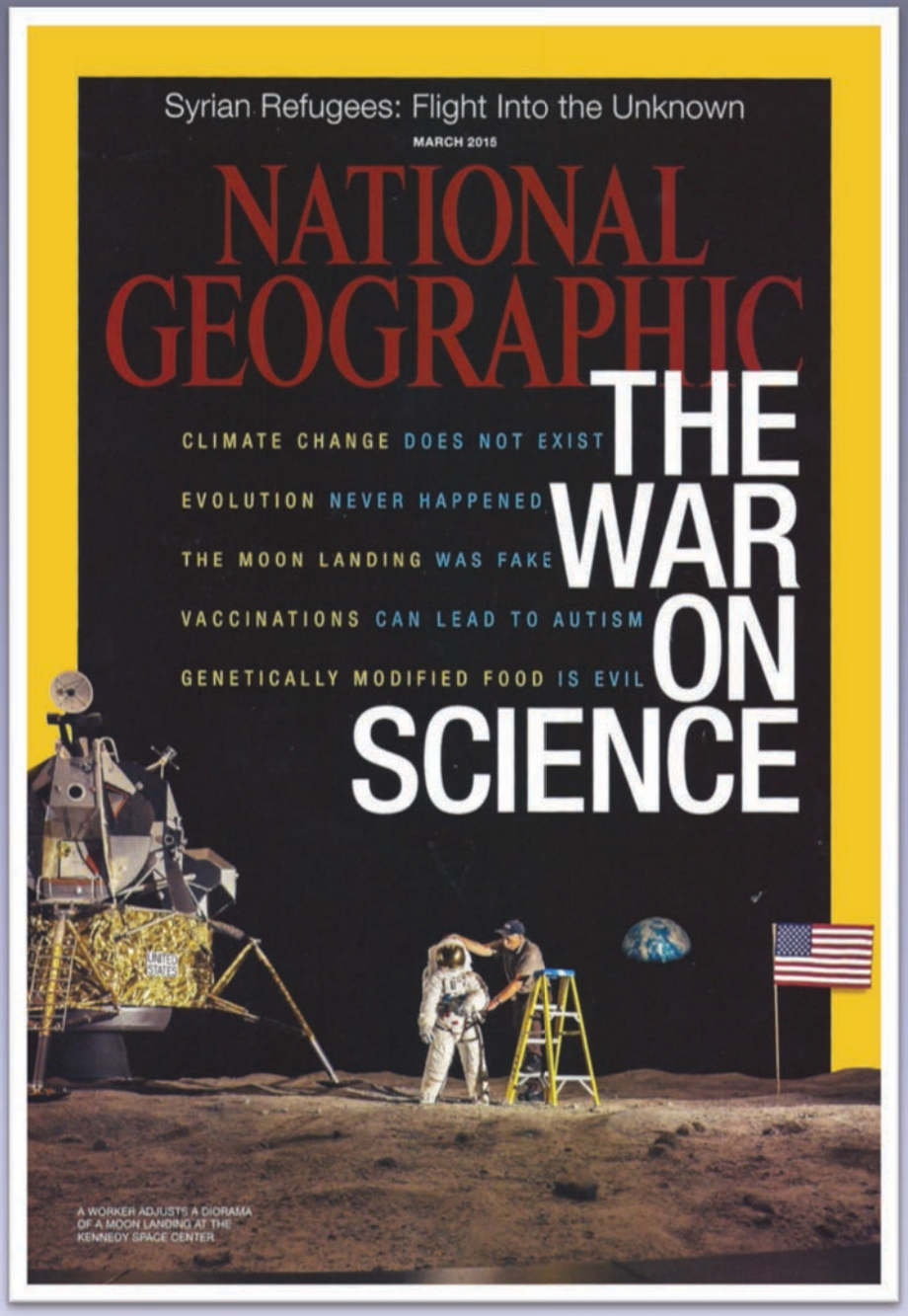
Current Status of GMO's

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



There seems to be doubt about many contemporary science issues

Consider the March 2015 *National Geographic* article highlighting public concerns about:

- Climate Change
- Evolution
- Moon Landing
- Vaccination
- Genetically Modified Foods, GMO's

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But, views of the public and scientists often disagree on these issues

Agree to disagree?

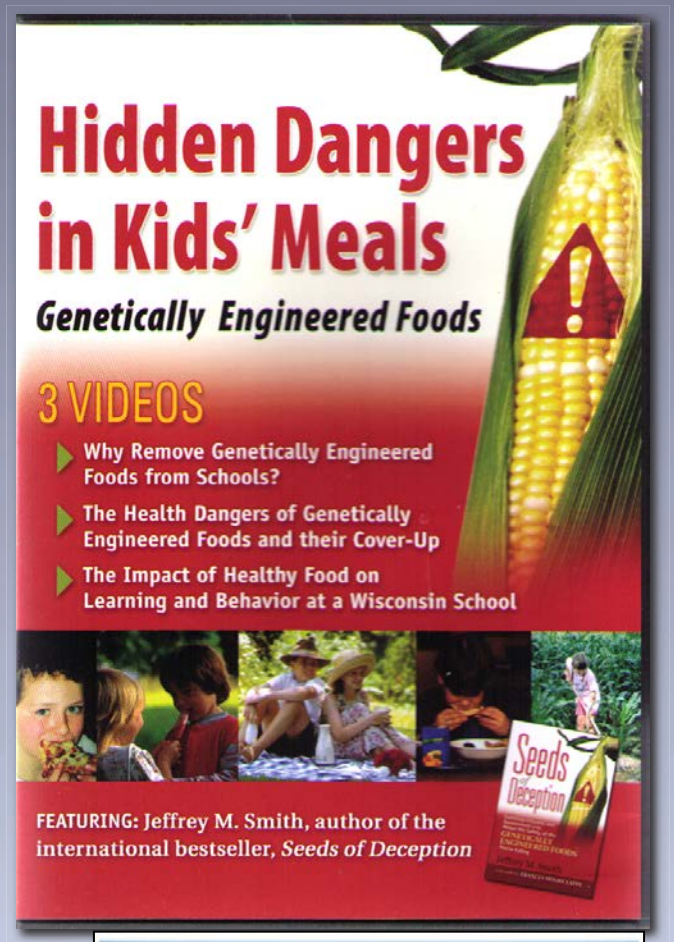
Percent of U.S. adults and AAAS scientists who say the following...

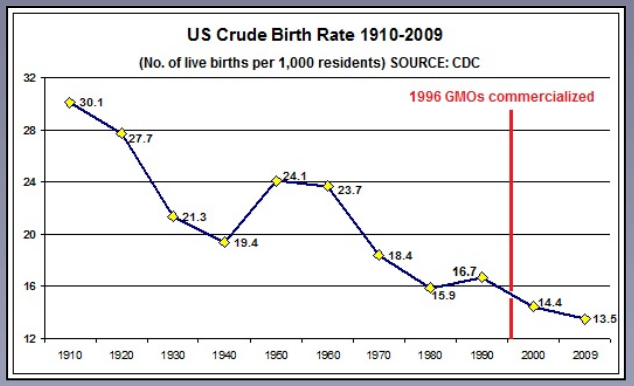
	U.S. ADULTS	SCIENTISTS
GMO foods are OK to eat.	37%	88%
Humans have evolved.	65%	98%
Require childhood vaccines.	68%	86%
Humans worsen climate change.	50%	87%
Increase fracking.	39%	31%
Drill more offshore.	52%	32%

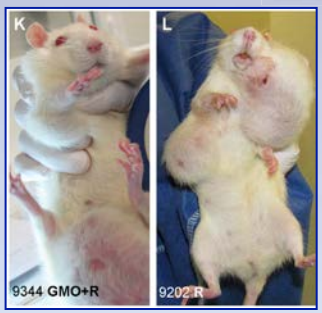
SOURCE: Pew Research Center, January 29, 2015, "Public and Scientists' Views on Science and Society"
http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

My focus today will be primarily on genetically engineered (GE, GMO) crops and foods and some of the issues.

oldamericancentury.org







What Will I Cover?

What is genetic modification, genetic engineering (GE), biotechnology, GMO?

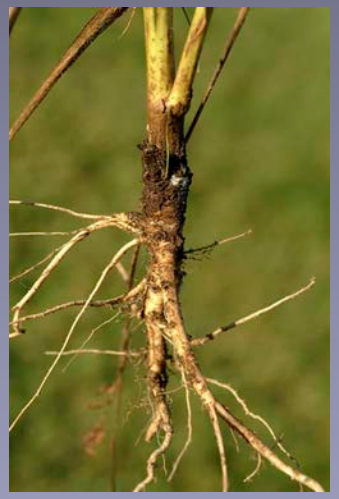
What GMO (genetically engineered, GE) crops are commercial? What's in the pipeline?

How are GE crops and foods regulated? Problems?

What are some food safety and environmental issues?

What is genetic modification, genetic engineering (GE), biotechnology, GMOs?

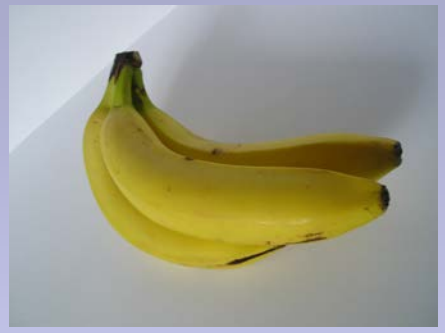
Have Foods Been Modified to Look Differently Today than Years Before?



Carrot

YES!

Eggplant



Banana

WHY?

Broccoli, Kale, Cabbage

Historically modifications happened via spontaneous mutations, crossing, and selection

In recent times humans have intentionally modified plants using classical breeding?

Triticum monococcum

Ancient variety

Triticum aestivum

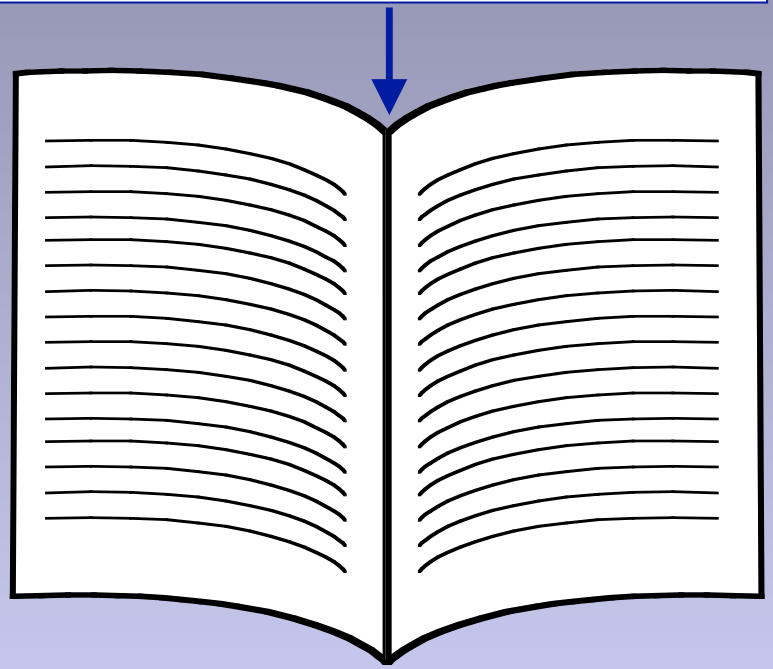
Modern bread variety

What happens genetically during classical breeding of two plants

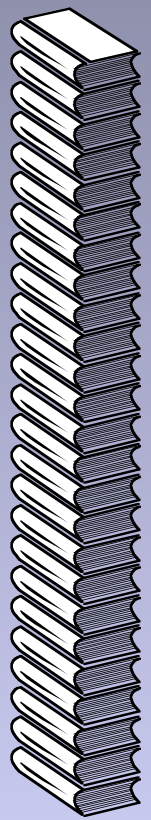
Genetic Information in Cells of Wheat Plant

Genetic information is made of chemical units – represent each unit with alphabetic letter

...CTGACCTAATGCCGTA...

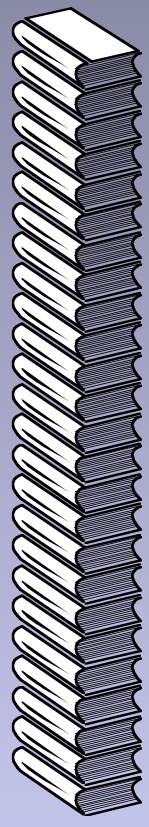


1700 books
1000 pages each



1700 books
(or 1.7 million pages)

What happens during classical breeding?



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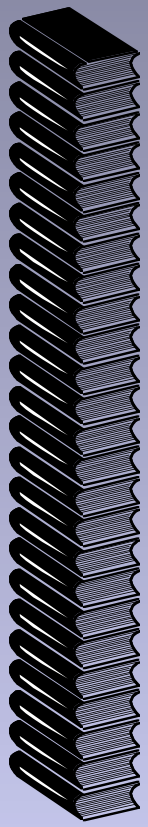

Random retention of ~50% of the information from each

What is the outcome of the cross?

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

1700 books (or 1.7 million pages)

Genetic modification that is not GE or GMO

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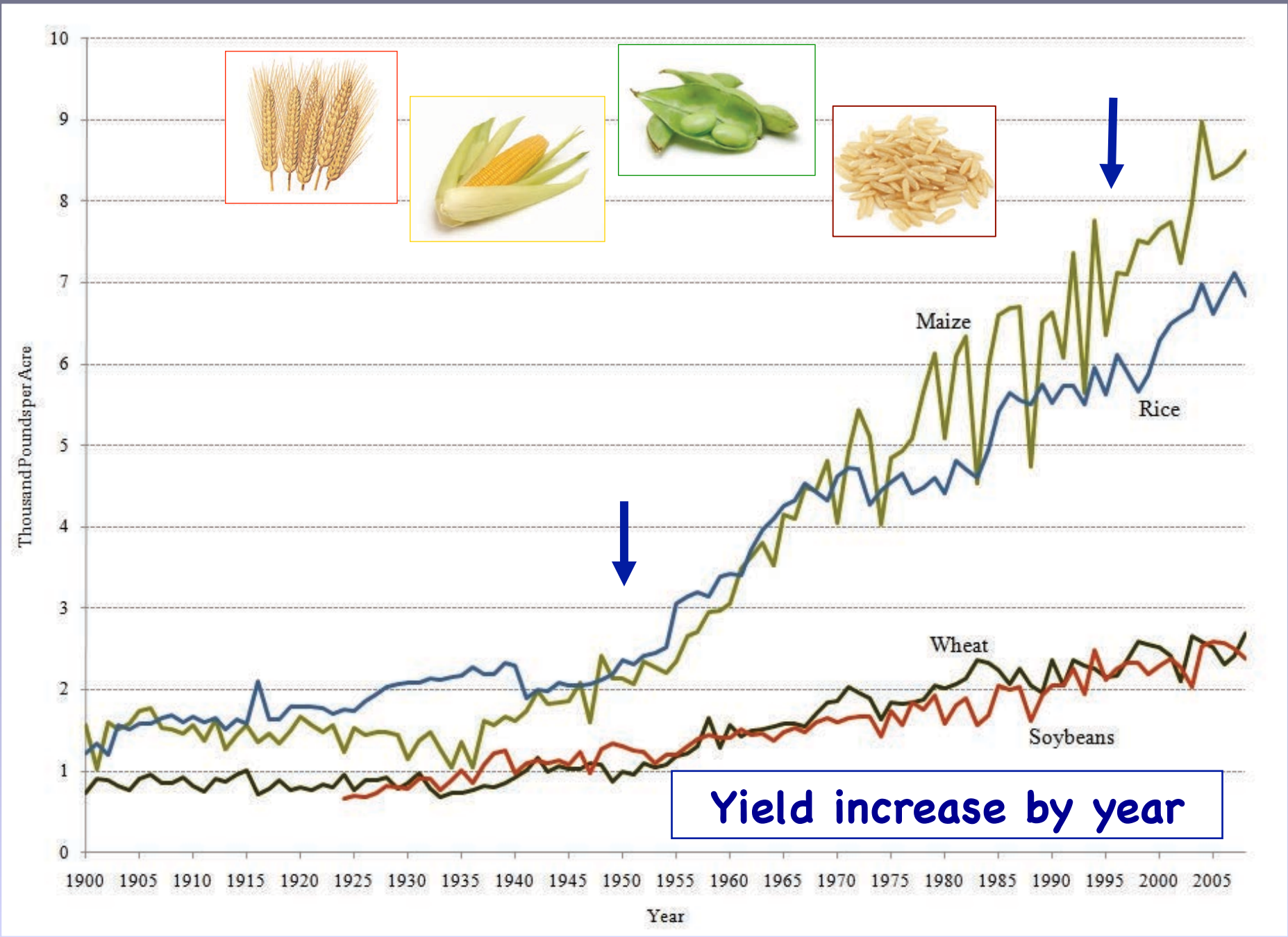
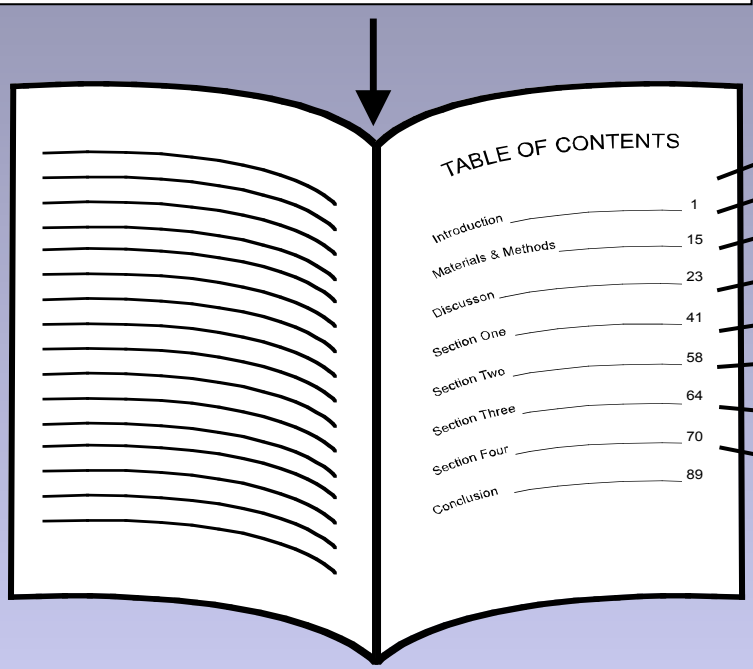


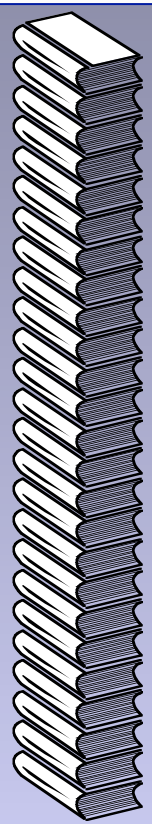
http://www.choicesmagazine.org/magazine/print.php?article=95

There are new ways to do breeding...

Uses table of contents of genes (genomics) for marker assisted selection

...CTGACCTAATGCCGTA...





Increases speed of breeding process

Genetic modification that is not GE or GMO

1700 books
(or 1.7 million pages)

Can't We Just Do All Modification This Way?

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

Limited to diversity in crop and compatible relatives


What other ways can the modern tools of genetics be used to create new varieties?
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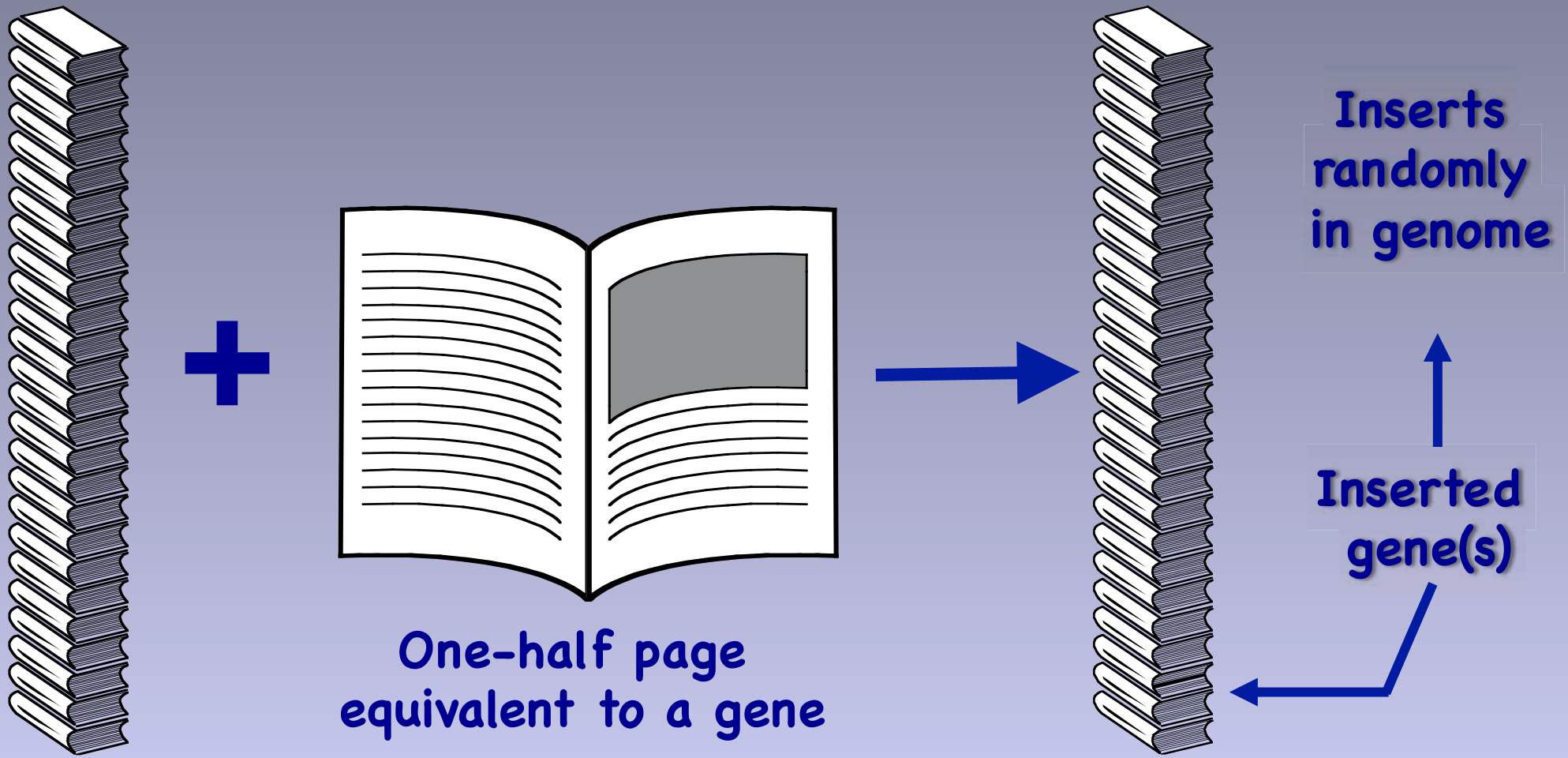
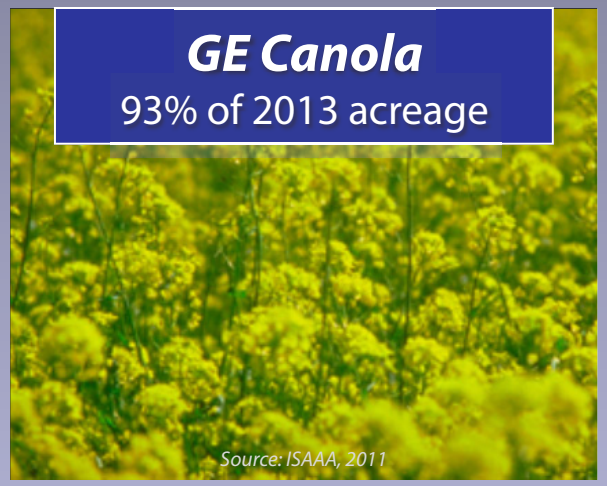
Genetic Engineering

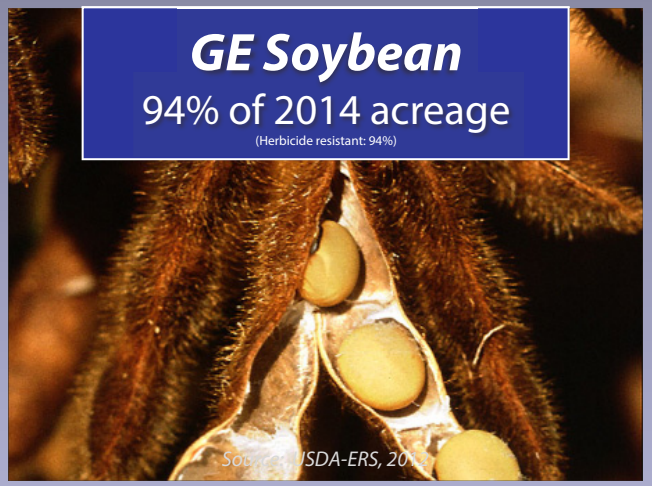


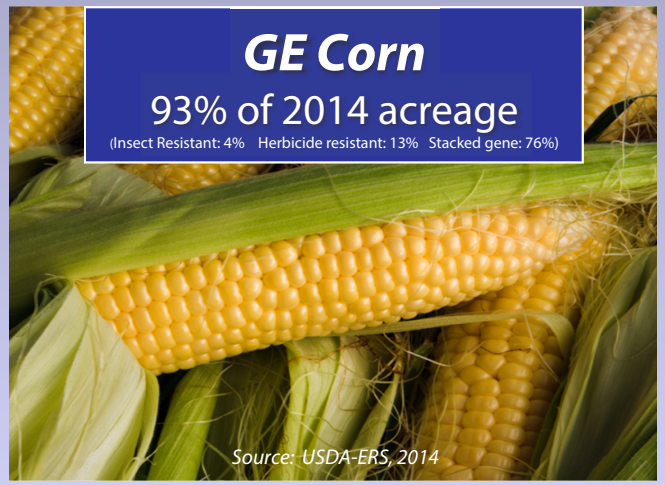
Genetic modification that is GE and GMO

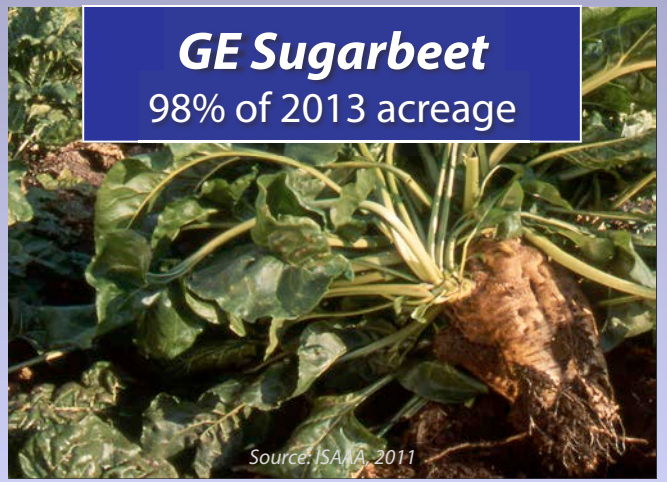
What Kinds of GE Crops and Foods Are in the Commercial Market?

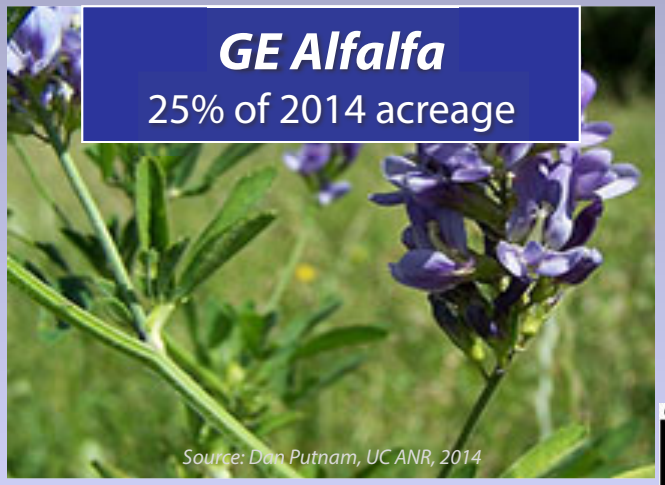
Number of commercial large acreage GE crops in U.S. is limited











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Number of different traits available in large acreage GE crops is also limited

Insect-tolerant Bt crops - engineered for resistance using gene from naturally occurring bacterium

Herbicide-tolerant - engineered with gene to tolerate herbicide application

Crops with stacked traits - both Bt and HT - are available

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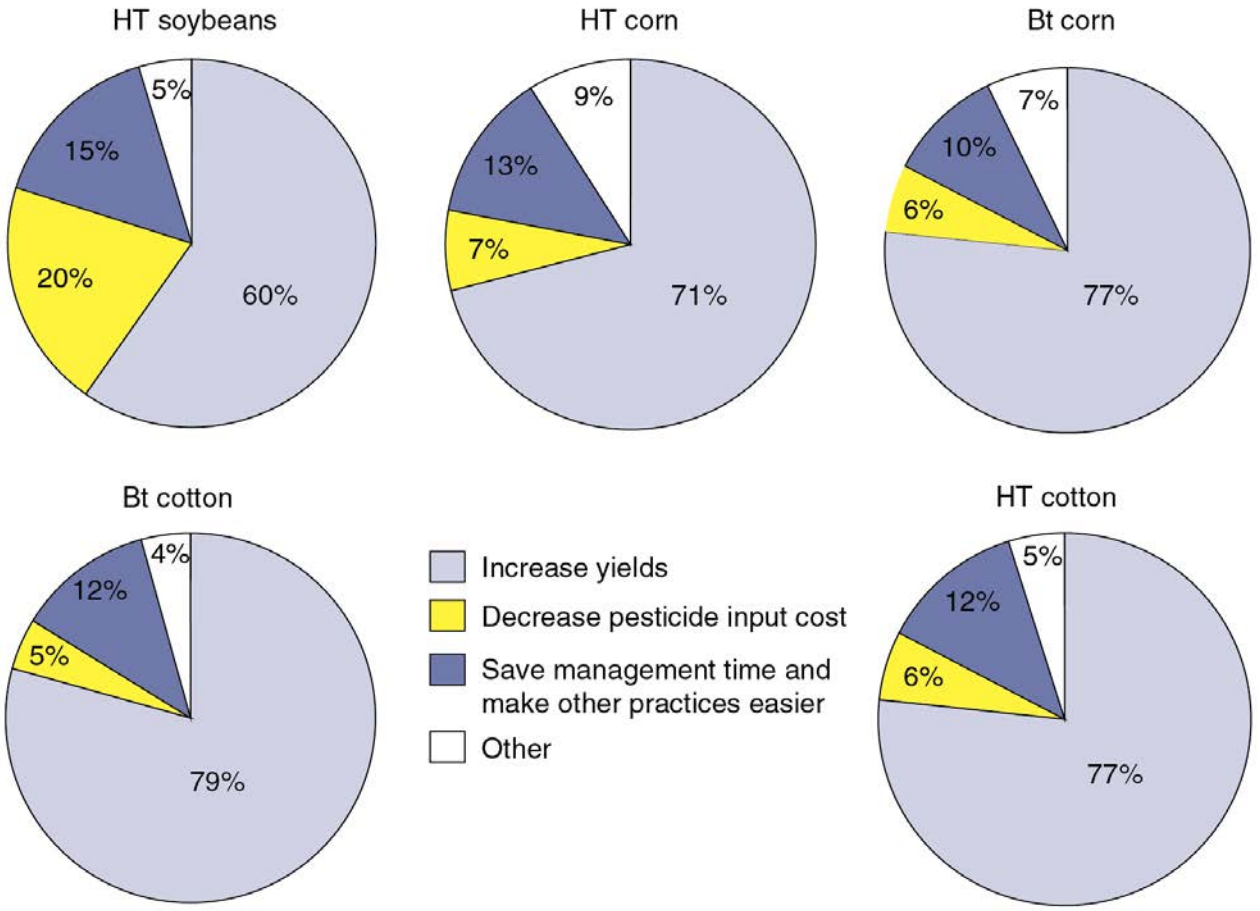
Why do U.S. growers use GE crops?



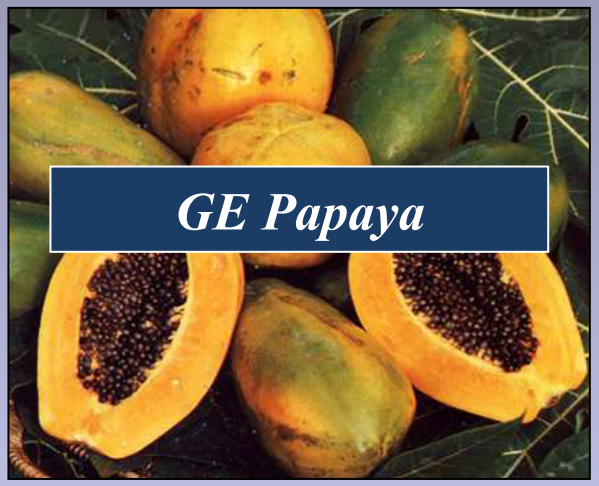
Reasons vary from crop-to-crop but primary reason is improved yields

SOURCE: Fernandez-Cornejo, J., Wechsler, S., Livingston, M. and Mitchell, L. 2014. Genetically Engineered Crops in the United States. USDA Economic Research Service Report No. 162, February 2014.

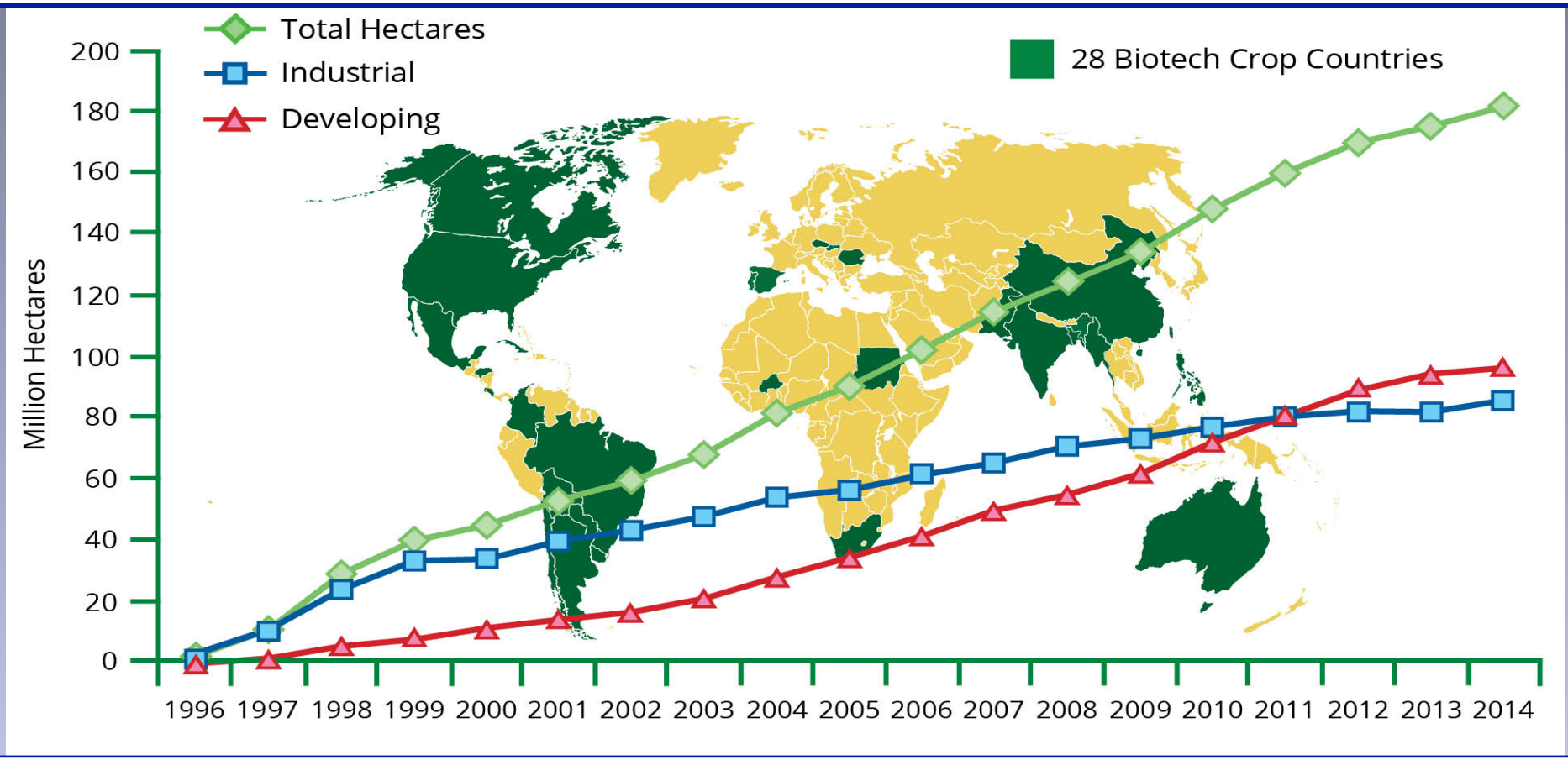
These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients

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

Only a few whole, GE foods are in the commercial U.S market



Despite limited crop and trait types, worldwide acreage is increasing in 20 developing, 8 developed countries



2014: 18 million farmers in 28 countries planted 448M acres (>4X size of California)
>90% small acreage farmers in developing countries

Clive James 2014 http://www.isaaa.org/resources/publications/briefs/46/executivesummary/

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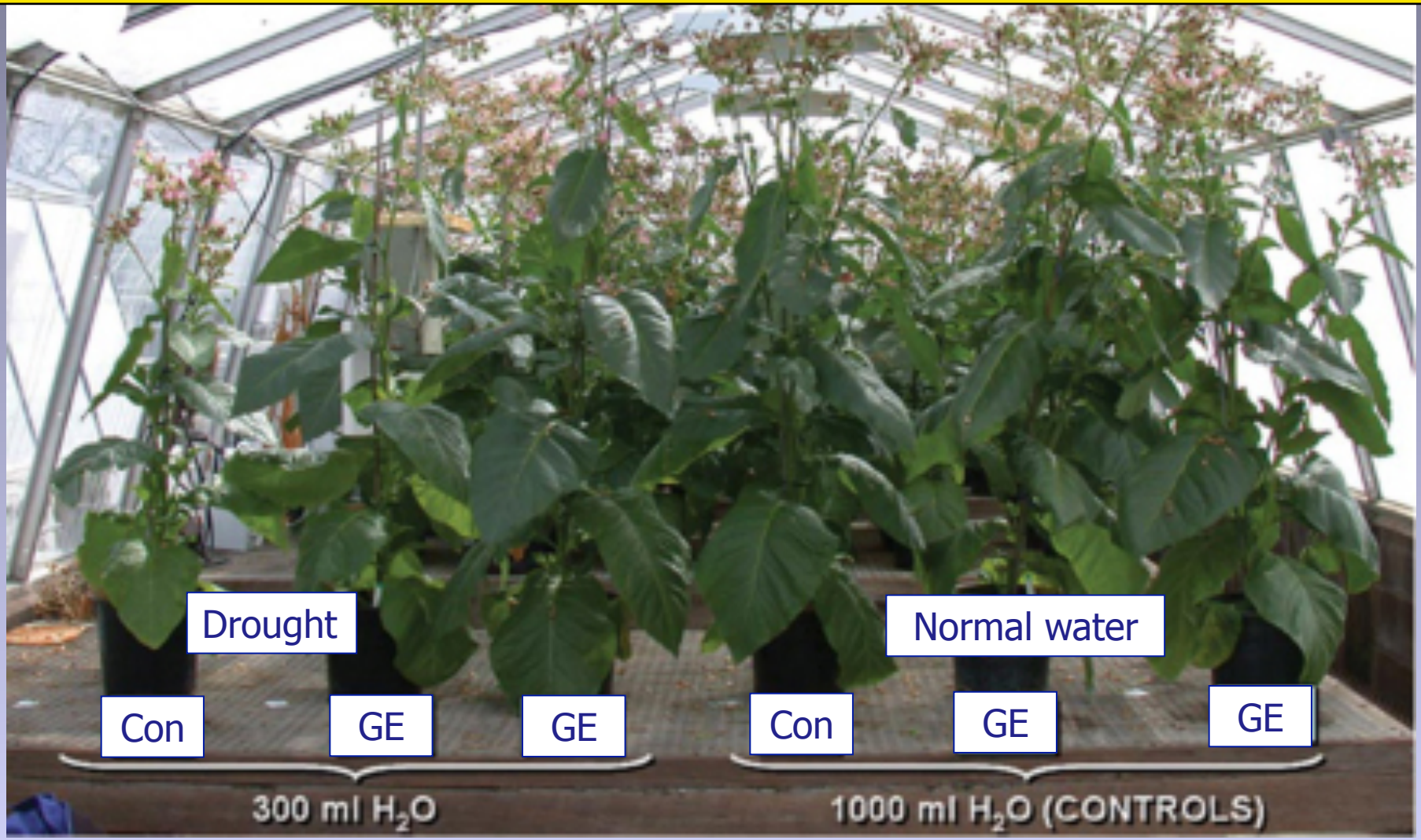
What Kinds of GE Crops and Foods Are in the Pipeline?

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

UC Davis researcher engineers drought tolerance: vigorous growth after prolonged drought



SOURCE: Rivero, R.M., Kojima, M., Gepstein, A., Sakakibara, H., Mittler, R., Gepstein, S. and Blumwald, E. 2007. Delayed leaf senescence induces extreme drought tolerance in a flowering plant. Proceedings of the National Academy of Sciences USA 104: 19631-19636.

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2013 GE potato field study – Ireland
Desiree potato variety, highly susceptible to late blight, engineered with gene from wild potato variety

amiga
Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

eagasc
Agriculture and Food Development Authority

WAGENINGEN UR
For quality of life

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Chestnuts engineered with a wheat gene prevents cankers from forming; replanted with $104K raised through crowd funding campaign

http://www.newscientist.com/article/dn25644-american-chestnut

High anthocyanin purple GE tomatoes protect against cardiovascular disease and certain cancers. Diets with 10% purple tomatoes increase lifespan of cancer-prone mice

MIT Technology Review

Chinese Researchers Stop Wheat Disease with Gene Editing

Researchers have created wheat that is resistant to a common disease, using advanced gene editing methods.

By David Talbot on July 21, 2014

Advanced genome-editing techniques have been used to create a strain of wheat resistant to a destructive fungal pathogen – called powdery mildew – that is a major bane to the world's top food source, according to scientists at one of China's leading centers for agricultural research.

Advanced genome-editing techniques used to create wheat resistant to powdery mildew

SOURCE: "Chinese Researchers Stop Wheat Disease with Gene Editing", MIT Technology Review, July 21, 2014
http://www.technologyreview.com/news/529181/chinese-researchers-stop-wheat-disease-with-gene-editing/

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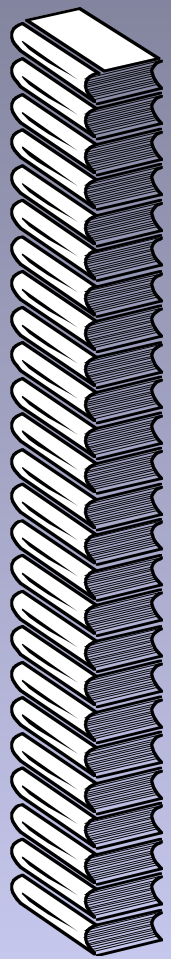
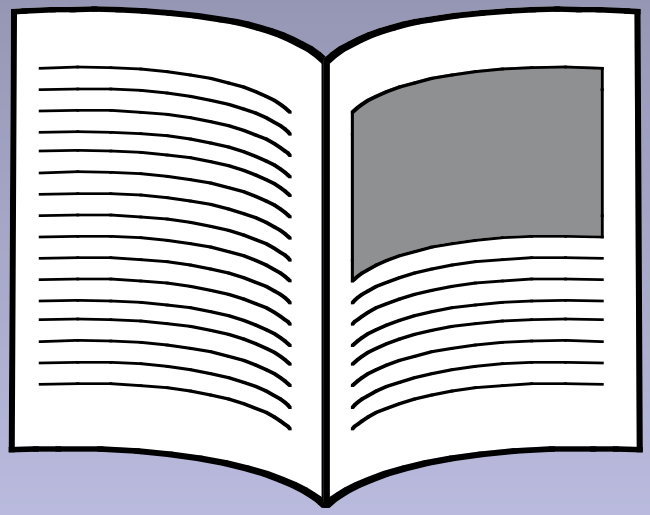
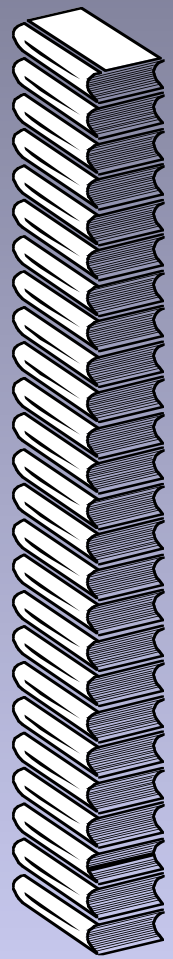
What is Genome Editing?



It is this one sentence which will be modified
It is that new sentence which will be modified



Find target text, cut out, paste in new modified text



Inserts specifically in genome

Insert gene edits

1700 books (or 1.7 million pages)

Genome editing may or may not be GE or GMO

1700 books (or 1.7 million pages)

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How are GE crops and foods regulated in the U.S.?

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?

USDA APHIS Determines Nonregulated Status

111 granted: 8-2-2014

When sufficient data is collected, crops are deregulated and no longer require APHIS review for release or movement in U.S.

- ✓ Alfalfa - HT – removed, reinstated
- Apple - PQ
- ✓ C
- ✓ Cotton - HT, IR
- ✓ Soybean - HT, PQ
- ❖ Potato - IR, VR
- ❖ Tomato - PQ
- Squash - VR
- ✓ Canola – HT
  - ✓Large-scale production
  - ❖Not on market
- Papaya - VR
- ❖ Plum - VR
- ❖ Rice - HT
- Rapeseed - HT, AP, PQ
- ✓ Sugar beet - HT - removed, reinstated
- ❖ Flax - HT
- ❖ Chicory - AP
- ❖ Tobacco – PQ
- ❖ Rose - PQ

But then the courts weighed in on regulation

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

Although deregulated, U.S. Circuit Court directed APHIS to demand full environmental impact statement, preventing growers from planting GE sugar beets and GE alfalfa until statement was complete

There are Other Regulatory Issues with GE Crops and Foods

Regulation of GE products unchanged since 1986 causing increased problems.

- New products emerge with no rules to govern them
- No clear path for commercialization of some old products
- New products created to step around regulation

USDA clears GMO tall fescue

68

Mateusz Perkowski
Capital Press

Published:
December 30, 2014 9:21AM

Last changed:
December 30, 2014 9:28AM

A new GMO variety of tall fescue turfgrass that's resistant to glyphosate herbicides has been cleared for cultivation by USDA.

The USDA has cleared the way for cultivation of genetically modified tall fescue without conducting an environmental review of the new crop.

The Scotts Miracle-Gro company developed the glyphosate-resistant turfgrass variety with genes from other plants through a process known as "biolistics," in which a "gene gun" essentially shoots

GE turfgrass: created without using a plant pest or plant pest part – sidestepping USDA regulation

Crops, being created using 'genome editing', were never imagined when regulations were created.

The Scientist

There's CRISPR in Your Yogurt

We've all been eating food enhanced by the genome-editing tool for years.

By Kerry Grens | January 1, 2015

ANDRZEJ KRAUZE

Two years ago, a genome-editing tool referred to as CRISPR (clustered regularly interspaced short palindromic repeats) burst onto the scene and swept through laboratories

These new methods may avoid regulatory rules and costs ($10-20M per event) and may provide opportunities for smaller companies and university researchers to engineer less common crops

Why Are GE (GMO) Crops and Foods So Controversial?

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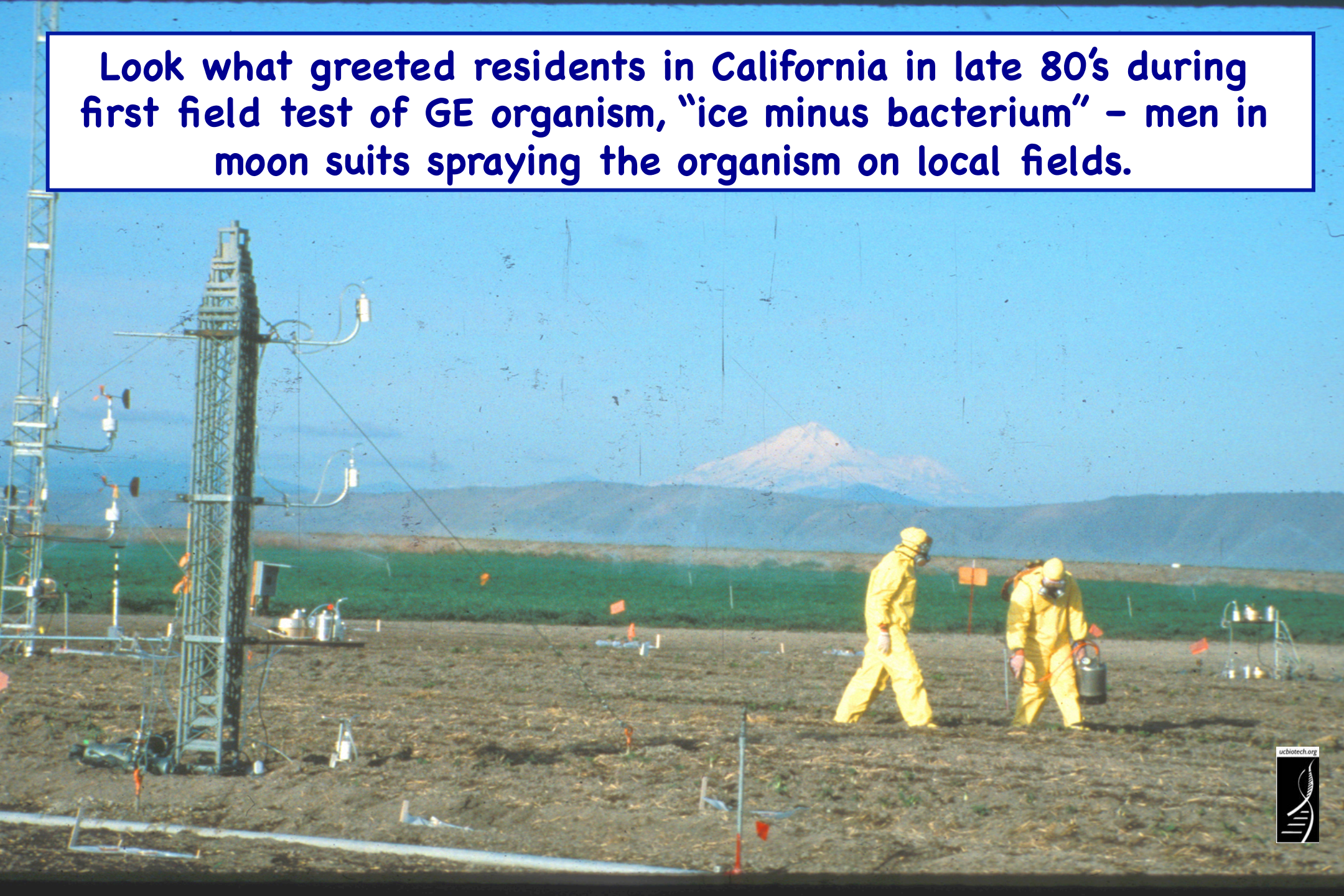
Look what greeted residents in California in late 80's during first field test of GE organism, "ice minus bacterium" – men in moon suits spraying the organism on local fields.



Then large-scale pushback started in the late 90's in Europe: Factors that fueled and continue to fuel controversy there

- Food safety scares
- Involuntary nature of change
- Cultural differences
- Economic incentives

1999
Lord Melchett participating in GM protest

2014
GM maize protest in Germany

And there are issues in the U.S. too

What are some food safety issues?

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

On occasion widely publicized studies cast doubt on safety of GE foods, e.g., one by French researcher in Sept. 2012

Later reviewed by European Food Safety Authority: study had no merit – but that was not as widely publicized

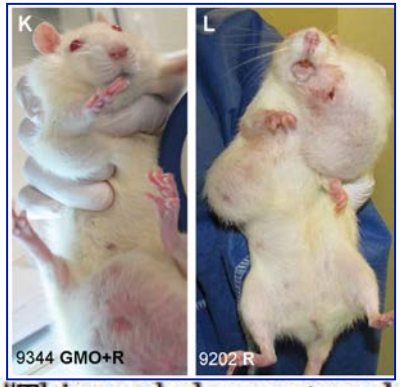
French academies trash GM corn cancer study

By **RFI**

A controversial study that linked genetically modified maize to cancer in l… six … in a…

The report's author, Gilles-Eric Séralini, with his book All Guineapigs
AFP /Jacques Demarthon

Featured on Dr. Oz Show



Claim that Monsanto's RR corn causes tumors in rats

"This work does not enable any reliable conclusion to be drawn," they say, adding that the publicity surrounding the publication has "spread fear among the public."

The joint statement - an extremely rare event in French science - is unsigned and issued in the names of the national academies of agriculture, medicine, pharmacy, science, technology and veterinary studies.

But are GM foods safe?

2012 French review of published results showed GE foods are:

- nutritionally equivalent to non GE foods
- can be safely consumed in food and feed.

Based on 12 long-term (>90d to 2yr) and 12 multigenerational (2 to 5 generations) feeding trials of GE feed in animals

maize

potato

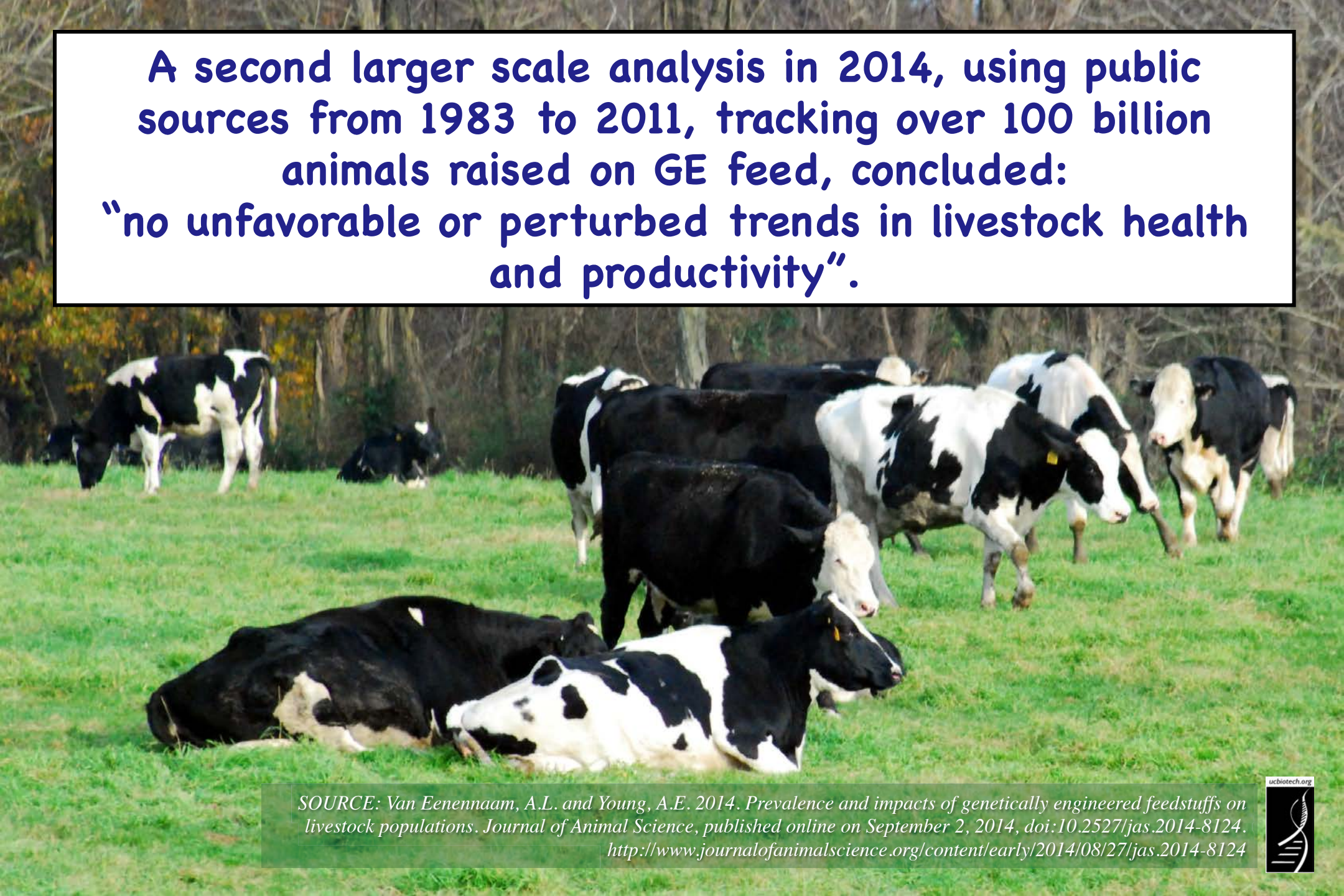
soy

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.

A second larger scale analysis in 2014, using public sources from 1983 to 2011, tracking over 100 billion animals raised on GE feed, concluded:
"no unfavorable or perturbed trends in livestock health and productivity".



SOURCE: Van Eenennaam, A.L. and Young, A.E. 2014. Prevalence and impacts of genetically engineered feedstuffs on livestock populations. Journal of Animal Science, published online on September 2, 2014, doi:10.2527/jas.2014-8124. http://www.journalofanimalscience.org/content/early/2014/08/27/jas.2014-8124

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What about labeling?

"Do you support or oppose the following government policies?"

Does the public want labels indicating they are GE? Anything else?

• A ta		
• A b		
• A ban on the sale of food products made with transfat	56%	44%
• A ban on the sale of raw, unpasteurized milk	59%	41%
• Calorie limits for school lunches	64%	36%
• Mandatory calorie labels on restaurant menus	69%	30%
• Mandatory labels on foods containing DNA	80%	20%
• Mandatory labels on foods produced with genetic engineering	82%	18%
• Mandatory country of origin labels for meat	87%	13%

SOURCE: "80% Of Americans Support Mandatory Labels On Foods Containing DNA. DNA!", iO9, 1/18/15. hom/80-of-americans-support-mandatory-labels-on-foods-cont-1680277802
Food Demand Survey, Oklahoma State University, January 16, 2015 http://agecon.okstate.edu/faculty/publications/4975.pdf)

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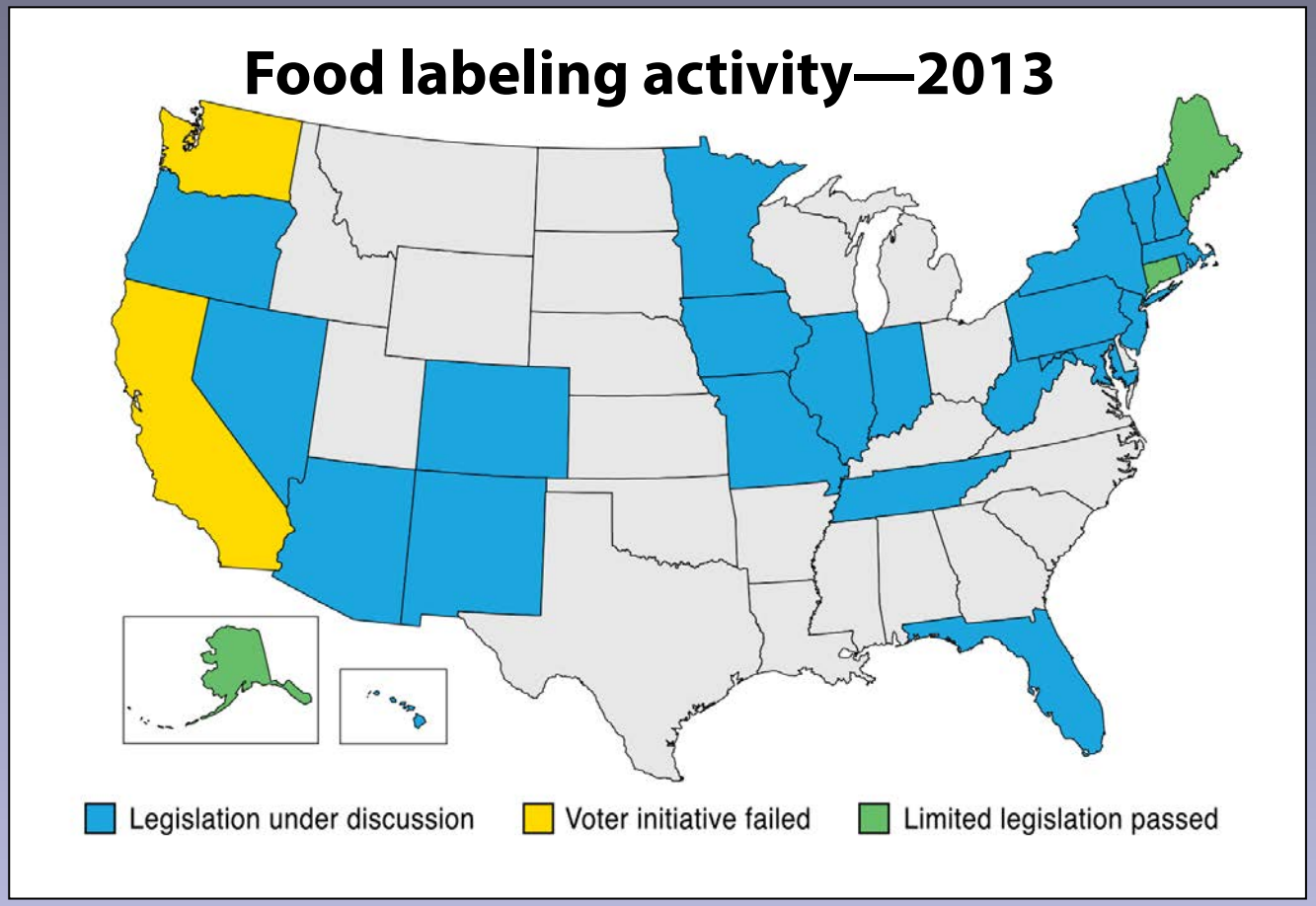

There is potential for a patchwork of local labeling laws because some states passed and others are considering such laws for products with GE ingredients – making it difficult for commerce.

SOURCE: "GE Labeling Resurrected in California, Petition For Ballot Measure Circulating in Colorado", March 25, 2014, Food Safety News. http://www.foodsafetynews.com/2014/03/gm-labeling-resurrected-in-california-petition-circulating-for-initiative-in-colorado/#.UznX9q1dVLM

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Non-legislative labeling efforts have arisen, like the popular Non-GMO Project label

SOURCE: "GMO Labeling: These Numbers Will Astound You", The Motley Fool, 2/7/15
http://www.fool.com/server/printarticle.aspx?file=/investing/general/2015/02/07/gmo-labeling-these-numbers-will-astound-you.aspx

SOURCE: Costanigro, M. and Lusk, J.L. 2014. The signaling effect of mandatory labels on genetically engineered food. Food Policy 49: 259-267

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USDA now *offers voluntary, for-a-fee verification of food companies' claims that products contain no GMO's - part of their audit program that verifies "grass-fed, antibiotic-free and humanely raised"*

SOURCE: "U.S. action on GMOs stops far short of mandatory labels", San Francisco Chronicle, 5/14/15. http://www.sfgate.com/science/article/U-S-plan-to-vouch-for-GMO-free-foods-disappoints-6264407.php

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POLITICO Pro

Learn more

GMO labeling bill would trump states

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Vermont could become the first state to set its own GMO rules. | AP Photo

By JENNY HOPKINSON | 4/9/14 4:57 PM EDT

Food manufacturers don't have to label products that contain genetically modified ingredients, and now they have a bill that would keep it that way.

Rep. Mike Pompeo on Wednesday morning introduced **The Safe and Accurate Food Labeling Act of 2014**, a bill that would give ultimate authority of GMO labeling to the Food and Drug Administration, which favors a voluntary approach to the issue. The measure, which has the support of the food, biotechnology and agriculture industries, looks to nullify efforts in no less

Also there is HR1599:

- Requires safety reviews of GE foods before sale
- Prevents states from having their own labeling laws
- FDA can't require labeling for GE foods only because they're engineered

Passed in House; awaiting Senate consideration

So, labeling issue has not yet been resolved.

SOURCE: "Food industry seeks voluntary GMO labeling", Washington Post, February 6, 2014. http://www.washingtonpost.com/politics/federal_government/food-companies-propose-voluntary-gmo-labels/2014/02/06/78d2487c-8f4e-11e3-878e-d76656564a01_story.html

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What are environmental and economic issues?

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

Insect Resistance

B.t. cotton and corn engineered for insect resistance with gene(s) from naturally occurring bacterium.

Development of resistant insects of herbicide-tolerant weeds

To date minimal insect resistance has occurred

Capital Press
Agriculture Newspaper

Groups seek glyphosate limits to protect butterflies

By MATEUSZ PERKOWSKI
Capital Press

Environmental groups seeking federal protection for monarch butterflies blame the use of genetically modified crops for the insect's steep decline.

Petitioners claim that while there were as many as 1 billion monarchs as recently as the 1990s, their numbers have dropped to around 33 million.

If the U.S. Fish and Wildlife Service agrees to list the species as threatened or endangered, protecting the insect may involve pesticide restrictions that affect biotech crops.

The alleged link between transgenic crops and the drop in monarch butterfly populations is milkweed, a plant that

of genetically engineered corn and soybeans in the Corn Belt region of the United States and to planting of genetically engineered cotton in California," the environmentalist petition said.

In the past, many herbicides had trouble killing milkweed because it's a perennial that regenerates from its roots, said Bill Freese, science policy analyst for the Center for Food Safety, a non-profit involved in the petition.

Glyphosate, on the other hand, is absorbed by the plant's roots and destroys it completely, he said.

After glyphosate-resistant biotech crops became common in the 1990s, farmers began spraying much more of the herbicide, Freese said.

They also applied it after

While several types of aggressive weeds have developed resistance to glyphosate due to frequent spraying, hundreds have not, including milkweed, he said. "Each weed is really different."

If the federal government extends Endangered Species Act protection to the monarch butterfly, the listing could result in restrictions on how often glyphosate and other herbicides can be used on crops, Freese said.

As a consequence, farmers may plant fewer acres of genetically engineered crops, since they wouldn't be able to spray the chemicals over the top of crops in certain fields, he said.

The Biotechnology Industry Organization, which repre-

endangered species program director for the Xerces Society, an environmental group involved in the petition.

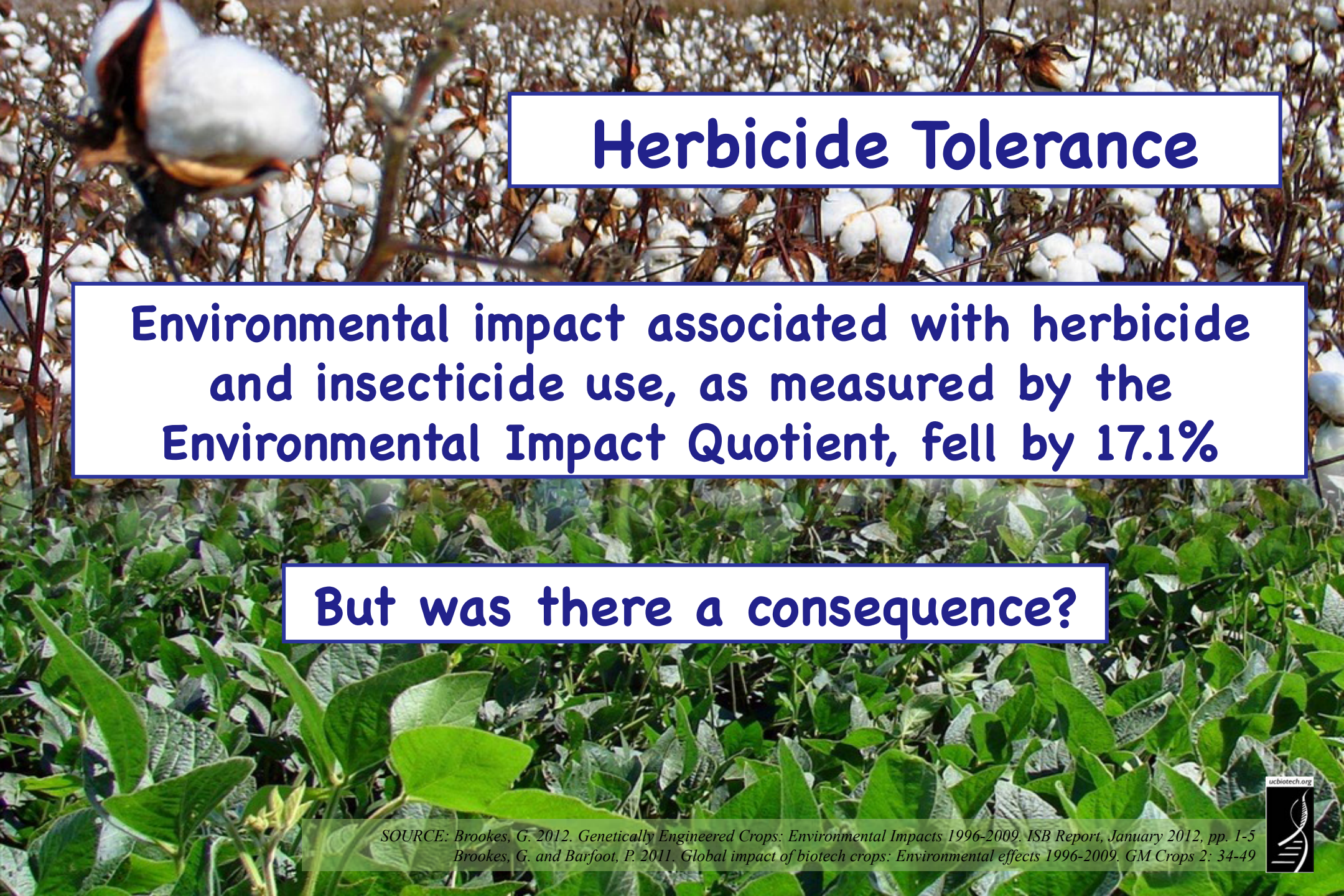
"We've seen real leadership from the agricultural sector in restoring habitat for the monarch butterfly," Jepsen said.

If the insect is listed as threatened, the Fish and Wildlife Service could enact 4(d) Special Rules that would allow routine farming practices to continue as long as they don't contribute to the insect's extinction, she said.

Jepsen said she didn't want to speculate about impacts to agriculture at this point, but she said 4(d) rules have been proposed for another butterfly species, the Dakota skipper, which the agency has pro-

B.t. originally thought to be detrimental to Monarch butterfly larvae but extensive research established minimal harm. But issue resurfaces due to Roundup's impact on milkweed – an exclusive feedstock for butterfly larvae

SOURCE: "Groups seek glyphosate limits to protect butterflies", Capital Press, September 3, 2014
http://www.capitalpress.com/Nation_World/Nation/20140903/groups-seek-glyphosate-limits-to-protect-butterflies



Herbicide Tolerance

Environmental impact associated with herbicide and insecticide use, as measured by the Environmental Impact Quotient, fell by 17.1%

But was there a consequence?

SOURCE: Brookes, G. 2012. Genetically Engineered Crops: Environmental Impacts 1996-2009. ISB Report, January 2012, pp. 1-5
Brookes, G. and Barfoot, P. 2011. Global impact of biotech crops: Environmental effects 1996-2009. GM Crops 2: 34-49

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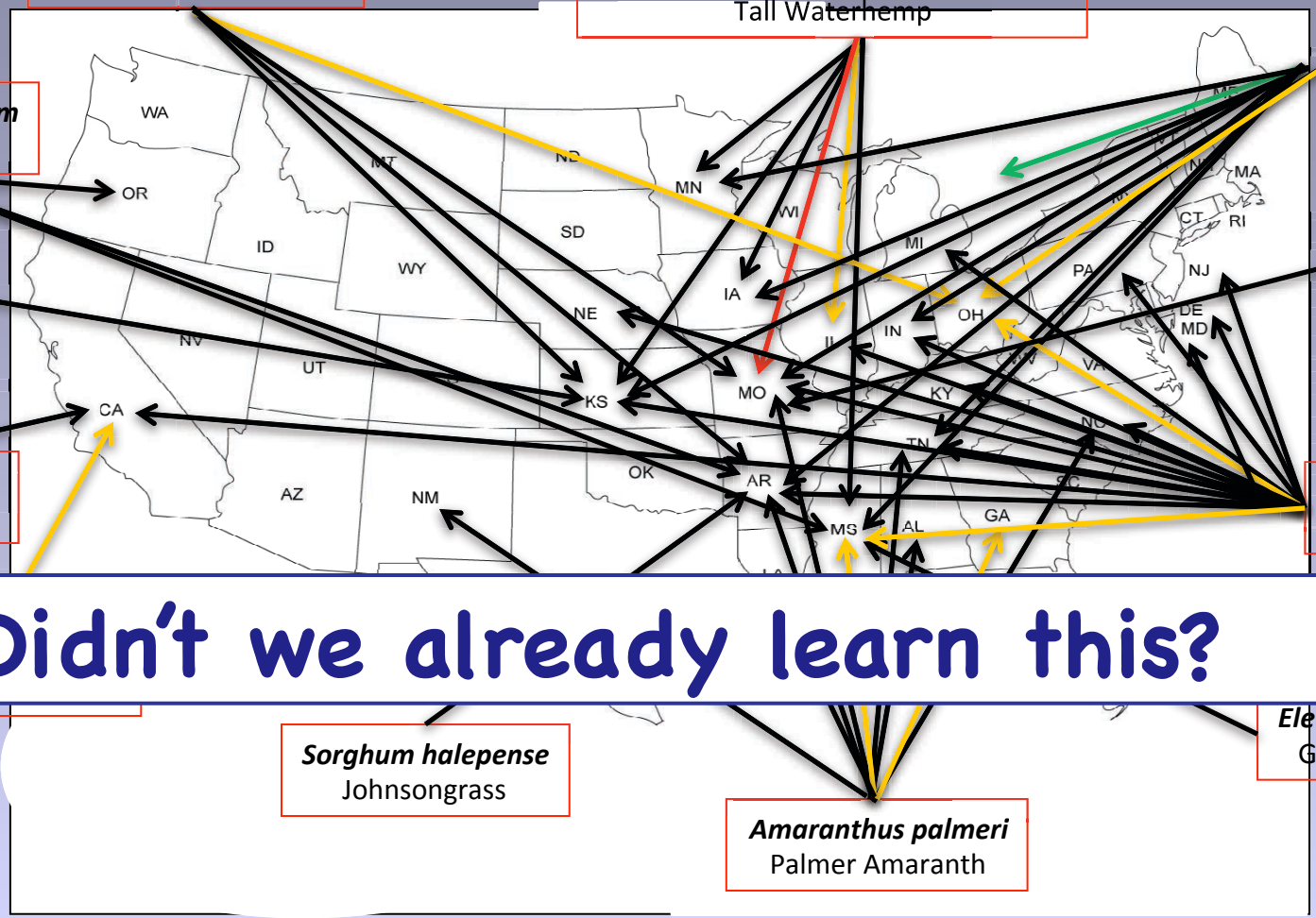
Occurrence of glyphosate-resistant weeds - due to mutation, gene flow, weed shift - was exacerbated when same herbicide is used repeatedly

Glyphosate- Resistant Weeds – USA

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



Ambrosia artemisiifolia
Common Ragweed

Amaranthus tuberculatus (syn. rudis)
Tall Waterhemp

Ambrosia trifida
Giant Ragweed

Lolium multiflorum
Italian Ryegrass

Poa annua
Annual Bluegrass

Kochia scoparia
Kochia

Lolium rigidum
Rigid Ryegrass

Conyza canadensis
Horseweed

Didn't we already learn this?

Conyz
Hai

Sorghum halepense
Johnsongrass

Eleusine indica
Goosegrass

Amaranthus palmeri
Palmer Amaranth

K. Neil Harker
AAFC - Lacombe, AB

Where to get more information on the issues?

http://ucbiotech.org