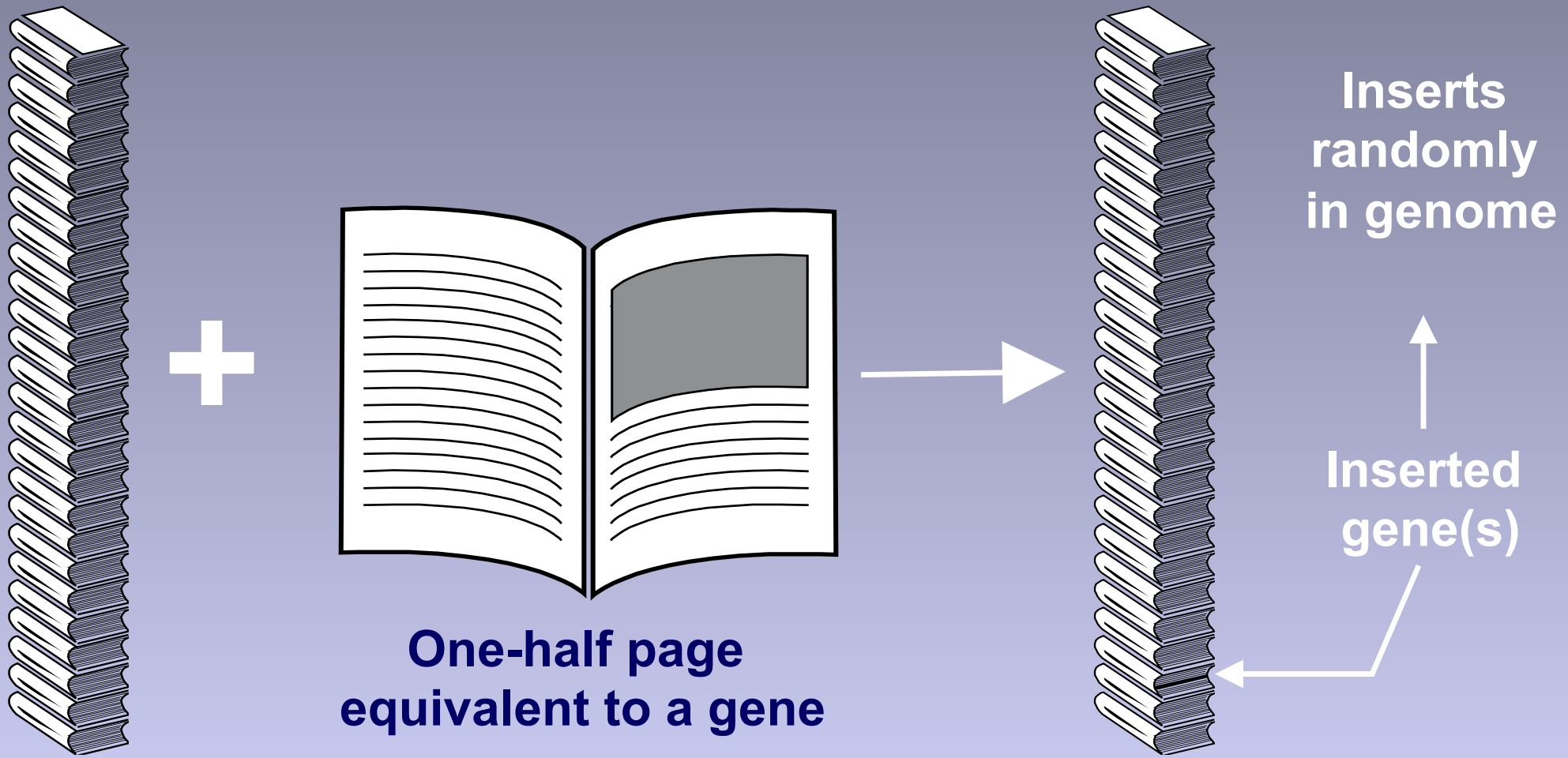
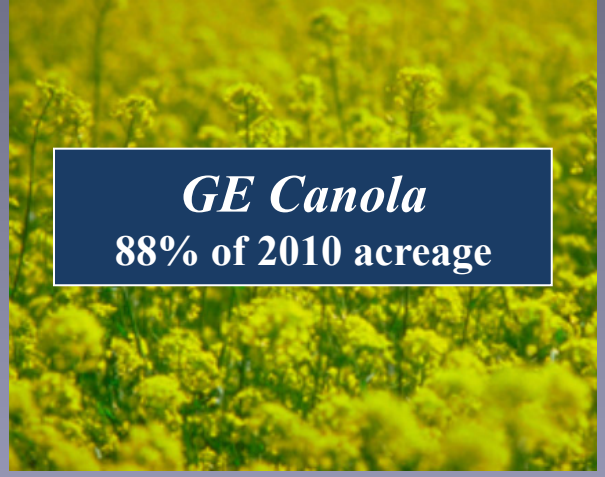
Genetic Engineering Methods

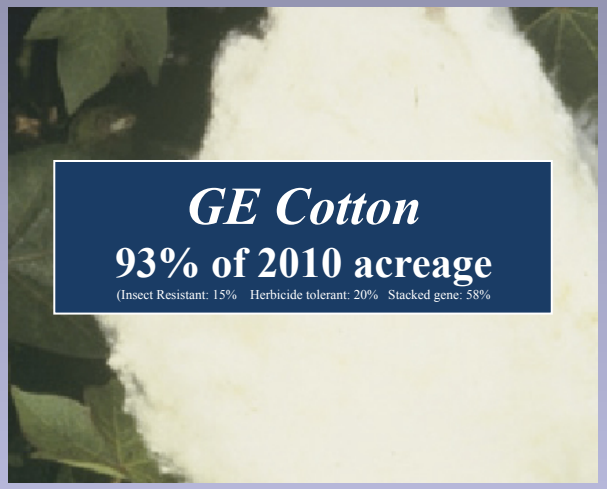


Classical Breeding	**compared to**	***Genetic Engineering***
Uses plant machinery in plant		Uses plant machinery in laboratory
Gene exchange is random involving whole genome		Gene exchange is specific involving single or few genes
When/where gene expressed not controlled by breeder		When/where gene expressed controlled precisely
Source of gene primarily within genera – not between kingdoms like plants & bacteria		Source of gene from any organism

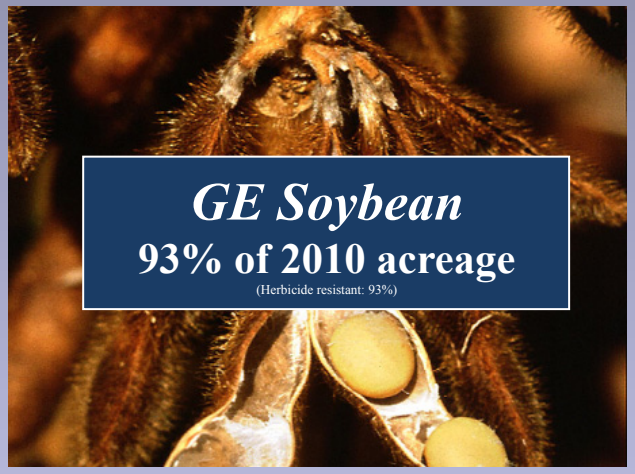
Number of different commercially available GE crops is limited



GE Canola
88% of 2010 acreage



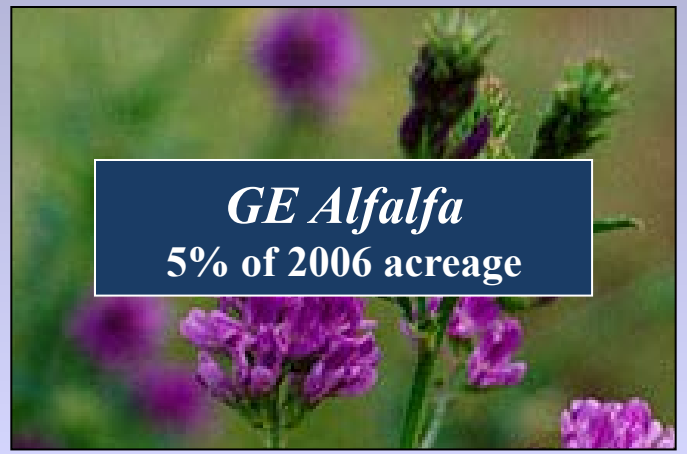
GE Cotton
93% of 2010 acreage
(Insect Resistant: 15% Herbicide tolerant: 20% Stacked gene: 58%



GE Soybean
93% of 2010 acreage
(Herbicide resistant: 93%)

GE Corn
86% of 2010 acreage
(Insect Resistant: 16% Herbicide resistant: 23% Stacked gene: 47%)
1% of corn with Bt (ECB) + Bt (rootworm) + herbicide

GE Sugarbeet
96% of 2010 acreage



GE Alfalfa
5% of 2006 acreage

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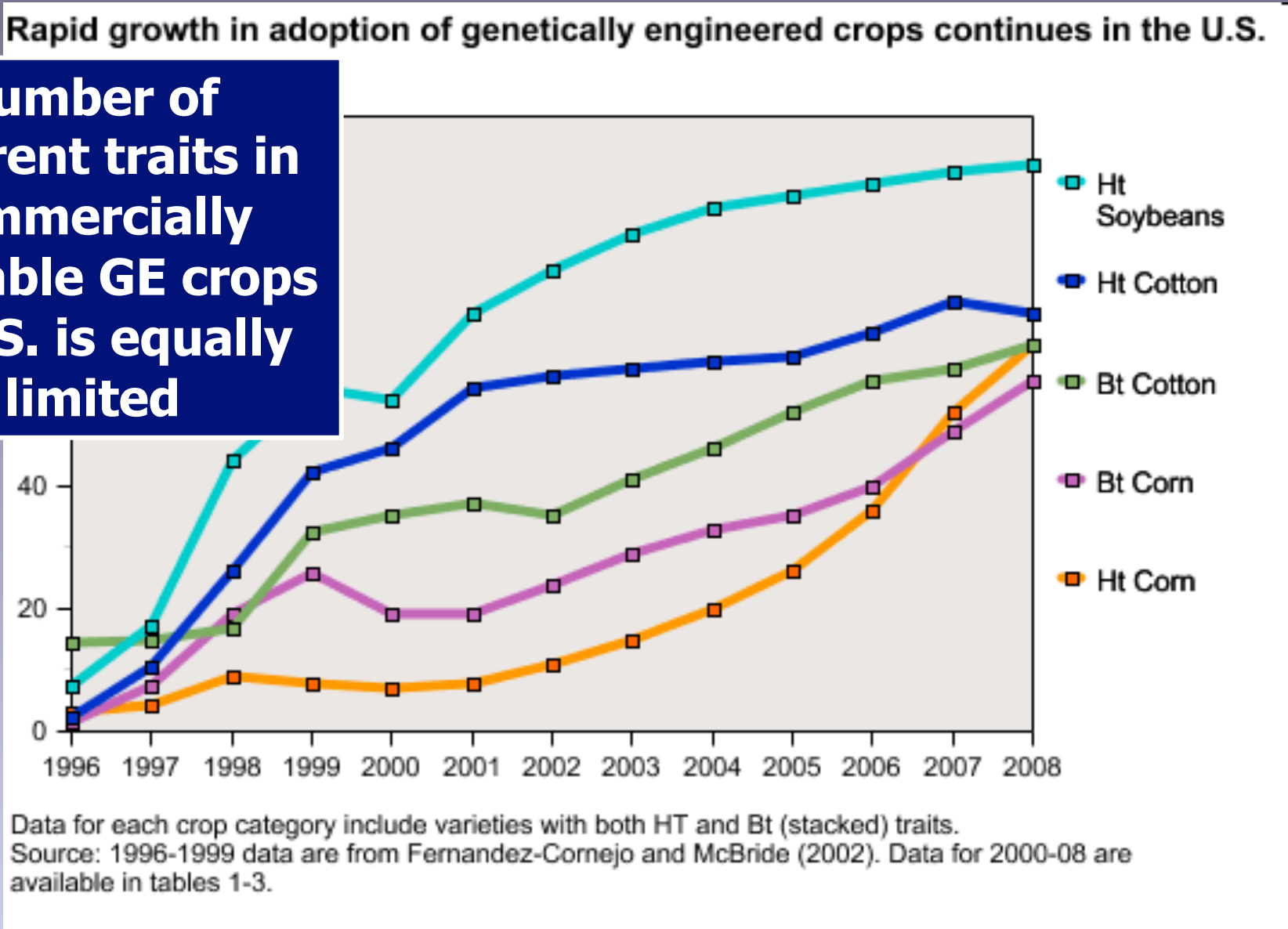
SOURCE: NCFAP; USDA ERS

These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients

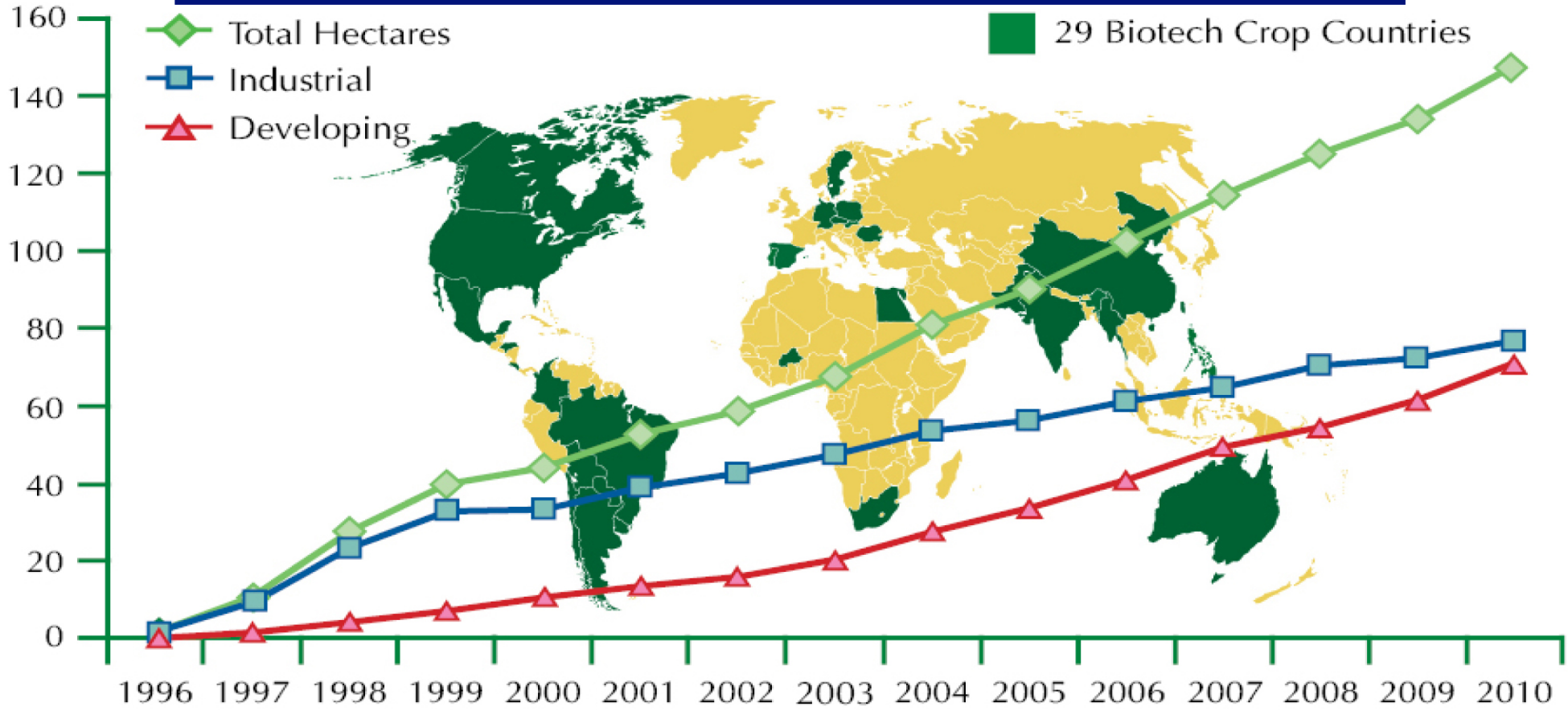
SOURCE: https://factsaboutgmos.org/disclosure-statement

Number of different traits in commercially available GE crops in U.S. is equally limited



SOURCE: http://www.ers.usda.gov/Data/BiotechCrops/

Despite limited crop and trait types, worldwide acreage is increasing



Total worldwide area cultivated = Areas of Texas + California + Colorado + South Carolina

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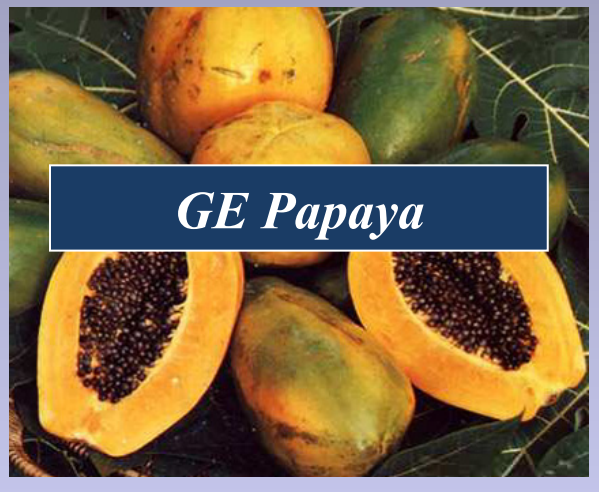
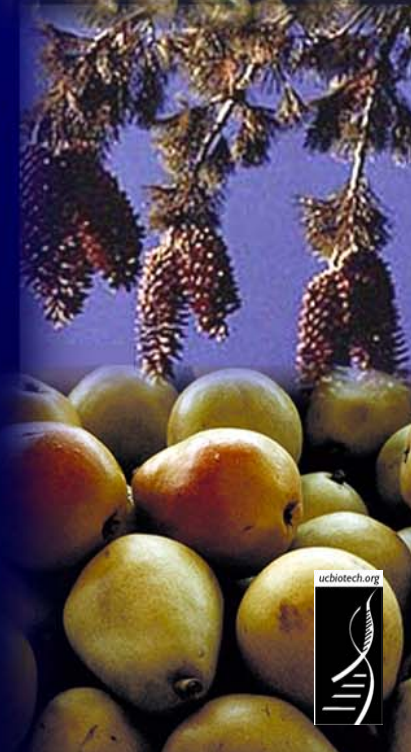
There are a few whole, genetically engineered foods in the U.S market



WHAT'S IN THE PIPELINE?



Field Trials Conducted in California with Grape Root Stocks Engineered for Resistance to Fanleaf Virus

SOURCE: http://www.democratandchronicle.com/apps/pbcs.dll/article?AID=/20080806/BUSINESS/808060336/1001

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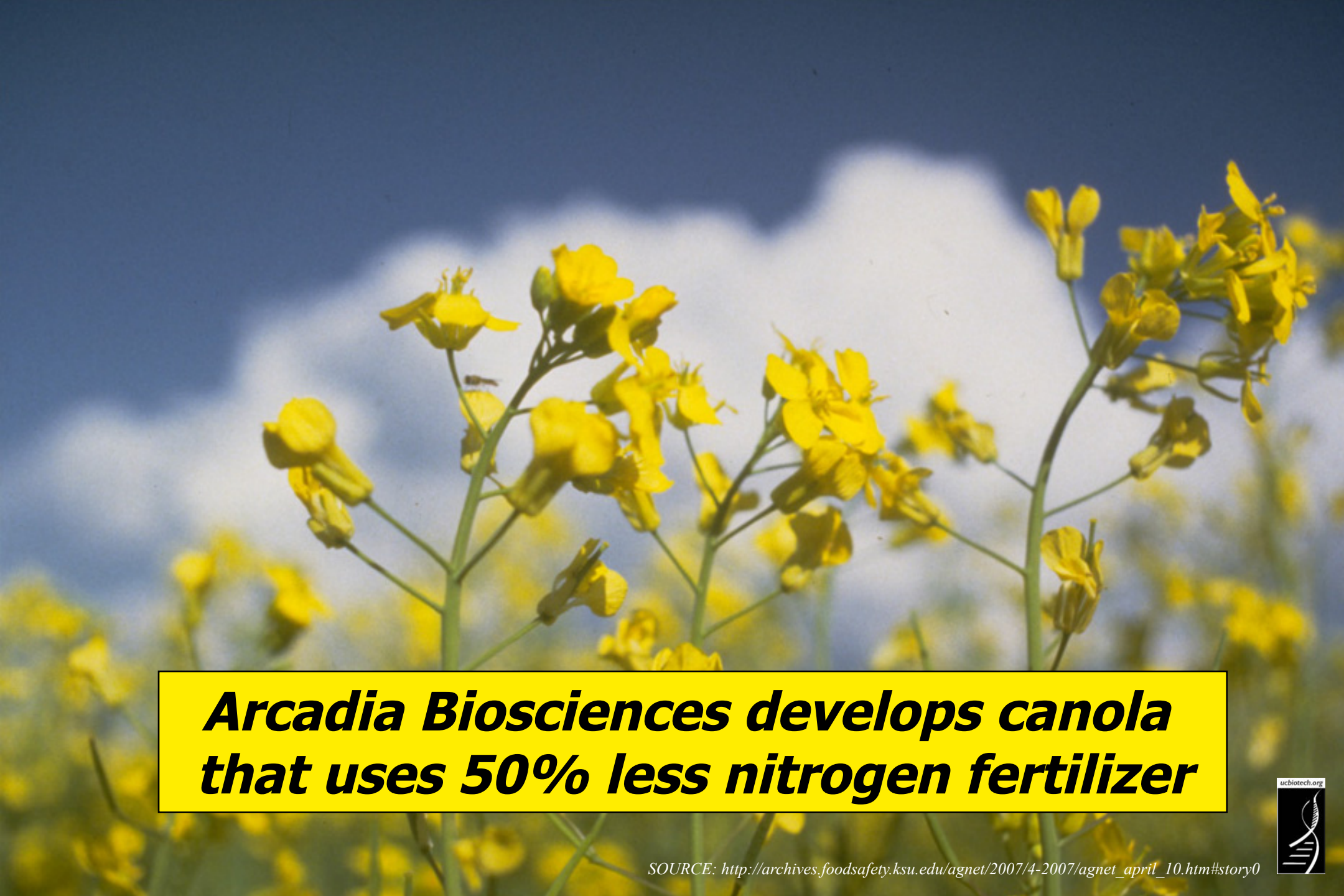
Australian researchers identify grape genes that provide resistance to powdery mildew

SOURCE: Western Farm Press, volume 26, number 16



SOURCE: http://archives.foodsafety.ksu.edu/agnet/2007/4-2007/agnet_april_10.htm#story0

Yields in rice and maize increase under water-limiting conditions

SOURCE: Castiglioni, P. et al. 2008. Bacterial RNA Chaperones Confer Abiotic Stress Tolerance in Plants and Improved Grain Yield in Maize under Water-Limited Conditions. Plant Physiology 147: 446-455.

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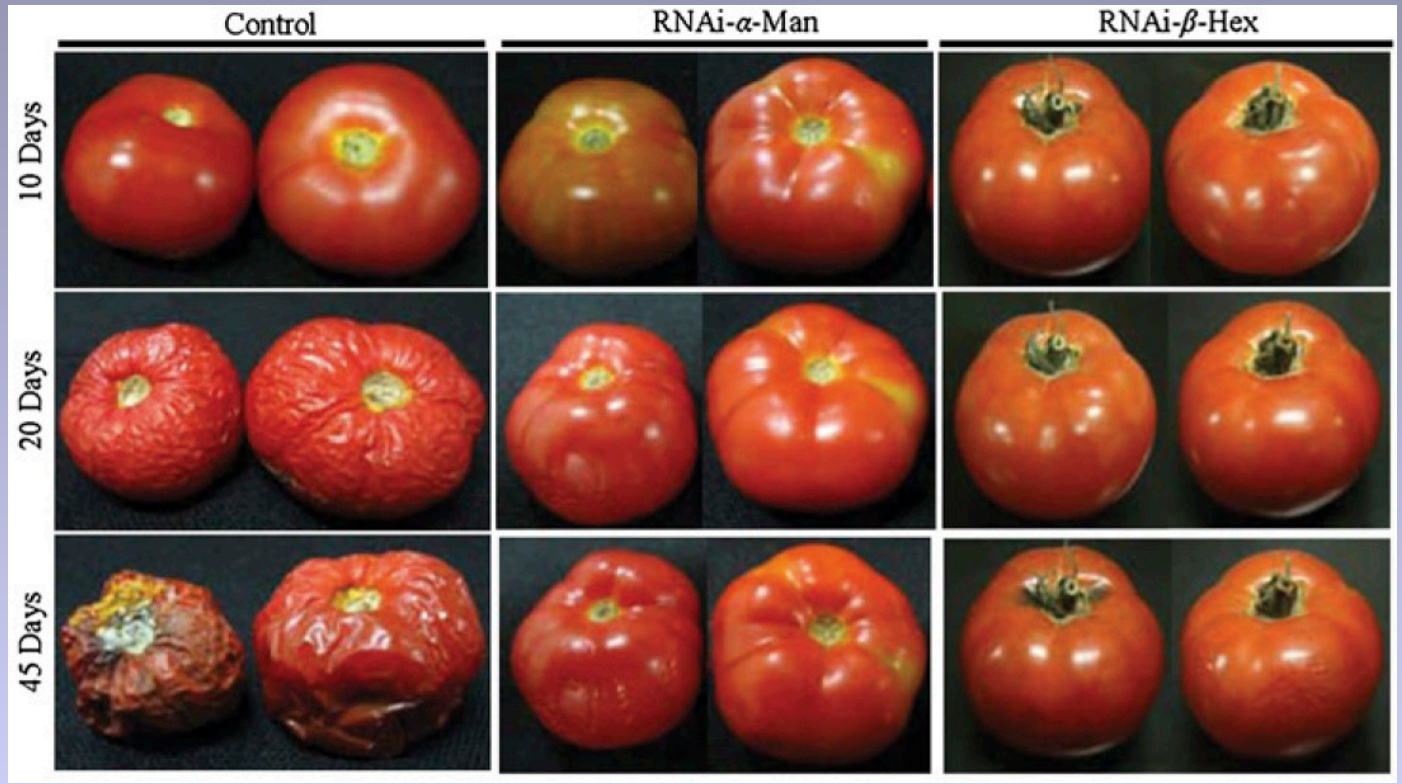
Salt-tolerant Tomatoes

Engineered ***Control***

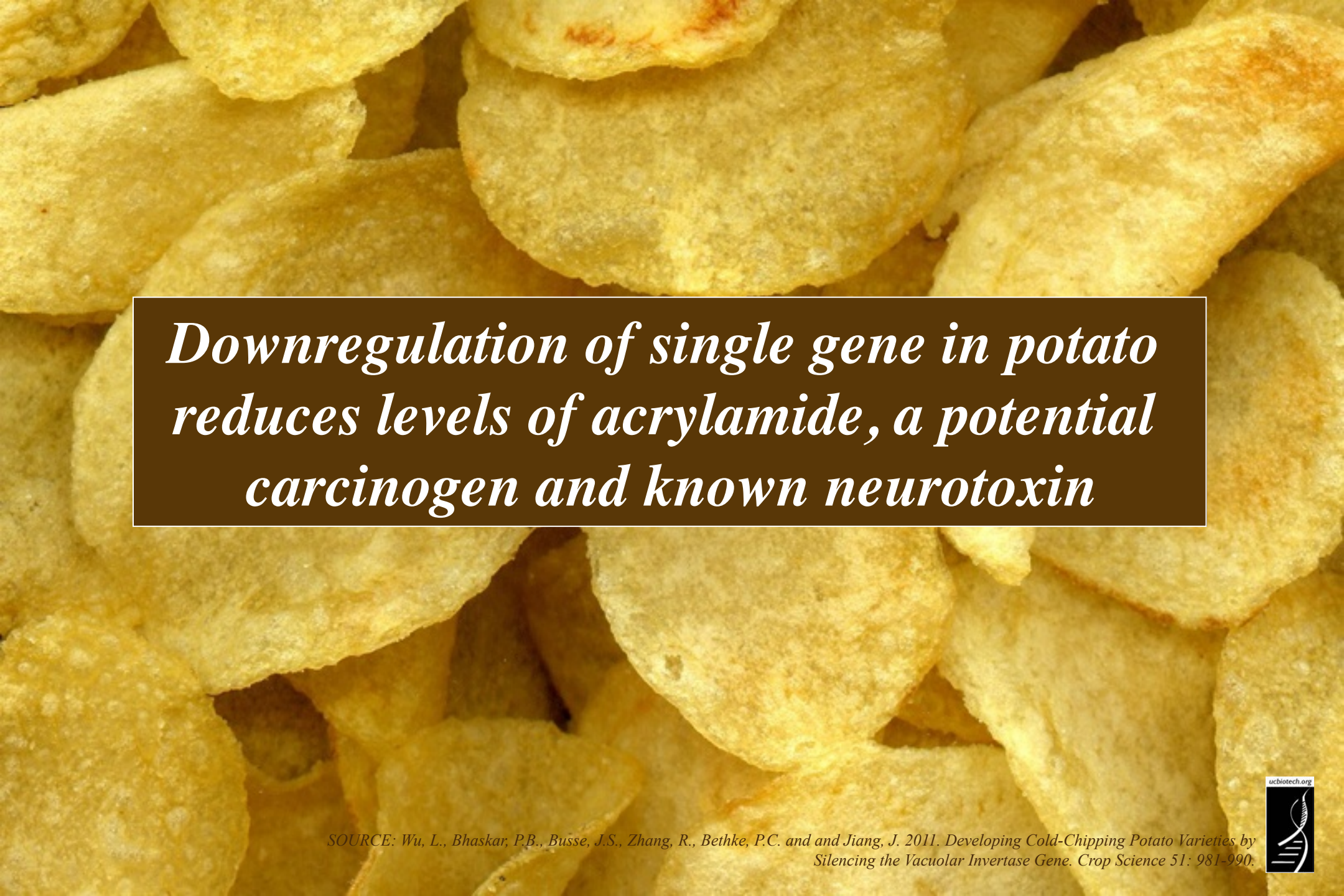
SOURCE: Zeraim Gedera L.T.D., Israel

"In a globalized economy, the control of fruit ripening is of strategic importance because excessive softening limits shelf life."

Engineered tomatoes have ~30 day extension of shelf life



SOURCE: Meli, V.S., Ghosh, S., Prabha, T.N., Chakraborty, N., Chakraborty, S., and Datta, A. 2010. Enhancement of fruit shelf life by suppressing N-glycan processing enzymes. Proceedings of the National Academy of Sciences USA, doi/10.1073/pnas.0909329107.



SOURCE: Wu, L., Bhaskar, P.B., Busse, J.S., Zhang, R., Bethke, P.C. and and Jiang, J. 2011. Developing Cold-Chipping Potato Varieties by Silencing the Vacuolar Invertase Gene. Crop Science 51: 981-990.

Non-browning GE apple may not get to market; it is opposed by U.S. Apple Association due to possible negative impacts on export market

SOURCE:" Stop Genetically Engineered Apples!", Organic Consumers Association, 3/24/11. http://www.organicconsumers.org/bytes/ob269.htm#SEC3

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Tear-free onion developed by turning off tear-inducing enzyme

SOURCE: "Scientists create 'no tears' onions", Herald and Weekly Times, 2/1/08
http://www.checkbiotech.org/green_News_Genetics.aspx?Name=genetics&infoId=16834

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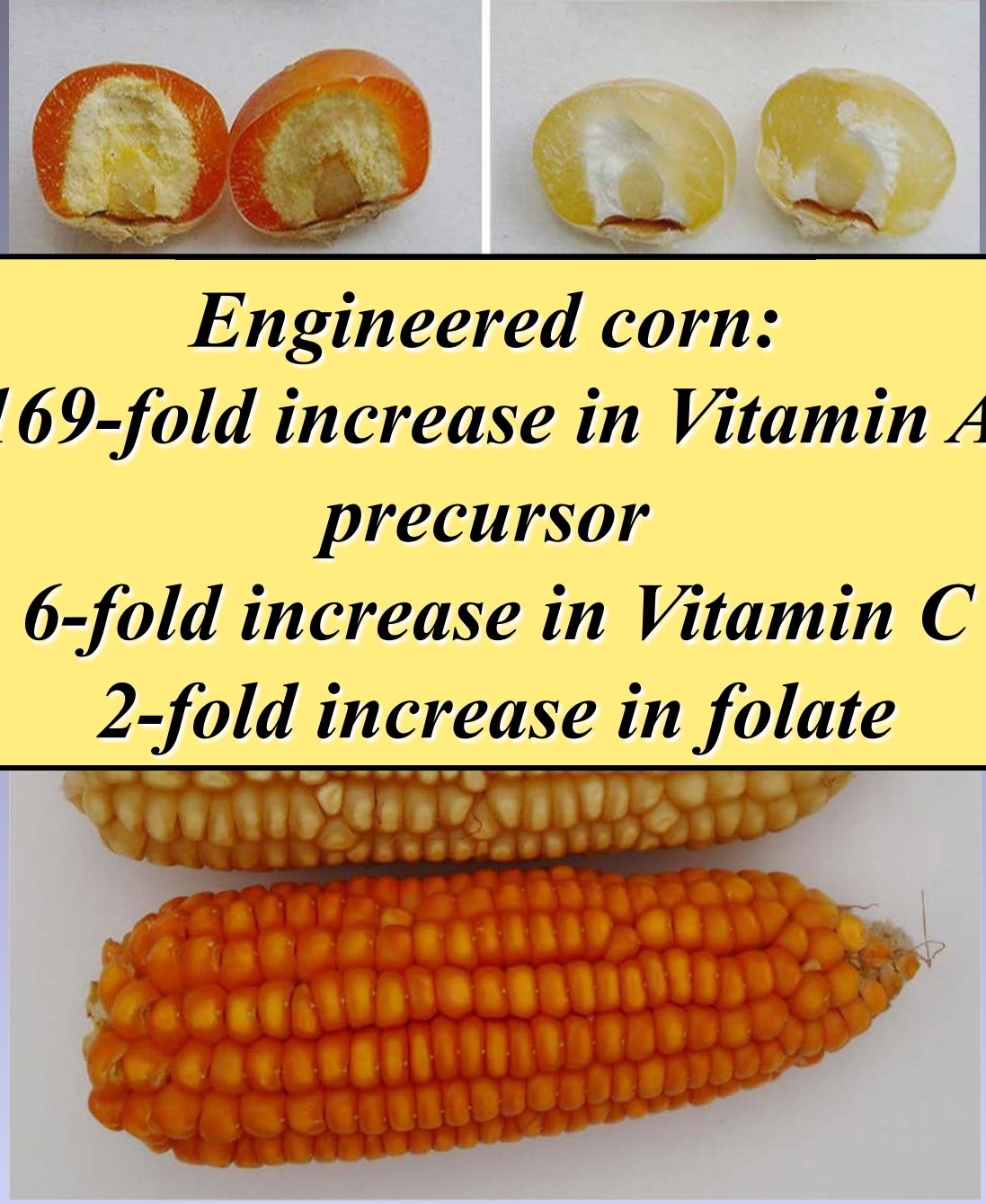


Engineered corn:
169-fold increase in Vitamin A precursor
6-fold increase in Vitamin C
2-fold increase in folate

SOURCE: Naqvi et al. 2009. Transgenic multivitamin corn through biofortification of endosperm with three vitamins representing three distinct metabolic pathways. Proceedings of the National Academy of Sciences USA, doi: 10.1073/pnas.0901412106.

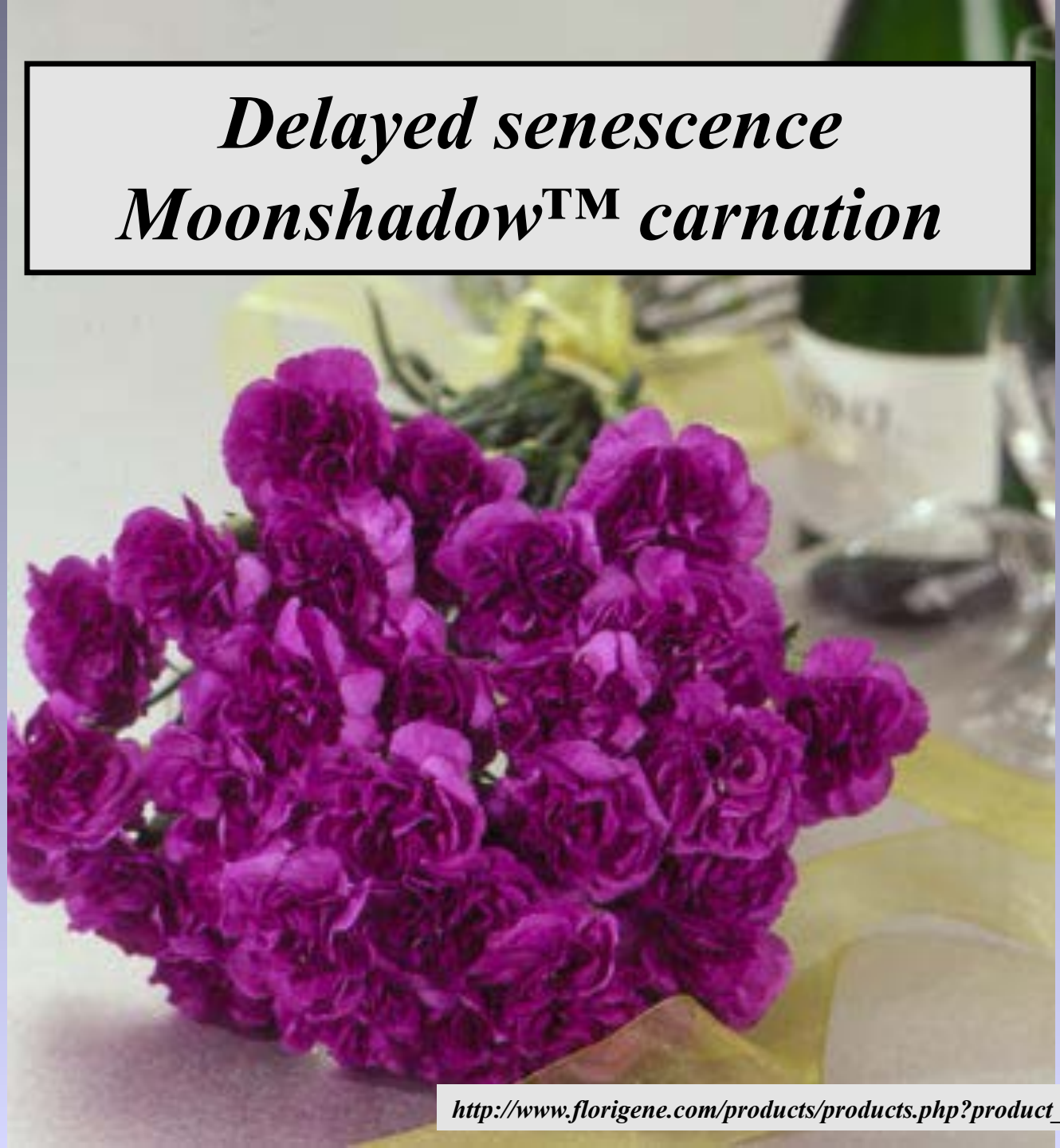
Engineered Pea Seeds Protect Chickens against Parasitic Coccidiosis

SOURCE: "Engineered pea seeds protect against parasites", BioMed Central, 9/10/09, http://www.eurekalert.org/pub_releases/2009-09/bc-eps090909.php
Zimmermann, J., Saalbach, I., Jahn, D., Giersberg, M., Haehnel, S., Wedel, J., Macek, J., Zoufal, K., Glunder, G., Falkenburg, D. and Kiprijanov, S.M. 2009. Antibody expressing pea seeds as fodder for prevention of gastrointestinal parasitic infections in chickens. BMC Biotechnology, in press.

Japanese scientists create blue rose with blue pigments from pansies

SOURCE: http://www.japantimes.co.jp/cgi-bin/getarticle.pl5?nn20040701a2.htm

Delayed senescence Moonshadow™ carnation



http://www.florigene.com/products/products.php?product_name=moonshadow

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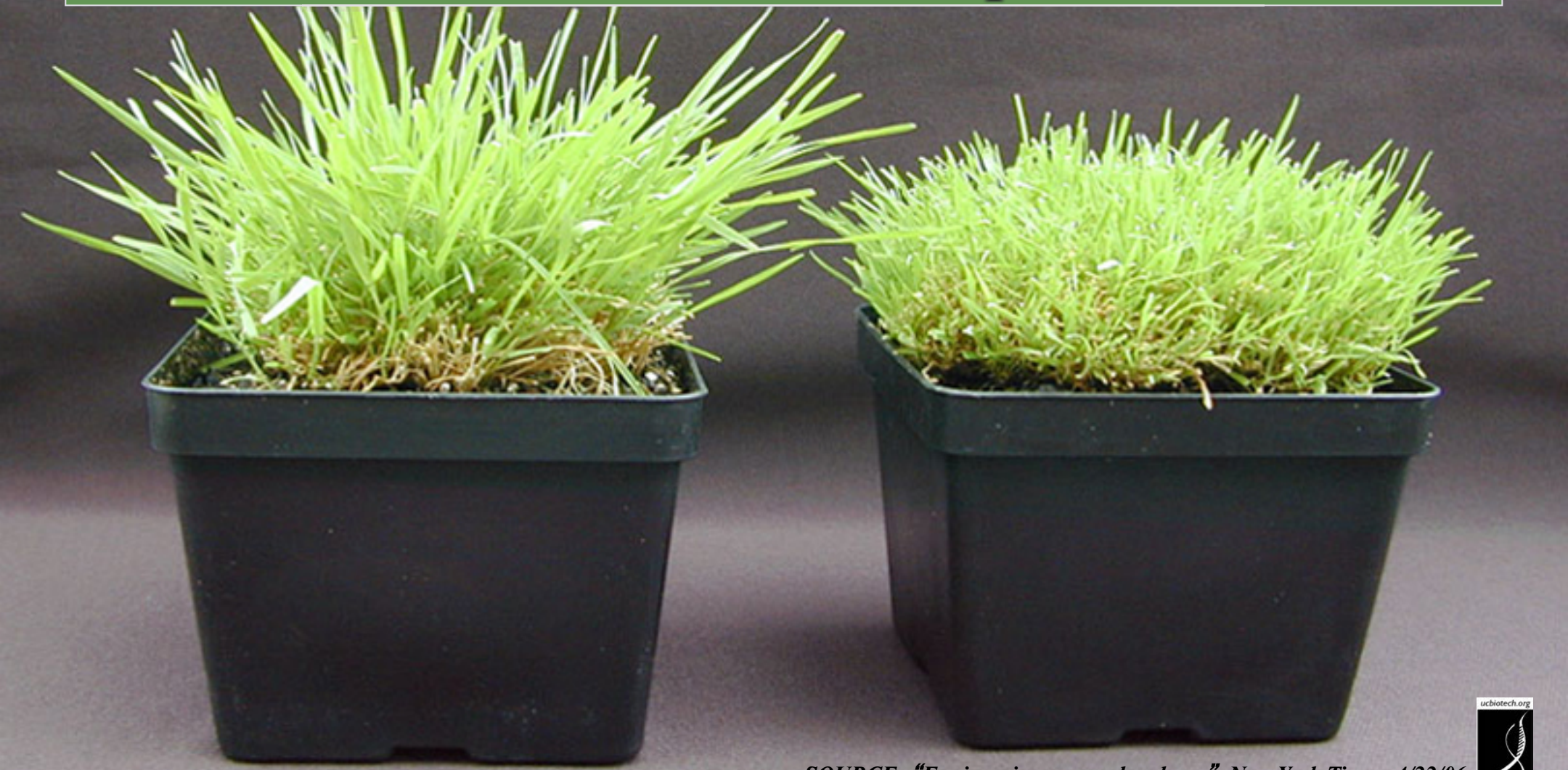
Slow-Mow grass addresses watering, maintenance and weed problems



SOURCE: "Engineering a mow-less lawn", New York Times, 4/22/06
http://www.nytimes.com/2006/04/22/business/22offline.html?_r=1&oref=slogin

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What is the U.S. regulatory process that governs these engineered plants?

U.S. Regulatory Agencies

USDA

- Field testing
  -Permits
  -Notifications
- Determination of non-regulated status

Plant pest?

FDA

- Food safety
- Feed safety

Danger to people?

EPA

- Pesticidal plants
  -tolerance exemption
  -registrations
- Herbicide registration

Risk to environment?

APHIS Determines Nonregulated Status – 75 granted

Once nonregulated, organism no longer requires APHIS review for movement or release in U.S.

Alfalfa – HT –removed/ reinstated

- ✓ Cotton - HT, IR
- ✓ Corn - HT, IR, AP
- ✓ Soybean - HT, PQ
- ❖ Potato - IR, VR
- ❖ Tomato - PQ

Squash - VR

- ✓ Canola – HT

Papaya - VR

- ❖ Rice - HT

Rapeseed - HT, AP, PQ

Sugar beet - HT

- ❖ Flax - HT

Chicorium - AP

Tobacco - PQ

✓Large-scale production

❖Not on market

(http://www.aphis.usda.gov/brs/not_reg.html)

What Are Some of the Issues?

First, what are some food safety issues?

- Changes in nutritional content
- No peer-reviewed food safety tests
- Creation of allergens or activation of toxins
- Pharma crops contaminating food supply
- Labeling
- Gene flow from food to intestinal bacteria increasing antibiotic resistance

What are some food safety issues?

- Changes in nutritional content
- Lack of peer-reviewed food safety tests
- Creation of allergens or activation of toxins
- Pharma crops contaminating food supply
- Labeling
- Gene flow from food to intestinal bacteria increasing antibiotic resistance

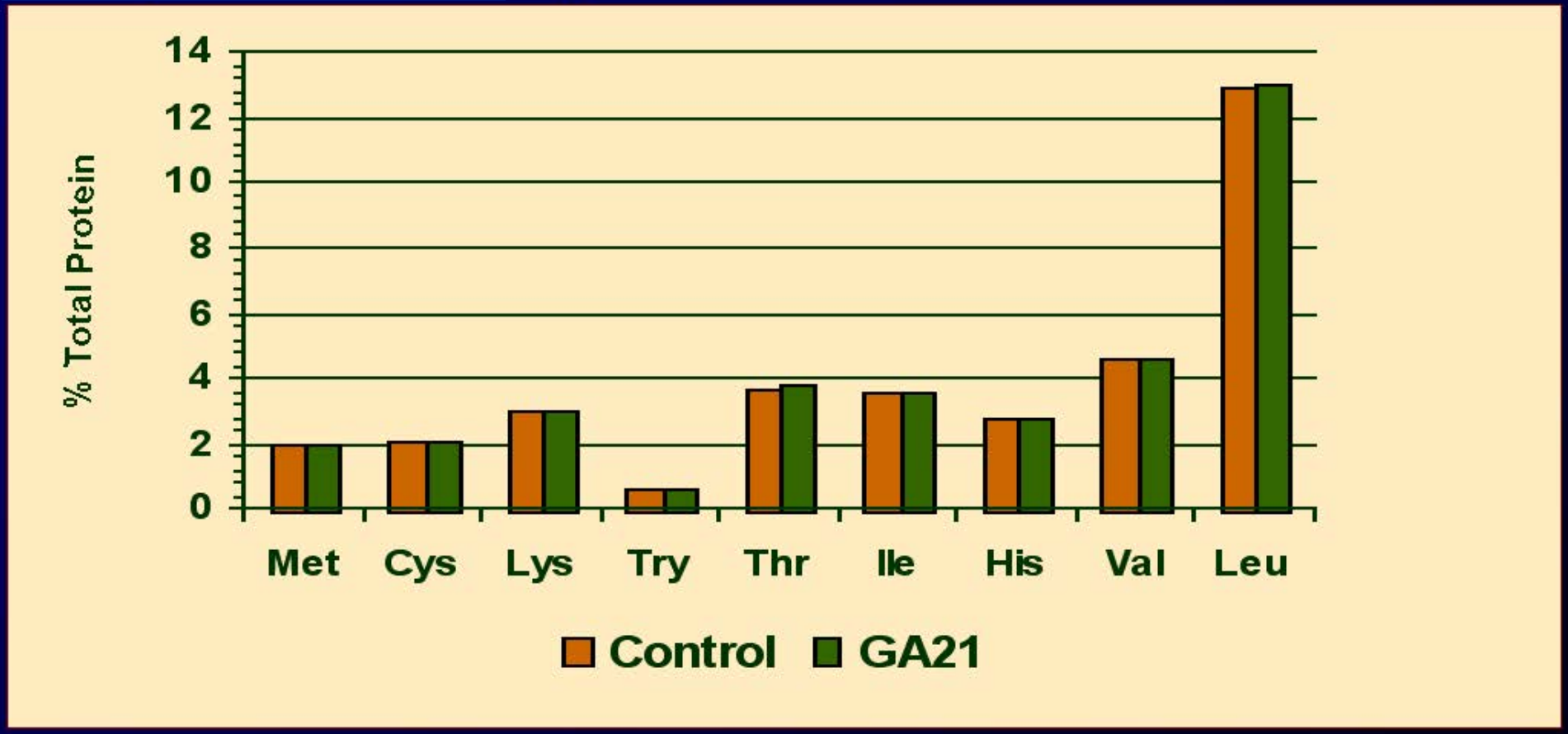
Concept of **substantial equivalence:**

Modified food has essentially all characteristics of nonmodified food with respect to food and feed value
except

for the introduced genetic material and the products made from it. These products are tested and analyzed separately. Regulators look at, for example, specificity and mode of action of protein, source of protein, stability during digestion and processing

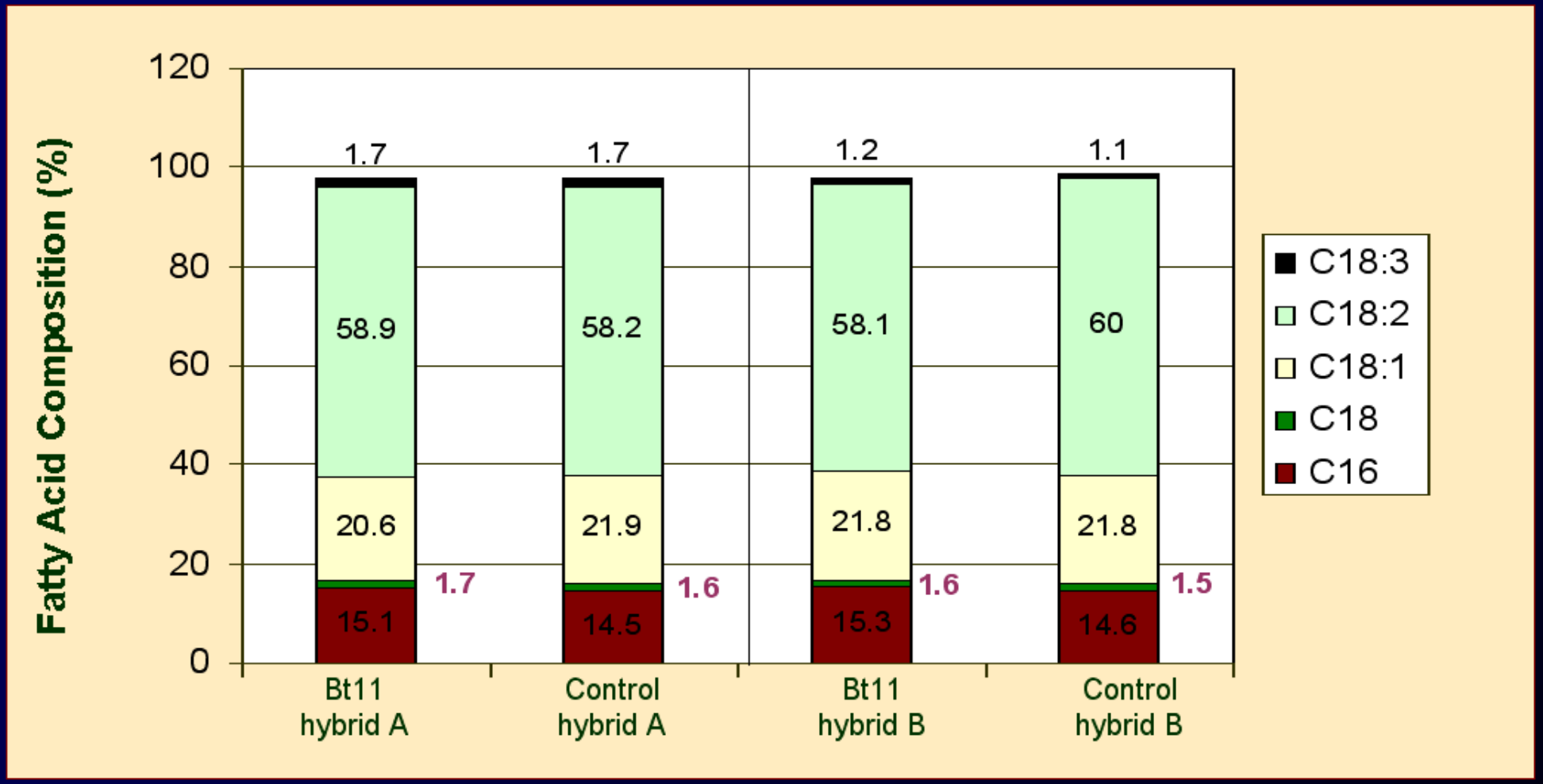
SOURCE: Safety of Genetically Engineered Foods: Aproaches to Assessing Unintended Health Effects 2004. Natl Acad Press

Substantial Equivalence: Amino Acids



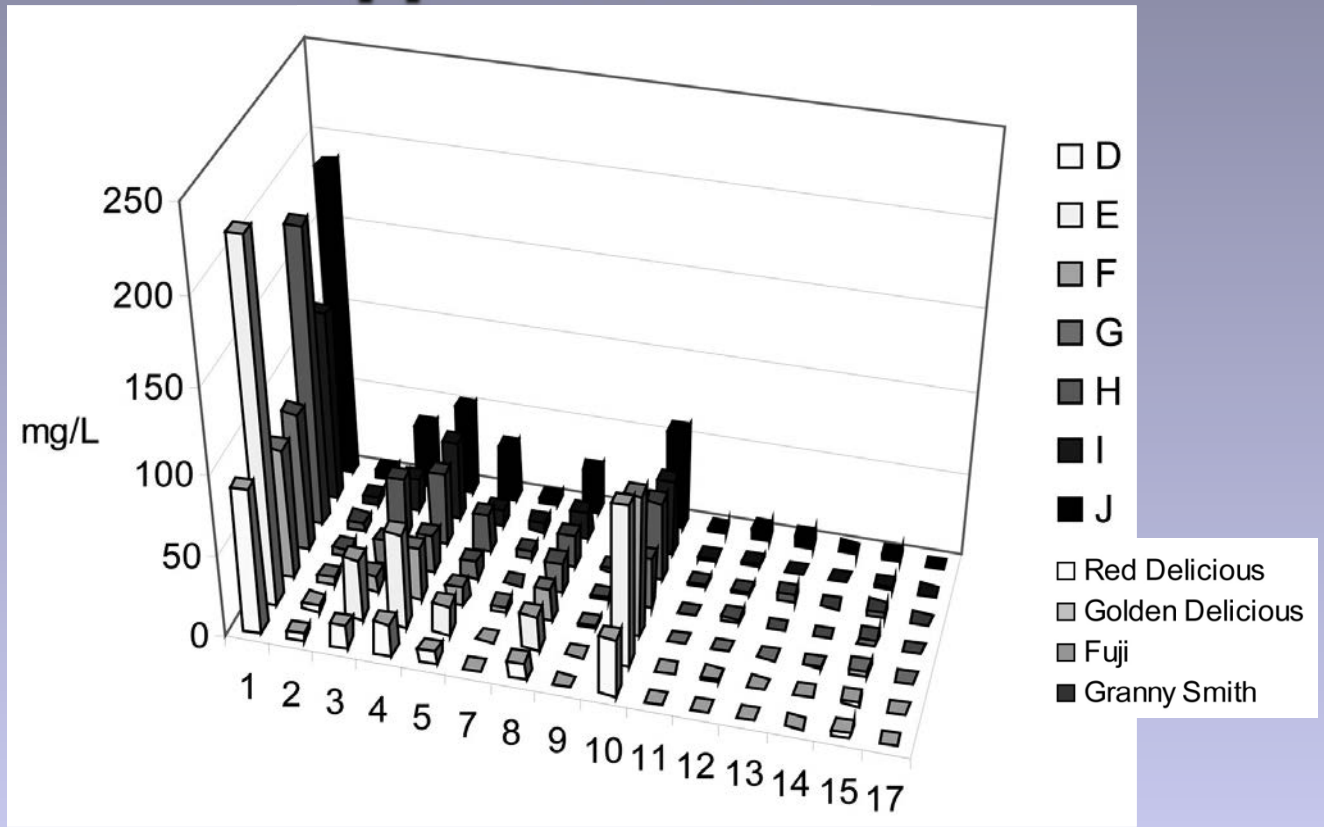
These results have been generated on event GA21. Data showing similar amino acid composition have been generated on the other corn events.

Substantial Equivalence: Fatty Acids



These results have been generated on Event Bt 11. Data showing similar fatty acid composition have been generated on the other corn events.

Important to remember that there are large variations in content of natural compounds in foods, like polyphenol antioxidants in fresh juices from eleven apple varieties



Polyphenol profile (mg/L) of juices freshly made from dessert apple cultivars determined by HPLC-DAD analysis

SOURCE: Kahle et al. 2005. Polyphenol profiles of apple juice. Mol. Nutr. Food Res 49:797-806

Also engineered crops can have purposeful nutritional alterations

Engineering tomato to increase health-promoting compounds

SOURCE: Butelli, E., Titta, L., Giorgio, M., Mock, H., Matros, A., Peterek, S., Schijlen, E.G.W.M., Hall, R.D., Bovy, A.G., Luo, J. and Martin, C. 2008. Enrichment of tomato fruit with health-promoting anthocyanins by expression of select transcription factors. Nature Biotechnology, online first (doi:10.1038/nbt.1506)

Golden Rice engineered to contain bioavailable pro-Vitamin A

Normal portion of Golden Rice 2 provides
half of a child's Vitamin A needs

What are some food safety issues?

- Changes in nutritional content
- Lack of peer-reviewed food safety tests
- Creation of allergens or activation of toxins
- Pharma crops contaminating food supply
- Labeling
- Gene flow from food to intestinal bacteria increasing antibiotic resistance

Difficulties with food safety testing
What to do and how to do it?

"It is difficult if not impossible to test food safety of whole foods and feeds with animal tests. Despite what non-experts commonly think, animal tests are not the gold standard. Compositional analysis and toxicity testing of individual components is much more sensitive than whole foods testing."

"Nutritional and Safety Testing of Foods and Feeds Nutritionally Improved through Biotechnology" 2004. *Comprehensive Reviews in Food Science and Food Safety,* ILSI

Poultry and Egg Study: Bt Protein Analysis

Example of type of animal safety tests conducted

- 14 day poultry feeding study
- Diet: contained 64% grain (Bt or non Bt)
- Eggs collected on days 13 & 14
- Muscle and liver samples collected on day 14

Tissue	Bt Protein Analysis
white muscle (10)	Not detected
dark muscle (10)	Not detected
liver (10)	Not detected
egg whites (10)	Not detected
egg yolk (10)	Not detected

Experiments comparing first generation GE crops with comparable non-GE crops

Animal (Species/categories)	Number of experiments	Nutritional assessment
Ruminants		No unintended effects in composition (except lower mycotoxins concentration in Bt plants)
Dairy cows	23	
Beef cattle	14	
Others	10	
Pigs	21	No significant differences in digestibility and animal health as well as no unintended effects on performances of animals and composition of food of animal origin
Poultry		
Laying hens	3	
Broilers	28	
Others		
(Fish, rabbits etc.)	8	

SOURCE: Flachowsky, G. 2007. Feeds from Genetically Engineered Plants - Results and Future Challenges. ISB News Report, March 2007, pp. 4-7.

What are some food safety issues?

- Changes in nutritional content
- Lack of peer-reviewed food safety tests
- Activation of toxins or creation of allergens
- Pharma crops contaminating food supply
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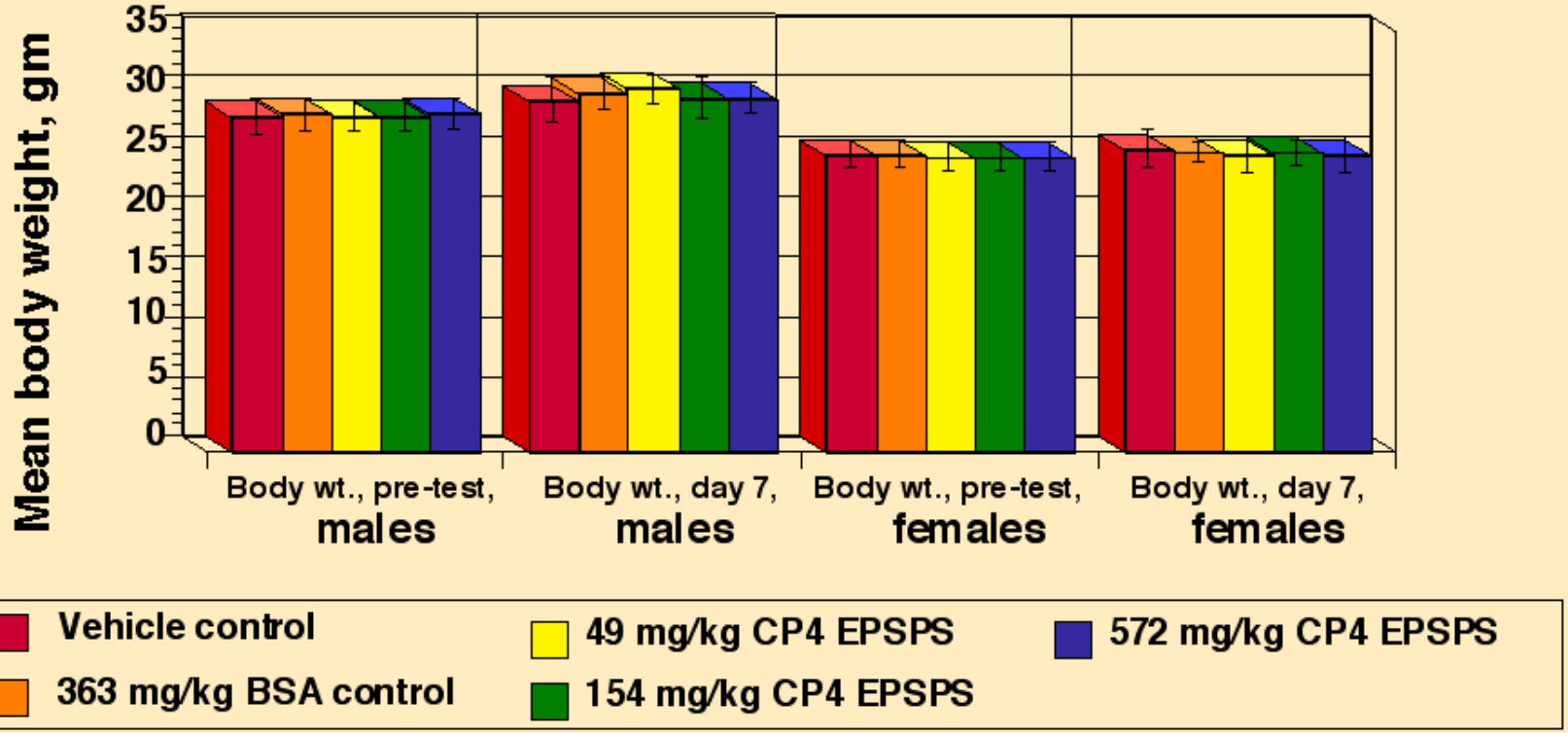
Toxicity Assessment: Roundup Ready/CP4 EPSPS protein

No deleterious effects at highest dose (572mg/kg)



Use Engineering to Reduce Toxins: Fumonisin Reduction with Bt-maize

- 1989: High levels of fumonisin cause large-scale outbreaks of lethal lung edema in pigs, brain tumors in horses
- Fumonisin contamination caused by insect infestation
- 20- to 30-fold fumonisin reduction with Bt-maize

Modified from Drew L. Kershen
University of Oklahoma

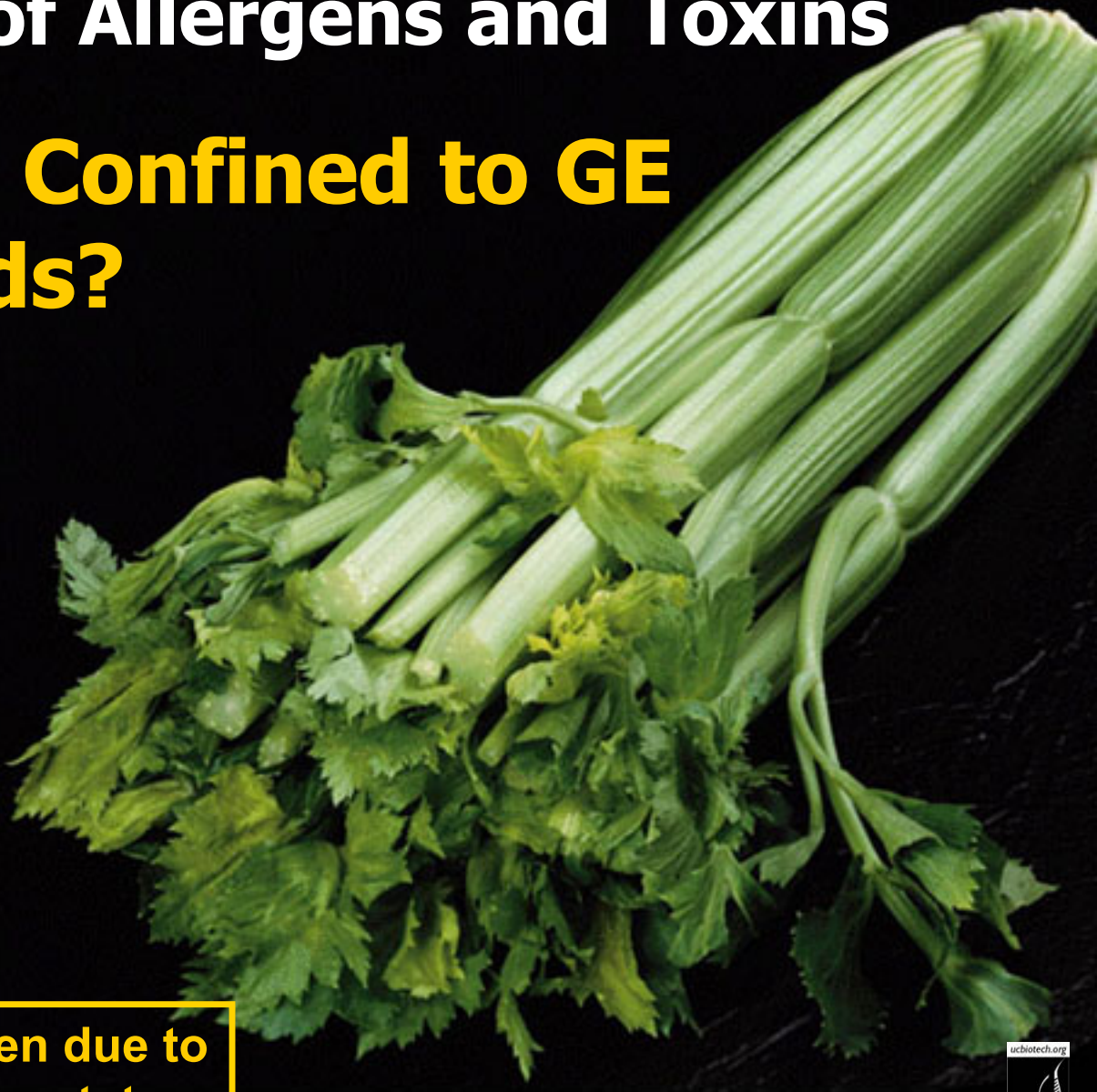
SOURCE; Hammond, B. et al., (Feb. 2004), Lower fumonisin mycotoxin levels in the grain of Bt-corn grown in the United States in 2000-2002, J. Agric. Food Chem. 52: 1390-1397

Australian scientists created weevil-resistant peas using gene from kidney beans

- Prior to commercialization tests indicated peas were harmless.
- Further tests found gene product made in peas slightly different from that in kidney beans.
- New mice feeding tests revealed immune reaction.
- Further project development halted before commercial release.
- Animal safety tests needed to insure foods created – whether GE or classically bred – are safe.

Inadvertent Creation of Allergens and Toxins

Is Toxin Creation Confined to GE Foods?



No – naturally occurring toxins happen due to classical breeding efforts also, *e.g.*, potato (glycoalkaloids) and celery (psoralens)

Allergy Creation Confined to GE Foods?

Classically bred foods can cause allergy problems too –

Example: Kiwi

Long-term Food Safety Studies: Should They Be Done, How and on What Foods? How long?

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Engineeering can be used to mitigate food allergies, like peanut, soy and wheat
ucbiotech.org

What are some food safety issues?

- Changes in nutritional content
- Lack of peer-reviewed food safety tests
- Creation of allergens or activation of toxins
- **Pharma crops contaminating food supply**
- Labeling
- Gene flow from food to intestinal bacteria increasing antibiotic resistance

The Washington Post

November 14, 2002

Biotech Firm Mishandled Corn in Iowa

By Justin Gillis

The biotechnology company that mishandled gene-altered corn in

Production of pharmaceuticals in edible crops cause concern

U.S. Department of Agriculture ordered 155 acres of Iowa corn pulled up in September and incinerated.

ProdiGene

- Planted soybeans in field previously used for transgenic corn.
- USDA APHIS discovered "volunteer" corn plants growing among soybeans; ProdiGene instructed to remove corn.
- Soybeans harvested before corn was removed, became mixed with 500,000 bushels of soybeans.
- Soybeans destroyed. ProdiGene ordered to pay $250,000 civil fines, reimbursement for lost crops, $1 million in regulatory fees.

In part because of examples like Prodigene, USDA tightened rules on Pharm/Industrial Crops

- Crop inspection 7 times; 5 in growing season, 2 after harvest
- Field isolation distances increased
- Dedicated farm equipment required
- Permits required for industrial crops, like pharm crops

The Mercury News
MercuryNews.com

'Pharm crop' debate takes root in California Biotech

By Paul Jacobs and Lisa M. Krieger
Mercury News

YUBA CITY - An experimental new form of rice, engineered to produce commercial

California company growing pharma rice with two genes to speed recovery from childhood diarrhea told to move field production. Ultimately production facility moved to Kansas away from rice-growing area.

commercial producer of genetically engineered ``pharm crops." Scientists

Zavaleta, N et al. 2007. J Ped Gastroenterol Nutrition 44:258-264

But other products are in the pipeline – not necessarily in the U.S.

Rice seed-based edible vaccine for allergic diseases like asthma, seasonal allergies and atopic dermatitis

SOURCE: March 2006, ISB News Report
http://www.isb.vt.edu/news/2006/news06.mar.htm#mar0601

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Expression of human immune protein, CD14, in plants could prevent ocular infections in infants

SOURCE: Information Systems for Biotechnology News Report, July 2006, p. 2
http://www.isb.vt.edu/news/2006/news06.jul.htm#jul0601

Japanese engineer rice to reduce beta amyloid levels in brains of mice with Alzheimer's disease

SOURCE: "Researchers use GM rice to decrease protein linked to Alzheimer's disease", Mainichi Japan, August 29, 2011
http://mdn.mainichi.jp/mdnnews/news/20110829p2a00m0na006000c.html

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Why Doesn't FDA Have a Labeling Policy for GM Foods?

Actually it does…

Foods produced through biotechnology are subject to same labeling laws as all other foods and food ingredients

Govt-mandated label information relates to composition or food attributes not agricultural or manufacturing practices

No label needed if food essentially equivalent in safety, composition and nutrition

GM food labeled if:

1. **Different nutritional characteristics,**
2. **Genetic material from known allergenic source *e.g.*, peanut, egg**
3. **Elevated levels of antinutritional or toxic cmpds**

Should fresh produce items, packages or displays be labeled to identify...? Summary of "yes" responses

Nutritional value	77.1%
Country of origin	85.9% ←
Chemicals used in production	90.7% ←
Organically grown	86.0% ←
Irradiated	77.8%
Use of biotechnology	78.4%
Use of waxes and/or coatings	84.5% ←

SOURCE: Fresh Trends 2002 (courtesy of Roberta Cook, UC Davis)

Why not just label?

Putting a label on a whole food is relatively easy, but…

…processed foods are different. Tomato sauce can contain

8 or more different varieties – each would require tracking to assure accurate content information.

May contain genetically modified tomatoes

Contains genetically modified tomatoes

Contains tomatoes genetically modified with polygalacturonase gene from tomato, phosphinothricin acetyl transferase from *Streptomyces hygroscopicus*, crystal toxin from *Bacillus thuringiensis*, alpha amylase gene from barley, s-adenosyl methionine transferase gene from tobacco, N protein gene from tobacco, coat protein gene from tomato bushy stunt virus

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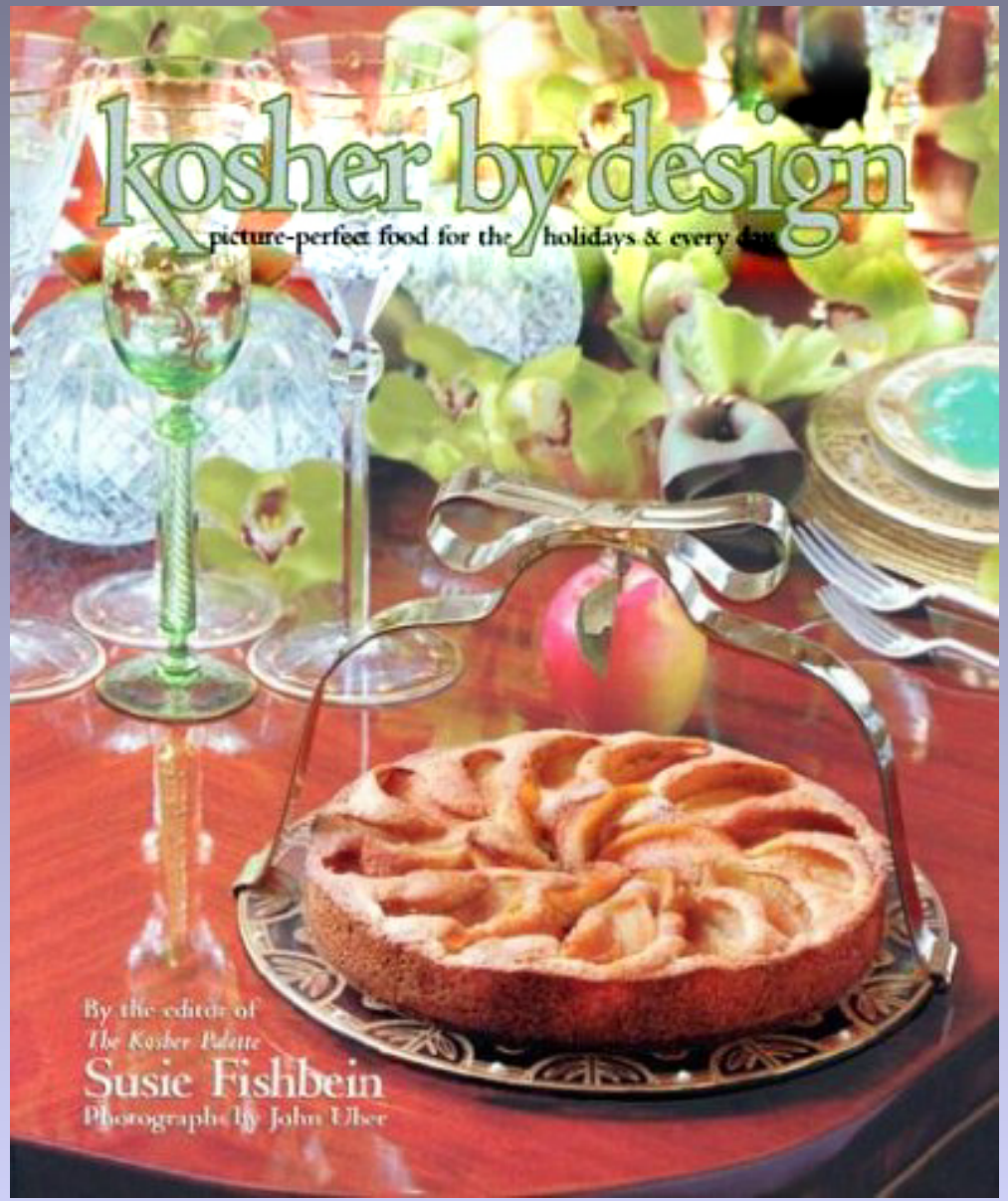
But there are foods that are tracked for consumer choice… like organic and…

…Kosher

For which people pay premium prices



Should everyone pay a premium price for GE-free foods if there are no food safety or nutritional differences?

If there is demand, might another solution be to allow the creation of a specialty market for GE-free foods for which people pay a premium price and for which farmers are paid premium prices to grow them?

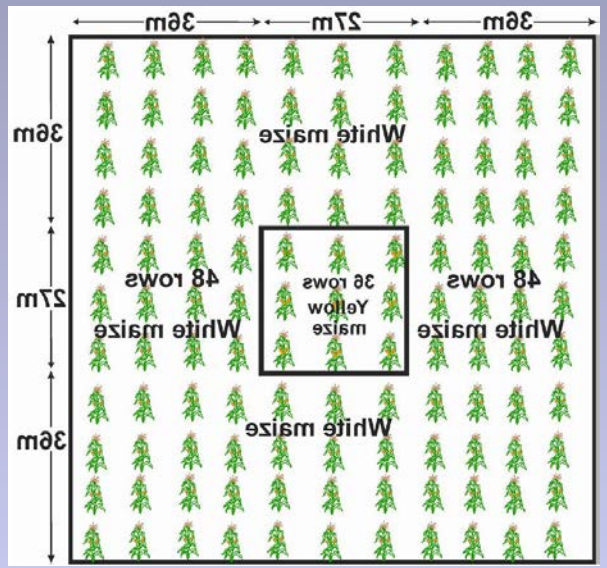
Now to some environmental issues?

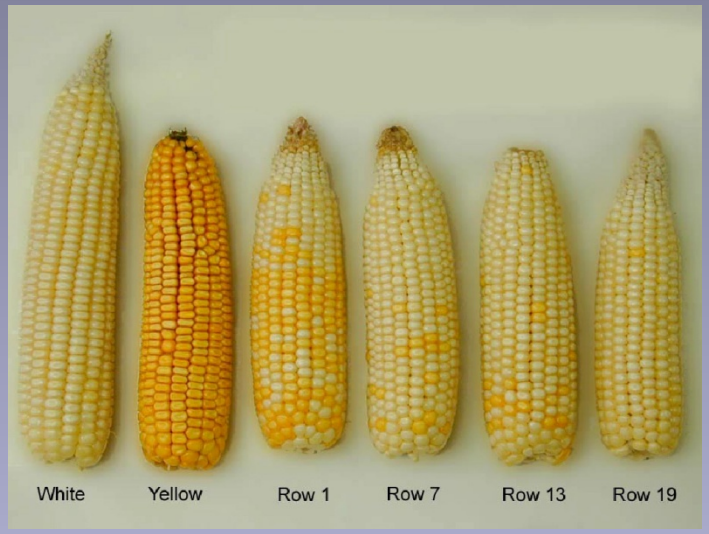
- Gene flow to generate "superweeds" (herbicide tolerance to wild/ weedy species)
- Transfer of transgenes to organic crops?
- Spread of pharmaceutical genes into commercial crops?
- Loss of genetic diversity?
- Property rights (gene patents)?

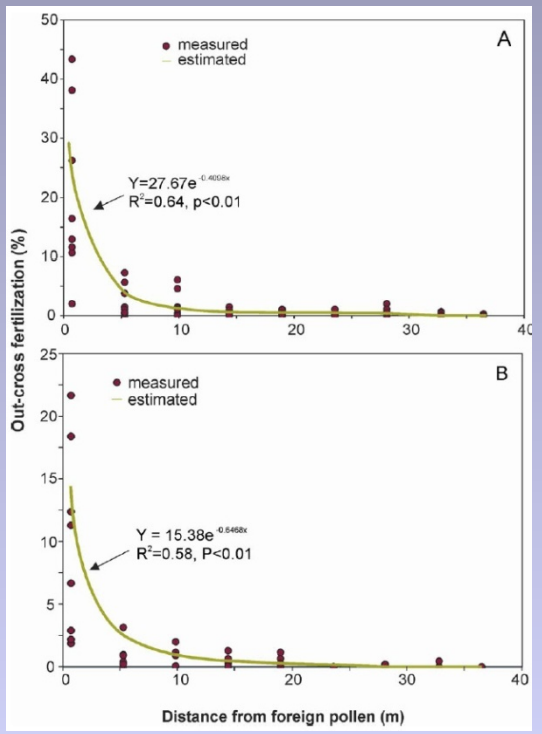
What are some environmental issues?

- Gene flow to generate superweeds" (herbicide tolerance to wild/weedy species)
- Transfer of transgenes to non-GMO / organic crops?
- Loss of genetic diversity?
- Property rights (gene patents)?
- Spread of pharmaceutical genes into commercial crops?

Pollen Drift of Corn







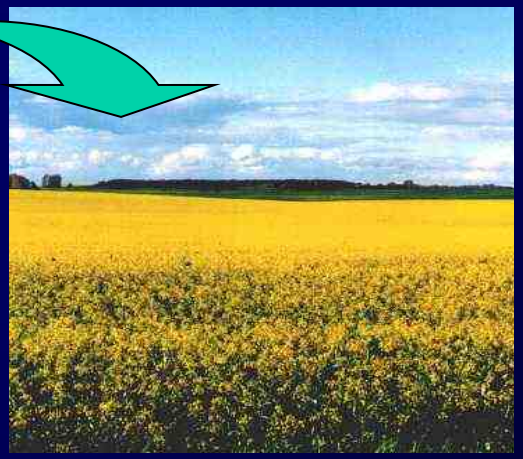
SOURCE: Ma, B.L. 2005. Frequency of Pollen Drift in Genetically Engineered Corn. ISB News Report, February 2005.

Pollen Flow Distances for Crop Species of Interest

Crop Type	Mode of Pollination	Means of Movement	Fdn Seed Prod Isolation Distance	Measure Pollen Movemnt Dstance
Alfalfa	Self-sterile; obligate outcrossing	Bees	900 ft (0.17 mi)	2000 ft (0.48 mi)
Bentgrass	Clonal (stolons); type outcrossing dep on environment	Wind	900 ft (98%purity) (0.17 mi)	13.05 mi
Canola	Predom. selfing; 30% outcrossing	Wind/insects	>1320 ft (0.25 mi)	1.9 mi
Corn	Almost exclusively outcrossing	Wind	660 ft (0.125 mi)	~2 mi
Cotton	Predom. Seslfing; outcrossing with insects	Insects	>1320 ft (0.25 mi)	n.a.
Rice	Self-pollinating (99.5%); pollen viable 3-15 min	Physical touching/wind	10 ft	30 ft
Squash	Obligate outcrossing	Insects (predom. bees)	1320 ft (0.25 mi)	0.8 mi
Soybean	Self-pollinating (99%)	Physical touching/wind	5 ft	n.a.
Wheat	Self-pollinating (99.9%)	Physical touching/wind	5 ft	>160 ft

Consequences of gene flow from GE crops to weedy species in field

GM canola



non-GM canola

Question – What Are the Consequences of Gene Flow? Consider Vitamin A Genes vs. Herbicide Tolerance Genes from GE Rice to Weedy Red Rice

Pollen Flow between Herbicide-Tolerant Canola: Cause of Multiple Resistant Canola Variety

crossing

"Triple-resistant canola"
(Two GE traits; one mutation)
Hall et al. (2000)

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Consequences of Triple-Resistant Canola and HT-Wild Hybrids?

canola

What is the actual risk?

- HT doesn't necessarily translate into increase in weediness
- HT gene only helps plant if you spray target herbicide
- Eventually can't use specific herbicide

Who stands to lose?

- Herbicide manufacturer
- HT plant developer
- Farmer

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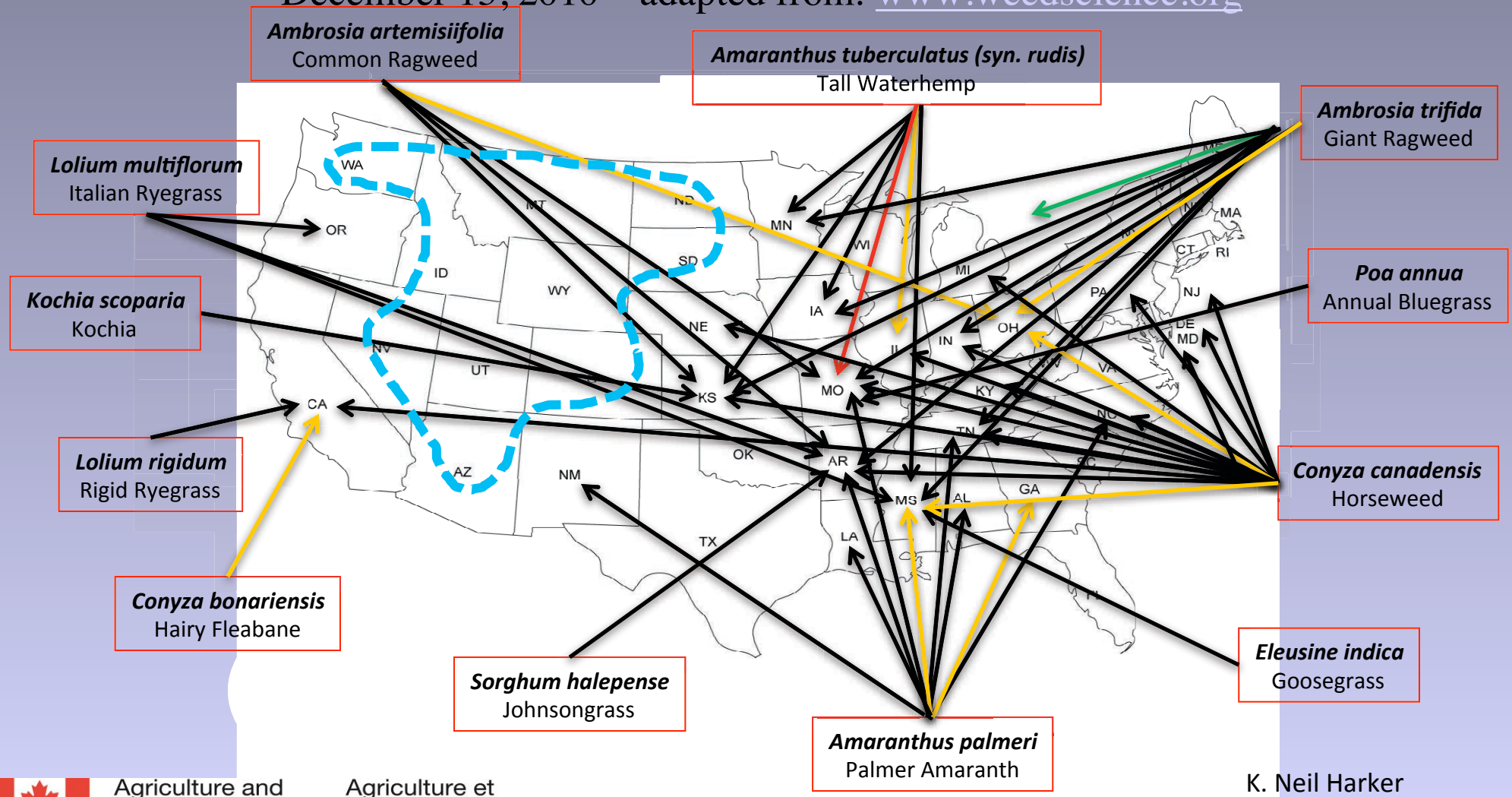
Not due to gene flow but naturally resistant weeds that flourish when the same herbicide is used over and over…haven't we learned this before?

Glyphosate- Resistant Weeds – USA

December 13, 2010 – adapted from: www.weedscience.org



Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

K. Neil Harker
AAFC - Lacombe, AB

Capital Press
Agriculture Newspaper

Biotech corn loses edge over pests

Rootworms develop resistance to Bt corn across Midwest

Research Center

2003, so-called Bt corn seemed

on the roots of Bt corn in parts of four Midwestern states, suggesting that some of the insects are becoming resistant to the

which hit a record in June.

"Right now, quite frankly, it's very profitable to grow corn," said Michael Gray, a Universi-

ing whether rootworms capable of surviving the Bt toxin were the cause.

University of Minnesota en-

He said the damage he observed in Minnesota came to light only because storms in 2009 toppled corn plants with damaged roots.

Bt corn targeted at lepidopteran pests has lasted with few resistances for over 15 years. But most recent release of a new Bt corn targeted at rootworm beetles resulted in relatively rapid development of resistance

sophisticated weaponry.

When it was introduced in

But over the last few summers, rootworms have feasted

ers have eschewed the practice to cash in on high corn prices,

Minnesota and Nebraska, but researchers are still investigat-

aged at the roots but remain upright, concealing the problem.

tance have emerged sooner than many expected.

SOURCE: Capital Press, February 2, 2012
http://www.capitalpress.com/print/AP-US-Biotech-corn-at-risk-122811

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What are some environmental issues?

- Gene flow to generate superweeds" (herbicide tolerance to wild/weedy species)
- Transfer of transgenes to organic crops?
- Loss of genetic diversity?
- Property rights (gene patents)?
- Spread of pharmaceutical genes into commercial crops?

What Exactly Is Organic Agriculture? It is a production system that…

- Places a priority on health of crops, animals, farmers, environment, and consumers
- Doesn't use synthetic pesticides and fertilizers
- Focuses on improving soil fertility through use of organic matter and cover crops
- Supports and enhances an abundance of beneficial insects
- Must have 3 years with no prohibited material and be inspected on an annual basis by a USDA accredited certifier to be certified organic

P. Ronald UC Davis

US Organic Sales Figures

Total Foods and Organic Foods Consumer Sales and Market Penetration: 1997-2005				
	Organic Food ($mil)	Organic Food Growth	Total Food Sales ($mil)	Organic Penetration
1997	$ 3,594	n.a.	$443,790	0.81%
1998	$ 4,286	19.2%	$454,140	0.94%
1999	$ 5,039	17.6%	$474,790	1.06%
2000	$ 6,100	21.0%	$498,380	1.22%
2001	$ 7,360	20.7%	$521,830	1.41%
2002	$ 8,635	17.3%	$530,612	1.63%
2003	$10,381	20.2%	$535.406	1.94%
2004	$11,902	14.6%	$544,141	2.19%
2005	$13,831	16.2%	$556,791	2.48%

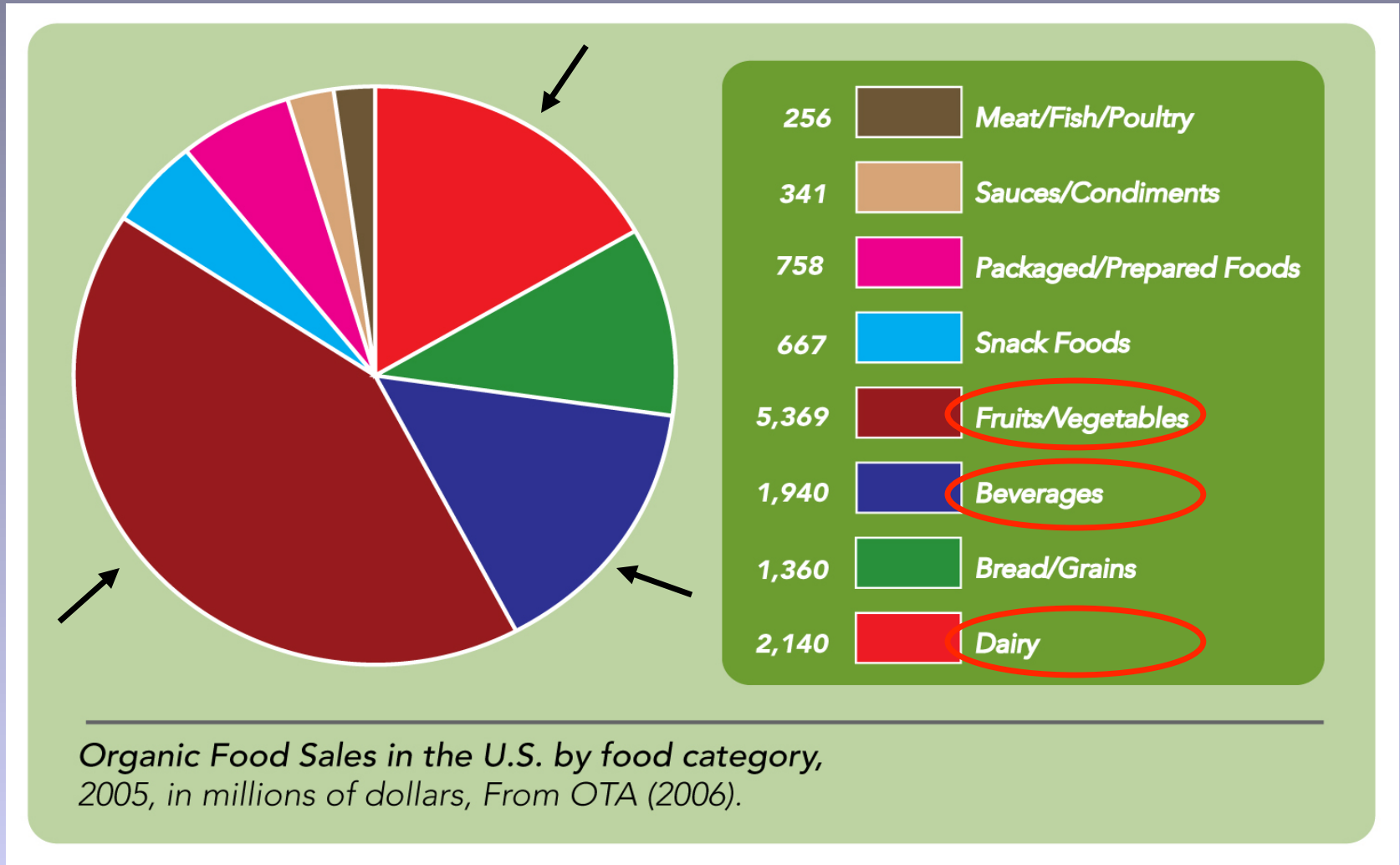
3-fold increase in market share since 1997 at a rate of growth of ~15-20%/year. This represents $13.8 billion

The % of total food market remains low at 2.5%

Source: Nutrition Business Journal estimates based on Organic Trade Association's 2006 marketing survey, annual Nutrition Business Journal marketing surveys and other sources (http://www.ota.com/pics/documents/short%20overview%20MMS.pdf)

Organic Food Sales in the U.S. by food category, 2005

(Source: Organic Trade Association, 2006)



Organic Food Sales in the U.S. by food category, 2005, in millions of dollars, From OTA (2006).

SOURCE: Winter, C.K. and Davis, S.F. 2007. Are organic foods healthier? CSA News 52: 2-13.

In 2001 organic acreage (cropland and pastureland) was 0.3% of U.S. agricultural acreage; >2% for some vegetables

(most recent figures: ers.usda.gov/publications/aib780a.pdf)

CA Organic Production Acreage

	Total acres 2004[1]	Organic acres 2004[2]	GE Acres 2004 estimates[3]
Alfalfa	130,000	4920 (~3.78%)	0 (not available)
Field Corn	540,000	383 (~0.07%)	300,000 (~57%)
Upland Cotton	560,000	273 (~0.01%)	260,000 (~54%)
Gross Value ($)	**$31.8 billion**	**$752 million (~ 2%)**	

[1] http://www.nass.usda.gov:8080/QuickStats/PullData_US

[2] http://www.cdfa.ca.gov/is/i&c/docs/2004CountyReport.pdf

[3] Martin Lemon, Monsanto, personal communication.

Organic Agriculture

Can It Coexist with GE Crops? How?

Capital Press, September 16, 2005

Communicate to avoid pesticide drift, winemaker says

Is this the first time coexistence between conventional and organic agriculture has been an issue?

By MATEUSZ PERKOWSKI
Freelance Writer

Fifteen years ago, David Adelsheim received some bad news. His vineyard manager had noticed

MATEUSZ PERKOWSKI/For the Capital Press
David Adelseheim examines some grapes at his vineyards near Newberg, Ore. Fifteen years ago, herbicide drift damaged several acres of his grapevines, and Adelsheim said the affected plants have never fully recovered.

was overgrown with blackberry bushes with a growth regulator herbicide containing 2,4-D. Aside from killing the blackberries, some of the herbicide had drifted onto the rows of grapevines growing only 15 feet away.

Roughly five acres were affected by the drift, which was about a third of Adelsheim Vineyards at the time. The first several rows were the most badly damaged, but even grapevines 30 rows down were showing some deformation. Because the neighbor had sprayed in mid-spring – after the grape bud break but prior to bloom – much of the year's crop had been aborted, and the remaining vines were too damaged to ripen any grapes.

In the decade and a half since then, Adelsheim Vineyards has managed to overcome the injury caused by the incident – the company has expanded to 180 acres, and the five acres ravaged by the herbicide have largely recovered. Nonetheless, Adelsheim said the effects of the

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One of the most divisive issues regarding genetic engineering is the suggestion that a choice must be made between EITHER "organic agriculture" OR "GMOs".

As long as these issues are polarized into "all is permitted" or "nothing is permitted", rational social discussion is impossible. Dualism (right versus wrong) is the enemy of compromise.

Co-existence

development of best management practices used to minimize adventitious presence of unwanted material and effectively enable different production systems to co-exist to ensure sustainability and viability of all production systems. General concept of co-existence is well established in California with conventional, organic and IPM systems working together.

How might a GE crop be a co-existence issue for an organic farmer?

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...What Genetic Modification Input Methods Are PERMITTED?

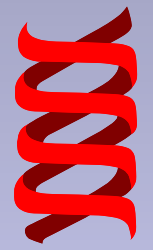
(§ 205.2 National Organic Program)

- they "...include the use of traditional breeding, conjugation, fermentation, hybridization, in vitro fertilization, or tissue culture."

F.J. Chip Sundstrom CCIA

…And What Genetic Modification Input Methods Are **PROHIBITED?**
(§ 205.2 National Organic Program)

- **"A variety of methods…are not considered compatible with organic production. Such methods include cell fusion, micro- and macro-encapsulation, & recombinant DNA technology (including gene deletion, gene doubling, introducing a foreign gene, & changing the positions of genes when achieved by recombinant DNA technology)."**



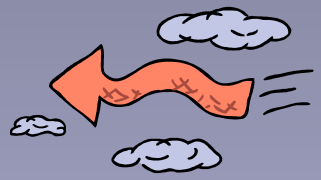
Are There Tolerances for GE in Organic Products?

From NOP preamble…

- **Organic Production is a PROCESS certification NOT a PRODUCT certification – it allows for Adventitious Presence (AP) of certain excluded methods.**
  - **"As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods …unintentional presence of products of excluded methods should not affect status of an organic product or operation."**

F.J. Chip Sundstrom CCIA

- **Pesticides**: "When residue testing detects prohibited substances at levels that are greater than 5% of the EPA's tolerance for the specific pesticide residue detected…the agricultural product must not be sold or labeled, or represented as organically produced."



- **GMOs**: At the present time there are no specified tolerances for GMOs in organic products. Organic products are not 'guaranteed' GMO-free, although some organic farmers sign contracts guaranteeing GMO-free

So, will an organic farmer automatically lose his accreditation if his/her crop is found contaminated with a GE crop?

No.

"As long as an organic operation has not used excluded methods and takes reasonable steps to avoid contact with the products of excluded methods, as detailed in their approved organic system plan, the unintentional presence of the products of excluded methods should not affect the status of an organic product or operation."

SOURCE: AMS National Organic Program Q&A

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An organic farmer can lose the ability to sell a crop as organic if a contract is voluntarily signed stating the crop is 100% GE- free and evidence of GE contamination is found.

This is not an NOP organic rule but a private agreement.

SOURCE: AMS National Organic Program Q&A

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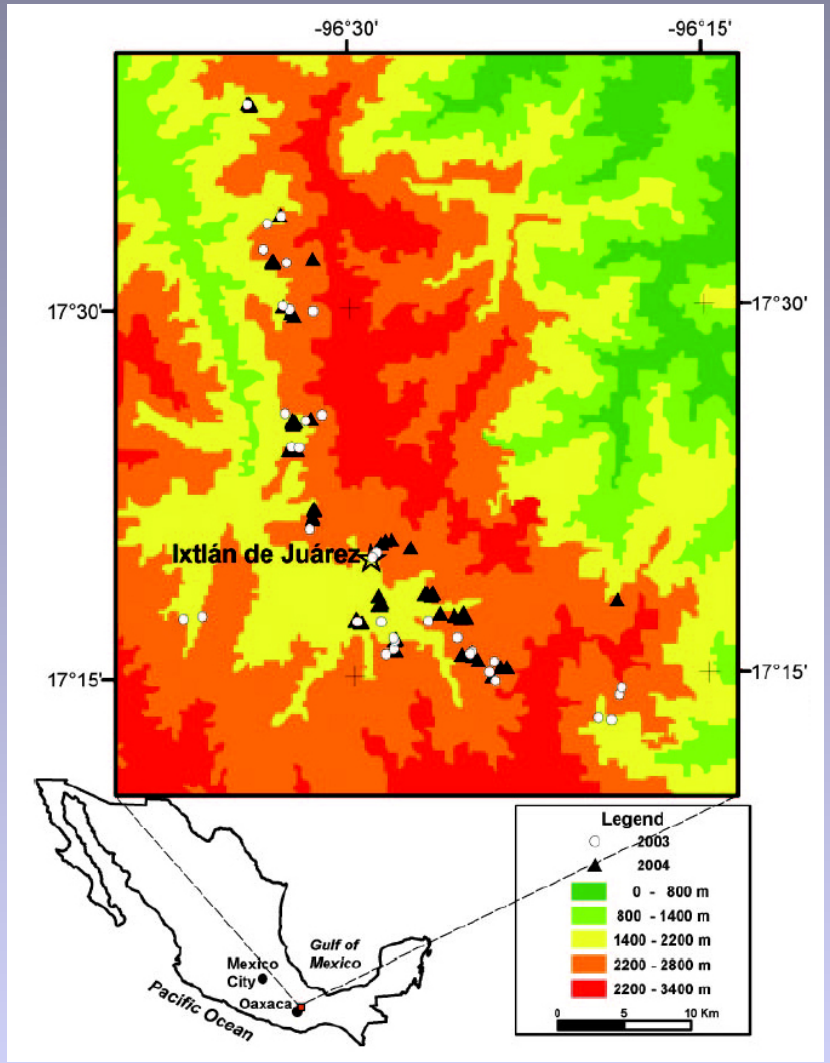
What are some environmental issues?

- Gene flow to generate superweeds" (herbicide tolerance to wild/weedy species)
- Transfer of transgenes to organic crops?
- Loss of genetic diversity?
- Property rights (gene patents)?
- Spread of pharmaceutical genes into commercial crops?

Genetic Modification Taints Corn in Mexico

SOURCE:New York Times, October 2, 2001

Map of fields in Oaxaca, Mexico, where seeds were collected from maize landraces in 2003 and 2004.



No evidence of GE corn found in 2005 study in specific area of Mexico where evidence was found in 2001

SOURCE: Ortiz-Garcia et al. (2005) PNAS 102:12338-12343

Gene flow in Mexican maize: consequences for genetic diversity?

State of Jelisco

Near Amecameca in Chalco area

How does pollen and gene flow occur in Mexico?

Is this the first time gene flow has occurred into Mexican landraces?

What implications does transgene flow have for wild and domesticated maize?

What are some environmental issues?

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- Loss of genetic diversity?
- Property rights (gene patents)?
- Spread of pharmaceutical genes into commercial crops?

Capital Press
Agriculture Newspaper

Investigative report

Monsanto's practices weed out competition

Licensing pacts, science propel seed company to dominate position

their products, according to a review of several Monsanto licensing

practices reveal how the world's biggest seed developer protects its dominance over the multibillion-dollar market for genetically altered crops, an Associated Press investigation has found.

Companies have taken the lead in creating today's commercial GE crops and control most of the key intellectual property, making it difficult for small companies or the academic sector to play a meaningful role in addressing agricultural challenges with genetic engineering.

SOURCE: Capital Press, December 18, 2009

Capital Press
Agriculture Newspaper

US regulators examine competition in agriculture

By CHRISTOPHER LEONARD
Associated Press

Related story
See story package — "Antitrust action looms" — on Page 1.

ANKENY, Iowa — Federal officials concerned about how much control a few corporations have over the nation's food supply pledged March 12 to begin a new era of antitrust enforcement, seeking to balance agricultural power between companies, farmers and

brewing sense of powerless and frustration in small towns that was on display March 11 at a farmer's rally. More than 200 people packed a small ball-

And even among companies there is a lot of competition with just a few companies jockeying for a position. This may or may not be good for agriculture.

side to open the hearing, called the workshop an unprecedented act of cooperation between their agencies.

"I think you will see an historic era of enforcement that will almost inevitably grow from the partnership that we have established," Holder said.

Some Obama administration officials have made clear

try production.

Those in the audience at the hearing paid keen attention, trying to discern just how aggressive the Obama administration will be.

For farmers, it is an effort to constrain corporations like Monsanto Co., Archer Daniels Midland Co. and Tyson Foods Inc., which producers say wield

cession and stifle innovation and investment.

Holder and Vilsack said it's not clear yet what actions will ultimately result from the five hearings, which will examine competition in the dairy, seed, meatpacking and crop production.

But they said it won't just be a series of lawsuits. They're

suffers.

"This is not just about farmers and ranchers," Vilsack said. "It's really about the survival of rural America. We've seen a significant decline in the number of farmers and ranchers and that translates into a significant decline in the number of people living in rural America."

The hearings play to a long-

Chuck Grassley, R-Iowa, Iowa Attorney General Tom Miller and others outlined their concerns about consolidation in the farm sector.

"Bigger isn't per se bad," Grassley said. "But it can lead to predatory business practices and behaviors and that's what we've got to be concerned about."

SOURCE: Capital Press, March 19, 2010

More of world's crops are genetically engineered

By Elizabeth Weise, USA TODAY

February 23, 2011

The amount of land devoted to genetically engineered crops

Lemaux says "because of the expenses involved, creating engineered crops for developing countries requires humanitarian contributions by philanthropists like (Bill) Gates and the Rockefeller Foundation, or perhaps by companies who see value in such endeavors."

<u>And, although many academic scientists want to play a meaningful role, they have limited resources to do so.</u>

SOURCE: "More of world's crops are genetically engineered", USA Today, February 23, 2011.
http://www.usatoday.com/tech/news/biotech/2011-02-22-biotech-crops_N.htm

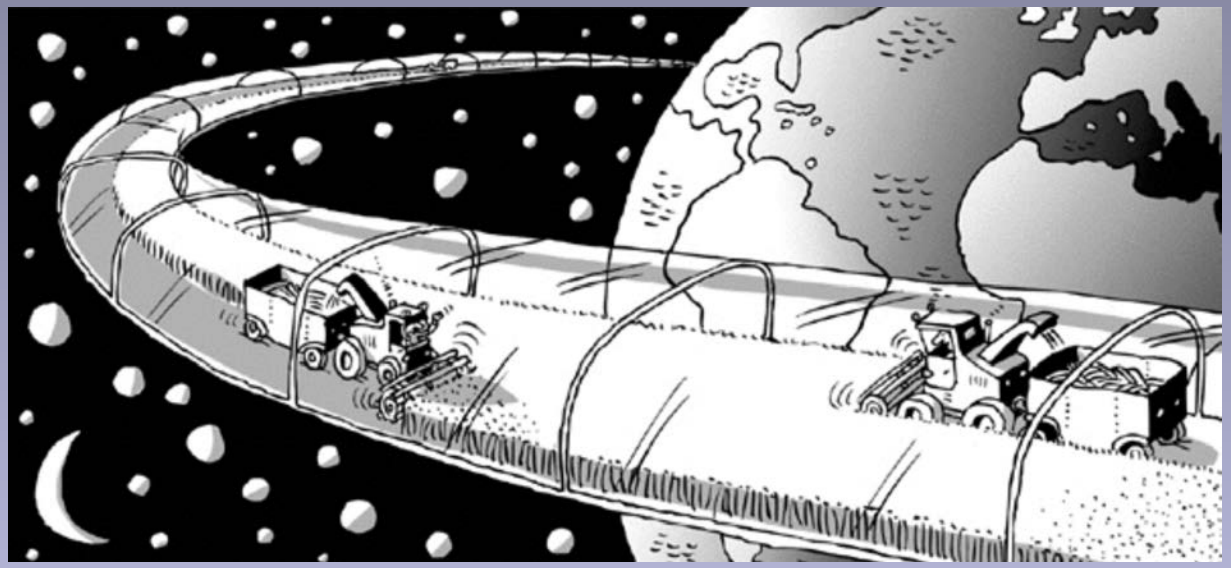
What are some environmental issues?

- Gene flow to generate superweeds" (herbicide tolerance to wild/ weedy species)
- Transfer of transgenes to organic crops?
- Loss of genetic diversity?
- Property rights (gene patents)?
- Spread of pharmaceutical genes into commercial crops?

The New York Times

How to Confine the Plants of the Future?

April 8, 2007



"A new generation of genetically engineered crops that produce drugs and chemicals is fast approaching the market — bringing with it a new wave of concerns about the safety of the global food and feed supply."

SOURCE: "How to Confine the Plants of the Future", New York Times, 4/8/07
http://www.nytimes.com/2007/04/08/business/yourmoney/08frame.html?_r=1&ref=yourmoney&oref=slogin

ucbiotech.org

The Mercury News
MercuryNews.com

'Pharm crop' debate takes root in California Biotech

California company growing pharma rice with two genes to speed recovery from childhood diarrhea causes a "raging international dispute" over use of edible GE crops to produce drugs

Sacramento-based Ventria Bioscience is seeking state approval to grow rice that can make two human proteins, normally found in breast milk and tears, for use in treating human illnesses.

If it gets the necessary approvals, the decade-old company would become the first commercial producer of genetically engineered ``pharm crops." Scientists

Zavaleta, N et al. 2007. J Ped Gastroenterol Nutrition 44:258-264

The Washington Post

November 14, 2002

Biotech Firm Mishandled Corn in Iowa

By Justin Gillis

The biotechnology company that mishandled gene-altered corn in

2002: Production of pharmaceuticals in edible crops cause concern

U.S. Department of Agriculture ordered 155 acres of Iowa corn pulled up in September and incinerated.

USDA tightens rules on Pharm/Industrial Crops

- Crop inspection 7 times; 5 in growing season, 2 after harvest
- Field isolation distances increased
- Dedicated farm equipment required
- Permits needed for industrial crops, like pharm crops
- Pharma crops will not be deregulated

Planting Pharma rice in Kansas has supporters and opponents

SOURCE: "Company's plan for modified rice creates debate", Lawrence Journal-World, 3/25/07.

ucbiotech.org

Where to get more information on the issues?