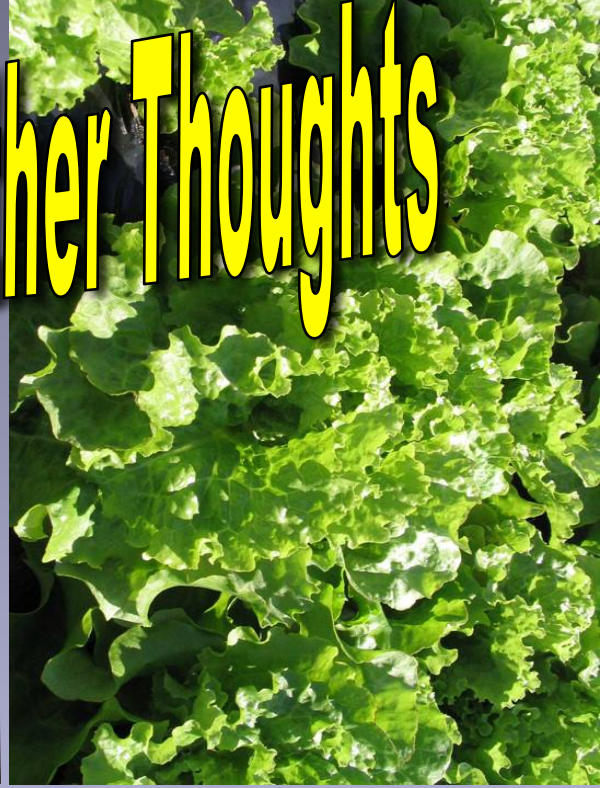


Crops, Food, Biotechnology and Some Other Thoughts



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





What will be covered?

1. Background on genes, genomes, genetic engineering, genome editing

2. What GE crops are commercialized? In the pipeline?

3. What is the regulatory structure for GE crops?

4. What are some food safety issues with GE foods?

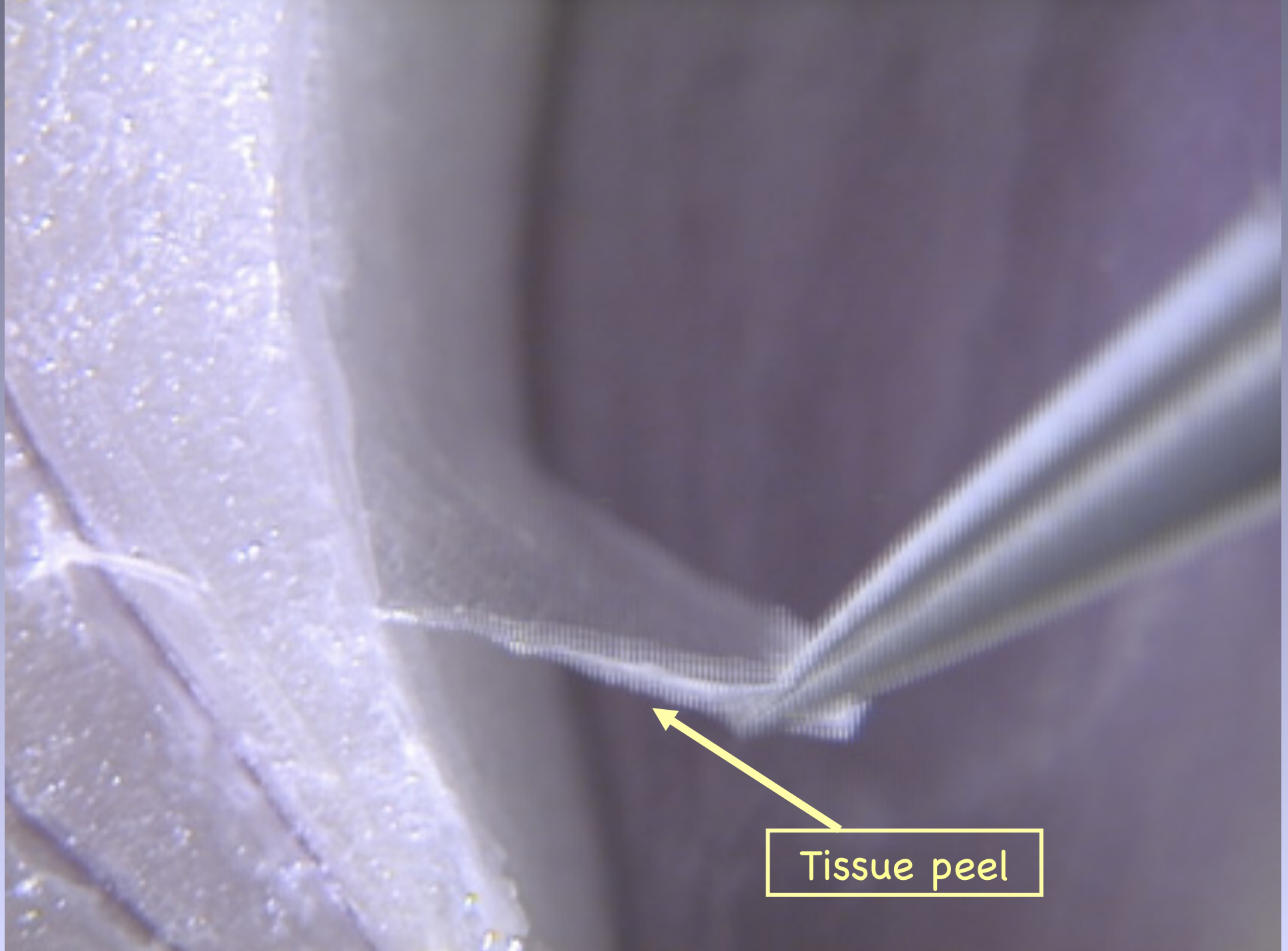
5. What are some environmental issues with GE crops?

6. Some food for thought...

Tour d'Onion

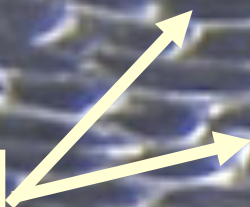


Or what makes an onion, an onion?



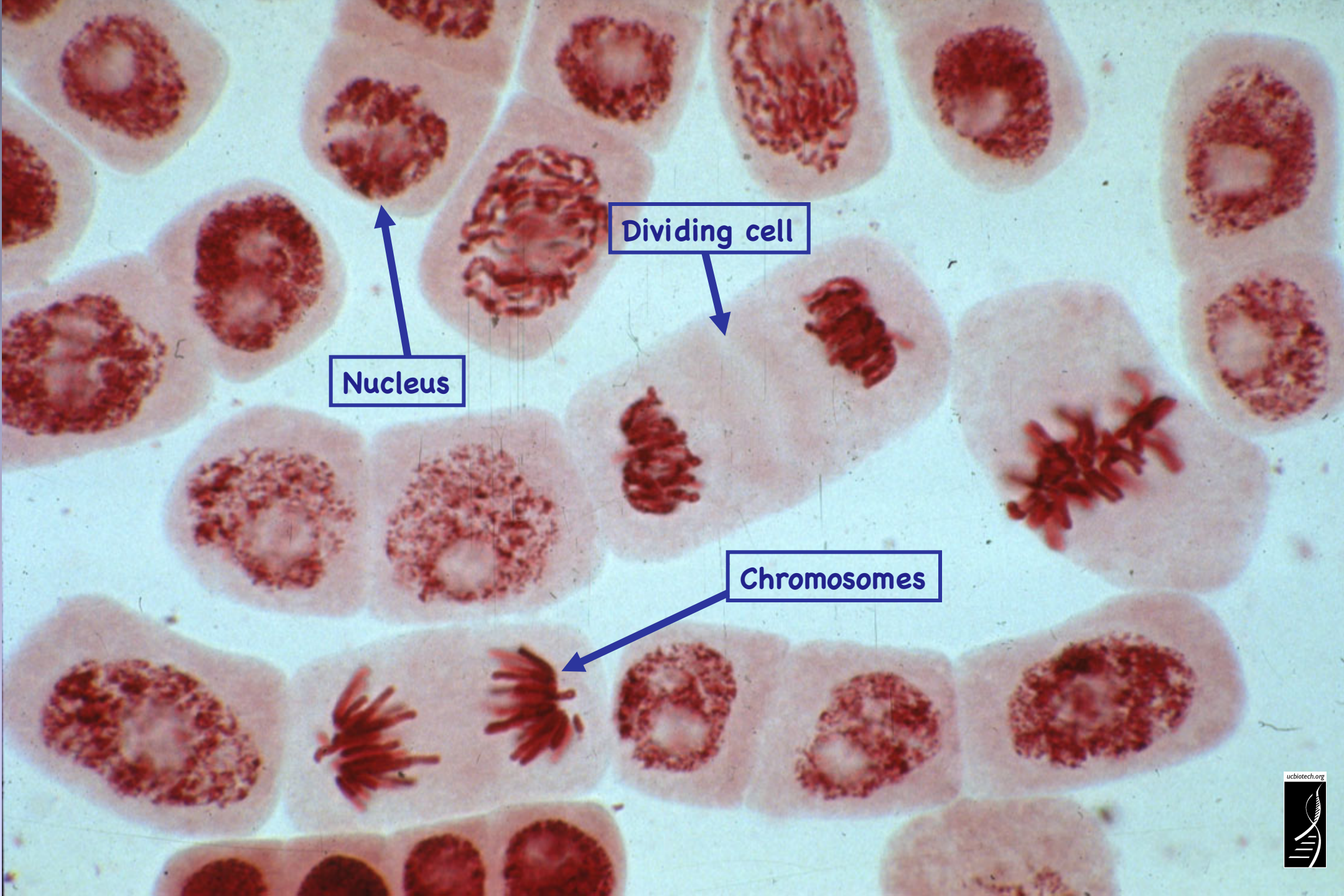
Tissue peel

CELLS



Nucleus

Cell Wall



Nucleus

Dividing cell

Chromosomes



All Chromosomes = Genome

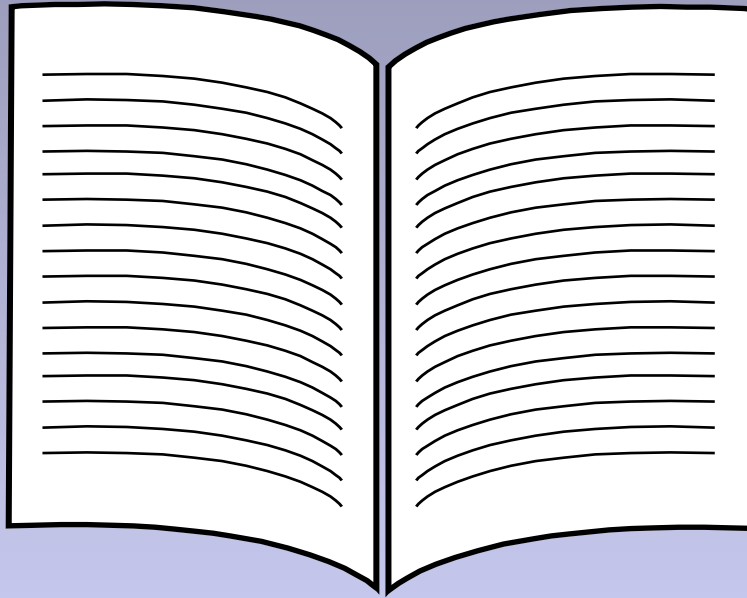
Genetic information in the genome is responsible for traits

Represent chemical units in genome by alphabetic letters

...CTGACCTAATGCCGTA...



...CTGAACTAATGCCTTA...



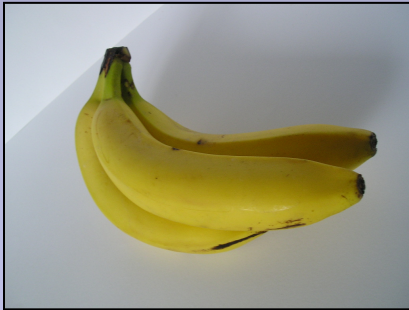
Sometimes mistakes happen when copying information in books (genome) → creating changes, called mutations

**Mutations Have Gotten These
Plants from Looking Like This...**

To Looking Like They Are Now



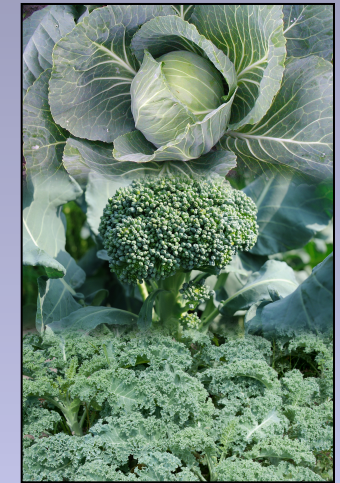
Carrot



Banana



Eggplant

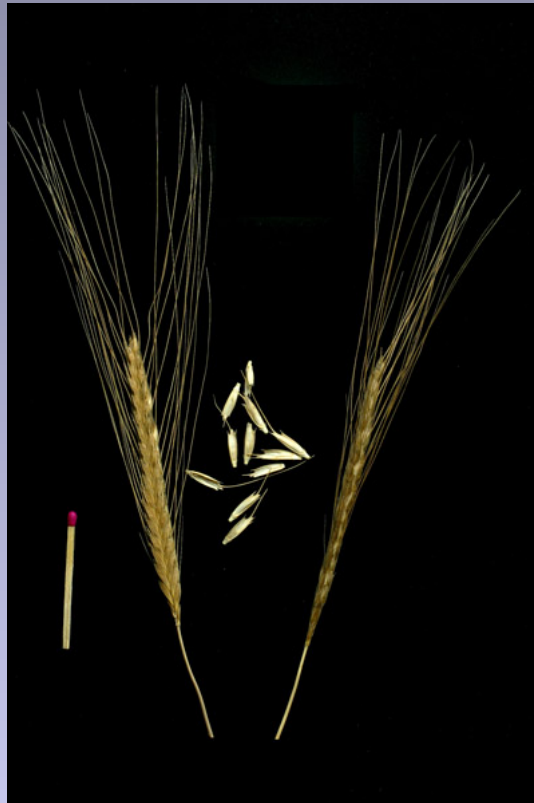


**Broccoli,
Kale,
Cabbage**

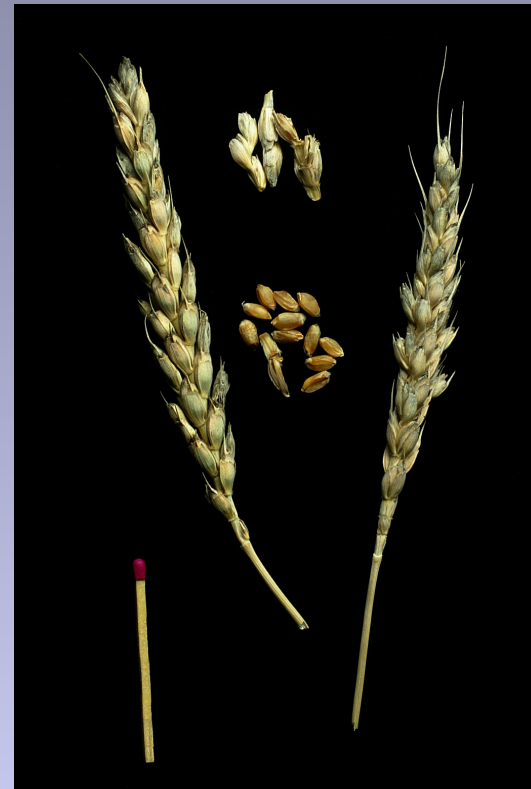
Intentional mutation breeding: used since the 1950s, has created >3200 officially released crops – like 600 maize, rice, wheat varieties. Although modified genetically, they are not under regulations used for genetically engineered (GMO) varieties.



But genes and chromosomes have also been changed to create new plant varieties by classical breeding?



Triticum monococcum
Ancient variety

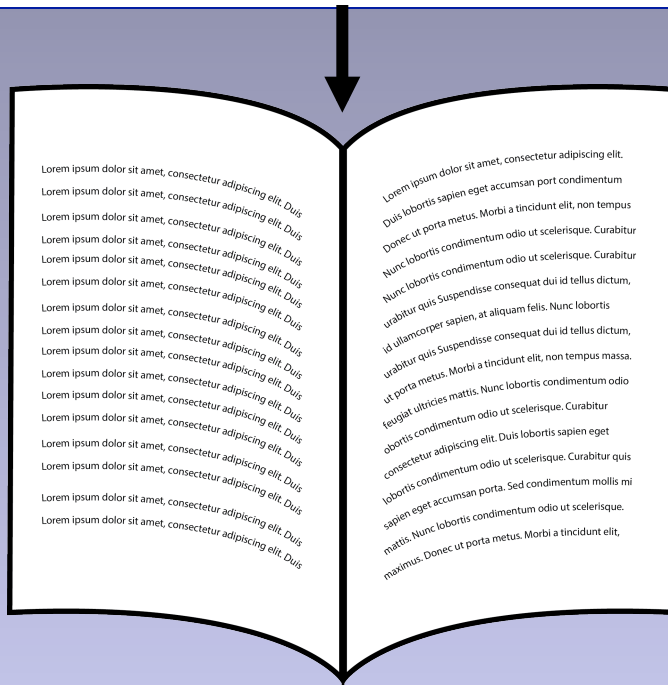


Triticum aestivum
Modern bread variety

Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

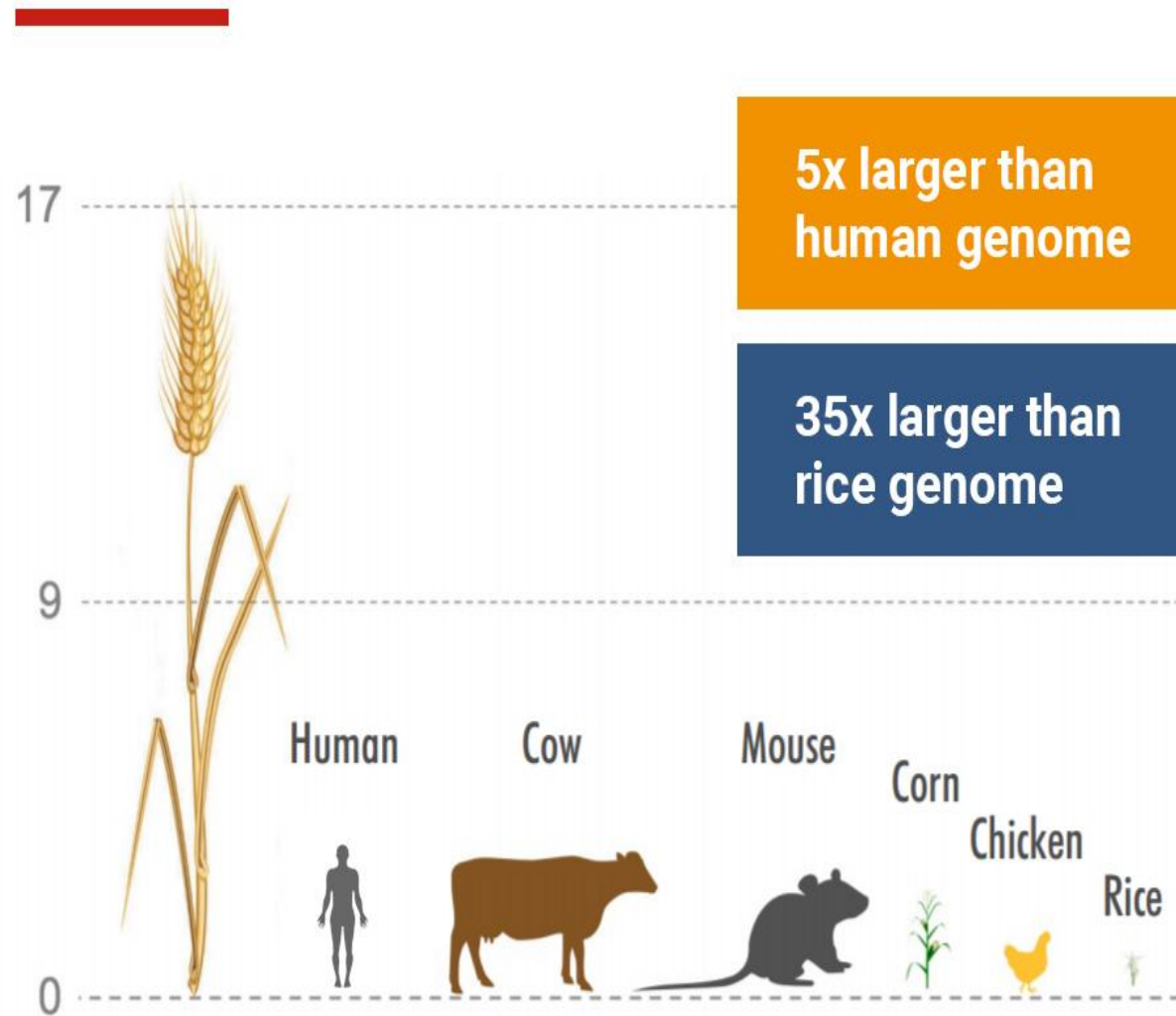


1700 books
1000 pages each



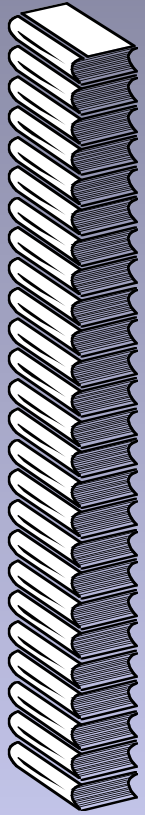
1700 books
(or 1.7 million pages)

How does the wheat genome compare to the human genome?

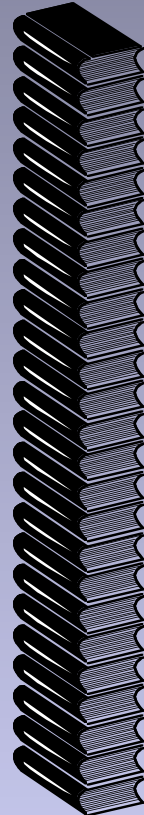


Source: Earlham Institute communications team, Chris Bennett

Hybridization or cross breeding of wheat



X



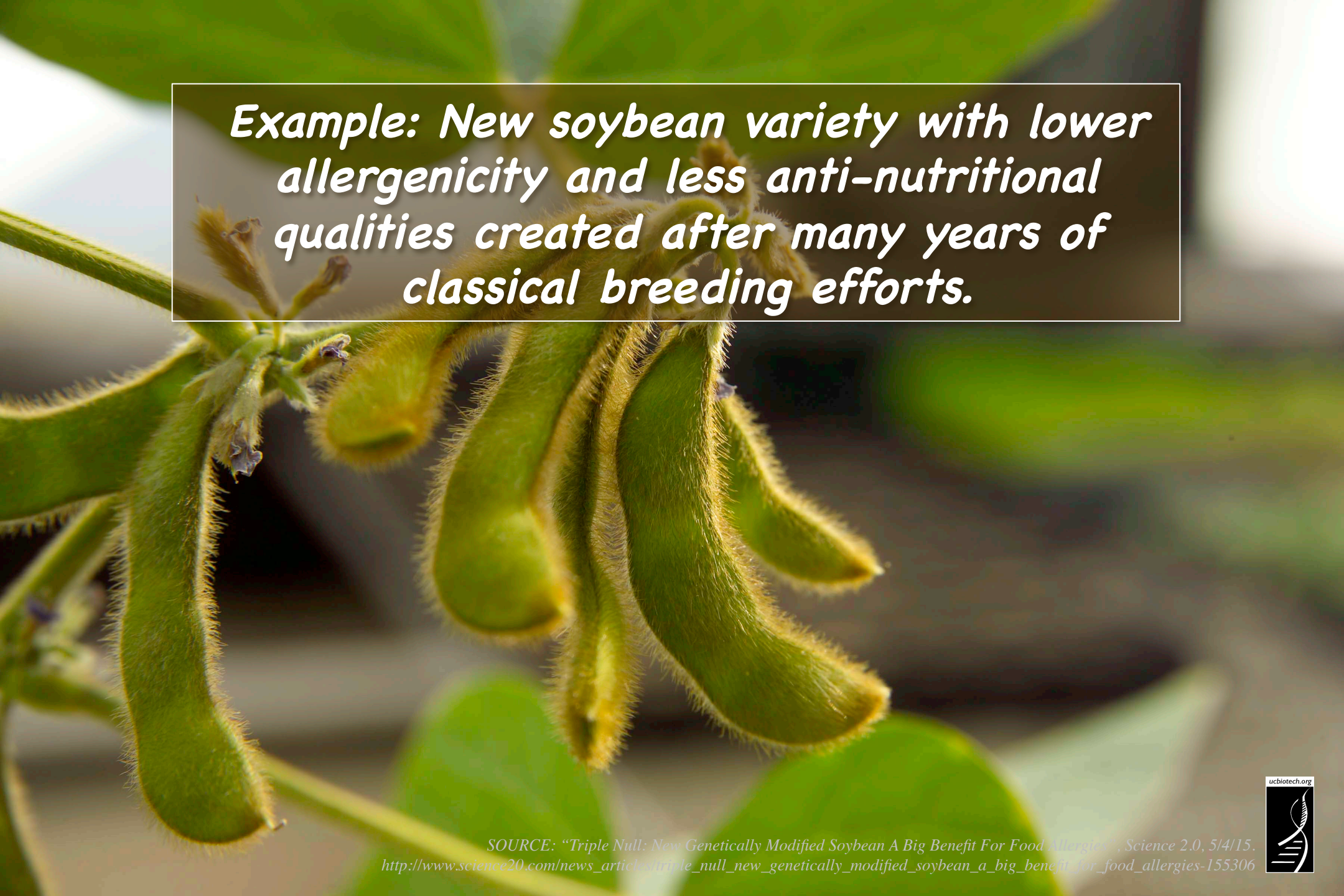
Random
retention of
information
from each
parent

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

Genetic modification by hybridization is not GE or GMO




A close-up photograph of several green soybean pods hanging from a plant stem. The pods are covered in fine, light-colored hairs. The background is a soft-focus green, suggesting more foliage.

Example: New soybean variety with lower allergenicity and less anti-nutritional qualities created after many years of classical breeding efforts.

SOURCE: "Triple Null: New Genetically Modified Soybean A Big Benefit For Food Allergies", Science 2.0, 5/4/15.
http://www.science20.com/news_article/triple_null_new_genetically_modified_soybean_a_big_benefit_for_food_allergies-155306



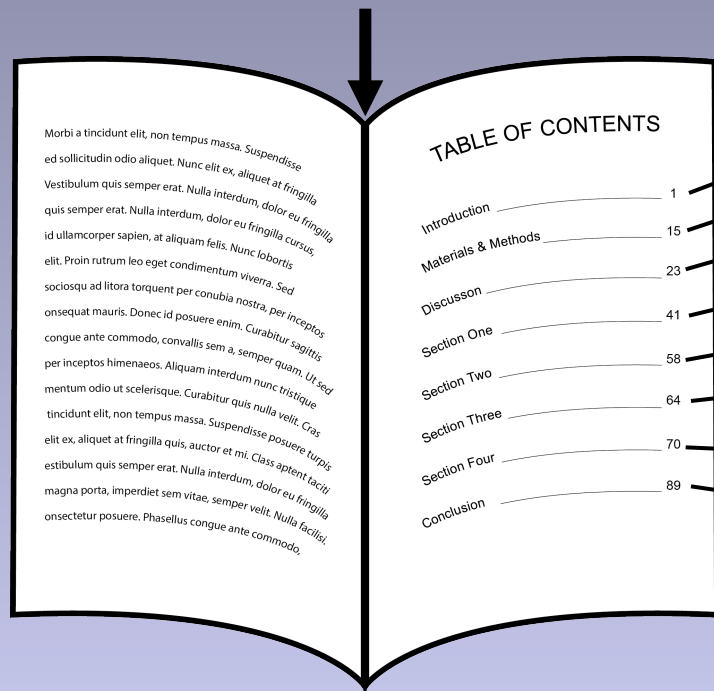
Putting this in context, these breeding efforts were critical to increasing crop production...

Product	2014 total production	2014 acreage	Acreage needed at 1950's rate	Additional Resources needed
Soybeans 	3.927.090,000 bu 235,562,540,000 lb	82,591,000 acres	180,971,889 acres	~98 million acres (= size CA)
Corn 	14,215,532,000 bu	83,136,000 acres	372,134,346 acres	~289 million acres (= 3X size CA)
Broiler Chickens 	51,373,100,000 lbs	8,544,100,000 head	16,679,545,455 head	~8 billion head requiring 81.5 billion lbs feed

New breeding methods

Uses table of contents of genes for marker assisted selection

...CTGACCTAATGCCGTA...



1700 books
(or 1.7 million pages)

Genetic modification that is not GE or GMO

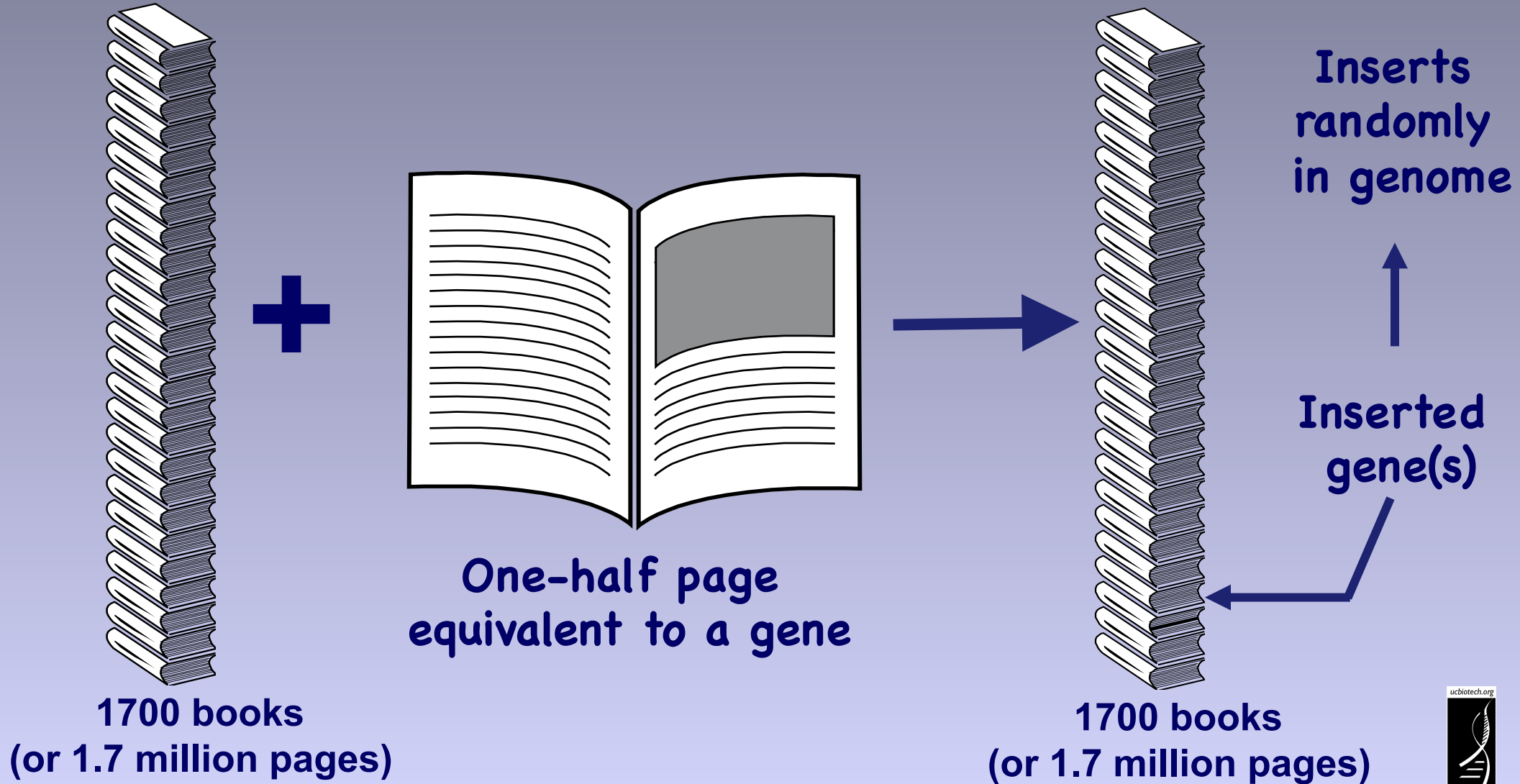


Can't we just do all modifications this way?

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

**Protection limited to diversity in crop and
compatible relatives**

Another means to modify genomes uses genetic engineering to create "GMOs"



Genetic Engineering

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

Inserts
randomly
in genome

Inserted
gene(s)

One-half page
equivalent to a gene

1700 books
(or 1.7 million pages)

**Genetic modification
that is GE and GMO**

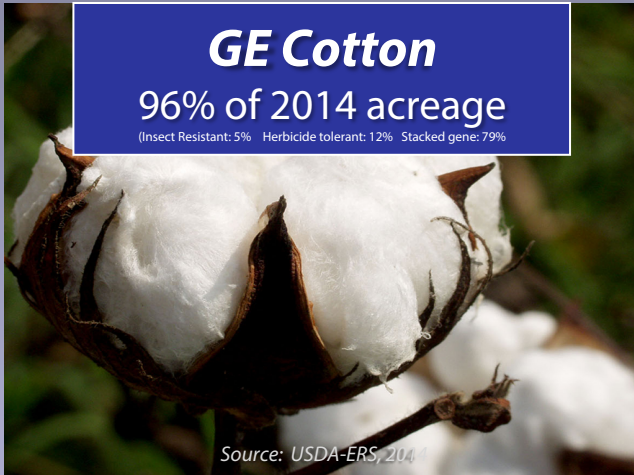
1700 books
(or 1.7 million pages)

Number of different commercially available, large acreage GE (GMO) crops is limited

GE Cotton

96% of 2014 acreage

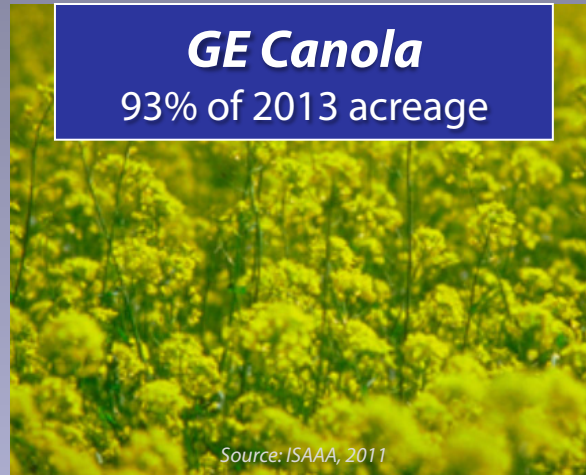
(Insect Resistant: 5% Herbicide tolerant: 12% Stacked gene: 79%)



Source: USDA-ERS, 2014

GE Canola

93% of 2013 acreage



Source: ISAAA, 2011

GE Soybean

94% of 2014 acreage

(Herbicide resistant: 94%)

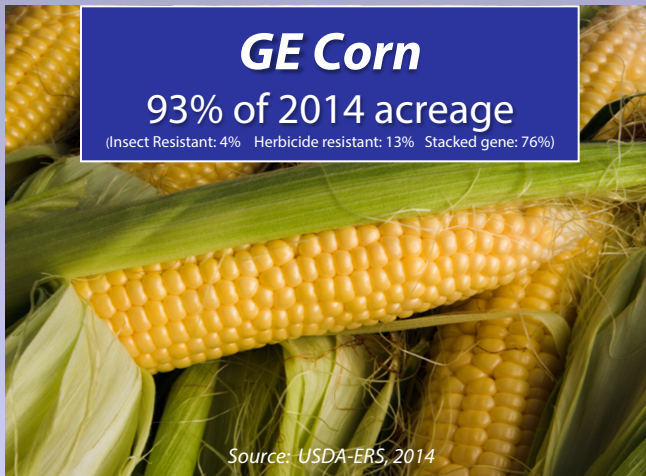


Source: USDA-ERS, 2014

GE Corn

93% of 2014 acreage

(Insect Resistant: 4% Herbicide resistant: 13% Stacked gene: 76%)



Source: USDA-ERS, 2014

GE Sugarbeet

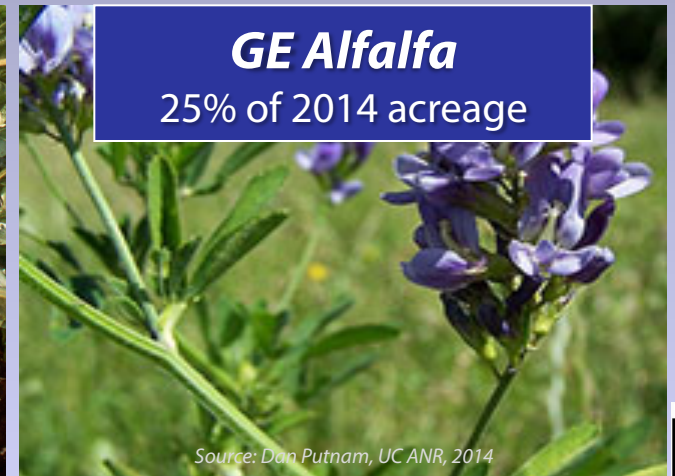
98% of 2013 acreage



Source: ISAAA, 2011

GE Alfalfa

25% of 2014 acreage



Source: Dan Putnam, UC ANR, 2014

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



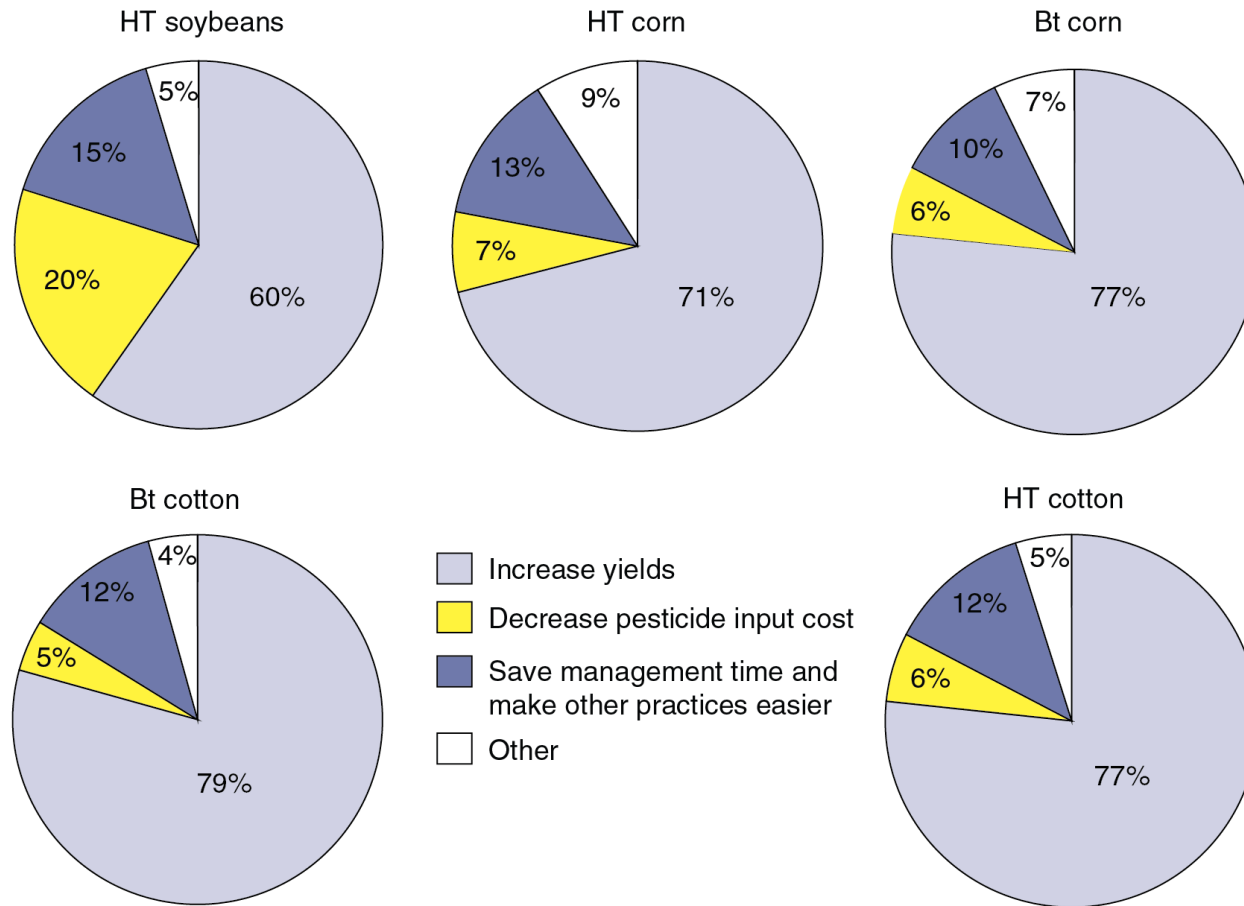
Insect-tolerant Bt crops - engineered for resistance using gene from naturally occurring bacterium



Herbicide-tolerant - engineered with gene to tolerate herbicide application

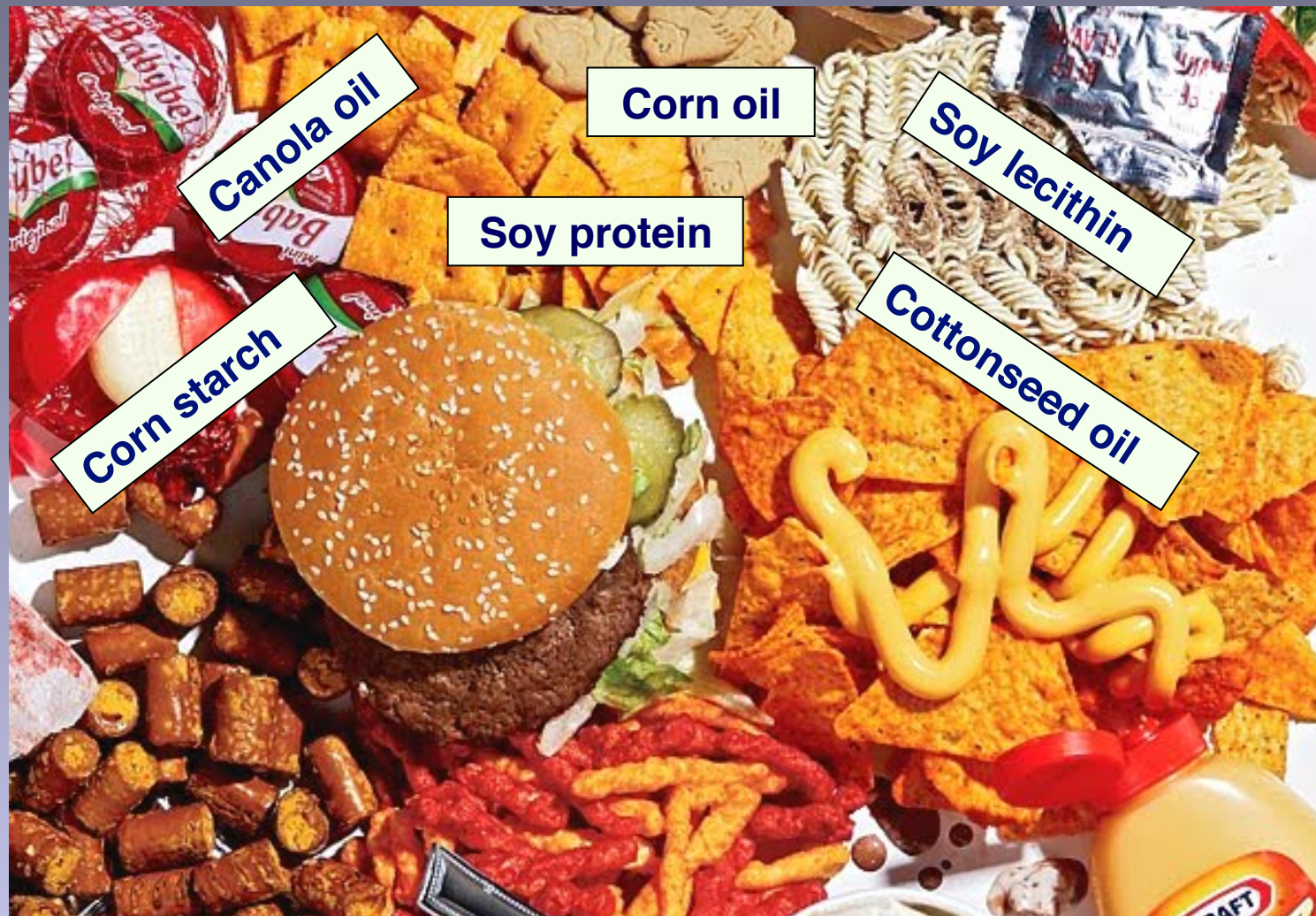
Crops with stacked traits - both Bt and HT - are available

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 – often only a minor ingredient

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

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

GE Squash

~25,000 acres in 2011



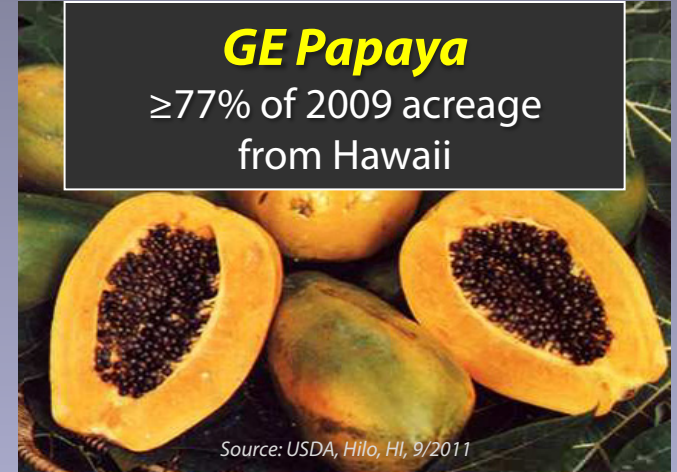
Source: Non-GMO Project

GE Sweet Corn Acreage unknown



GE Papaya

≥77% of 2009 acreage
from Hawaii

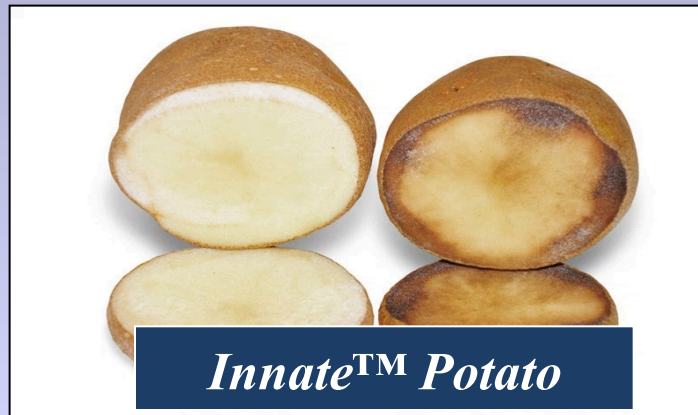


Source: USDA, Hilo, HI, 9/2011

Two more are just being introduced

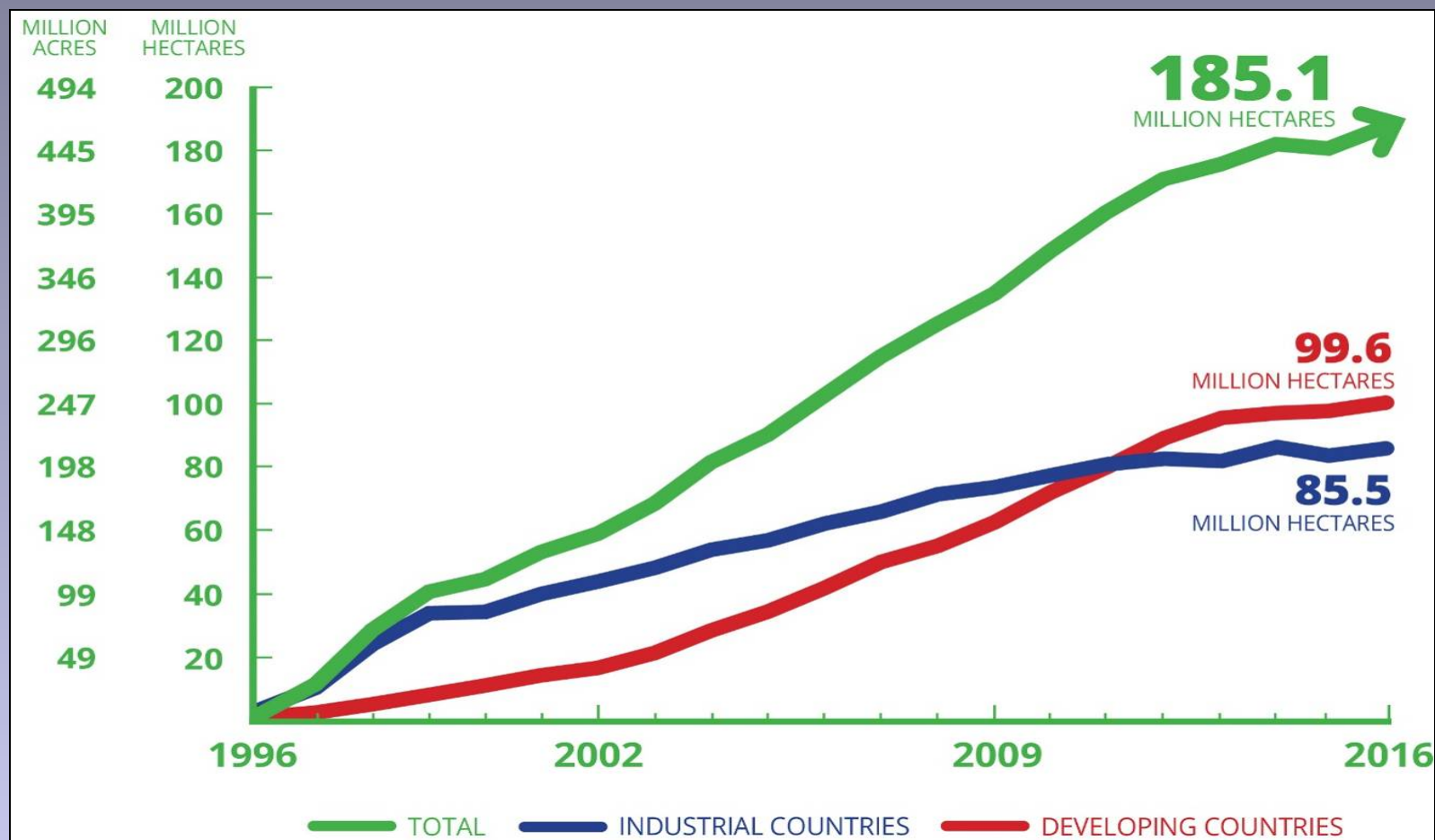


Arctic Apple™



Innate™ Potato

Despite the same limited U.S. crop and trait types, worldwide acreage is increasing in 19 developing, 7 developed countries



In 2016 ~18 million farmers in 26 countries planted 457M acres (>4X size of California) – 54% in developing countries; 41% stacked traits

WHAT'S IN THE PIPELINE?



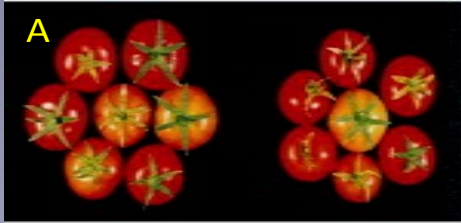
A close-up photograph of several green grapes. The grapes are covered in a fine, white, powdery substance, which is powdery mildew. The background is dark and out of focus.

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

SOURCE: Western Farm Press, volume 26, number 16



Salinity and Drought Tolerance - UC Davis



Wild type
200 mM NaCl (~1/2 sea water)



AtNHX1



Wild type
15 days drought, 7 days re-watered



IPT gene

Salt-tolerance

Drought-tolerance

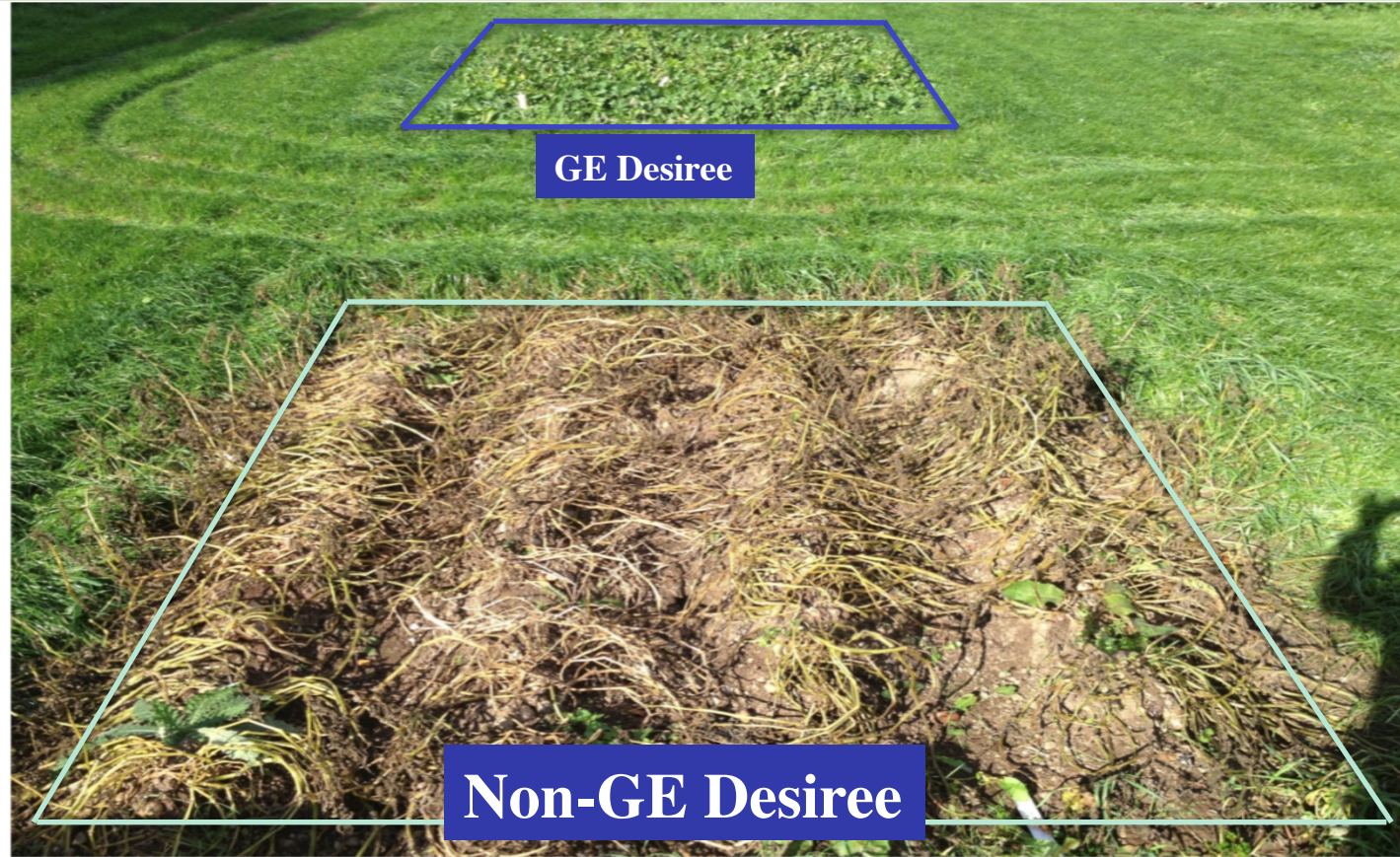


***Arcadia Biosciences in Davis develops GE
canola that uses 50% less nitrogen fertilizer***

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



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





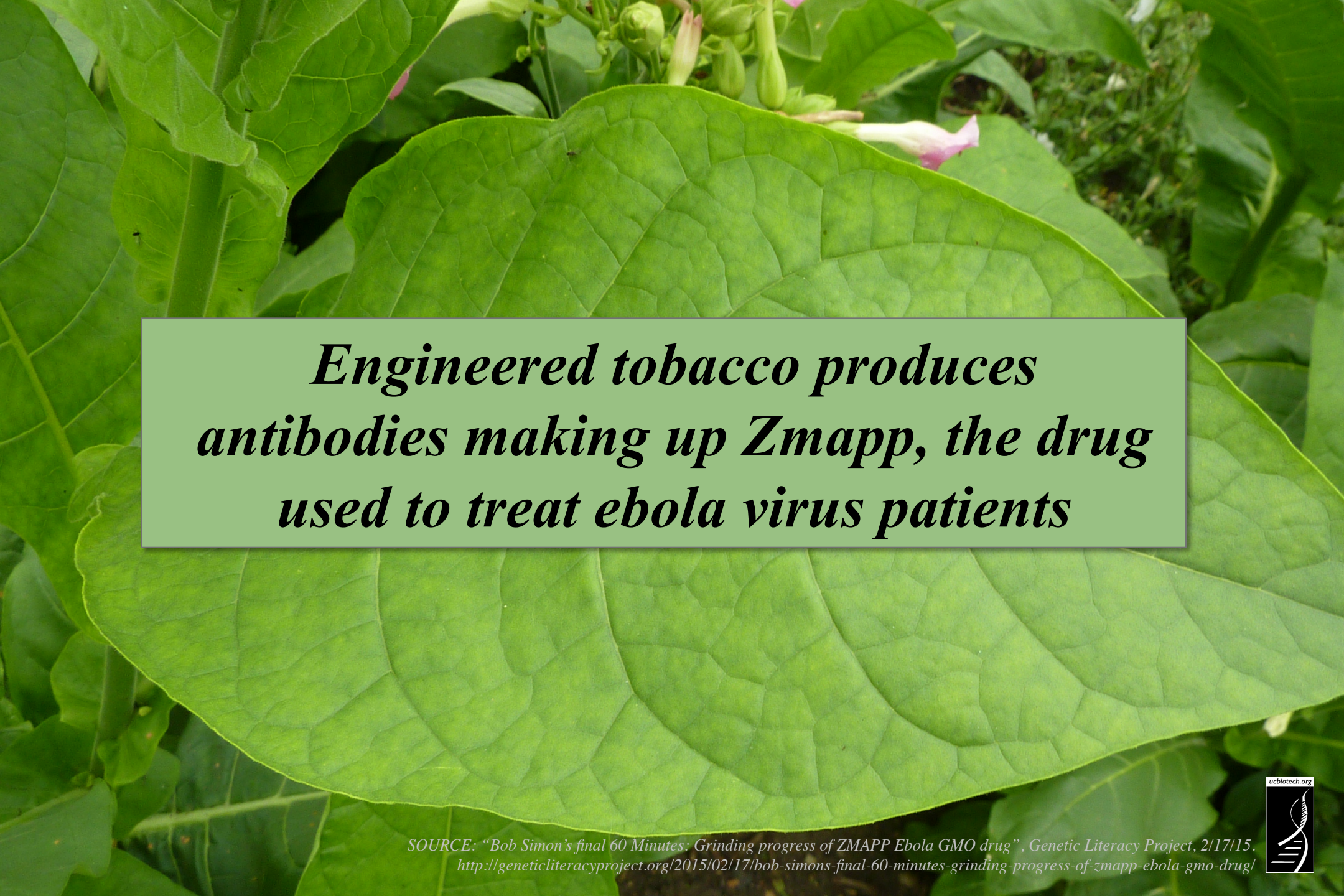
Chestnuts engineered with a wheat gene prevents cankers from forming; replanted with \$104K raised through crowd funding campaign

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



High anthocyanin purple GE tomatoes. Diets with 10% purple tomatoes increased lifespan of cancer-prone mice

Butelli et al. 2008. <https://www.jic.ac.uk/staff/cathie-martin/purple-tomatoes.html>



***Engineered tobacco produces
antibodies making up Zmapp, the drug
used to treat ebola virus patients***

SOURCE: "Bob Simon's final 60 Minutes: Grinding progress of ZMAPP Ebola GMO drug", Genetic Literacy Project, 2/17/15.
<http://geneticliteracyproject.org/2015/02/17/bob-simons-final-60-minutes-grinding-progress-of-zmapp-ebola-gmo-drug/>



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

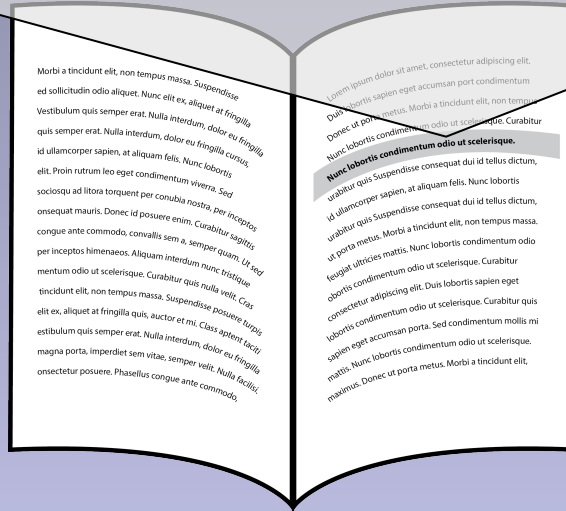
Advanced genome-editing techniques have been used to create a strain of wheat resistant to a destructive fungal pathogen – called powdery mildew – that is a major bane to the world's top food source, according to scientists at one of China's leading centers for agricultural research.



*Wheat resistant to powdery mildew created
using new genome-editing techniques*

What is Genome Editing?

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



**Inserts
specifically
in genome**

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

**1700 books
(or 1.7 million
pages)**

**Genome edited plants can
be GE or GMO or not**

**1700 books
(or 1.7 million pages)**

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



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

Then they came to Monterey – and were not welcomed here either!



**But 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



2014

GM maize protest in Germany



1999

Lord Melchett participating in GM protest

And there are issues in the U.S. too

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling
- Environmental issues
- Some additional food for thought...

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Labeling
- Environmental issues
- Some additional food for thought...

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?

Are they as safe as conventional foods?

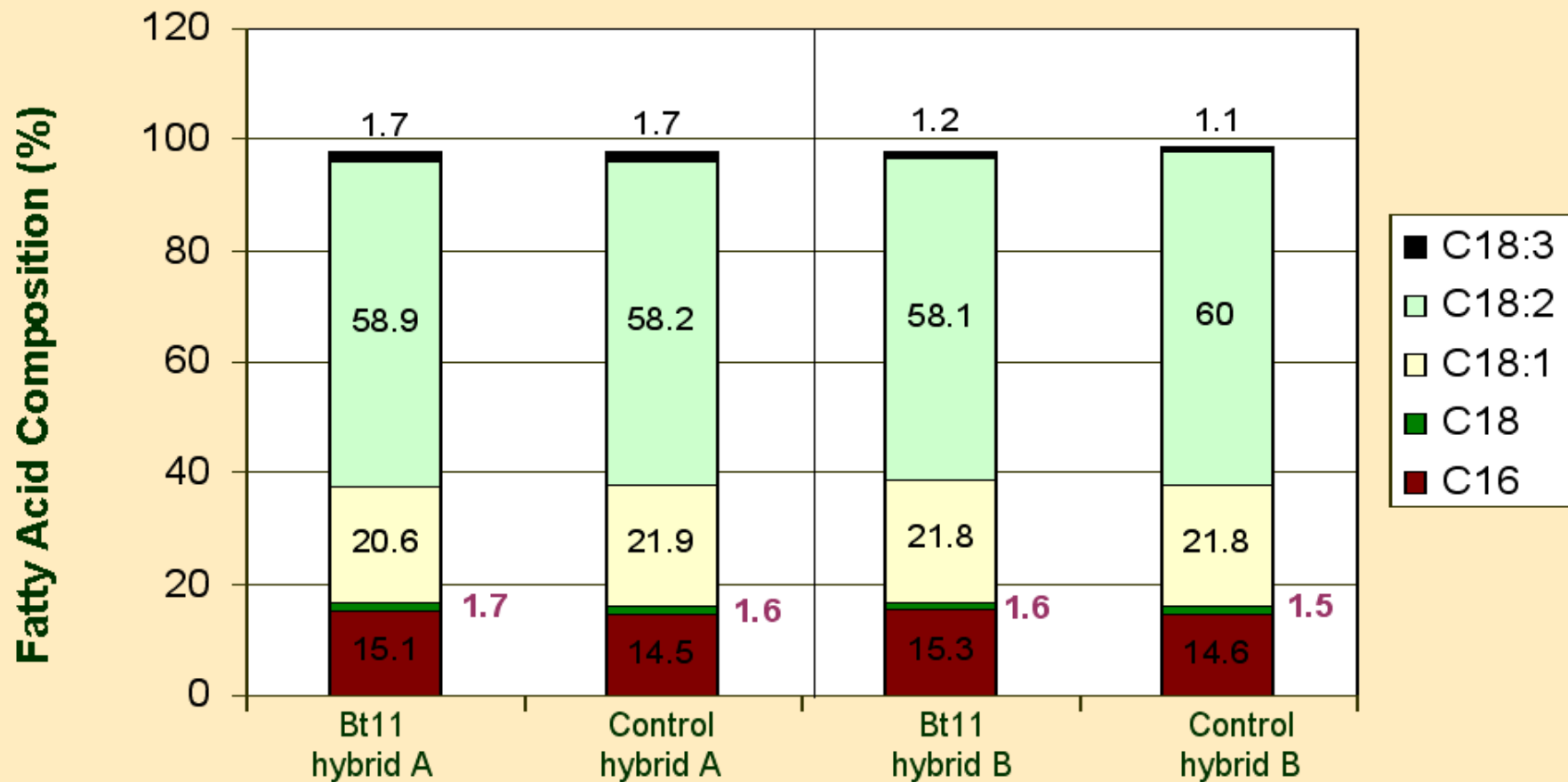
**This is based on the concept of
substantial equivalence**

**Modified food has essentially all characteristics
of nonmodified food with respect to food and
feed value except for introduced trait**

**Product of introduced genetic
information tested for safety separately**

How is substantial equivalence tested?

Substantial Equivalence: Fatty Acids

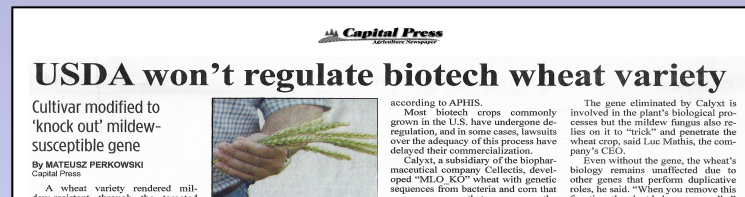


These results have been generated on Event Bt 11. Data showing similar fatty acid composition have been generated on the other corn events.

Regulation is based on an outdated regulatory system, created in 1986, which is causing problems:

- New products emerge with no rules to govern them
- Old products are not on the market because there are no clear pathways for commercialization
- New products created to step around regulatory system

EXAMPLES:



**In April 2016: USDA APHIS decided not to regulate a mushroom and corn genetically modified with genome editing.
Reason: no DNA from other species introduced.**

These types of examples have resulted in loud calls for revamping U.S. regulatory oversight

Genetically engineered crops that fly under the US regulatory radar

A first step taken on July 2, 2015 by a White House Initiative to modernize biotech regulation

Charge: update 1986 Coordinated Framework to clarify roles of three agencies to determine what products fall under authority of what agencies.

Also need to decide how to regulate products created with genome editing tools.

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Labeling
- Environmental issues
- Some additional food for thought...

Occasionally there are widely publicized studies that cast doubt on safety of GE foods - one published by French researcher in Sept. 2012

Later reviewed by European Food Safety Authority and found to have no merit

But did you ever hear that on Dr. Oz?

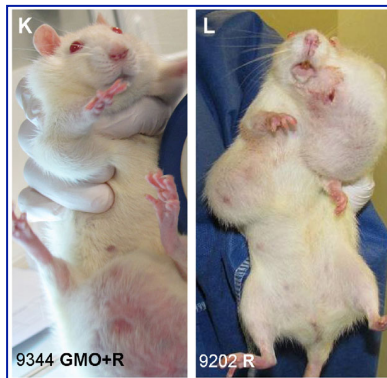
French academies trash GM corn cancer study

By RFI

A controversial study that linked genetically modified maize to cancer in laboratory "scientific experiments" was criticized by six members of the French Academy of Sciences in a report published on Monday.



Featured on Dr. Oz Show



Claim that Monsanto's RR corn causes tumors in rats



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

"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.



What have other published studies shown?

Meta-analysis from France in 2012 showed GE foods are nutritionally equivalent to non GE foods and can be safely consumed in food and feed.

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



maize

potato



soy

rice



triticale

2014 study

- 9 B food-producing animals in U.S
- 95% consumed feed with GE ingredients
- Analysis of public data from 1983 to 1996, before GE crops, vs. 1996 to 2011
- Included >100 B animals



Conclusion:

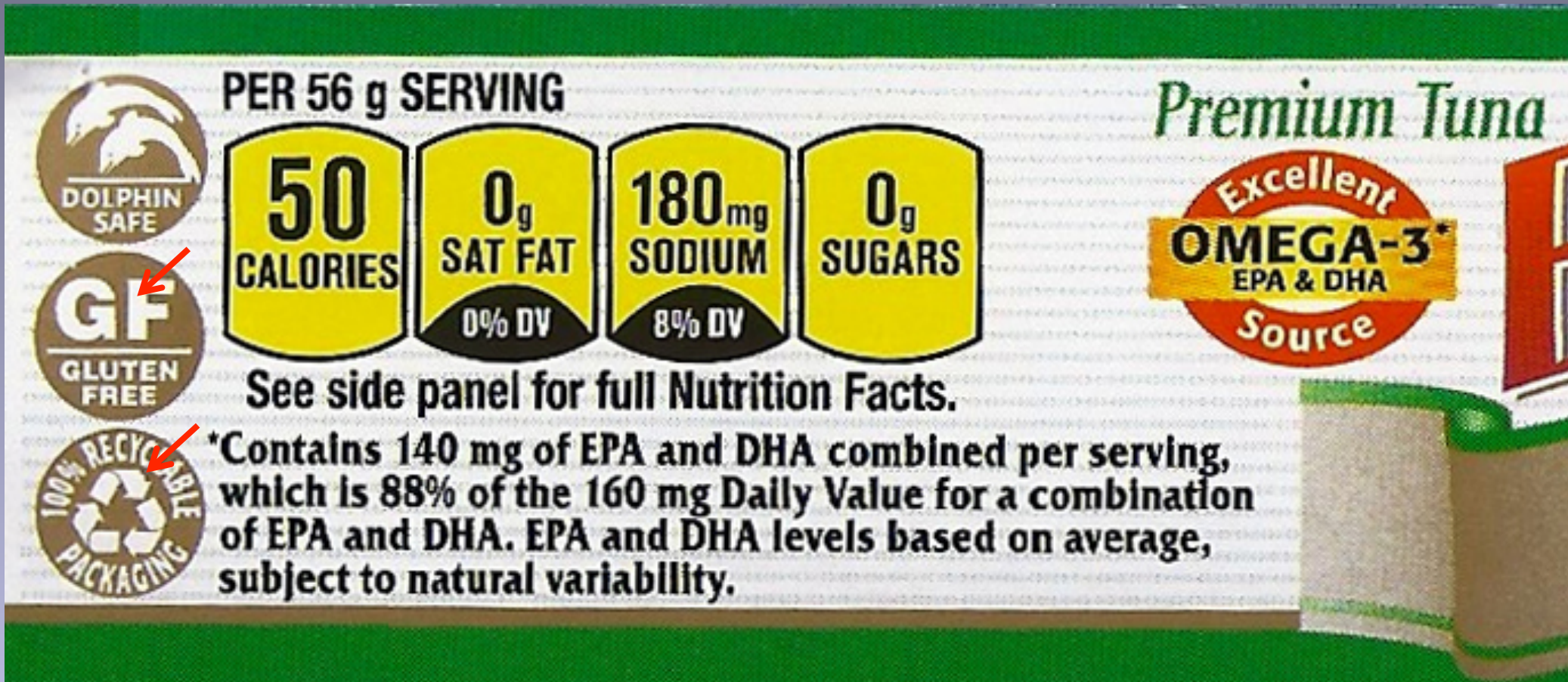
- ❖ No unfavorable or perturbed trends in livestock health and productivity.
- ❖ No differences in nutritional profile of animal products from GE-fed animals.



SOURCE: "Prevalence and impacts of genetically engineered feedstuffs on livestock populations"
A. L. Van Eenennaam and A. E. Young, *J. Animal Science* September 2014

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Labeling
- Environmental issues
- Some additional food for thought...



There are already many labels on foods– from gluten-free to dolphin-safe – none are mandated. And, up to now, there were no federally mandated labels on foods with GE ingredients.

Food Safety News

Breaking news for everyone's consumption

GE Labeling Resurrected in California, Petition For Ballot Measure Circulating in Colorado

BY DAN FLYNN | MARCH 25, 2014

California's 2012 food-labeling ballot measure, rejected by state voters, makes a return from the grave tomorrow with a public hearing in Sacramento. And another state initiative is in the offing in Colorado.

Since the narrow loss for the Golden State's Proposition 37, which called for labeling foods made with genetically modified organisms (GMOs), almost half the states have seen bills introduced containing similar



This led to numerous statewide labeling laws for GE foods that would have led to a patchwork of regulation – causing problems for commerce and enforcement

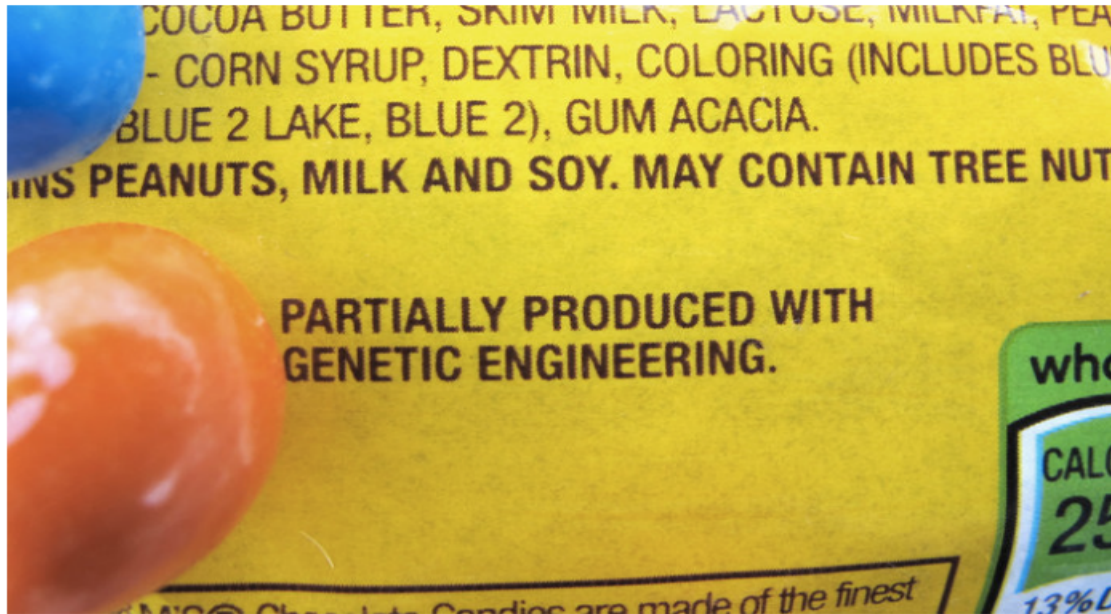
SOURCE: "GE Labeling Resurrected in California, Petition For Ballot Measure Circulating in Colorado", March 25, 2014, Food Safety News.
<http://www.foodsafetynews.com/2014/03/gm-labeling-resurrected-in-california-petition-circulating-for-initiative-in-colorado/#.UznX9q1dVLM>



Senators Reach Deal On National GMO Labeling Bill

June 23, 2016 · 6:39 PM ET

PEGGY LOWE



A new disclosure statement on a package of peanut M&M's candy notes they are "partially produced with genetic engineering."

And then...

July 8, 2016: Senate passes bill by Senators Roberts (R, KN) and Stabenow (D, MI) for a mandatory national system for GM disclosures on food products, nullifying Vermont's labeling law, which took effect July 1. Obama signed on July 29.

Legislation requires USDA to decide what ingredients are from genetically modified organisms and labels will be added on foods using words, pictures or a bar code that can be scanned by smartphones.

<http://deltafarmpress.com/soybeans/senate-passes-roberts-stabenow-gmo-labeling-bill-preempts-vermonts>

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Labeling
- Environmental issues
- Some additional food for thought...

Insect Resistance

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

**Development of herbicide-tolerant weeds
or resistant insects**

To date minimal insect resistance has occurred

The background of the slide is a photograph of a cotton field. In the upper half, there are cotton plants with white, fluffy bolls. A white bird, possibly a egret or heron, is partially visible in the top left corner. The lower half of the image shows a dense field of green cotton leaves.

What about Herbicide Tolerance?

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

But is 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



Herbicide-resistant Weeds Threaten Soil Conservation Gains: Finding a Balance for Soil and Farm Sustainability

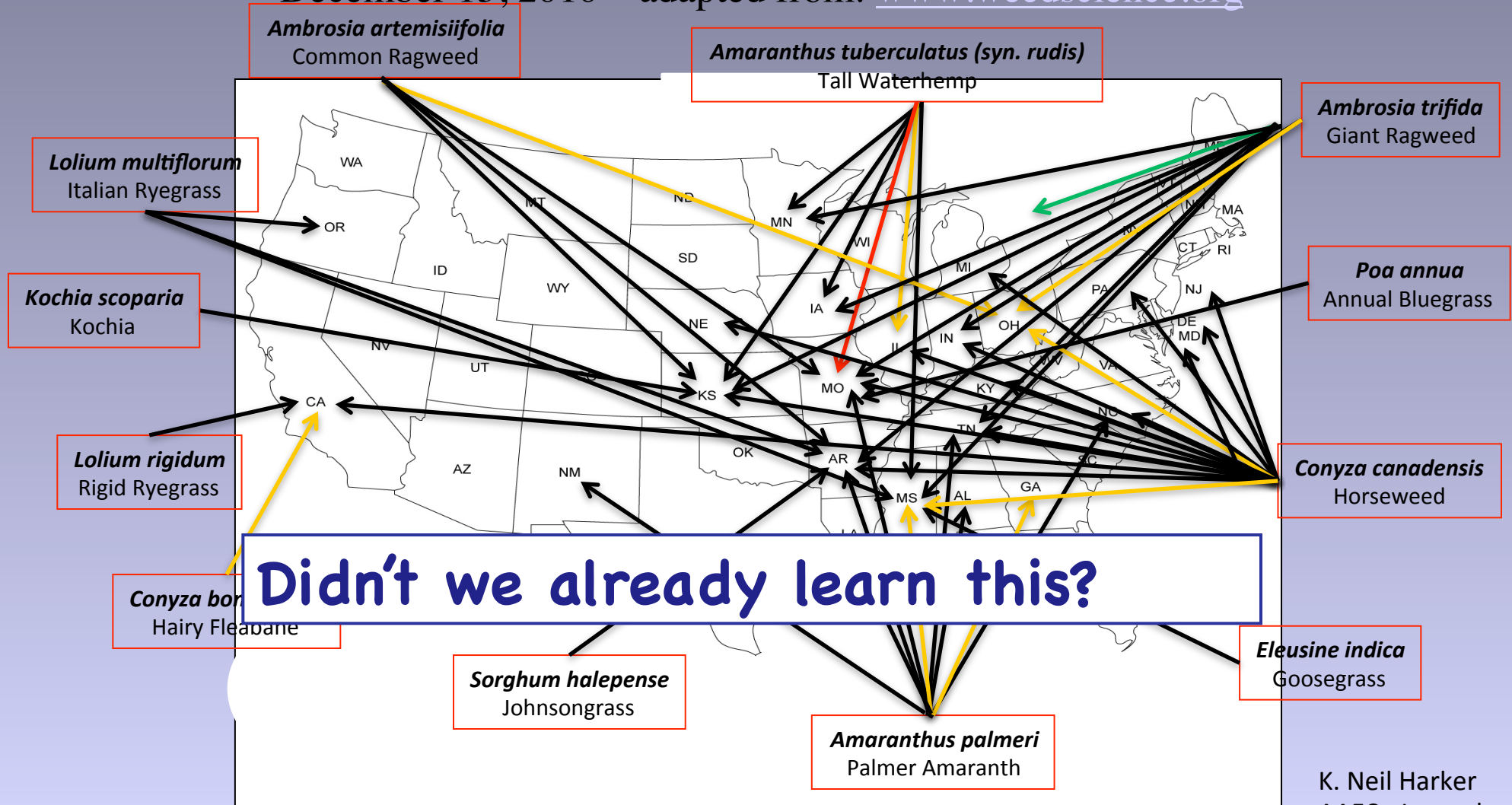
“When any single herbicide mechanism of action is used repeatedly without alternative management tactics, selection pressure becomes intense for plants that are tolerant or resistant to that herbicide.”

SOURCE: Council for Agricultural Science and Technology (CAST). 2012. Herbicide-resistant Weeds Threaten Soil Conservation Gains: Finding a Balance for Soil and Farm Sustainability. Issue Paper 49. CAST, Ames, Iowa. <http://bit.ly/wd0AXOq>

Glyphosate-resistant weeds due to mutation, gene flow, weed shift – exacerbated when same herbicide is used repeatedly

Glyphosate- Resistant Weeds – USA

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



K. Neil Harker
AAFC - Lacombe, AB

What are some issues with GE crops & foods?

- Regulatory oversight
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Consider This As Food For Thought



- Nigeria: little over twice the size of California
- 75% more arable land than U.S.
- Five times less land per capita in Nigeria vs. U.S.
- In 2050, expected to be third most populous country in the world overtaking the U.S.

Also...Consider This As Food For Thought

If food waste were a country, it would rank behind only the US and China for greenhouse gas emissions.



And...production of wasted food uses 28% of the world's agricultural area.

Also...Consider This As Food For Thought

Big mergers “could change food supplies and costs worldwide”

1. U.S.: Dow Chemical is buying Dupont-Pioneer
2. Germany: Bayer is buying Monsanto
3. China: ChemChina is buying Syngenta

This \$170B in consolidation deals will have a profound effect on future of global agriculture

And frankly this scares me!



AGRICULTURE

CHINA'S \$43 BILLION BID FOR FOOD SECURITY

ChemChina's acquisition of ag-tech giant Syngenta is part of a broader strategy that could change food supplies and costs worldwide.

By Geoff Colvin

▲ PHOTOGRAPHS BY
STEFEN CHOW

Source" Colvin, G. "China's \$43Billion Bid for Food Security" *Fortune* May 2017: 79-86.



Where to get more information on the issues?



ucbiotech.org SCIENCE-BASED INFORMATION & RESOURCES
ON AGRICULTURE, FOOD & TECHNOLOGY

ABOUT US | NEWS | ISSUES & RESPONSES | GMO LABELING | RESOURCES | LINKS | GLOSSARY | SEARCH

Select Language ▼

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 LECTURE VIDEO

"Feast, Famine and the Future of Food"

Outreach in Biotechnology
Food for Thought Lecture Series
Oregon State University
January 25, 2012

BIOTECHNOLOGY INFORMATION



Labeling:
Informational resources available.



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.



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 worksheet in English and Spanish.

Gene-IE Juice Bars: Interactive activity to isolate DNA from common fruits and vegetables.

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.

