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#### 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...

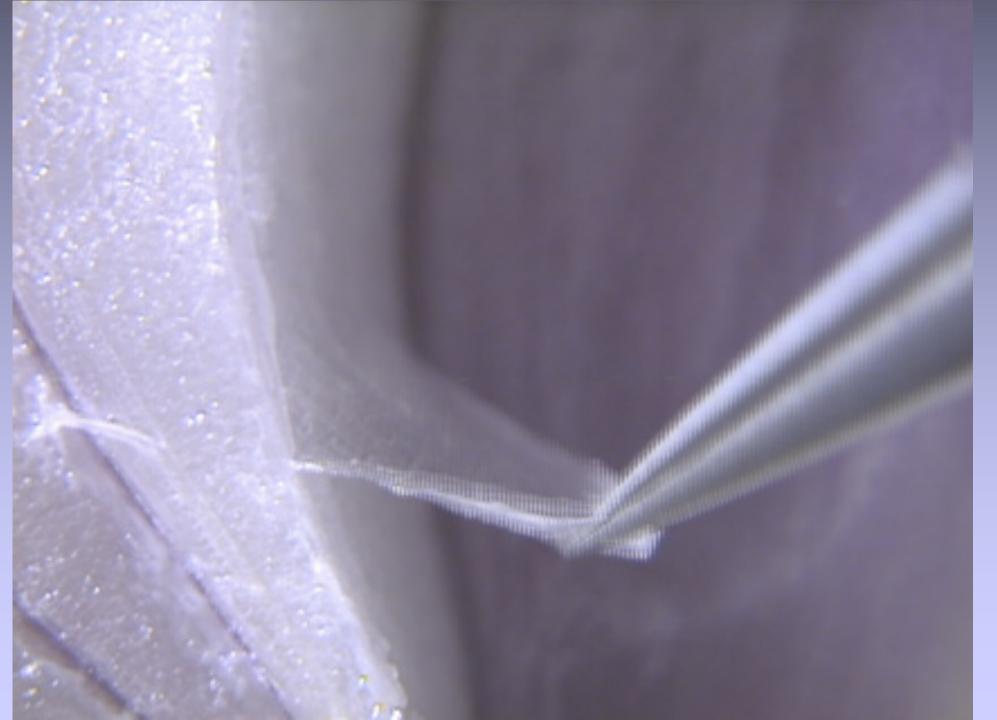


# Tour d'Onion

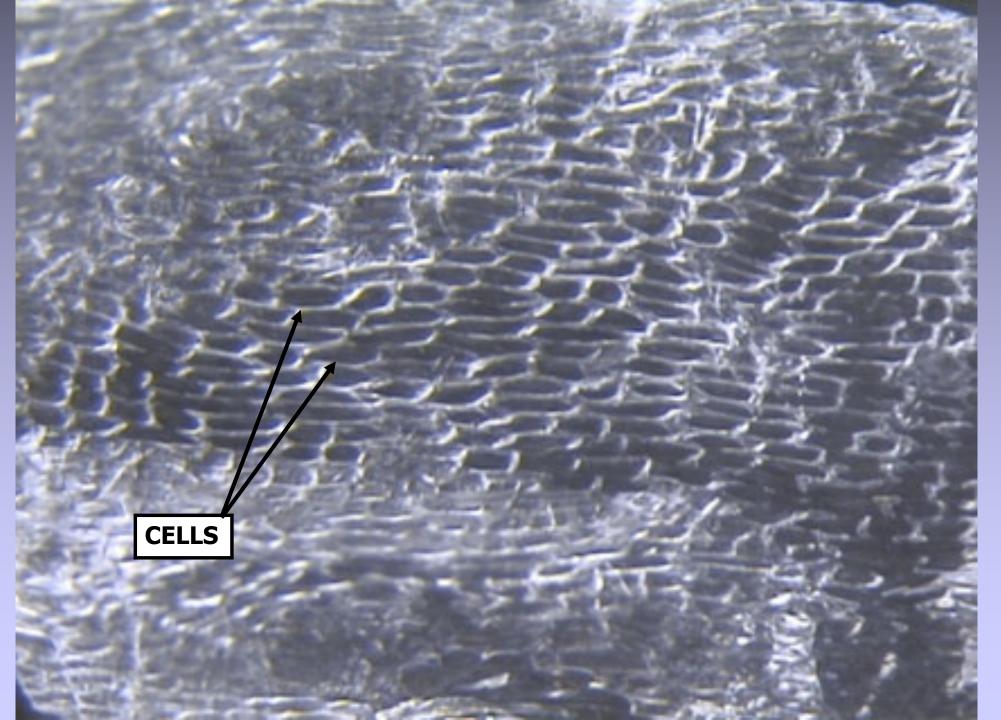


Or, what makes an onion and onion?

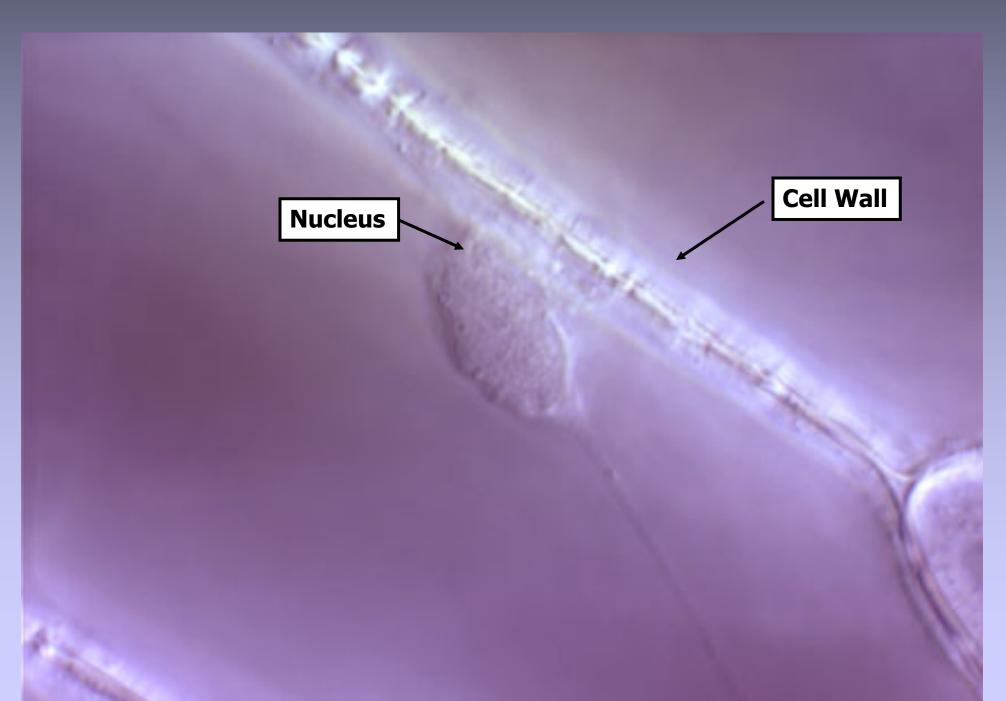






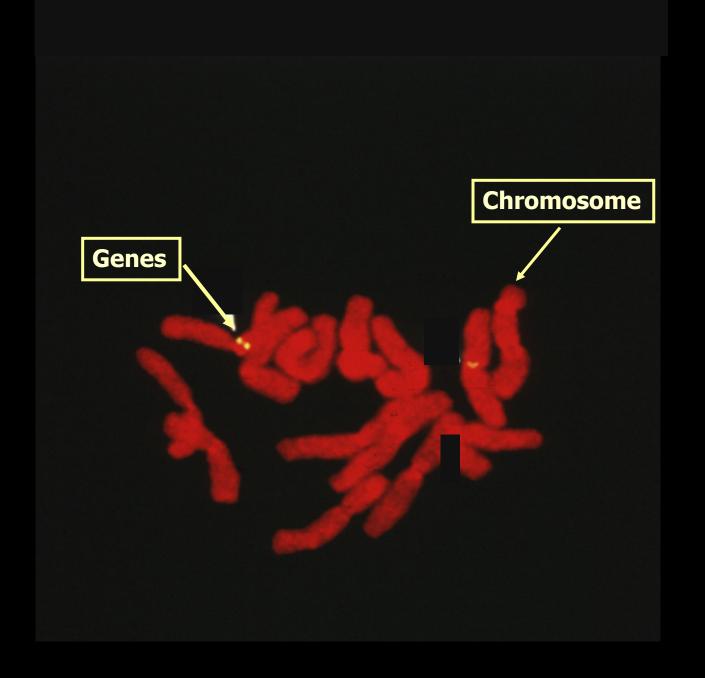








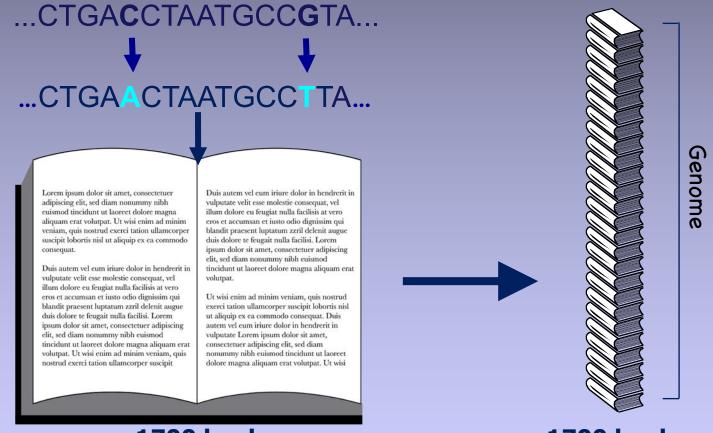






#### Genetic information in cell is responsible for traits

Chemical units in DNA represented by alphabetic letters



1700 books 1000 pages each 1700 books (or 1.7 million pages)

Sometimes mistakes happen when copying information in books (genomes) -> creating changes, called <u>mutations</u>





Carrot

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

#### To Looking Like They Are Now





Banana









**Eggplant** 



Broccoli, Kale, Cabbage



Since 1950's intentional mutation breeding has created >3200 crops - e.g., 600 maize, rice, wheat varieties. Although modified genetically, they are not under regulations for genetically engineered (GMO) varieties.





#### Modern Example

Japanese Farmer Creates Mongee Banana With Softer, Digestible Skin



### But genomes have also been modified by classical breeding to create new plant varieties?



Triticum monococcum

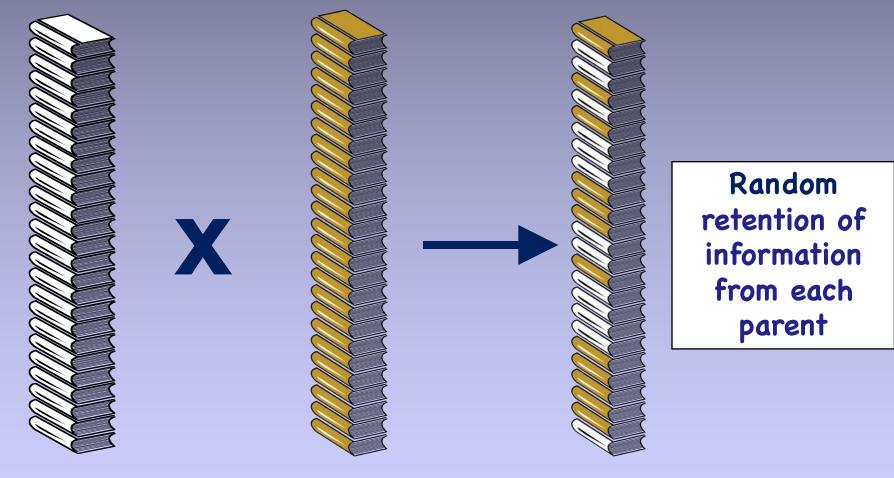


Triticum aestivum





#### Hybridization or Cross-breeding of Wheat



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

Genetic modification by hybridization is not GE or GMO







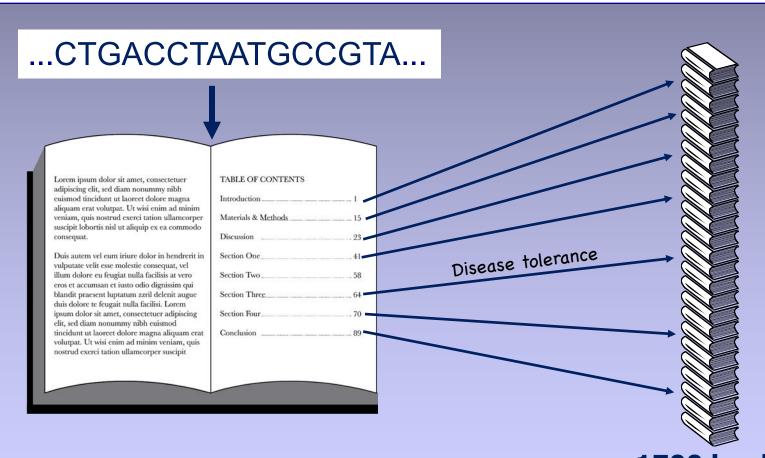
## Breeding efforts were critical to increases in crop production...

Product	2014 acreage	Acreage needed at 1950's rate	Additiona Resources needed
Soybeans	82,591,000 acres	180,971,889 acres	~98 million acres (= size CA)
Corn	83,136,000 acres	372,134,346 acres	~289 million acres (= 3X size CA)
Broiler Chickens	8,544,100,000 head	16,679,545,455 head	~8 billion head requiring 81.5 billion lbs feed



#### New Breeding Method

Uses table of contents of genes for marker assisted selection



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

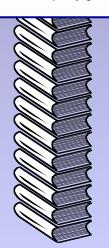


#### Also modify genomes with genetic engineering -> GMOs





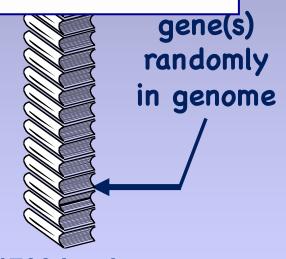
## What Kinds of GE Crops and Foods Are in the Commercial Market?



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One-half page equivalent to a gene

1700 books (or 1.7 million pages)

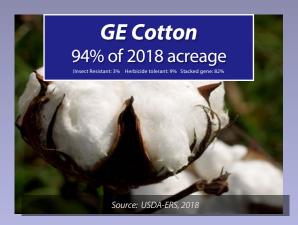


1700 books (or 1.7 million pages)

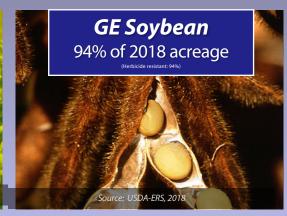


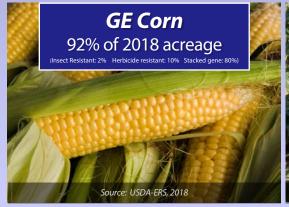
Genetic modification by genetic engineering is GE or GMO

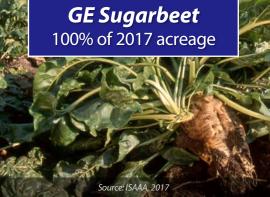
### Number of different commercially available, large acreage GE (GMO) crops is limited















#### 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

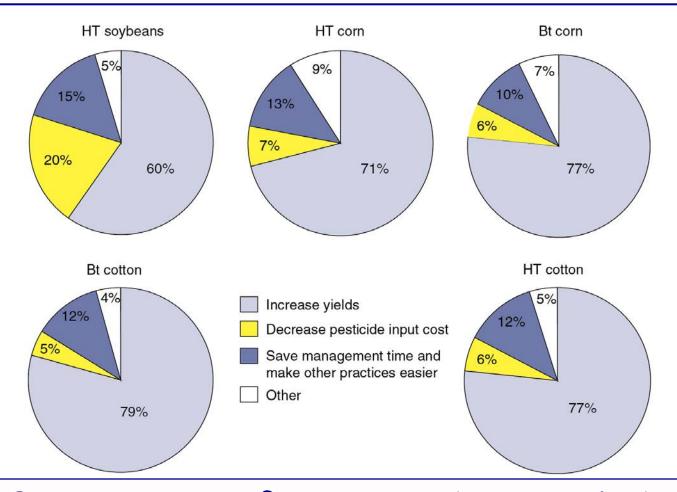


Herbicide-tolerant engineered with gene to
tolerate herbicide
application

Crops with stacked traits - Bt and HT - are available

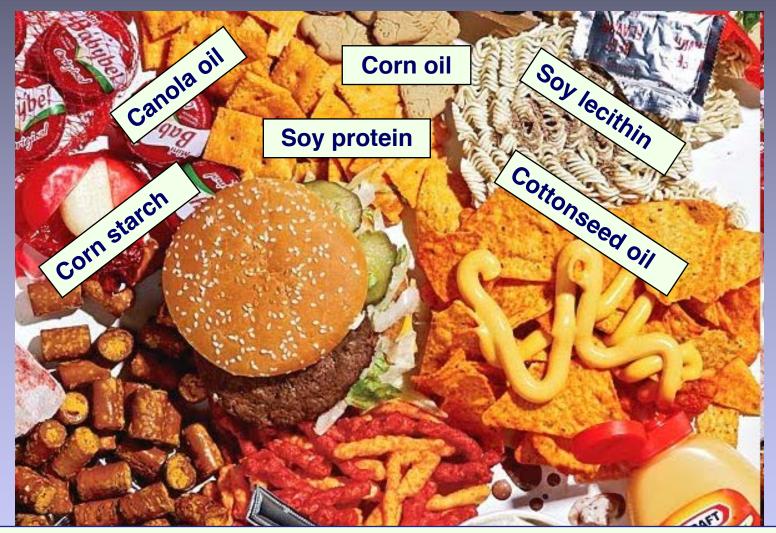


#### Why do U.S. growers use GE crops?



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



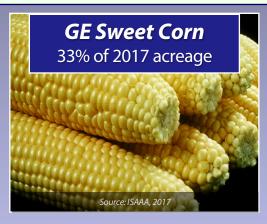


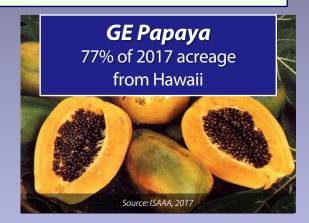
These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients - often only a minor ingredient



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







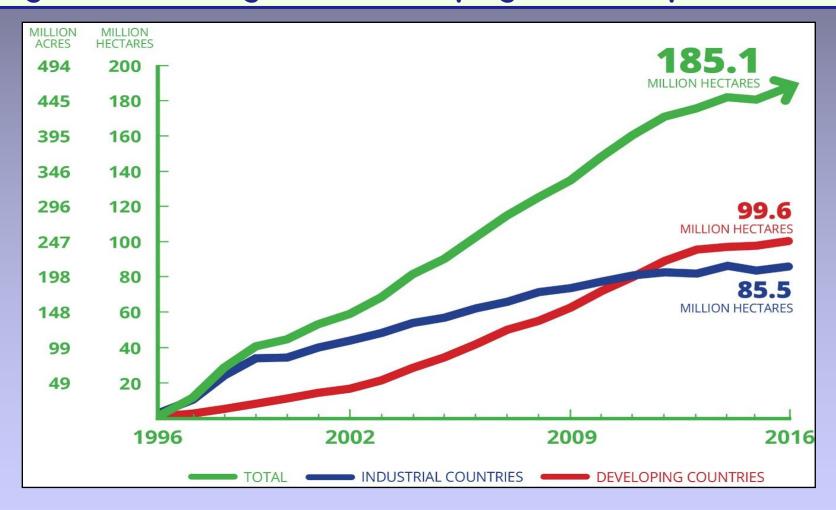
#### Two more are just being introduced





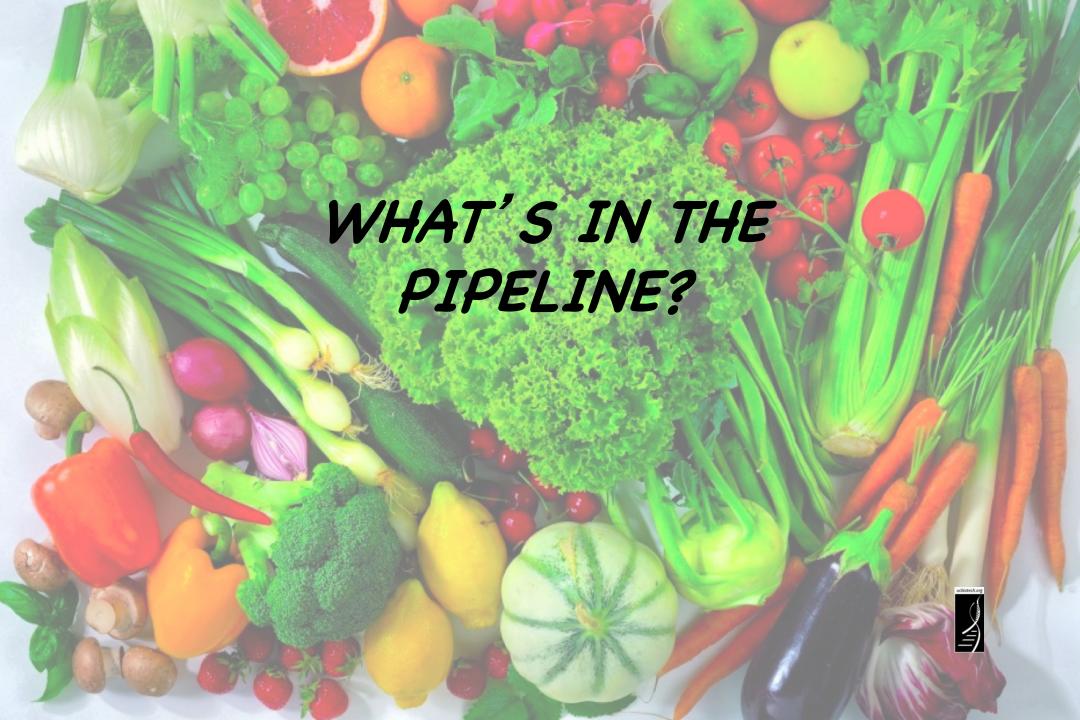


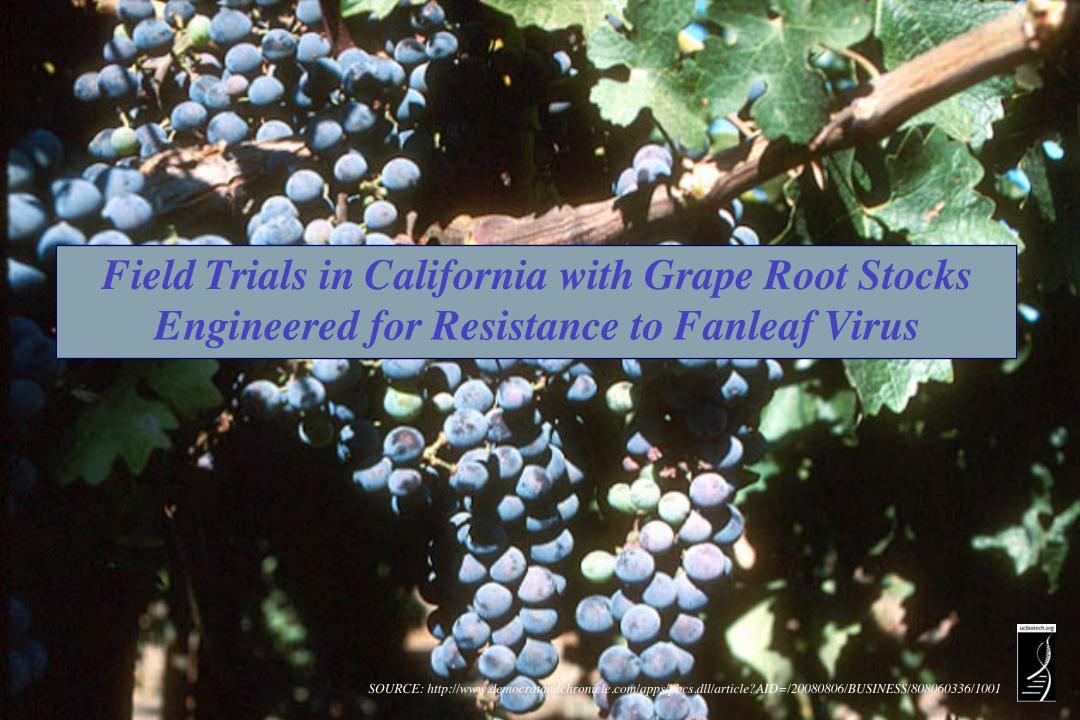
### Despite the same limited U.S. crop and trait types, worldwide acreage is increasing in 19 developing, 7 developed countries



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





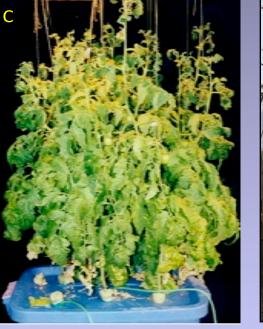


#### Salinity and Drought Tolerance - UC Davis













Wild type AtNHX1 200 mM NaCl (~1/2 sea water)

IPT gene Wild type 15 days drought, 7 days re-watered

Salt-tolerance

Drought-tolerance



### GE potato + pest management controls potato blight - reducing chemical fungicide use by up to 90%:









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





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



# Genetically modified wheat used to make coeliac-friendly bread

New genome editing technology used to turn off expression of genes responsible for traits

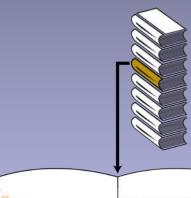


Daily bread: if gluten's not for you Superstock

"Knocked out" 35 of the 45 gliadin genes involved in coeliac; efforts now using genome editing (CRISPR)



#### New Genetic Method: Genome Editing-Mutation



Wheat is grown on more land area than any other food crop [2203, million hectares, 2014). World trade in wheat is greater than for all other crops combined. In 2016, world production of wheat was 74 pmillion tonnes, making it the second most-produced cereal after maize-Since 1950, world production of wheat and other grains crops has tripled and is expected to grow further through the middle of the 21st century. Wheat includes members like pasts and bread varieties. Global demand for wheat is uncreasing due to the unique viscochastic and adhesive properties of gluten proteins, which facilitate the production of

screasing as a result of the worldwide

Find target text, inserts gene edit at specific location in genome

#### **MUTATION**

Wheat includes members like pasta and bread varieties.

Changing "includes" to "contains"

1

Wheat contains members like pasta and bread varieties.



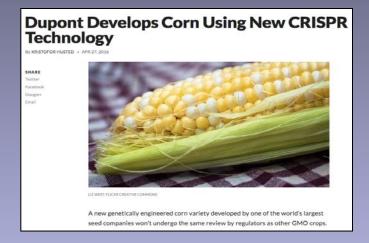
#### **EXAMPLES** of edited products:



#### University



#### Company



#### Company



Cultivar modified to 'knock out' mildewsusceptible gene

By MATEUSZ PERKOWSKI

A wheat variety rendered mil-denversistant brough the targeted "knockout" of a gene can be commer-cialized without clearing USDA repu-latory hardles for biotech crops. The ageory's Aliminia and Plant Health Inspection Foreign the properties of the properties of the properties of the Health Inspection Service has found that the cultivar deem't fail under its start institut culture down't fail under start institut culture down

Service has found that a new mixtew re-sistant wheet cuttiver doesn't fail under its jurisdiction for regulating peretically:
"It does not change the wheen's "It does not change the wheen's

seconding to APHIS.

Most bisords crops commonly moved in the U.S. have undergone decorated in the U.S. have undergone decorate in the U.S. have undergone decorated in the U.S. have undergone deco

engineered crops, which is limited to engineered crops.

While the wheat was developed with genetic elements from discover-coming betteria, they served to USDA's deregulatory described by the content and marky is and public comment.

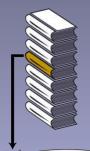
The content remains the state of the content of the crops and thus its basic biology or produce a plant that when the content of the crops and thus its basic biology or produce a plant that when the content of the crops and thus its basic biology or produce a plant that when the content of the crops and the crops and the content of the crops and the crops and the content of the crops and the crops and the content of the crops and the cr

Company

In 2016/2017, USDA said they can't regulate these edited crops because no DNA from plant pests or pathogens is introduced

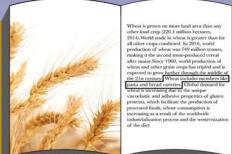


#### Another Way of Genome Editing-Modification



#### Inserts edits specifically in genome

#### MODIFICATION

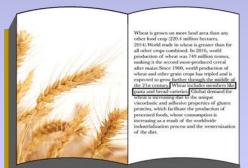


Wheat includes members like pasta and bread varieties.

Changing "includes" to "may contain"

**INSERTION** 

Wheat may contain members like pasta and bread varieties.



Wheat includes members like pasta and bread varieties.

Changing "includes" to "has"

DELETION

Wheat has members like pasta and bread varieties.

This type of genome editing <u>may or may not be</u> GE or GMO for federal regulation



# 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.

hen they went to Monterey - and were not welcomed there 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





1999 Lord Melchett participating in GM protest

And there are issues in the U.S. too

2014
GM maize protest in Germany



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



- Regulatory oversight
- Lack of peer-reviewed food safety tests
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## U.S. Regulatory Agencies

# USDA

# FDA

# **EPA**

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

- Food safety
- Feed safety

- Pesticidal plants

   tolerance
   exemption
   registrations
- Herbicide registration

Plant pest?

Danger to people?

Risk to environment?



## Are they as safe as conventional foods?

# This is based on the concept of substantial equivalence

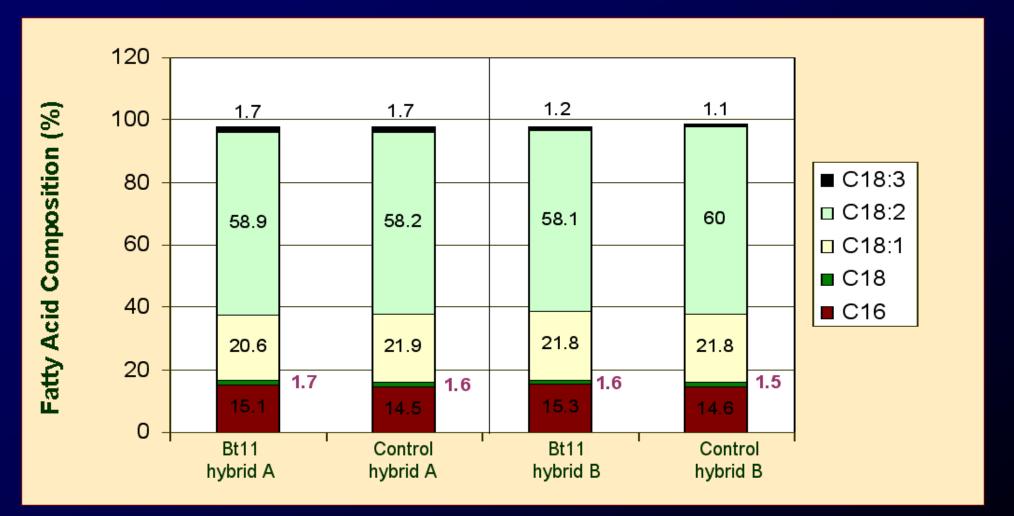
Modified food has essentially all characteristics of nonmodified food with respect to food and feed value except for introduced trait

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 based on a 1986 regulatory system, creating problems:

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

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

## Genetically engineered crops that fly under the US regulatory radar

#### To the Editor:

Recently, the US Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) has categorized as outside the scope of its regulations several genetically engineered (GE) crops that rely on either new approaches or new wrinkles on traditional recombinant DNA techniques in their provenance. Indeed, a survey of recent inquiries to APHIS suggests that the number of entities seeking nonregulated status for their products has been on the increase. Many of these inquiries originate from public institutions or small biotech companies, suggesting that the use of technologies, such as null segregants, novel delivery systems,

cisgenesis/intragenesis and site-directed nucleases, may be a deliberate strategy for smaller entities to navigate the US GE crop regulatory framework. The fact that the US Coordinated Framework is on the one hand failing to oversee these new product types and on the other overregulating GE crops and technologies with proven track records of safety should be a cause for concern. We conclude that it is time to reevaluate the US regulatory framework for GE crops and build a system that is based on science, with enough flexibility to evolve with accumulating scientific knowledge and technologies and, importantly, that allows the participation of small companies and public sector institutions. But to date not a lot of progress made in US but EU and other countries are making decisions - some accepting, some not



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



Occasional widely publicized studies cast doubt on safety of GE foods one in Sept. 2012 by French researcher

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

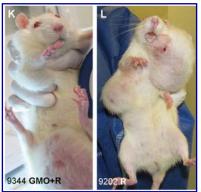
By RFI

A controversial study that linked genetically modified maize to cancer



in la

## six Featured on Dr. Oz Show



Claim that Monsanto's RR corn causes tumors in rats



The report's author, Gilles-Eric Séralini, 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 about other published studies?

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



SOV

rice





triticale



#### 2014 study

- •9B 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

#### Conclusions:

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









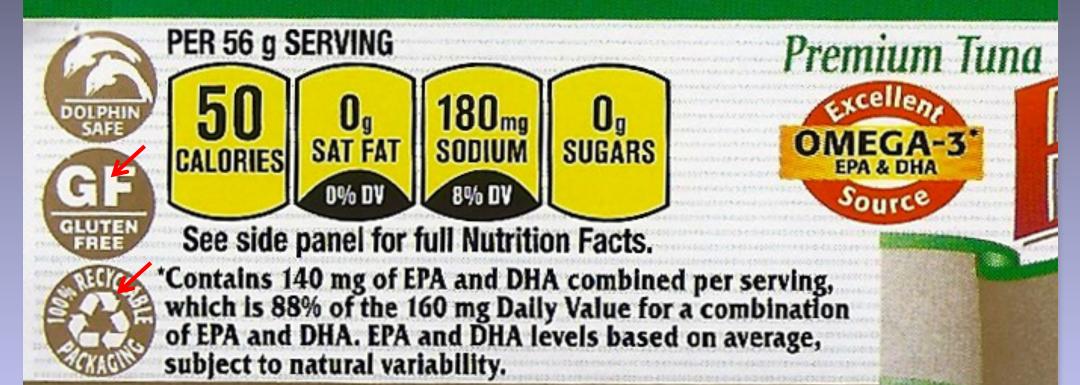


SOURCE: "Prevalence and impacts of genetically engineered feedstuffs on livestock populations"

A. L. Van Eenennaam and A. E. Young, J. Animal Science September 2014

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Labeling
- Environmental issues
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There are already many labels on foods- from gluten-free to dolphin-safe - none are mandated.





Proposed symbols for foods with GE ingredient – must use bioengineered, not genetically modified

# What about labeling for GE foods?

July 8, 2016: Senate passes bill for mandatory national system for GM disclosures on food products; Obama signed on July 29. Nullified Vermont's labeling law

Law requires USDA to decide what ingredients in food are from GE organisms; labels to be added using words, pictures or a scannable bar code for smartphones. Starting in 2020.



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



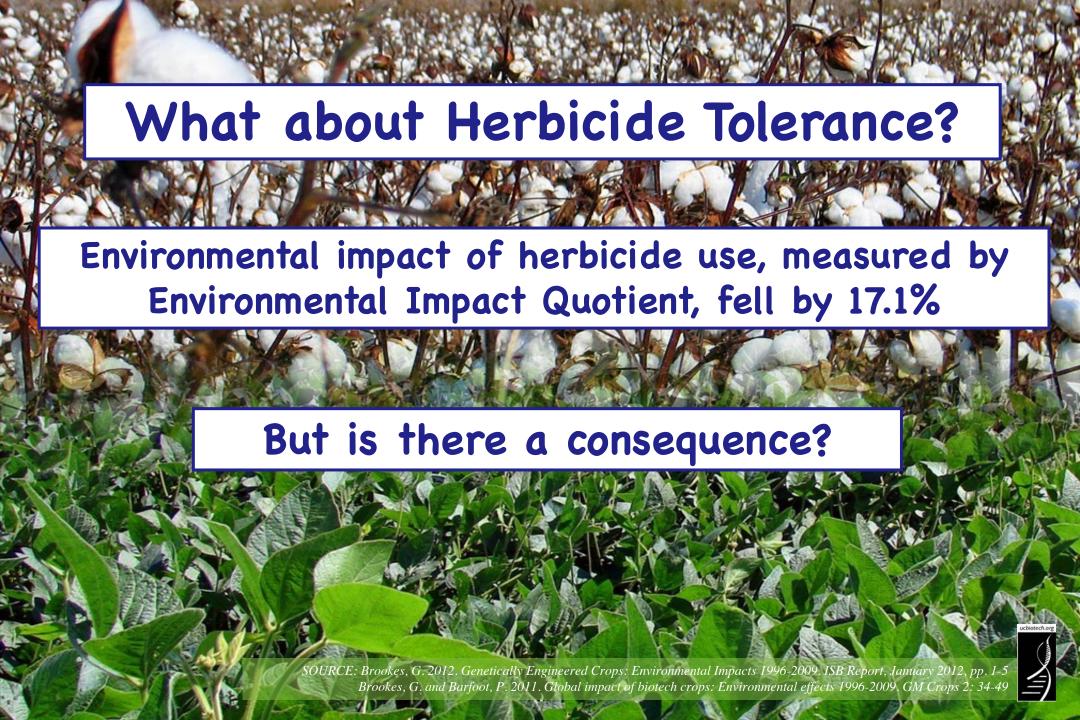
#### Insect Resistance

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





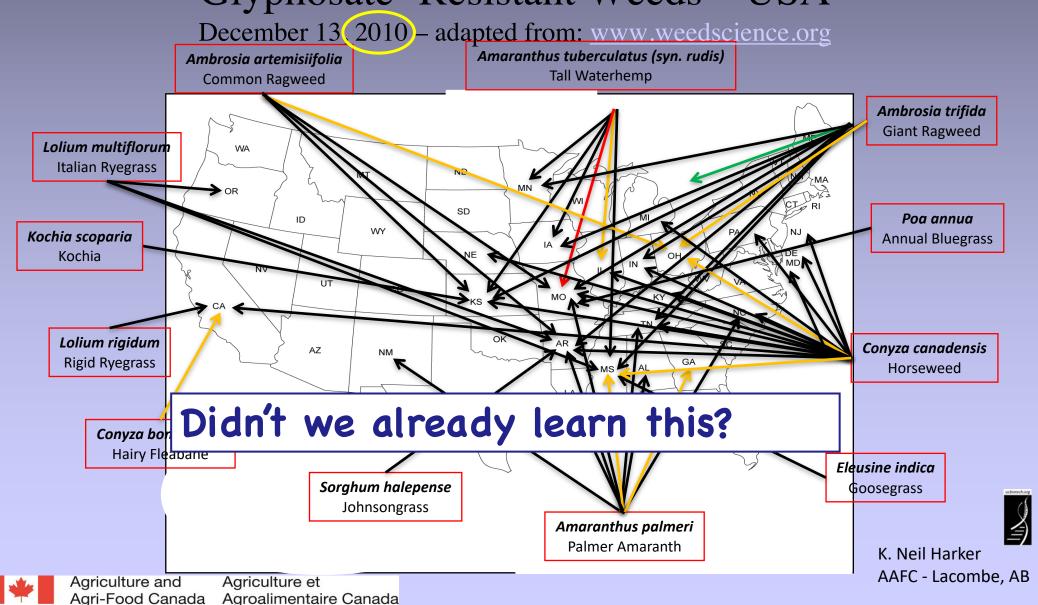
## Herbicide-resistant Weeds Threaten Soil Conservation Gains: Finding a Balance for Soil and Farm Sustainability

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



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

### Glyphosate- Resistant Weeds – USA





# And there are/were ways to avoid this

Example: "Sugar beet engineered for resistance to three herbicides gives growers more options"



- Regulatory oversight
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#### Consider This...





- > Nigeria: little over twice the size of California
- >75% more arable land than U.S.
- > But 5 times less land per capita than in U.S.
- In 2050, expected to be third most populous country in the world overtaking the U.S.



#### And this...

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.





### Where to get more information on issues?

Copies of my talks are here



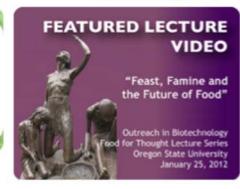


ABOUT US NEWS

ISSUES & RESPONSES GMO LABELING RESOURCES LINKS GLOSSARY

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.



#### BIOTECHNOLOGY INFORMATION



Labeling: Informational resources available.



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



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 Bar: 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 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

