



DNA in your GARDEN

**How Genetics Affects What Plants
We Grow and How We Grow Them**



Peggy G. Lemaux
University of California, Berkeley
<http://ucbiotech.org>
<http://nature.berkeley.edu/lemauxlab>





1. Background on genes, genetics and genetic engineering (aka biotechnology, GMOs)

2. What engineered (GM) crops have been commercialized? What's in the pipeline?



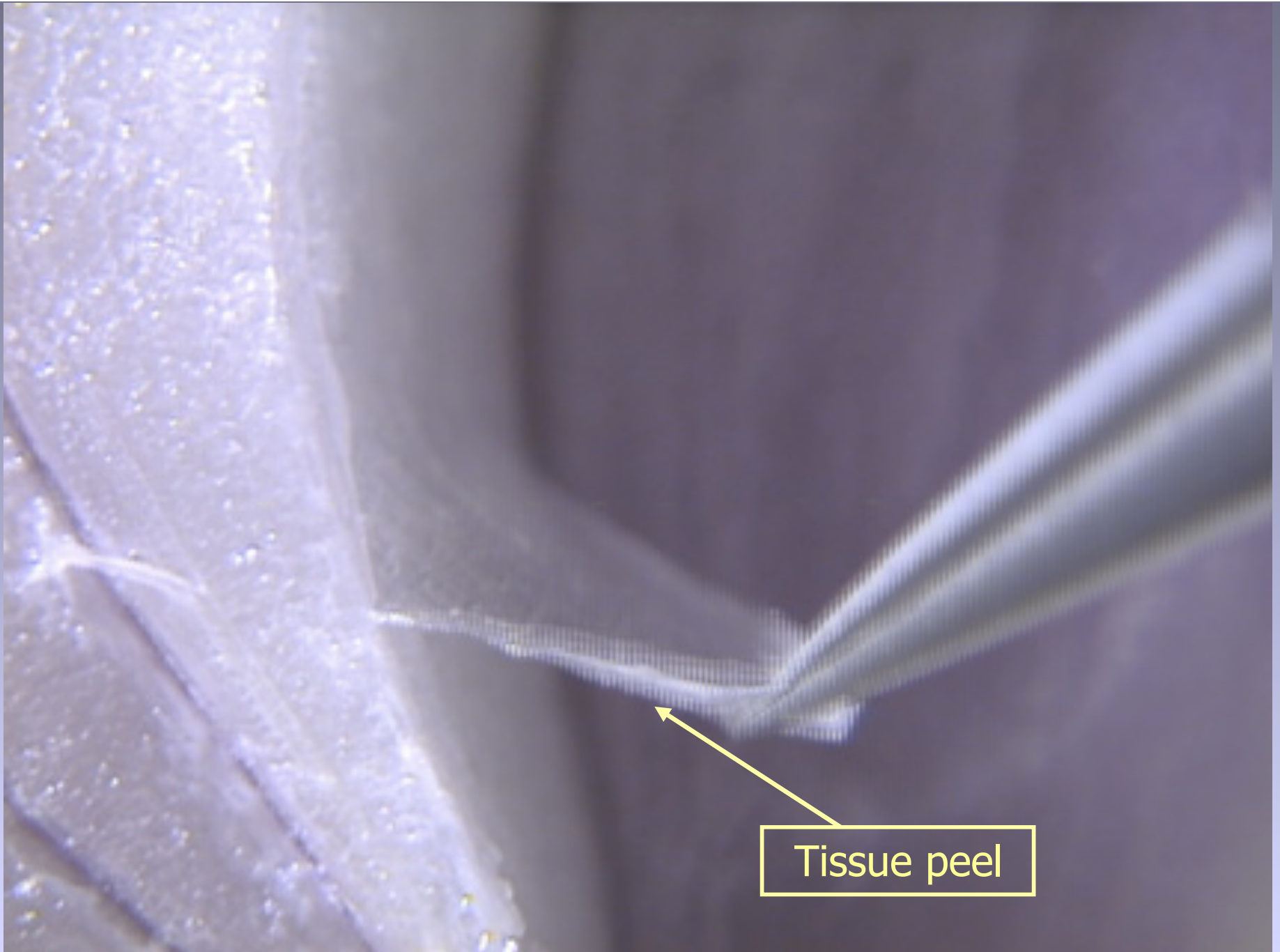
3. What is the regulatory structure for GE crops?

4. What are some food safety and environmental issues with GE foods? What about labeling?

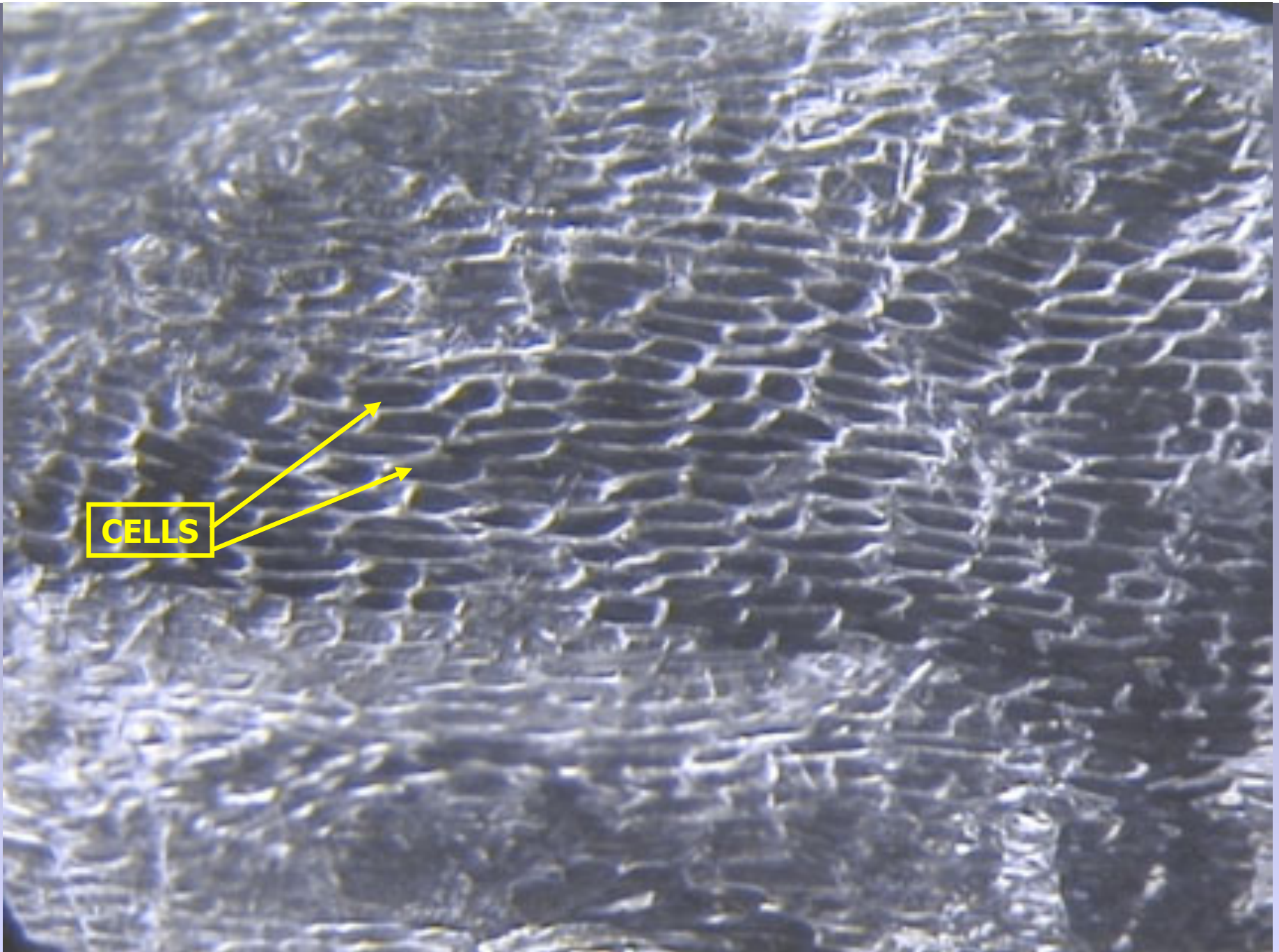
Tour d'Onion

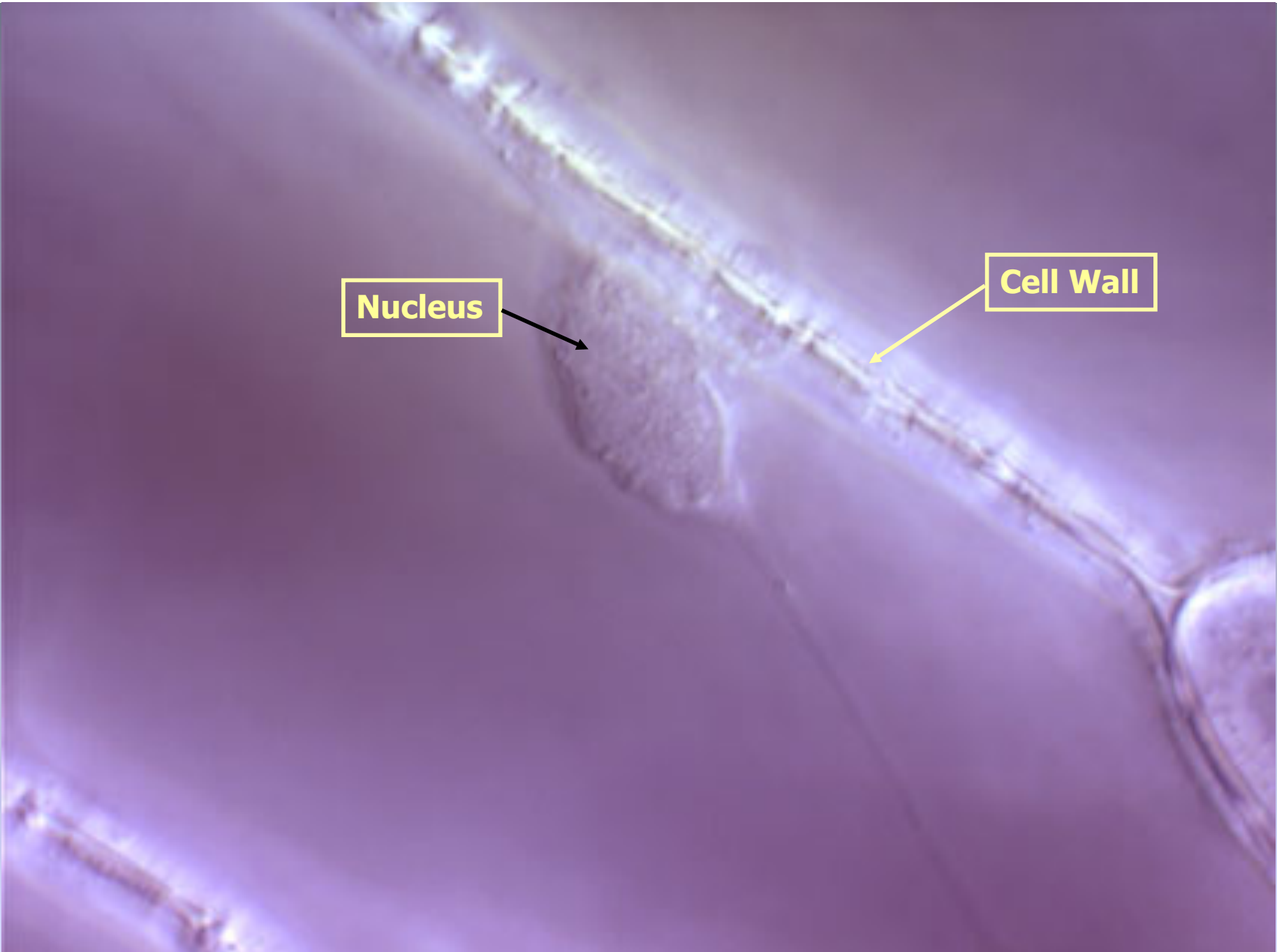


Or what makes an onion, an onion?



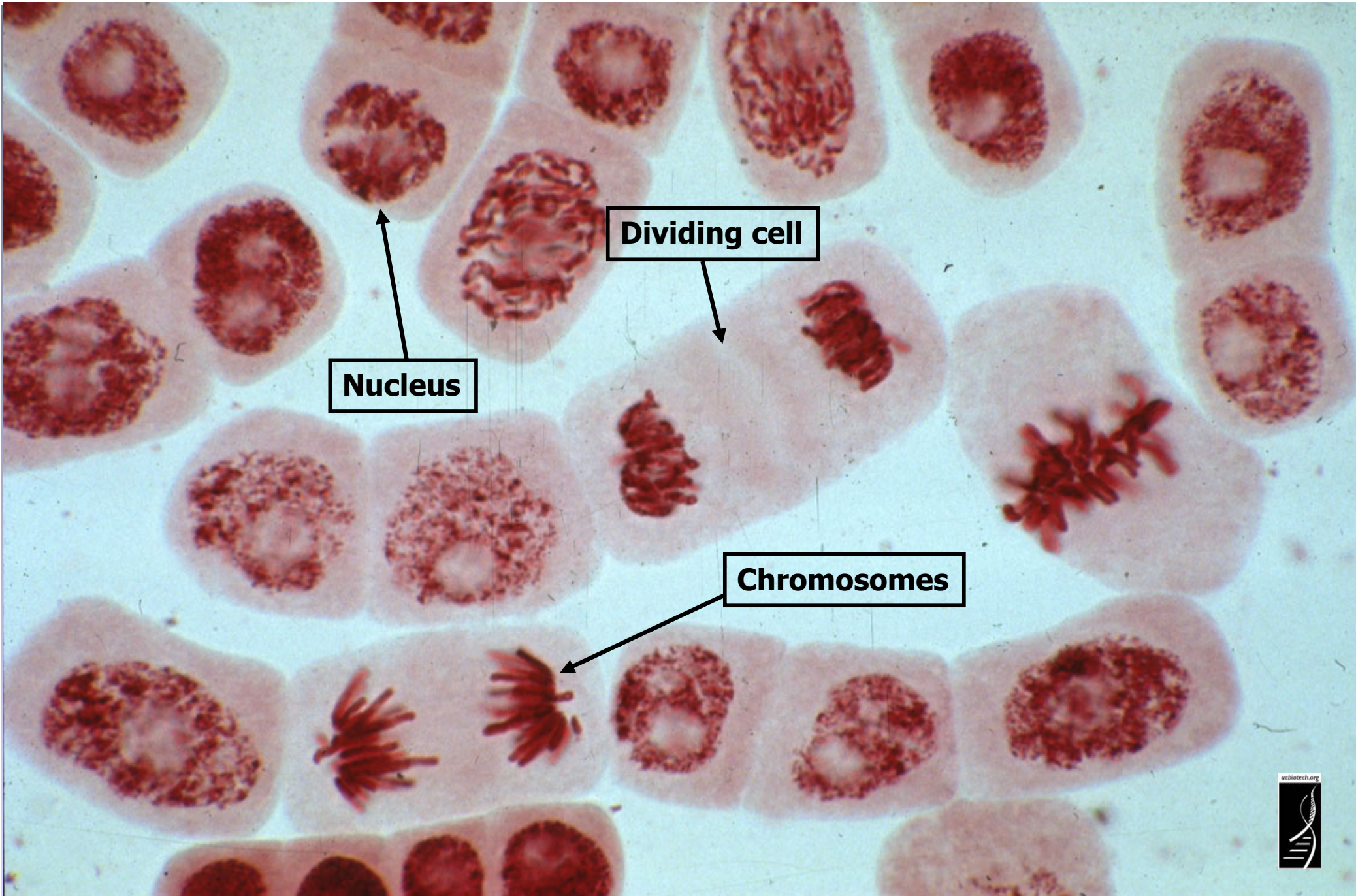
Tissue peel





Nucleus

Cell Wall



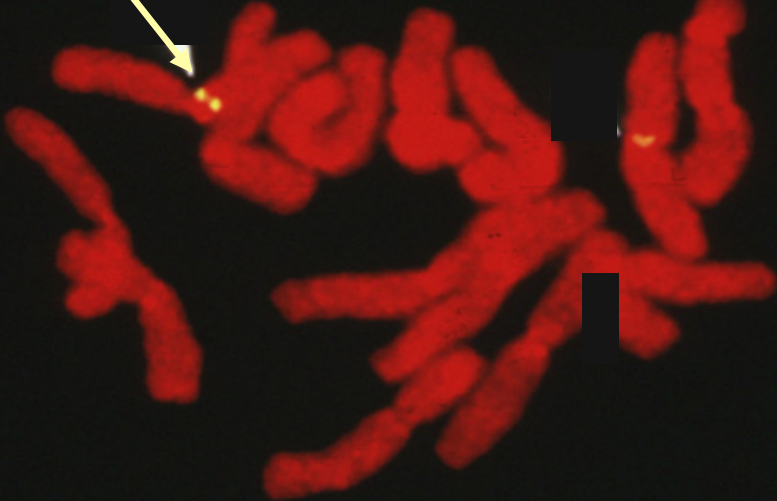
Nucleus

Dividing cell

Chromosomes

Genes

Chromosome



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



Triticum monococcum



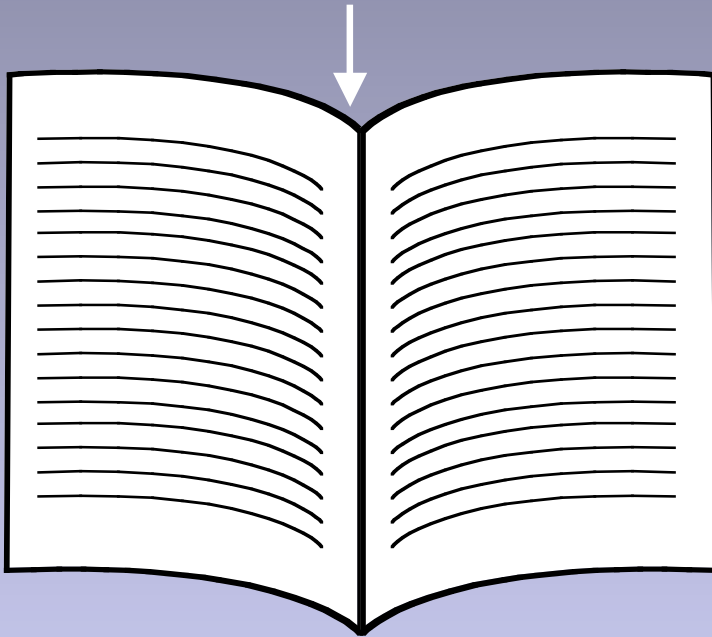
Triticum aestivum

Ancient variety Modern bread variety

Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

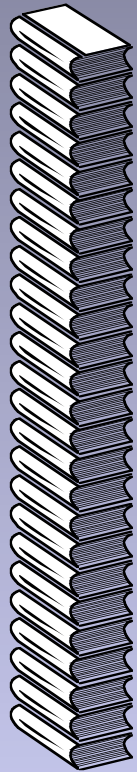


1700 books
1000 pages each

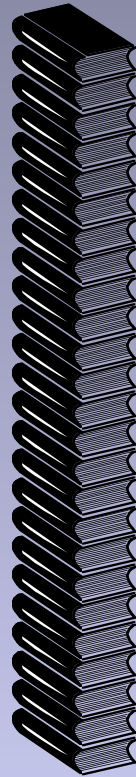


1700 books
(or 1.7 million pages)

Hybridization or cross breeding of wheat



X



Random retention of

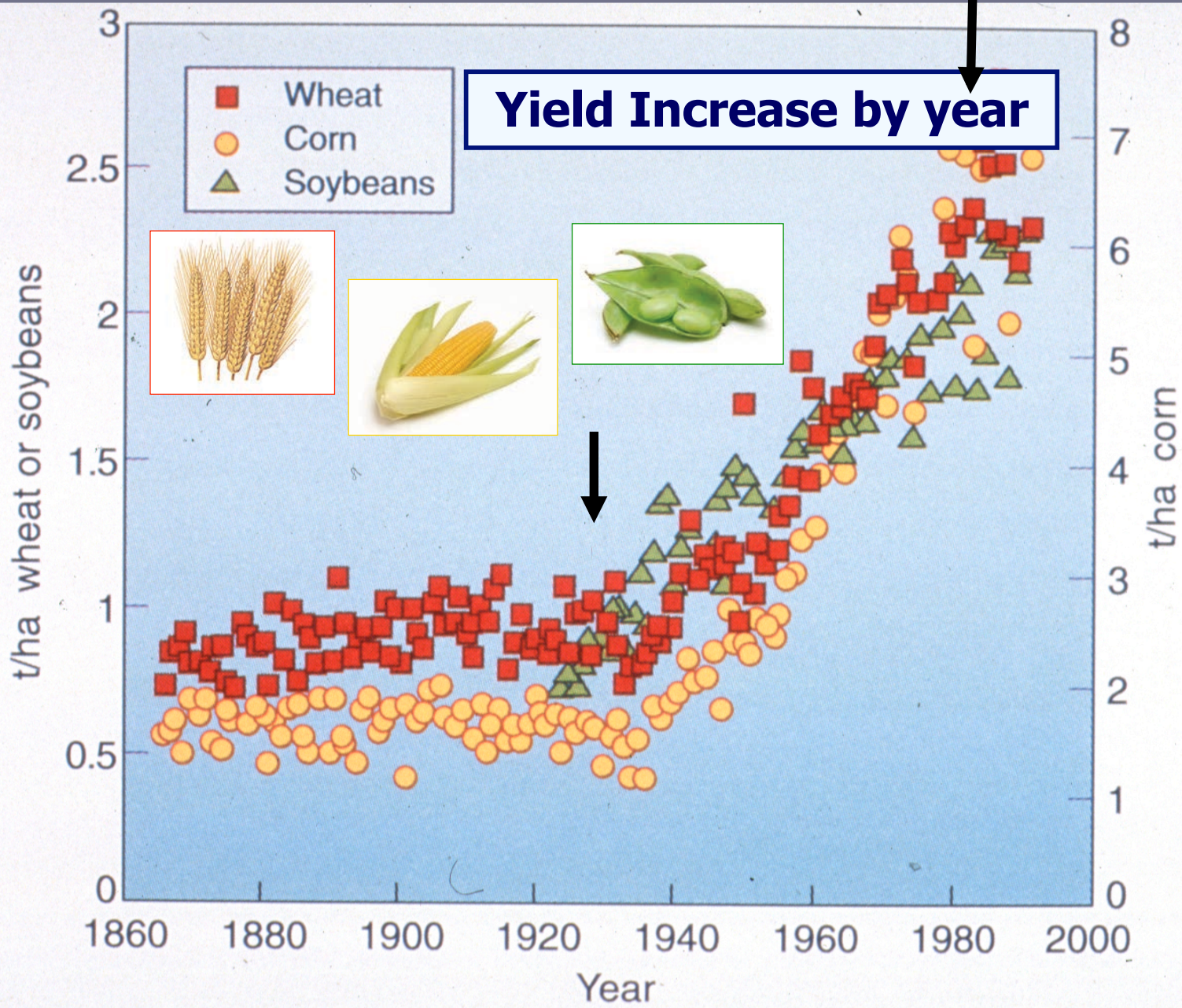
What is the outcome of the cross?
How many books are in the progeny?



1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

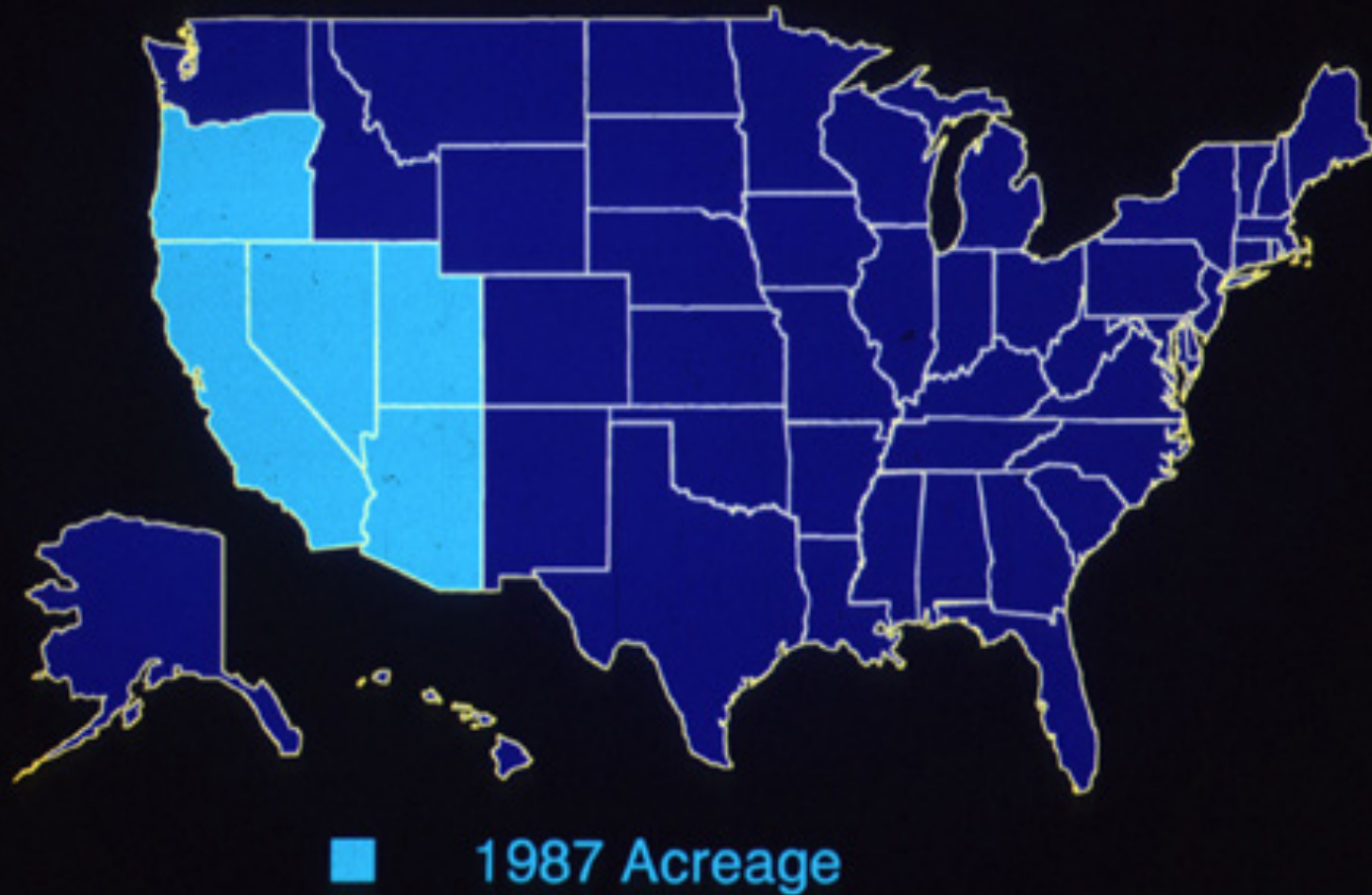


U.S. Cultivated Land



Acreage Needed at 1929 Production Levels

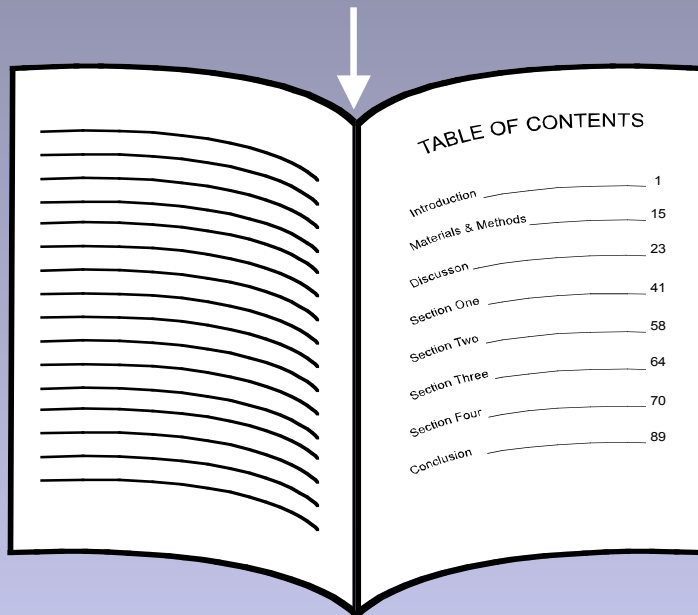
U.S. Cultivated Land



There are new ways to do breeding...

Using a table of contents for the genes
to perform marker assisted selection

...CTGACCTAATGCCGTA...




1700 books
(or 1.7 million pages)

Genomics



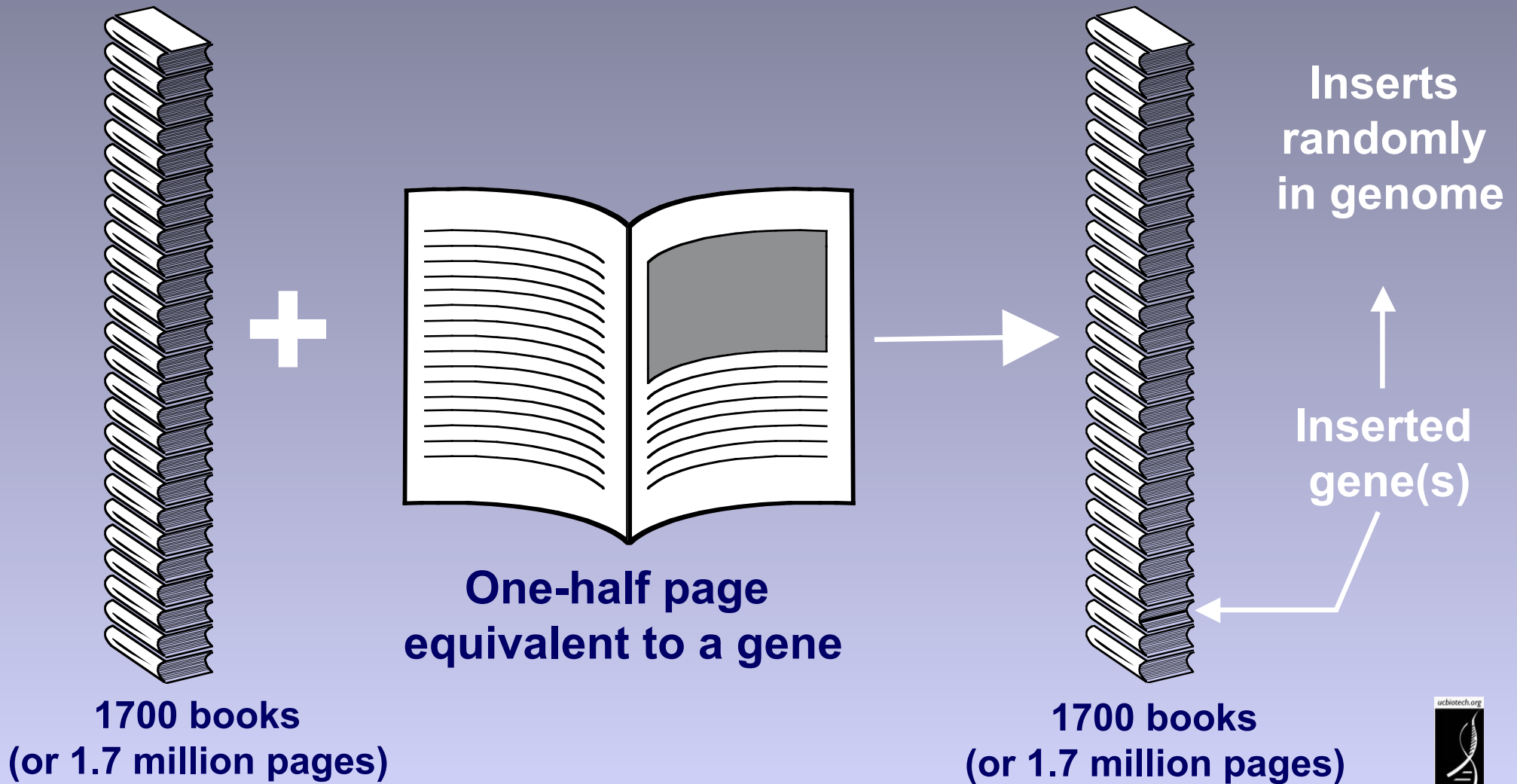
Marker-assisted selection used to protect rice against bacterial blight and blast disease

Limited to diversity in crop and compatible relatives



**But there are other ways to create
new varieties using the modern
tools of genetics**

Genetic Engineering Methods



What's the Process?

How Do You Prepare the Half Page of Information To Introduce into Plants?

On switch

Gene of interest

Off switch

Marker

On switch: controls when and where gene product is made

Off switch: turns off production of gene product

Gene of interest: foreign gene you want to put into the plant

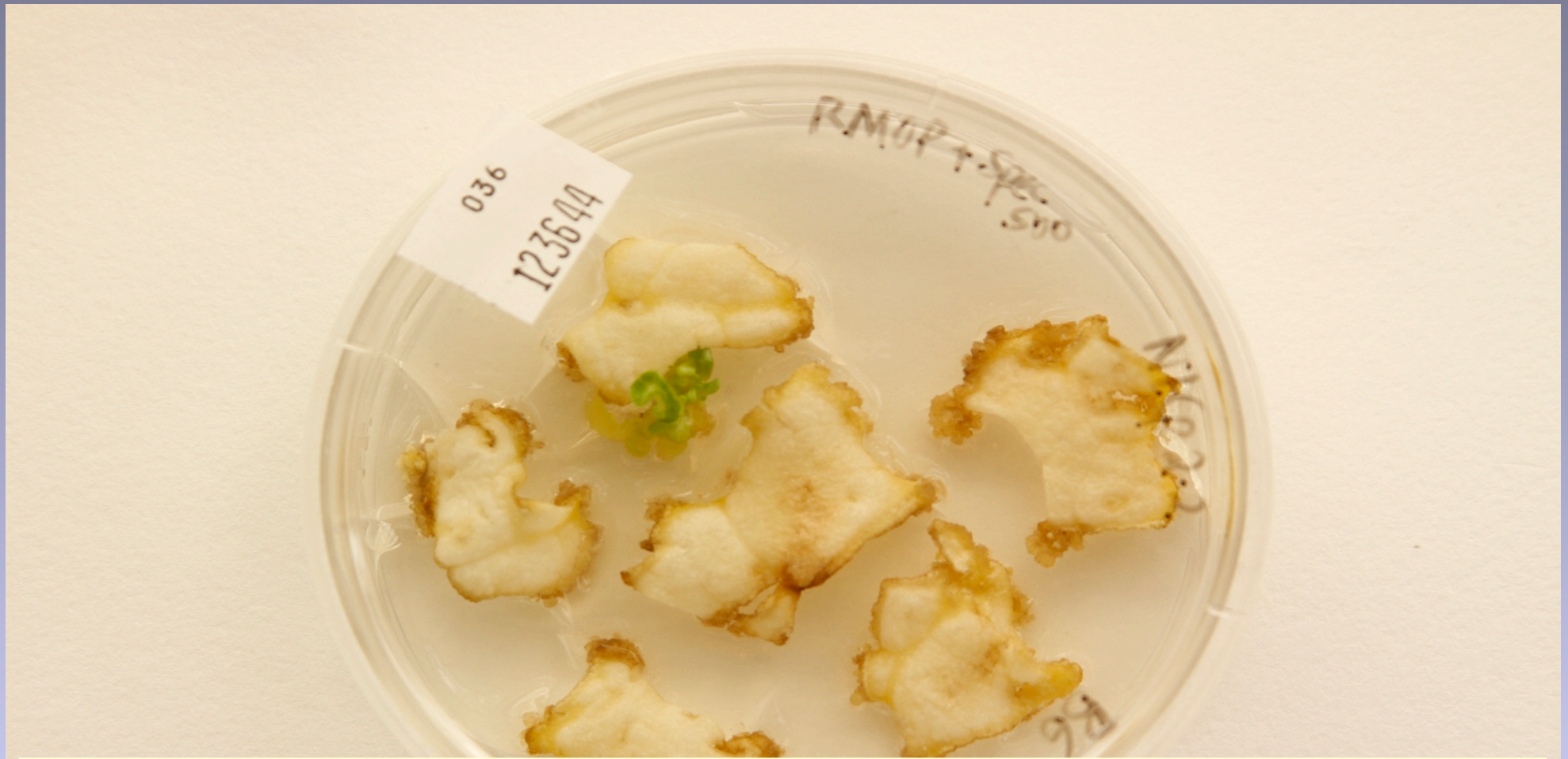
Marker: Indicates which plants have the gene of interest; antibiotic resistance, sugar usage

How Do You Get the Half Page into the Plant?

First cut pieces from the leaf. Introduce the gene with a gene gun or infect the plant tissue with a naturally occurring bacterium that transfers the gene into the plant cell



Put leaf pieces on selection for the marker gene.
Tissue without the marker gene dies, but...



A few cells that received the marker gene live and regenerate plantlet leaves, which are removed and..



Put into new medium, where leaflets expand and roots form. Plant can then be moved to soil. Every cell in the new plant now has the new genes.

*Classical
Breeding*

compared to

*Genetic
Engineering*

So How Is This Process Similar to and Different from Classical Breeding?

involving whole genome

When/where gene expressed
not controlled by breeder

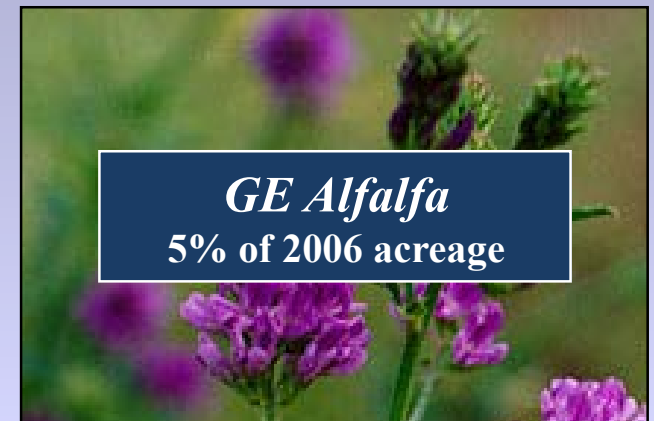
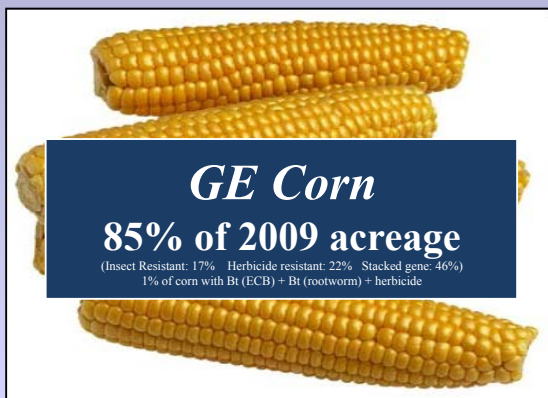
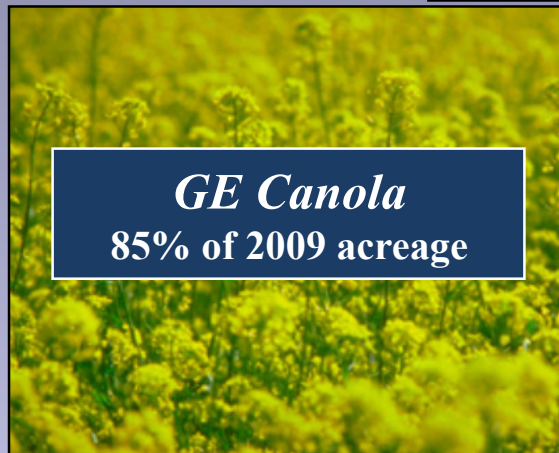
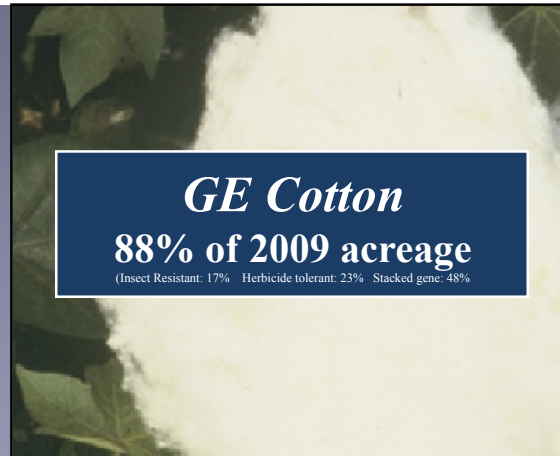
Source of gene primarily within
genera – not between kingdoms
like plants & bacteria

involving single or few genes

When/where gene expressed
controlled precisely

Source of gene from any
organism

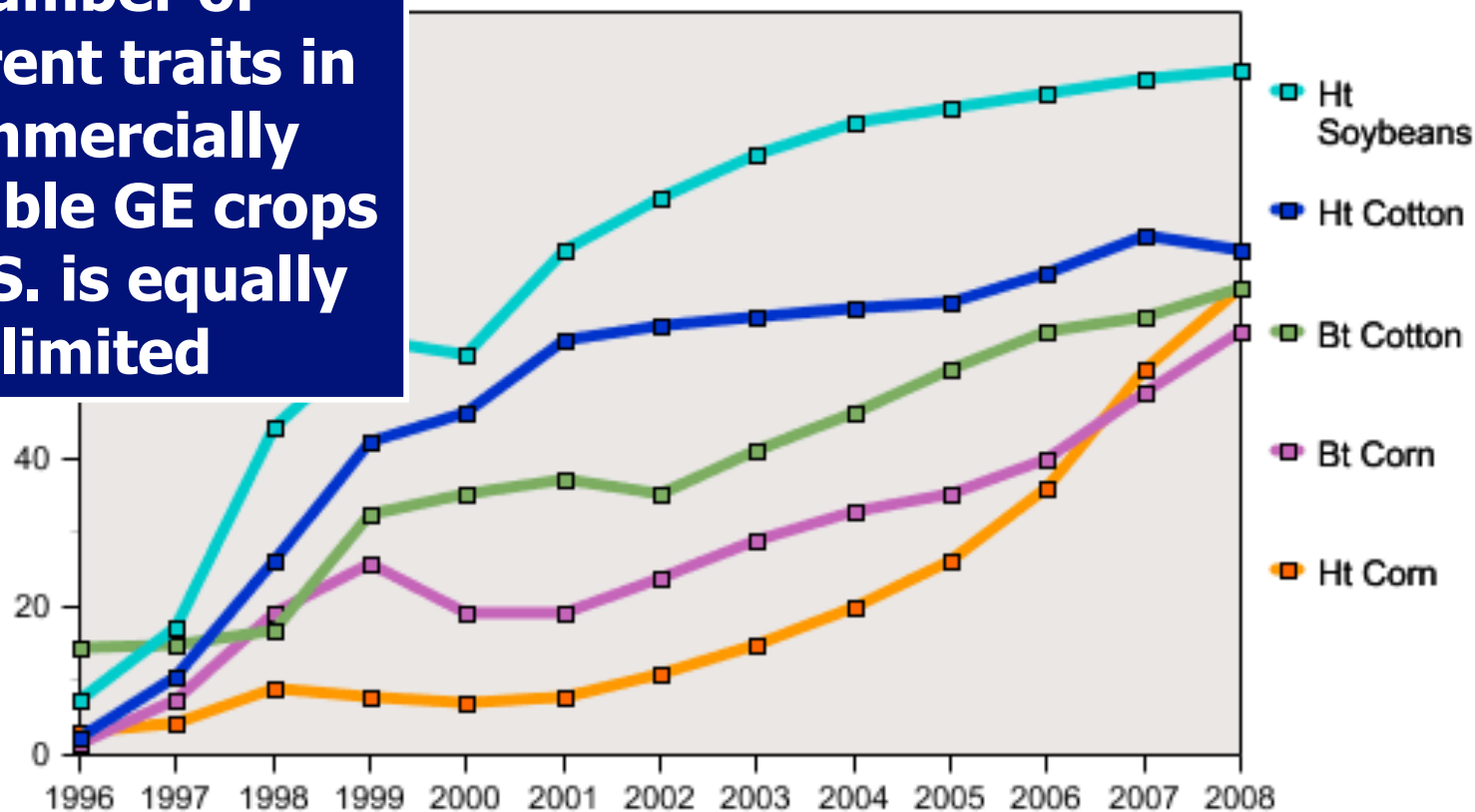
**Number of
different
commercially
available GE crops
is limited**



SOURCE: NCFAP; USDA ERS

Rapid growth in adoption of genetically engineered crops continues in the U.S.

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

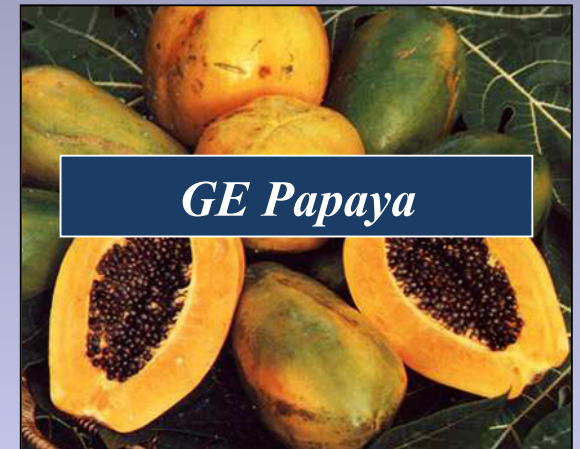


Data for each crop category include varieties with both HT and Bt (stacked) traits.
Source: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-08 are available in tables 1-3.



But these types of GE Crops Leads To Estimates that 75% of Processed Foods in U.S. Have GE Ingredients

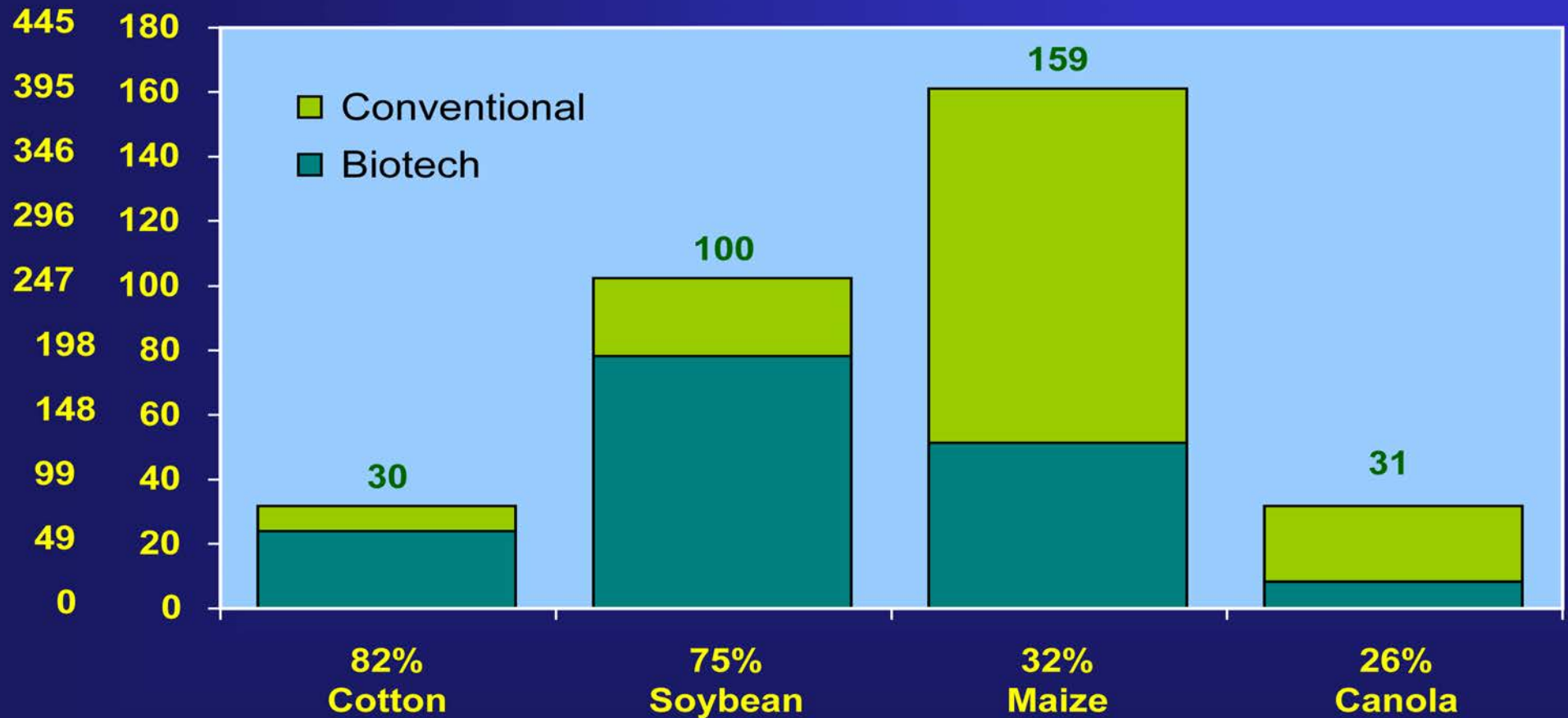
**There are a few whole,
genetically engineered
foods in the U.S market**



Worldwide adoption rates are high in 16 developing and 10 developed countries for same crops...



M Acres

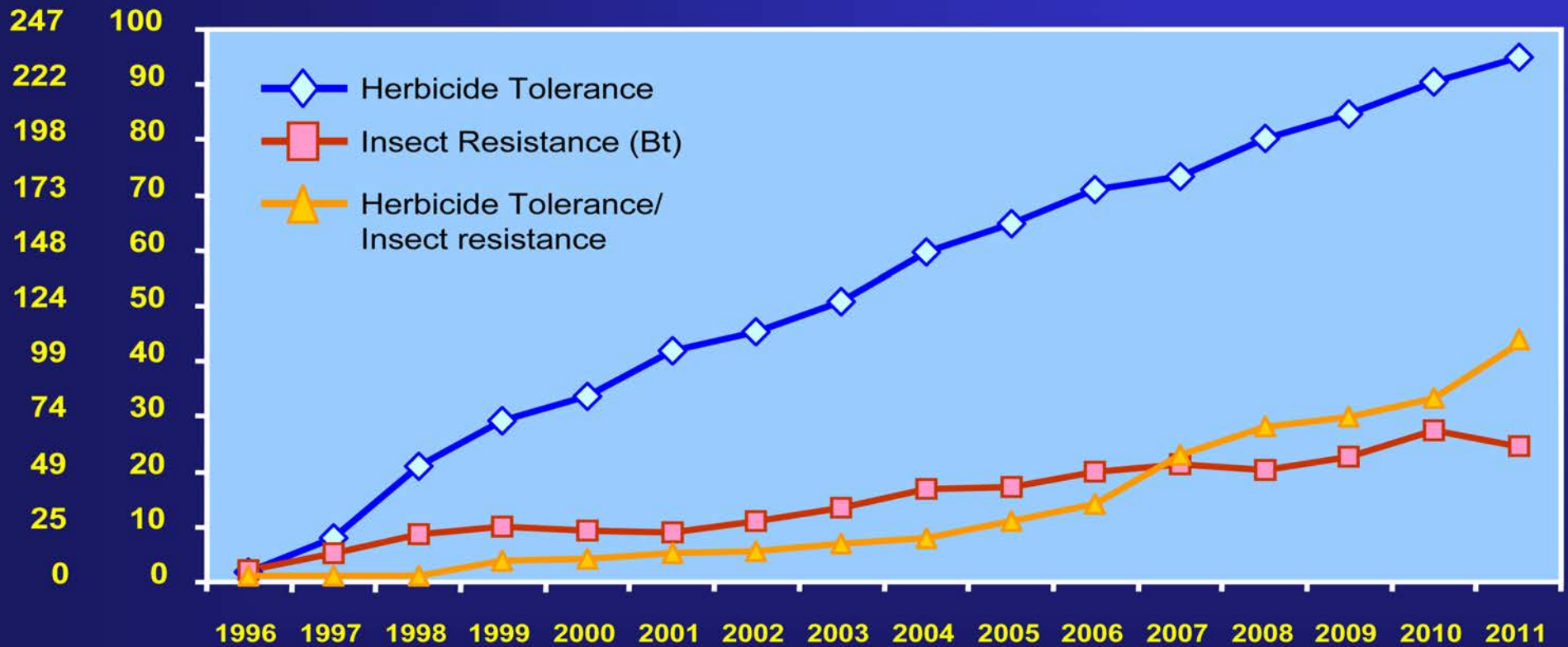


Source: Clive James, 2012

...and the same traits are used

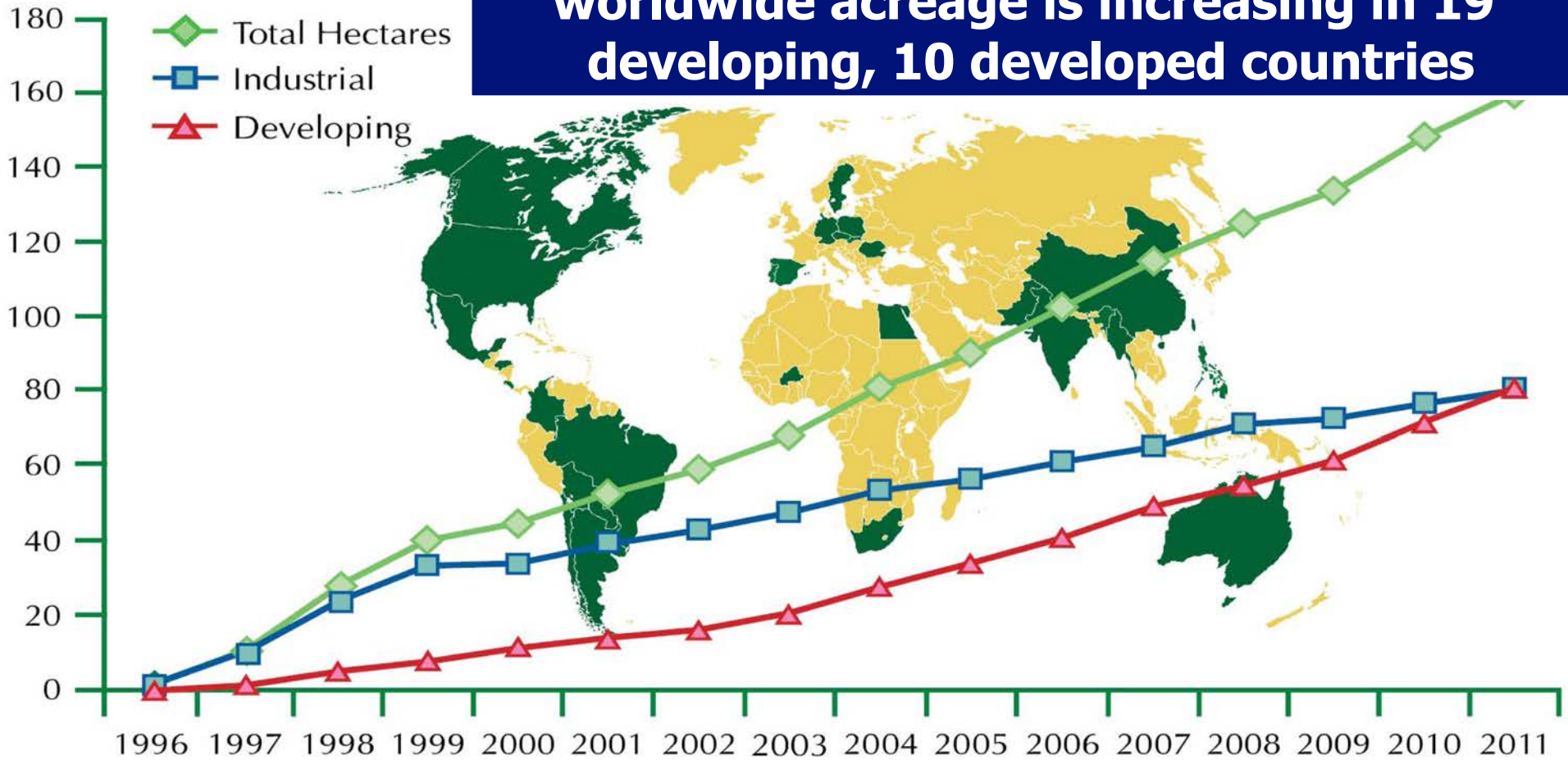


M Acres



Source: Clive James, 2012

Despite limited crop and trait types, worldwide acreage is increasing in 19 developing, 10 developed countries



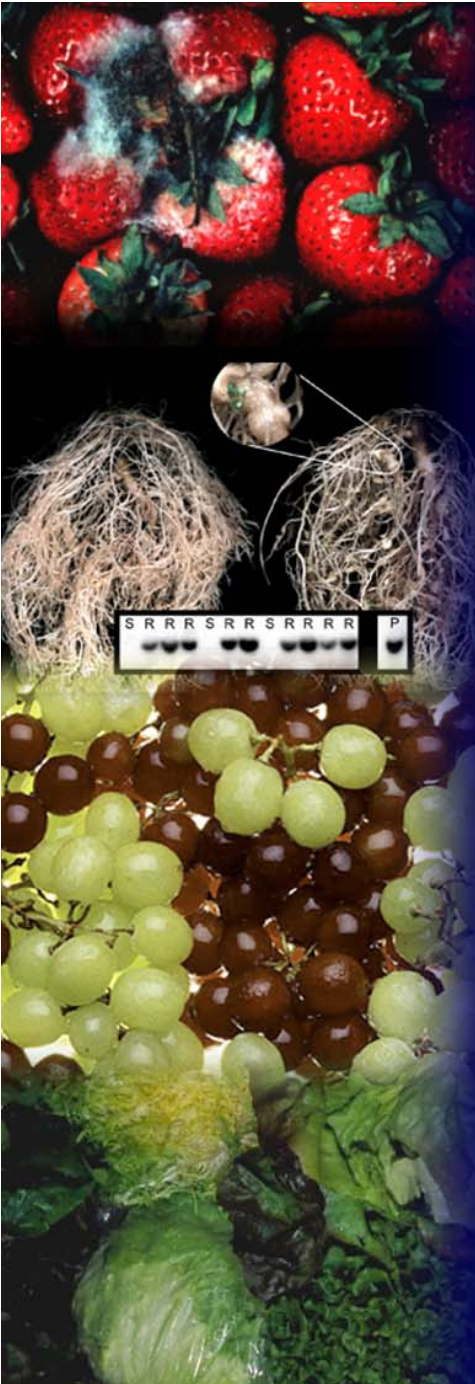
Total worldwide area cultivated = Areas of Texas + California + Nevada = 345 M acres

A

in

Sour

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>





*Australian researchers identify
grape genes that provide resistance
to powdery mildew*

SOURCE: *Western Farm Press*, volume 26, number 16

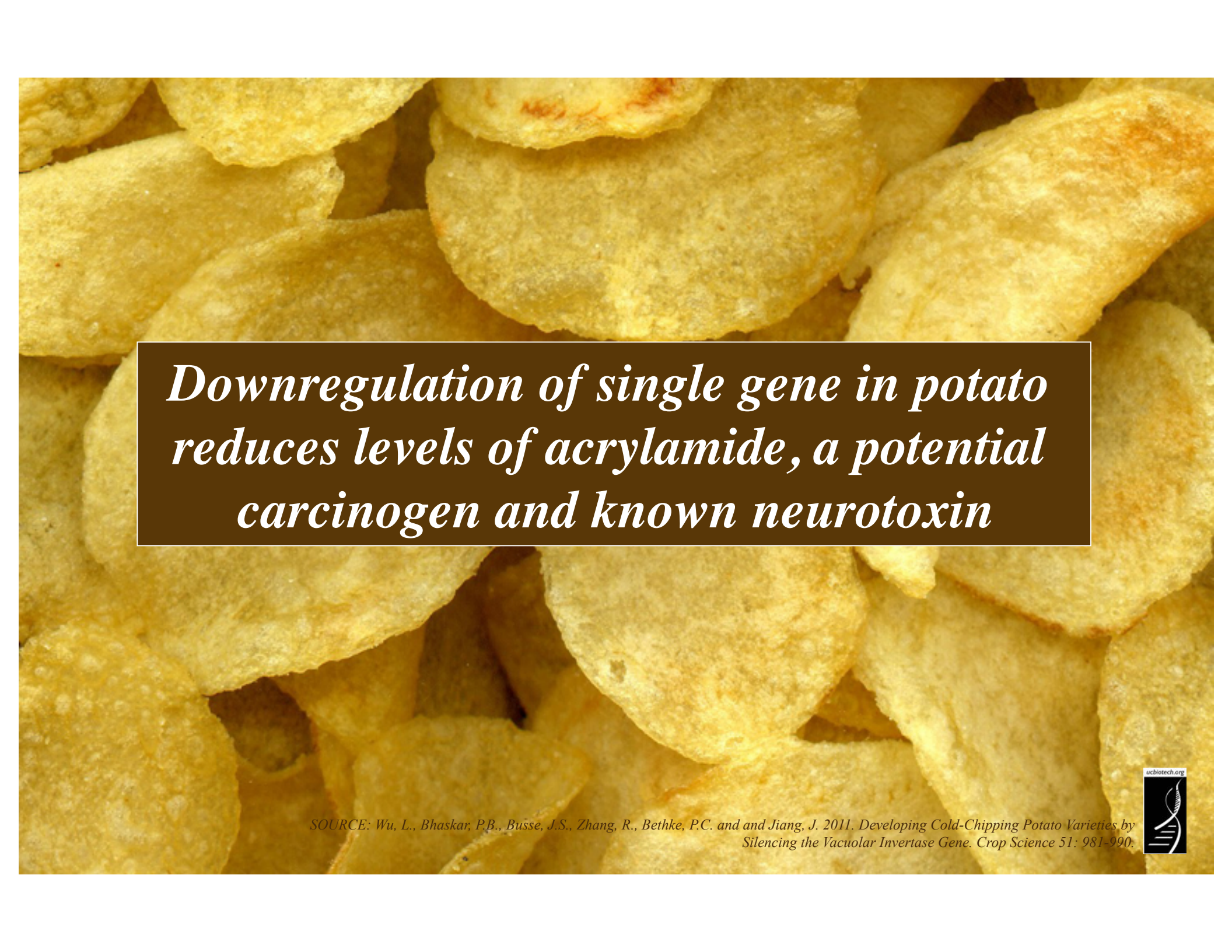




***Arcadia Biosciences develops canola
that uses 50% less nitrogen fertilizer***

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





Downregulation of single gene in potato reduces levels of acrylamide, a potential carcinogen and known neurotoxin

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



A close-up photograph of several tomatoes. The tomatoes are mostly yellowish-green, indicating they are not fully ripe. The blossom ends (the bottom of the tomatoes) are severely affected by blossom end rot, showing large, dark brown, sunken, and cracked areas. The background is a light blue surface.

*About 80% of tomatoes under conducive conditions suffer from blossom end rot.
Tomatoes engineered for high solids resist the disease*

SOURCE: "Transgenic processing tomato also resists blossom end rot", *The Grower*, 5/24/12
<http://www.thegrower.com/e-newsletters/fresh-from-the-field/Transgenic-processing-tomato-also-resists-blossom-end-rot-152327065.html>





*Non-browning GE apple 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>





***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*





*Japanese scientists create blue rose
with blue pigments from pansies*

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



*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*



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 – 86 granted

(8-11-2012)

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

Alfalfa – HT -removed

- ✓ 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
- Rose - PQ

- ✓ Large-scale production
- ❖ Not on market

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



What Are Some of the Issues?



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 environmental issues?

- **Efficacy of engineered trait?**
- **Transfer of engineered genes to non-GMO/organic crops?**
- **Spread of pharmaceutical genes into commercial crops?**
- **Loss of genetic diversity?**
- **Property rights (gene patents)?**

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

<u>Tissue</u>	<u>Bt Protein Analysis</u>
➤ white muscle (10)	Not detected
➤ dark muscle (10)	Not detected
➤ liver (10)	Not detected
➤ egg whites (10)	Not detected
➤ egg yolk (10)	Not detected

REVIEW STUDY FROM FRANCE

Twelve long-term (>90d to 2yr) and twelve multigenerational (2 to 5 generations) feeding trials in animals of GE feed showed evidence that GE foods are nutritionally equivalent to non GE foods and can be safely consumed in food and feed



maize



potato



soy



rice



triticale

SOURCE: Snell C, Bernheim A, Berge J-P, Kuntz M, Pascal G, Paris A, Ricroch AE. 2012. Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: A literature review. *Food and Chemical Toxicology* 50: 1134-1148.



Scottish microbiologist Anne Glover, a researcher on biosensors, recently took office as the first European chief scientific adviser. It appears she looks at science and technology in a different light than many Europeans.



“If we look at evidence from [more than] 15 years of growing and consuming GMO foods globally, then there is no substantiated case of any adverse impact on human health, animal health or environmental health, so that’s pretty robust evidence, and I would be confident in saying that there is no more risk in eating GMO food than eating conventionally farmed food...it has nothing to do with genetic engineering... I would argue that we use every technical possibility – not just GMOs – it requires every tool in our toolkit to deliver.”

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

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**

National GM Labeling Laws and Policies

Type of GM labeling	Countries that enforce labeling policies	Countries with partially enforced or unenforced labeling policies	Countries with probable plans to introduce a labeling policy
Mandatory	Australia, Brazil, China, European Union, Japan, New Zealand, Norway, Russia, Saudi Arabia, South Korea, Switzerland, Taiwan	Croatia, Ecuador, El Salvador, Indonesia, Malaysia, Mauritius, Serbia, Sri Lanka, Thailand, Ukraine, Vietnam	Nigeria, Uganda, UAE, Zambia
Voluntary	Argentina, Canada, Chile, Hong Kong, Kenya, Philippines, South Africa, USA		Peru

Other nations have mandatory labeling laws that vary dramatically from country to country, making international trade problematic

SOURCE: Marchant, G.E., Cardineau, G.A. and Redick, T.P. 2010. Thwarting Consumer Choice: The Case against Mandatory Labeling for Genetically Modified Foods. American Enterprise Institute, p. 71.





ucbiotech.org

SCIENCE-BASED INFORMATION & RESOURCES
ON AGRICULTURE, FOOD & TECHNOLOGY

Issue:

What Will and Won't Be Labeled Under the California Labeling Initiative?

Response:

California consumers would not be the first to encounter labeling of genetically engineered (GE) products in the marketplace if the CA Labeling Initiative were to pass. In 1996, British consumers were met with a tomato paste labeled as being "produced from genetically modified tomatoes". That product is no longer on the market but today there is vegetable oil made from GE soybeans on shelves in the U.K.

The purpose of the [California Labeling Initiative](#) is "...to create and enforce the fundamental right of the people of California to be fully informed about whether the food they purchase and eat is genetically...

California will vote on its own labeling law in November but, if passed, law suits will likely follow

not separately packaged or labeled, the label must be on the shelf or bin where the product is displayed.

- For any processed foods, unless exempted (see below), there must be clear and conspicuous language on front or back of package stating, "**Partially Produced with Genetic Engineering**" or "**May be Partially Produced with Genetic Engineering**".

ucbiotech.org



CA Labeling Initiative

Labeling Relating to Genetic Engineering

Any product offered for retail sale in CA that has been or may have been partially or wholly produced with genetic engineering must be labeled. Any

“One way (foods could be labeled) is that processed foods could be labeled "natural" only if they are free of GE ingredients. But Lemaux says the initiative could also be interpreted as saying that no processed food can be labeled "natural", whether or not it is GE or contains GE ingredients.”

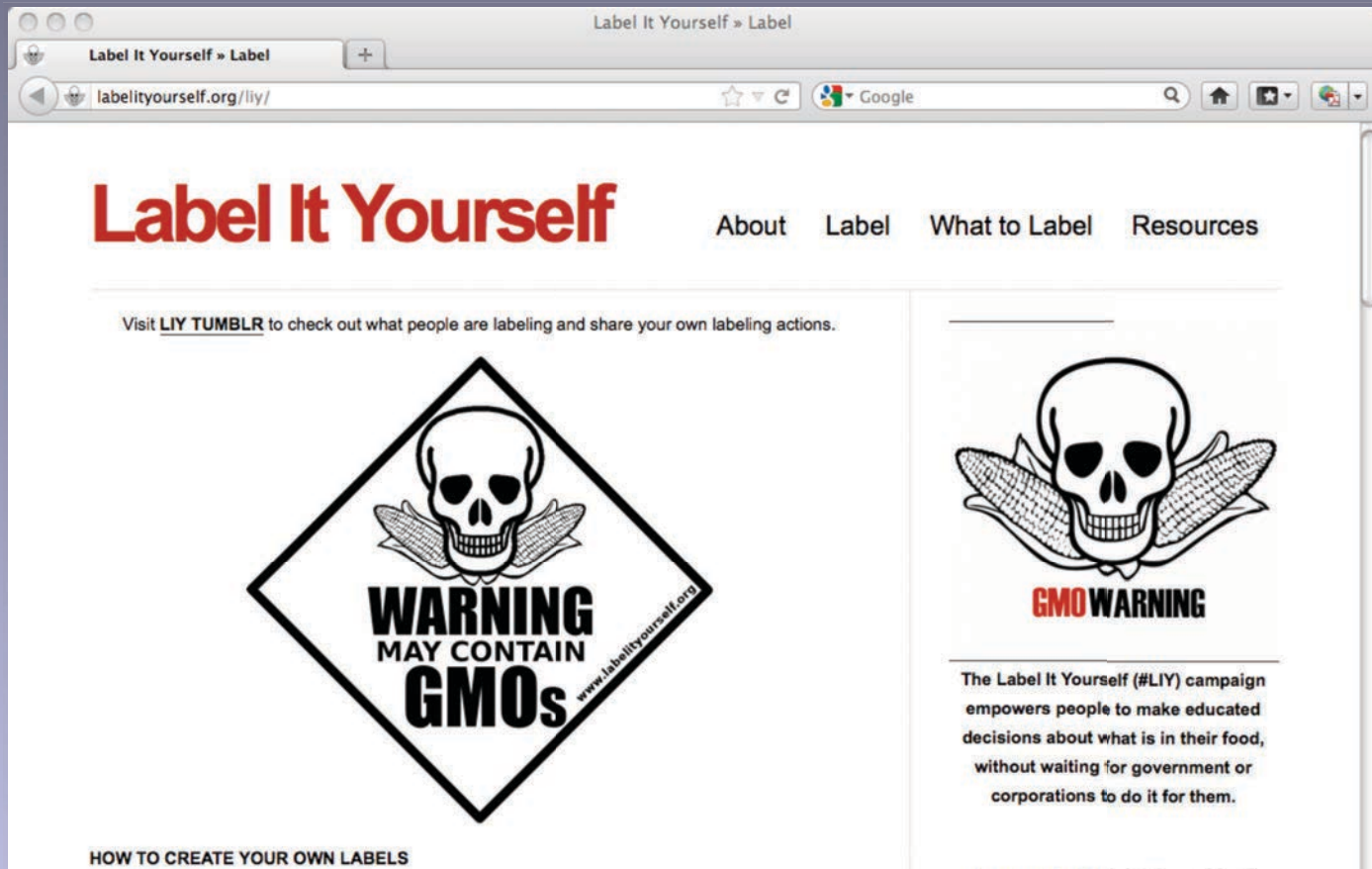
NPR Food Blog, Eliza Barclay May 14, 2012

Similar viewpoint shared in an Aug. 8 article in *Los Angeles Times* by Karin Klein

Processed food is defined as “any food other than a raw agricultural commodity and includes any food produced from a raw agricultural commodity that has been subject to processing such as canning, smoking, pressing, cooking, freezing, dehydration, fermentation or milling.”

What Exemptions Are There to Labeling?

- Animals that are not genetically engineered regardless of whether fed with GE feed or injected with GE drugs.
- Raw commodities or foods grown without intentional use of GE seed or food.
- Foods certified as “organic”.
- Any processed food, which would otherwise be labeled solely because it had one or more GE processing aids or enzymes.
- Processed foods containing one or more GE substances, like enzymes, added during processing but that are removed from or are present in very low amounts in the finished product.
- Alcoholic beverages.
- Processed food where no one ingredient is >0.5% of weight of processed).
- Processed food for immediate consumption in restaurants.
- Medical food.



But some are not waiting and have started their own labeling “initiative”

SOURCE: <http://labelityourself.org/liy/>



What Do Consumers Think?

If asked directly if they want genetically engineered foods to be labeled, the great majority of Americans say yes.

Age	
<35	94.1%
35-64	93.6%
65+	89.7%
Total	93.1%

Income	
<\$25k	92.5%
\$25k - \$49.9k	96.1%
\$50k - \$99.9k	91.5%
\$100k+	92.0%
Total	93.1%

Education	
High School or Less	95.1%
Some College	95.2%
College+	91.1%
Total	93.1%

Interest in Adding Information to Current Food Labels

Most Americans do not wish to see any additional information on food labels

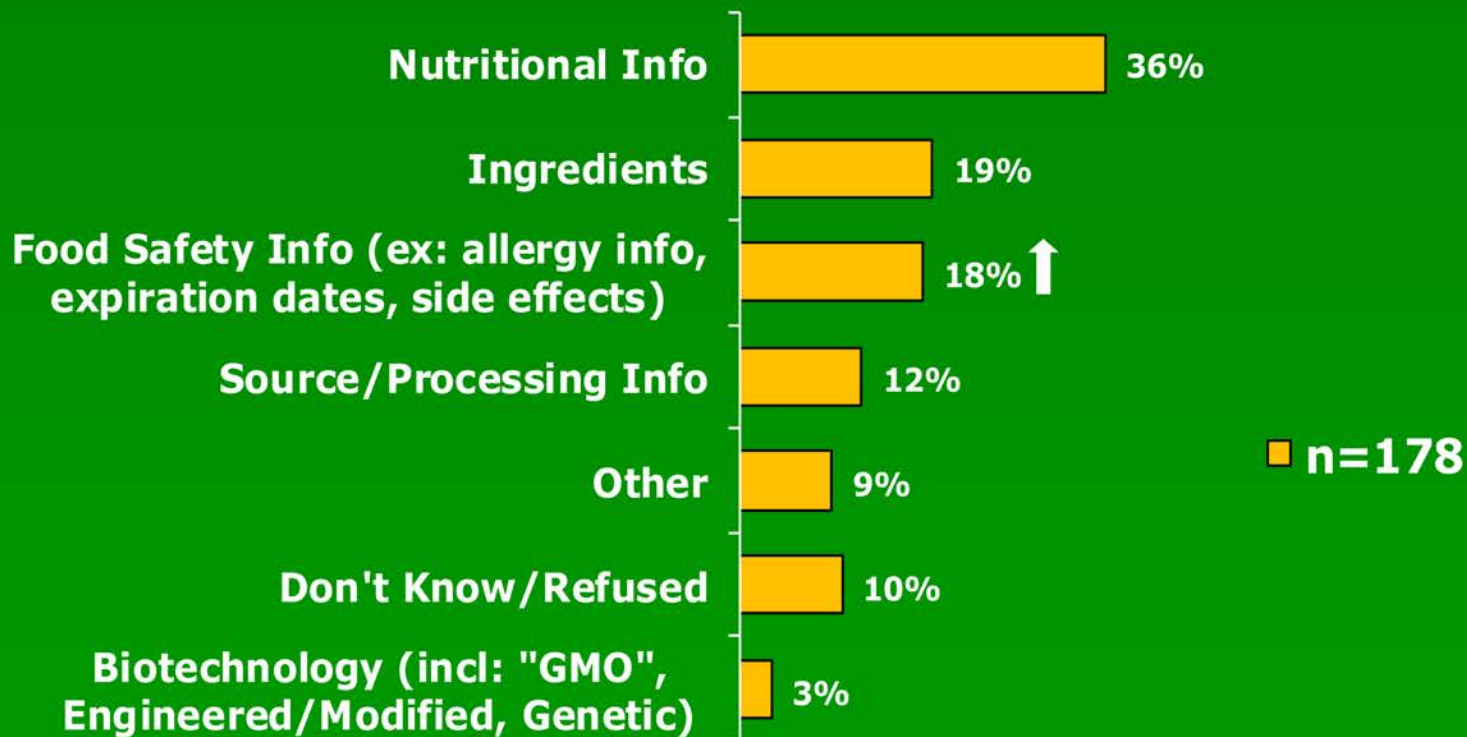


But, if asked if there is any information they would like to see on labels unprompted, most Americans say they don't want more information...
but number is increasing

Q 10. [IF YES] What types of information would that be? [OPEN END]
*Those who said "Nothing" or "Don't know" to Q10 were recoded as "No" answers in Q2.

More Label Information Desired

And, if unprompted, information about GMO content is not high on their list of additional label information



Q 9 . Can you think of any information that is not currently included in food labels that you would like to see on food labels?

Q10. [If yes . . .] What types of information would that be? [OPEN-END]

Why not just label?



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

...processed foods are different.
 Tomato sauce contains
 many varieties – a GM variety would
 have to be tracked to assure correct
 content information, depending on
 type of label required.



May contain
 genetically modified
 tomatoes



Contains
 genetically modified
 tomatoes

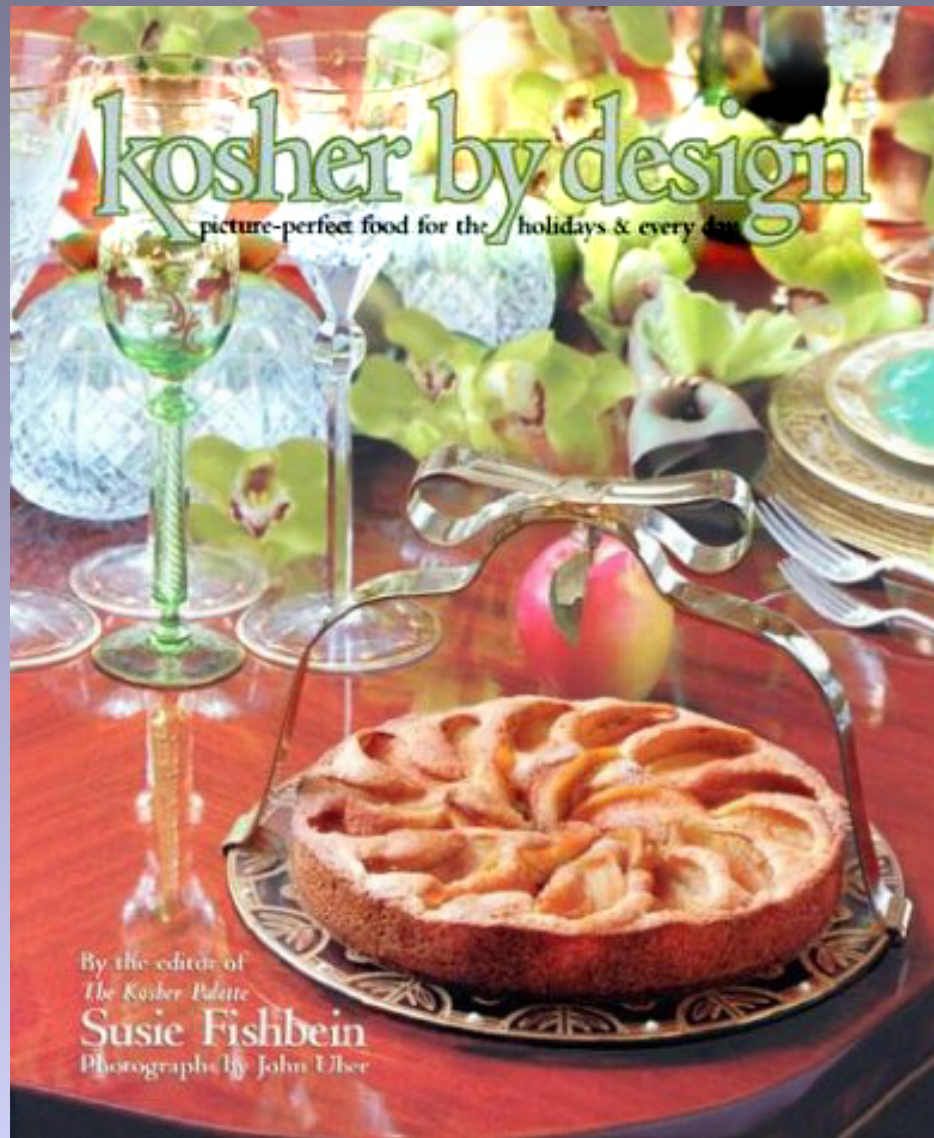


But there are foods that are tracked for consumer choice... like organic and...



...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 products for which people pay a premium price and for which farmers are paid premium prices to grow them?

And some companies are not waiting for changes in labeling laws. They have stepped up to fill this demand



Organic feed company carves out niche free of biotech ingredients

Effort grew out of customer fears of genetically modified soy products

By **STEVE BROWN**
Capital Press

BELLINGHAM, Wash. — Scratch and Peck Feeds is the first feed company in North America to be certified as a source of nongenetically modified products.

Owner Diana Ambauen-Meade started the company

in 2009, obtaining organic grain from Pacific Northwest farmers and formulating feed for chickens, turkeys and pigs. Her feeds are sold online and at more than 70 retailers in the West.

The feed company was certified July 9 by the Non-GMO Project, which since 2005 has put its stamp of approval on nearly 300 businesses and 5,000 products in the U.S. and Canada.

Those businesses include restaurants and food processors that make products ranging from boxed cereals and

baking mixes to confections and bee products.

Courtney Pineau, communications manager for the non-profit, said 60 percent of the companies verified are certified organic, but they want to go above those standards.

"The National Organic Program identifies genetic engineering as an excluded method but not as a prohibited substance," she said. "Many biotech crops are being planted with genetically modified traits, which risk contamination of organic crops. If you don't test, you don't know."

However, she said, "We never call something GMO-free, only non-GMO."

The Non-GMO Project started at a small natural grocery store in Berkeley, Calif. In response to letters from customers concerned about a genetically modified soy lecithin the store was carrying, a group of employees initiated the "People Want to Know Campaign."

That effort grew to include 161 grocery stores and co-ops in a letter-writing campaign to manufacturers of natural food products and supplements.



Capital Press file photo

A package of Scratch and Peck feed labels its contents as non-GMO. The company was recently certified as such by the Non-GMO Project, which uses a third-party to test for the presence of biotech traits.

They discovered there was no consistent, industry-wide standard for nonbiotech crops.

In cooperation with a third party, FoodChain Global Ad-

visors, the Non-GMO Project established a product verification program that includes traceability, segregation and testing at critical control points.

SOURCE: "Organic feed company carves out niche free of biotech ingredients", Capital Press, July 26, 2012
<http://www.capitalpress.com/content/SB-Non-GMO-Project-071112-art>



Now to some environmental issues?

- **Efficacy of engineered trait?**
- **Transfer of engineered genes to non-GMO/
organic crops?**
- **Spread of pharmaceutical genes into
commercial crops?**
- **Loss of genetic diversity?**
- **Property rights (gene patents)?**

What are some environmental issues?

- Efficacy of engineered trait?
- **Transfer of engineered genes to non-GMO/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**



Can Organic Agriculture Coexist with GE Crops?

Capital Press, September 16, 2005

Communicate to avoid pesticide drift, winemaker says

By **MATEUSZ PERKOWSKI**
Freelance Writer

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



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

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



MATEUSZ PERKOWSKI/For the Capital Press

David Adelsheim 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.

What is Co-existence

- Development of best management practices to minimize adventitious presence of unwanted material***
- 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***

One of the most divisive issues regarding coexistence is idea 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 discussion is impossible. Dualism (right versus wrong) – jeopardizes compromise



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

**...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.”



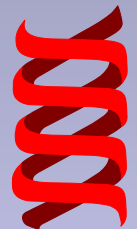
...And What Genetic Modification Input Methods Are PROHIBITED?

(§ 205.2 National Organic Program)

- “A variety of methods...are not considered compatible with organic production. Such

Are There Tolerances for GE in Organic Products?

positions of genes when achieved by recombinant DNA technology).”



There are tolerances for pesticides but not for GM content

☞ 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

Where to
get more
information
on the
issues?

ucbiotech.org - Science-Based Information and Resources on Agriculture, Food and Technology

ucbiotech.org - Science-Based I...

ucbiotech.org/index.html

Google



ucbiotech.org

SCIENCE-BASED INFORMATION & RESOURCES
ON AGRICULTURE, FOOD & TECHNOLOGY

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

Annual Review Articles | Issues & Responses

Select Language

know GMOS

This website provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them. Science-based information related to these issues is available, as well as educational tools and information, which can be used to promote informed participation in discussions about these topics.

FEATURED PRESENTATION



How Much Did You Pay for Your Lunch Today?

Center for Practical and Professional Ethics
California State University, Sacramento
February 7, 2012

BIOTECHNOLOGY INFORMATION



ANNUAL REVIEWS

Review articles:
Focused on food, environmental and socioeconomic issues of GE crops and foods.
[Part 1](#) | [Part 2](#)

RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS

DNA for Dinner 4-H curriculum:
For grades 5-8, covers topics from plant diversity to genetic engineering. Each of the five lessons has 3 to 5 activities.



DNA FOR DINNER?



Who's in YOUR family?

New Game: Who's In Your Family?
A free educational game to teach participants about the diversity of fruits and vegetables, and how they are related.

Slide Archive:
Extensive collection of PP slides on agriculture & biotechnology.

Available on loan:

Teaching Aids: Handouts and cards available, in both English and Spanish.



Educational displays: "Genetics and Foods" and "Genetic Diversity and Genomics" available with companion educational cards and teacher

HELPFUL SITES

Academics Review
Academics Review website
Testing popular claims against peer-reviewed science.

Biofortified website
Provides factual information to foster discussion about agriculture, especially plant genetics and genetic engineering.

Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis



Provides education on use of animal genomics & biotechnology in livestock production.



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

ucbiotech.org - Science-Based Information and Resources on Agriculture, Food and Technology

ucbiotech.org - Science-Based I...

ucbiotech.org/index.html

ucbiotech.org

SCIENCE-BASED INFORMATION & RESOURCES ON AGRICULTURE, FOOD & TECHNOLOGY

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

Annual Review Articles | Issues & Responses

Select Language

know GMOS

This website provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them. Science-based information related to these issues is available, as well as educational tools and information, which can be used to promote informed participation in discussions about these topics.

FEATURED PRESENTATION

How Much Did You Pay for Your Lunch Today?

Center for Practical and Professional Ethics
California State University, Sacramento
February 7, 2012

BIOTECHNOLOGY INFORMATION

ANNUAL REVIEWS

Review articles:
Focused on food, environmental and socioeconomic issues of GE crops and foods.
[Part 1](#) | [Part 2](#)

RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS

DNA for Dinner 4-H curriculum:
For grades 5-8, covers topics from plant diversity to genetic engineering. Each of the five lessons has 3 to 5 activities.

DNA FOR DINNER?

New Game: Who's In Your Family?
A free educational game to teach participants about the diversity of fruits and vegetables, and how they are related.

Slide Archive:
Extensive collection of PP slides on agriculture & biotechnology.

Available on loan:

Teaching Aids: Handouts and cards available, in both English and Spanish.

Educational displays: "Genetics and Foods" and "Genetic Diversity and Genomics" available with companion educational cards and teacher

HELPFUL SITES

Academics Review
Academics Review website
Testing popular claims against peer-reviewed science.

Biofortified website
Provides factual information to foster discussion about agriculture, especially plant genetics and genetic engineering.

Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis
Provides education on use of animal genomics & biotechnology in livestock production.





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.

ucbiotech.org - Issues and Responses

ucbiotech.org - Issues and Res... +

ucbiotech.org/search4.php

Google

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

ISSUES & RESPONSES

[Search Again?](#)

Your search for *bt corn safe to eat?* returned the following results

Results are given in order of relevance

Are Food Safety Studies Conducted on GE Foods? [Response](#)

Besides Genetically Engineered Crops, Does Genetic Engineering Play a Role in Producing Food? [Response](#)


Were Foods Made From Bt Corn Removed from the Market Because of Allergenicity Concerns? [Response](#)

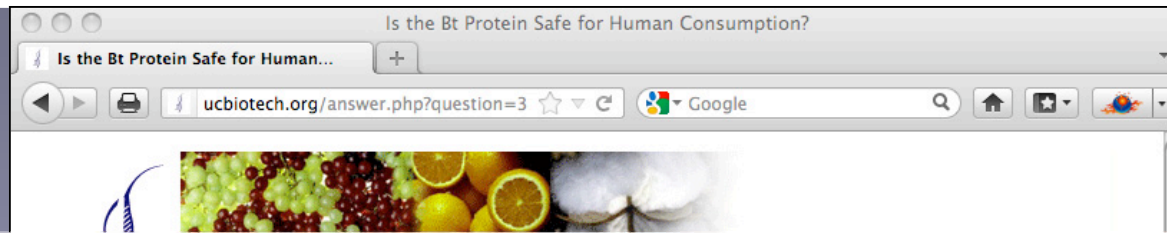
Is the Bt Protein Safe for Human Consumption?

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 ... [Read more...](#)

Filed under [Food Risks] [Food Safety] [Pest Tolerance] [Regulation]

Can Federal Regulatory Agencies Stop Planting of Genetically Engineered Crops That Pose Environmental Risks? [Response](#)





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?

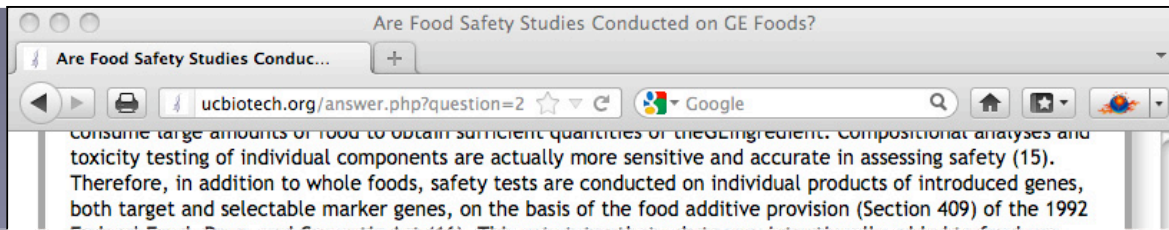
Response:

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



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

References:

1. Food Drug Adm. (FDA). 2005. Guidance for industry: Pharmacogenomic data submissions. <http://www.fda.gov/downloads/.../Guidances/ucm126957.pdf> Last accessed 2011-11-26. PDF

Now on to the topic at hand...

<http://www.epa.gov/scipoly/biotech/pubs/framework.htm>. Last accessed 2011-12-8. PDF

4. Kuiper HA, Kleter GA, Noteborn HPJM, Kok EJ. 2001. Assessment of the food safety issues related to genetically modified foods. *Plant J.* 27:503-28

5. Kessler DA, Taylor MR, Maryanski JH, Flamm EL, Kahl LS. 1992. The safety of foods developed by biotechnology. *Science* 256:1747-49

6. Berberich SA, Ream JE, Jackson TL, Wood R, Stipanovic R, et al. 1996. The composition of insect-protected cottonseed is equivalent to that of conventional cottonseed. *J. Agric. Food Chem.* 44:365-71

7. Sidhu RS, Hammond BG, Fuchs RL, Mutz J-N, Holden LR, et al. 2000. Glyphosate-tolerant corn: The composition and feeding value of grain from glyphosate-tolerant corn is equivalent to that of conventional corn (*Zea mays* L.). *J. Agric. Food Chem.* 48:2305-12

8. Taylor NB, Fuchs RL, MacDonald J, Shariff AR, Padgett SR. 1999. Compositional analysis of glyphosate-tolerant soybeans treated with glyphosate. *J. Agric. Food Chem.* 47:4469-73

9. Kahle K, Kraus M, Richling E. 2005. Polyphenol profiles of apple juices. *Mol. Nutr. Food Res.* 49:797-806

10. Chassy B, Hlywka JJ, Kleter GA, Kok EJ, Kuiper HA, et al. 2004. Nutritional and safety assessments of foods and feeds nutritionally improved through biotechnology: An executive summary. *Compr. Rev. Food Sci. Food Saf.* 3:25-104
Provides scientific information and recommendations on safety and nutritional aspects of crops with improved nutritional qualities.

11. Flachowsky G, Aulrich K, Böhme H, Halle I. 2007. Studies on feeds from genetically modified plants (GMP)—Contributions to nutritional and safety assessment; Table 3. *Anim. Feed Sci. Technol.* 133:2-30

12. König A, Cockburn A, Crevel RWR, Debruyne E, Grafstroem R, et al. 2004.



Genetically Engineered Plants and Foods: A Scientist's Analysis of the Issues (Part I)

Peggy G. Lemaux

Department of Plant and Microbial Biology, University of California, Berkeley, California 94720; email: lemauxpg@nature.berkeley.edu

Annu. Rev. Plant Biol. 2008. 59:771-812
First published online as a Review in Advance on February 19, 2008

The *Annual Review of Plant Biology* is online at plant.annualreviews.org

This article's doi:
10.1146/annurev.arplant.58.032806.103840

Copyright © 2008 by Annual Reviews.
All rights reserved

1543-5008/08/0602-0771\$20.00

Key Words

benefits, biotechnology, crops, food safety, genetic engineering, risks

Abstract

Through the use of the new tools of genetic engineering, genes can be introduced into the same plant or animal species or into plants and animals that are not sexually compatible—the latter is a discipline with classical breeding. This technology has led to the commercial production of genetically engineered (GE) crops on approximately 250 million acres worldwide. These crops generally are herbicide and pest tolerant, but other GE crops in the pipeline focus on traits such as improved nutrition, enhanced drought tolerance, and increased yield. For some farmers and consumers, planting and eating GE crops are acceptable; for others they raise issues about safety and the environment. In Part I of this



Genetically Engineered Plants and Foods: A Scientist's Analysis of the Issues (Part II)

Peggy G. Lemaux

Department of Plant and Microbial Biology, University of California, Berkeley, California 94720; email: lemauxpg@nature.berkeley.edu

Annu. Rev. Plant Biol. 2009. 60:511-59

The *Annual Review of Plant Biology* is online at plant.annualreviews.org

This article's doi:
10.1146/annurev.arplant.043008.092013

Copyright © 2009 by Annual Reviews.
All rights reserved

1543-5008/09/0602-0511\$20.00

Key Words

benefits, biotechnology, crops, economics, environment, risks

Abstract

Genetic engineering provides a means to introduce genes into plants via mechanisms that are different in some respects from classical breeding. A number of commercialized, genetically engineered (GE) varieties, most notably canola, cotton, maize and soybean, were created using this technology, and at present the traits introduced are herbicide and/or pest tolerance. In 2007 these GE crops were planted in developed and developing countries on more than 280 million acres (113 million hectares) worldwide, representing nearly 10% of rainfed cropland. Although the United States leads the world in acres planted with GE crops, the majority of this planting is on large acreage farms. In developing countries, adopters are mostly small and resource-poor farmers. For farmers and many consumers worldwide, the benefits of

Also in peer-reviewed articles:
Lemaux P.G. *Annual Review of Plant Biology* 2008
and 2009 and ANR Fact Sheets 2006



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



- 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.

Production of pharmaceuticals in edible crops caused concern because of transgenic corn contaminating subsequent soy crop – resulting in fines over \$1M

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**

'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

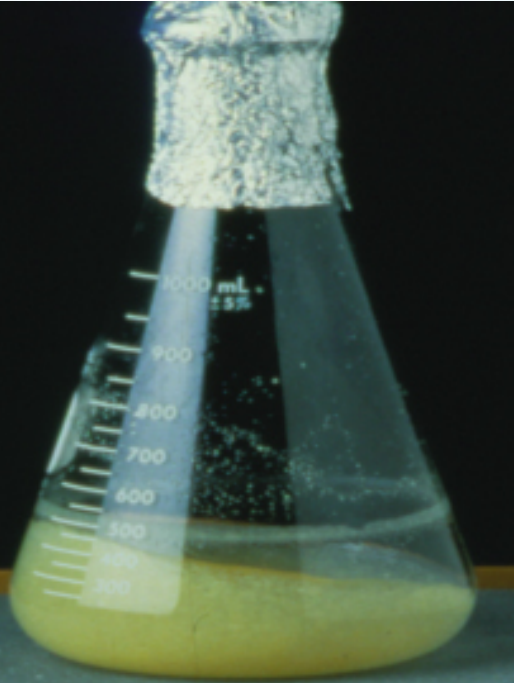
California company growing pharma rice with two genes to speed recovery from childhood diarrhea moved field production to Kansas away from rice-growing area.

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



elelyso™
(taliglucerase alfa) for injection



For first time, FDA approved a drug for Gaucher disease produced in a GE plant

Now production of pharma in plants has moved away from the field to cultured plant cells

SOURCE: "First plant-made drug on the market", Nature News Blog, 5/2/12

