What's Up with Engineering and Editing of Plants and Foodson and Some Other Thoughts

Peggy G. Lemaux
University of California, Berkeley
http://ucbiotech.org
http://pmb.berkeley.edu/lemaux
https://clear-project.org

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...

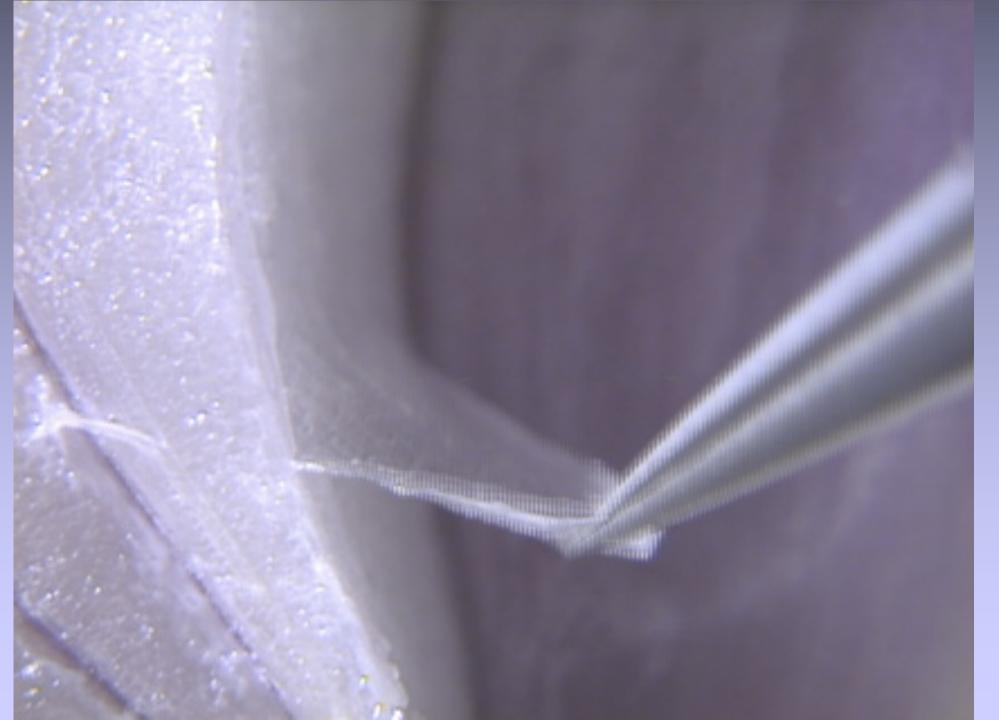


Tour d'Onion

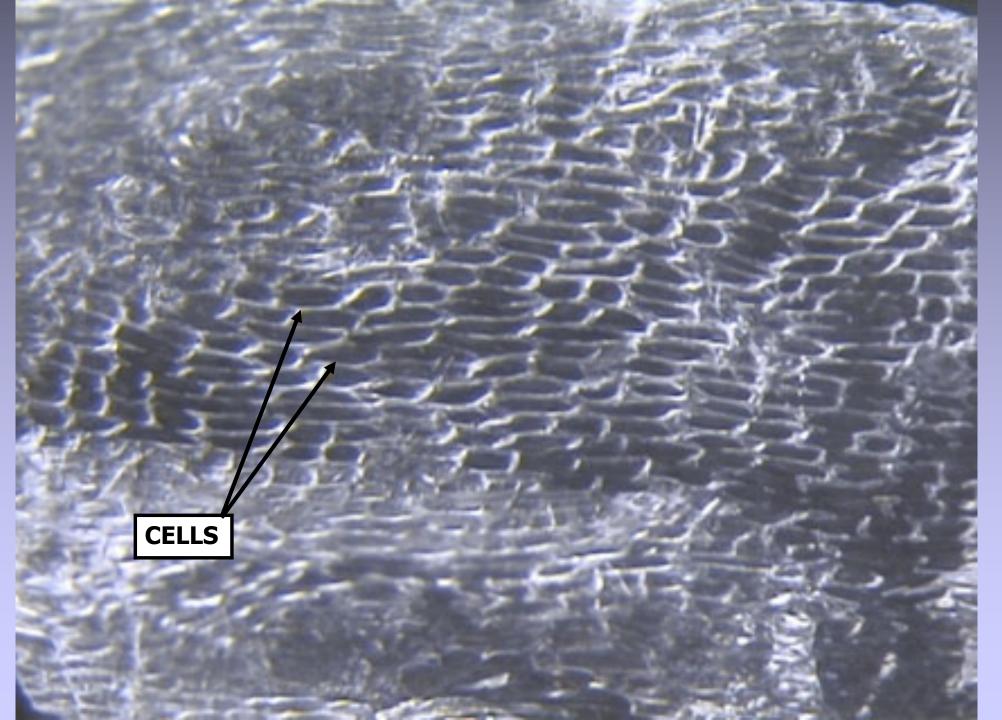


Or, what makes an onion and onion?

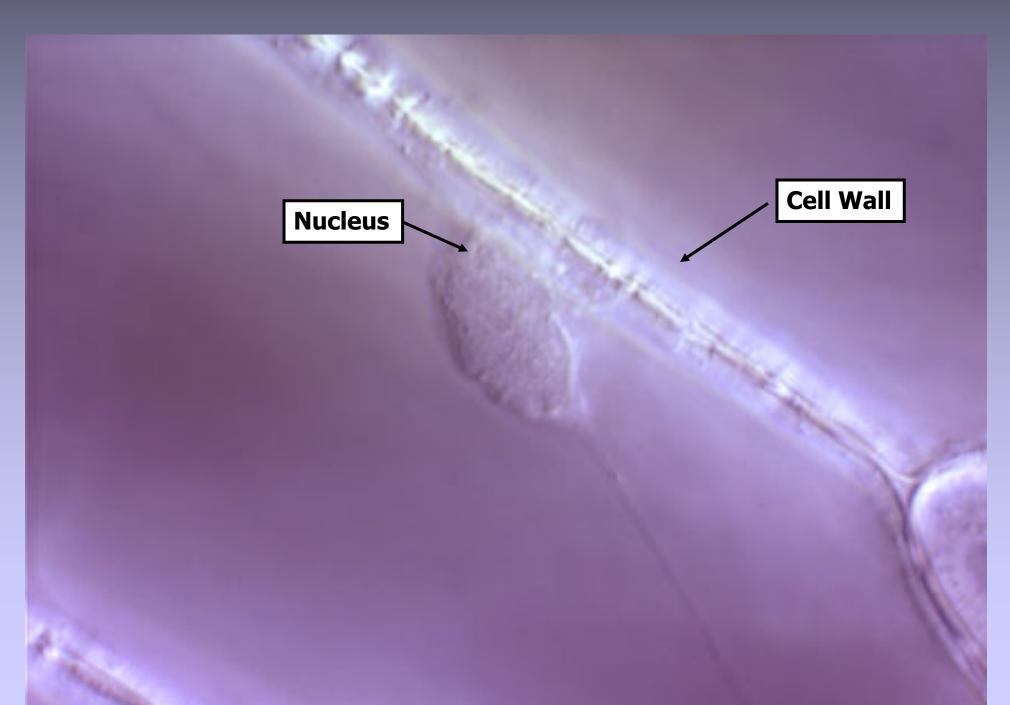




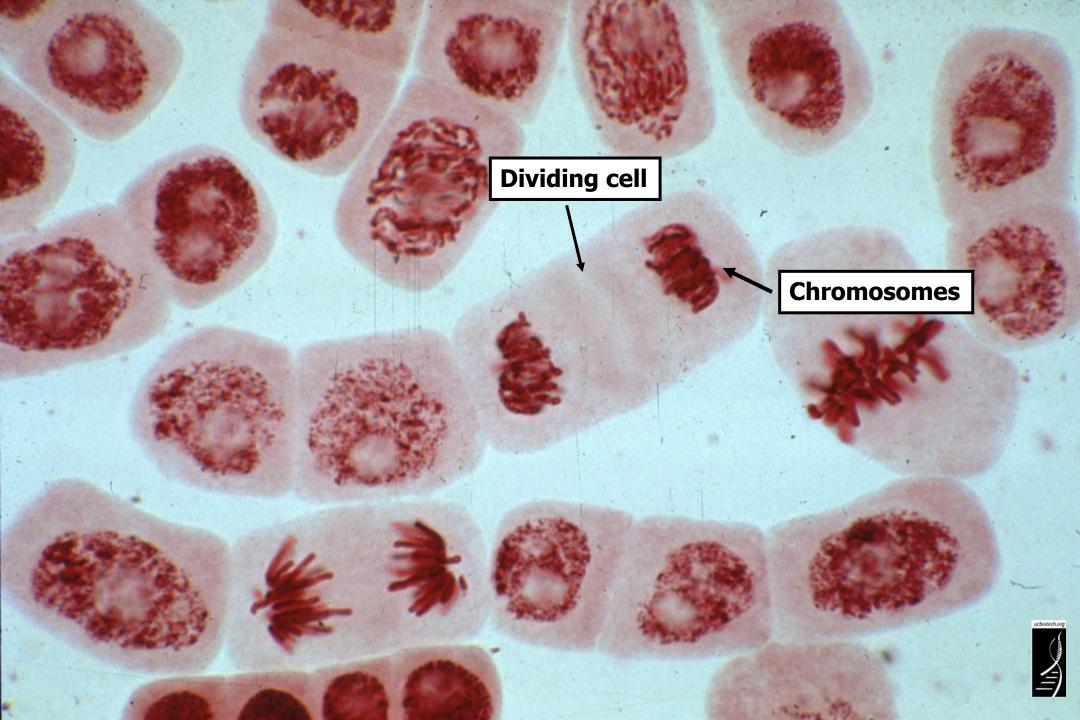


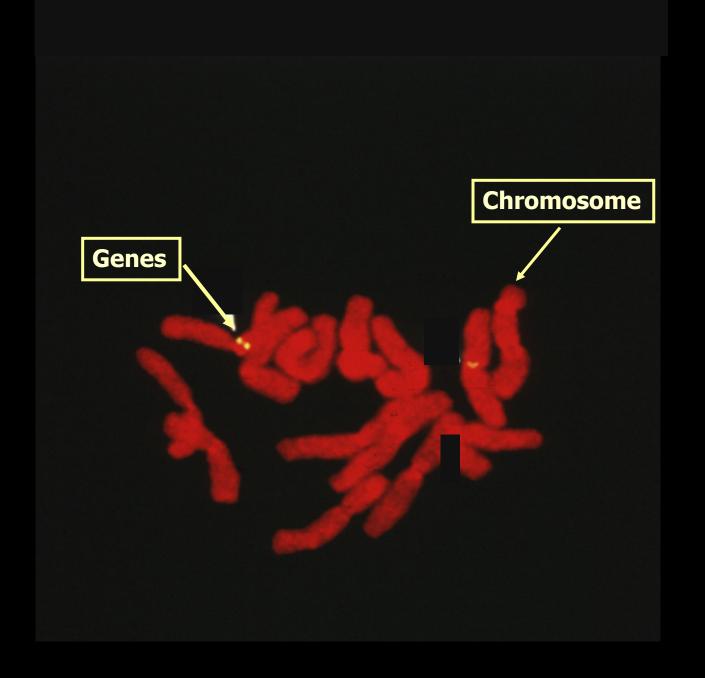








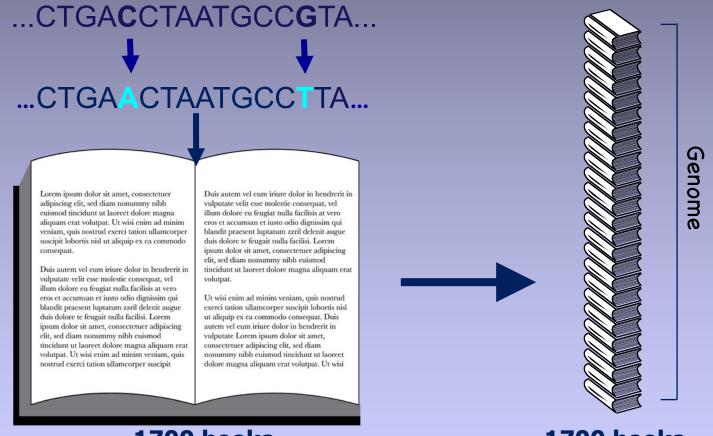






Genetic information in cell is responsible for traits

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) \rightarrow 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

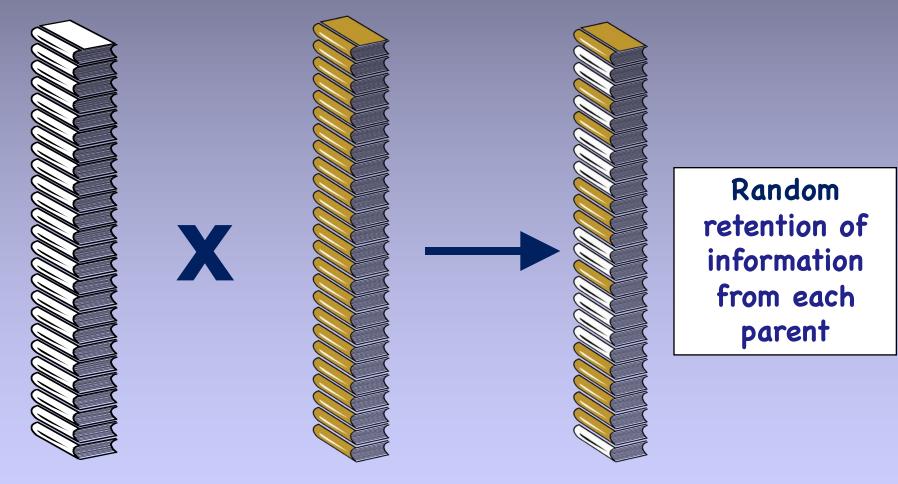


Triticum aestivum





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



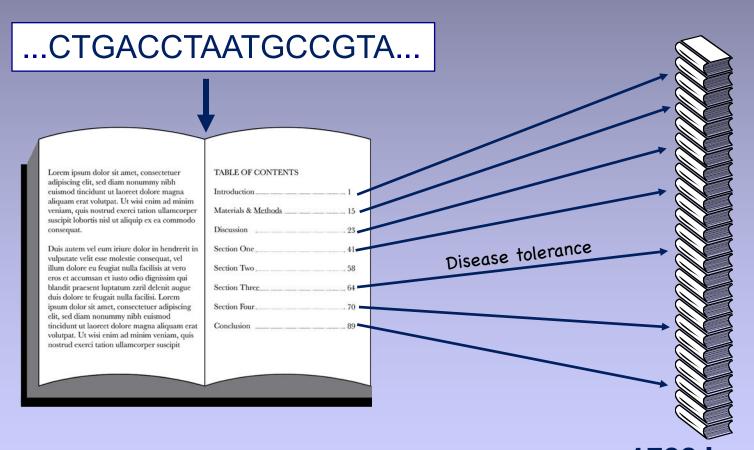
Breeding efforts were critical to increases in crop production...

Product	2014 US acreage	US 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

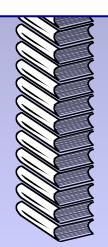


Also modify genomes with genetic engineering -> GMOs





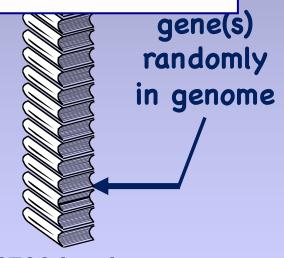
What Kinds of GE Crops and Foods Are in the Commercial Market?



cros et accumsan et iusto odio dignissim qui blandit praesent luptatum zzril delenit augue duis dolore te feugait nulla facilisi. Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam nonummy nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat. Ut wisi eniim ad minim veniam, quis nostrud exerci tation ullamoroprer suscipit Ut wisi enim ad minim veniam, quis nostrud exerci tation ullamcorper suscipit lobortis nisl ut aliquip ex ca commodo consequat. Duis autem vel cum iriure dolor in hendrerit in vulputate Lorem ipsum dolor sit amet, consectetuer adipiscing elit, sed diam nonumny nibh euismod tincidunt ut laoreet dolore magna aliquam erat volutpat. Ut wisi

One-half page equivalent to a gene

1700 books (or 1.7 million pages)

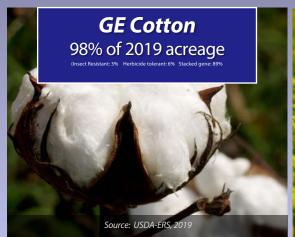


1700 books (or 1.7 million pages)



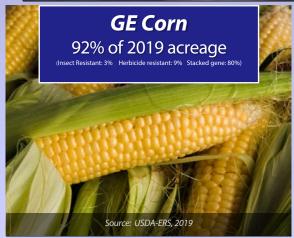
Genetic modification by genetic engineering is GE or GMO

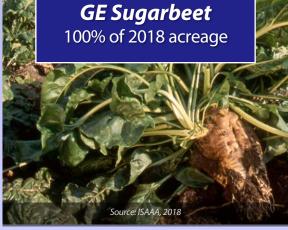
Number of different commercially available, large acreage GE (GMO) crops is limited















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

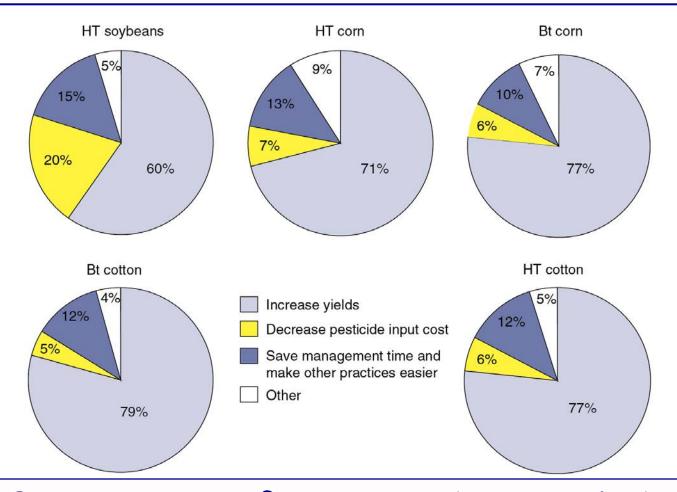


Herbicide-tolerant engineered with gene to
tolerate herbicide
application

Crops with stacked traits - Bt and HT - are available

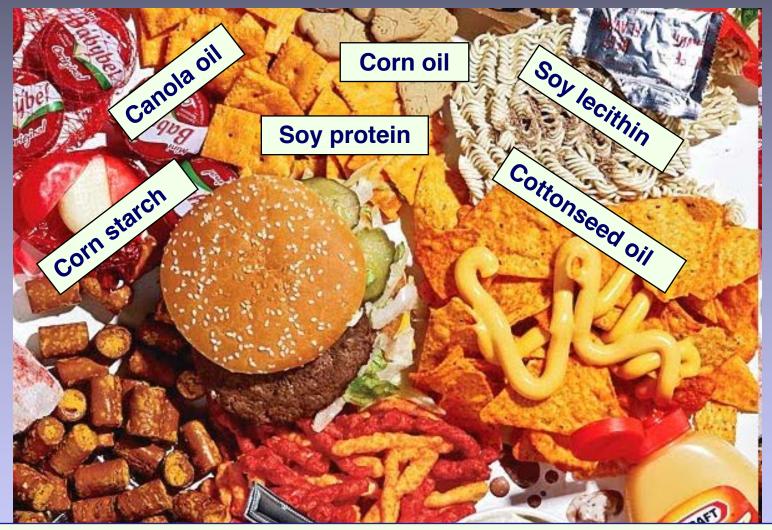


Why do U.S. growers use GE crops?



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



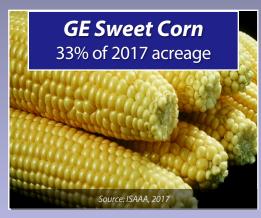


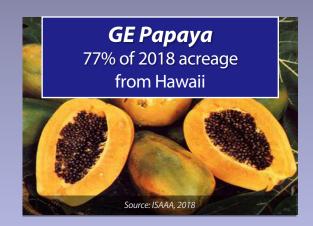
These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients - often only a minor ingredient



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

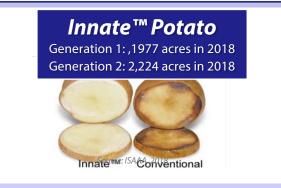






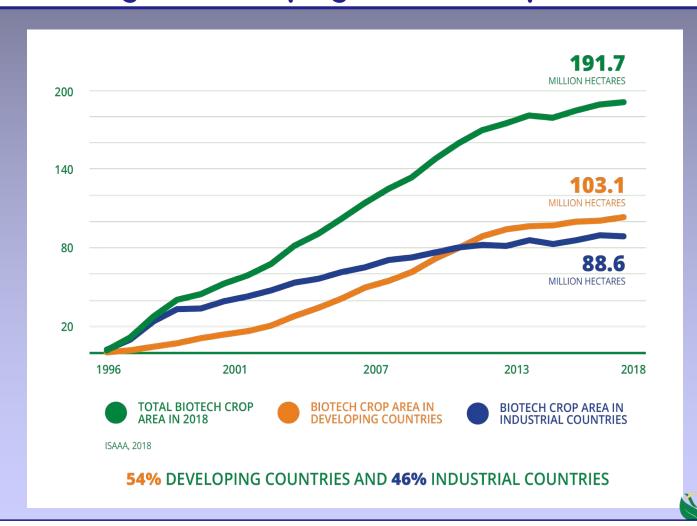
Two more are just being introduced







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



In 2018, 17M farmers in 26 countries planted 474M acres 191.7M hectares) ~4X size of CA



Salinity and Drought Tolerance - UC Davis





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



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

Salt-tolerance

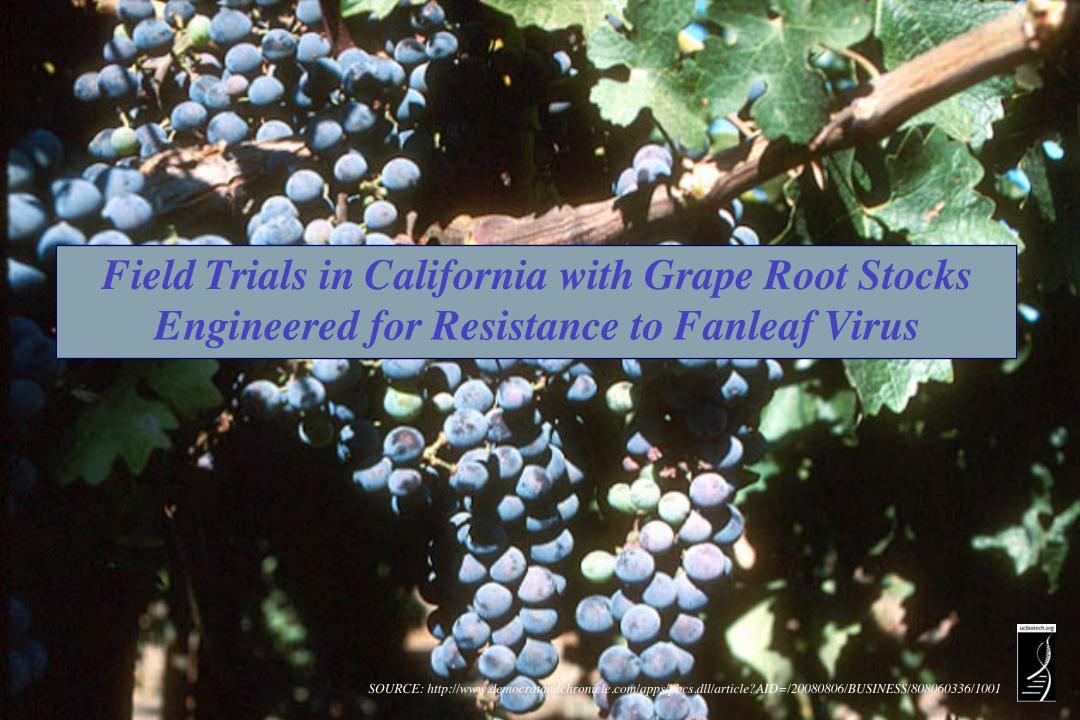
Drought-tolerance



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









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



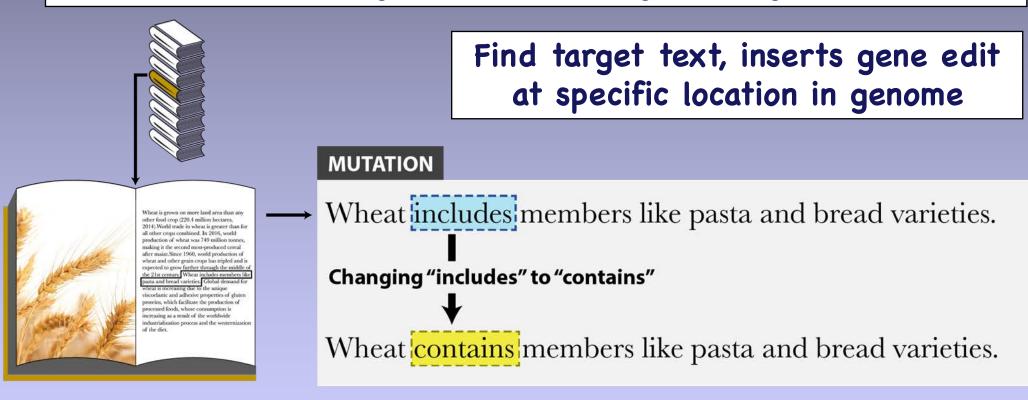
Daily bread: if gluten's not for you Superstock

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



What New Genetic Method? Genome Editing - Mutation

Genome editing a.k.a. New Breeding Technology (NBT)



This type of genome editing <u>is not</u> GE or GMO for USDA regulation - no pathogen introduction



EXAMPLES of edited products



University



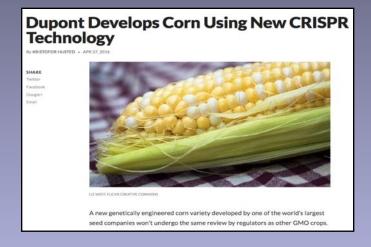
Company

Camelina is an oilseed that's been

without undergoing the USDA's regula-ny's chief science officer.

The agency has determined the studied as an alternative crop in Eastern

tory process for biotech crops.



Company

4 Capital Press USDA won't regulate biotech wheat variety 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

Animal and Plater Health inapperion

Service has found fall a new ribblew—the during natural cellular processes and no foreign generic material remains.

"It does not change the wheels' such that is reliable in the field service material remains.

"It does not change the wheels' service traits in client to the field service and remains the field service and remain

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

institute course coesat has under as in production for regulating generically production for regulating generically production for regulating generically gregories deepen. Contained in the crop and thus the While the wheat was developed with genetic elements from dis-process, which includes environ-ence-causing bacteria, they are? In example of the production of

Company

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

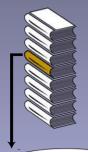
technology doesn't fall under the

ciated with increased oil content with Camelina modified using CRISPR

Turn to CAMELINA, Page 12 USDA's regulatory purview.



Another Type of Genome Editing - Modification



Inserts edits specifically in genome

Wheat is grown on more land area than sny other food cray (2224 million betates, 2014). World runde in wheat is greater than 50 at other crays contained. In 2016, world and other crays contained, in 2016, world making it the second mon-produced cereal after major. Since 1960, world production of wheat and other grain crops has tripled and it expected to goo further through the middle of the 21st century. Wheat includes members like the 21st century. Wheat includes members like passa and breast varieties. Usdood dermand for

wheat is increasing due to the unique visco-fastic and adhesive properties of gluten protein, which facilitate the production of processed foods, whose consumption is necrossing as a result of the worldwide ndustrislization process and the westerräzatio of the diet.

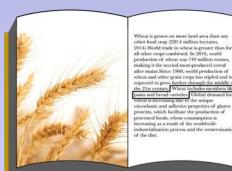
MODIFICATION

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



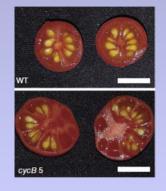
Use editing to exploit genetic diversity in wild plants





de novo domestication of wild *Solanum pimpinellifolium*





Edited wild tomato variety, S. pimpinellifolium, was edited to get 3X fruit size, 10X fruit number and 500% increase in lycopene.

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 went to another place in CA – and were not welcome 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
- Consumer attitudes and labeling
- Environmental issues
- Some additional food for thought...





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?

Regulation based substantial equivalence

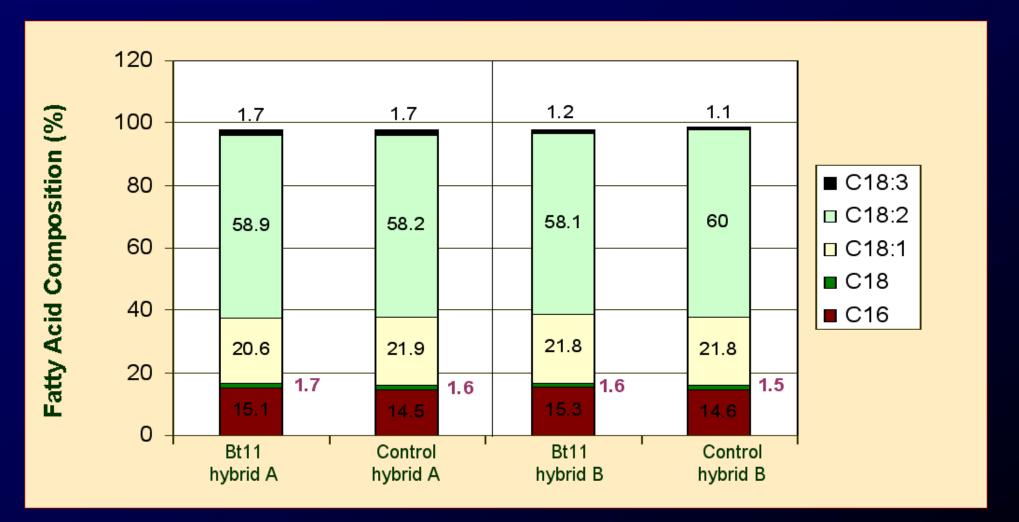
Which means modified food has essentially all characteristics of nonmodified food except for introduced trait

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 1986 regulatory system, creates problems:

- New products emerge with no rules to govern them
- Old products not in market because no pathway to commercialize
- New products created to step around regulatory system

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.

On July 2, 2015, Obama
White House Initiative
announced plan to
modernize biotech
regulation, but no progress
until...



Executive Order on Agricultural Biotechnology June 11, 2019

- Agencies to regulate end products, not processes used to make them. So, genetically edited pest resistant product not treated differently from one made with traditional breeding.
- Biotech products to be regulated proportional to risks.
- Perhaps applies only to gene edited products, not transgenic products or GMOs - still regulated on a case-by-case review.



- 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?

French academies trash GM corn cancer study

By RFI

A controversial study that linked genetically modified maize to cancer in lab rats is a "scientific non-event", six French scientific academies said in a rare joint statement Friday.



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?

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.











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





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. Mandatory in 2020.



Impossible Burger contains engineered soy and bears the new label





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

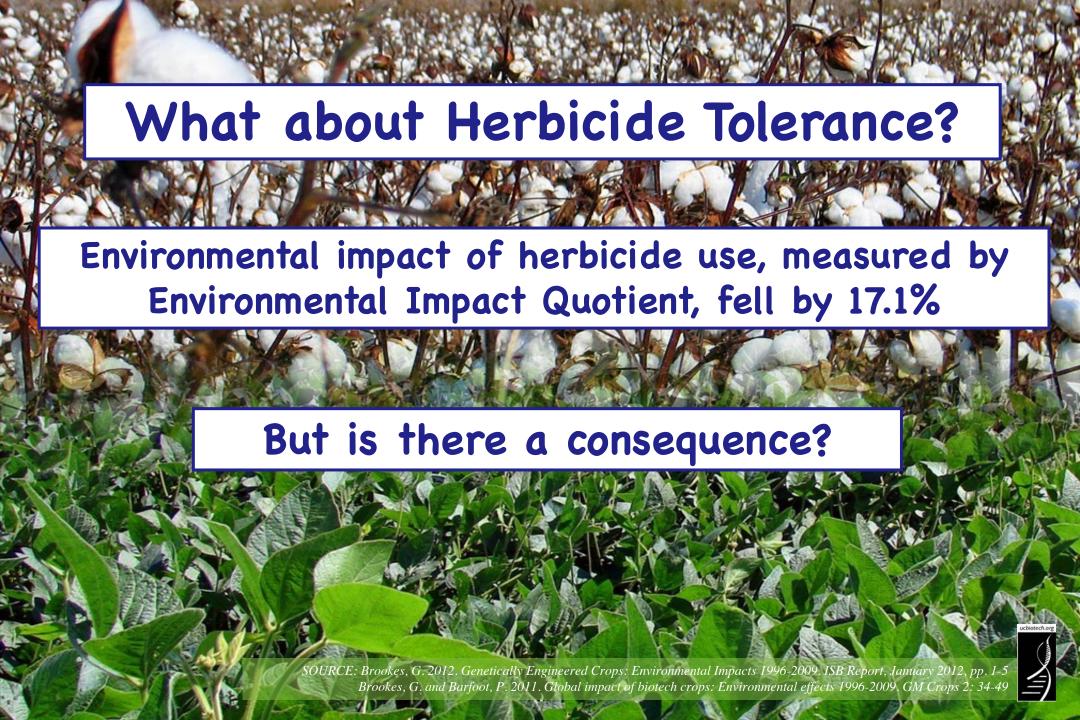
Insect Resistance

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





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."



Morning Ag Clips

friend/)

WEED MANAGEMENT ...

2 COMMENTS

Are we at a tipping point with weed control?

Like antibiotic-resistant "superbugs," resistant weeds can't be killed by herbicides

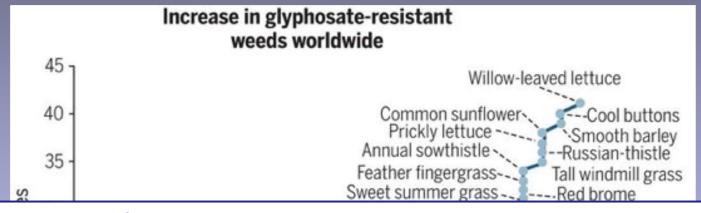
PUBLISHED ON OCTOBER 5, 2017



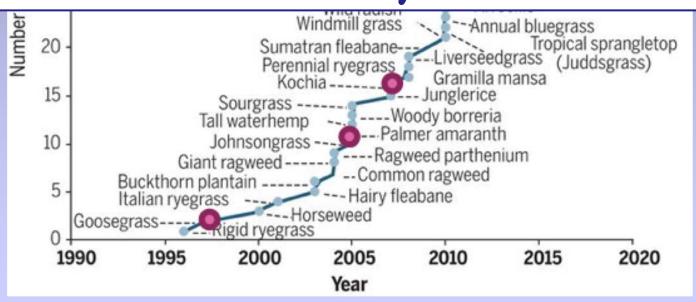
"We've reached a critical tipping point in our ability to control agricultural weeds with herbicides currently on the market." And no new classes have been developed in 30 yrs!



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



Didn't we already learn this?







And there are/were ways to avoid this

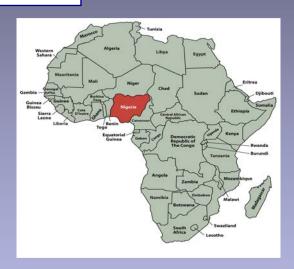
Example: "Sugar beet engineered for resistance to three herbicides gives growers more options"



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

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.



And this...



Loss of diversity

In the past 250 years, 571 plant species have gone extinct; four times more than the number of plant extinctions on record

And this...

The New York Times

CALIFORNIA TODAY

Are Wildfires Caused by Utilities or Climate Change? Yes

Wednesday: An expert writes that both contribute to



Impact of Climate Change

Camp and Woolsey Fires

NATIONAL PUBLIC RADIO LEADS WITH STORY ON REPUBLICANS' ANTI-SCIENCE POSITION ON OLIMATE CHANGE



NPR "All Things Considered" interviewed CSW director Rick Plitz, Rep. Bob Inglis (R-South Carolina), and environmentalist Bill McKibben for an October 23 lead story on Republicans and denial of the scientific evidence for human-caused climate change. The war on climate science has developed over a long period, but today is arguably worse than ever. Compared with the radical know-nothing litmus test for politicians we see now, on climate science most of the Bush Administration, bad as it was, was downright nuanced and moderate. Link to archived 11-minute audio webcast.

A majority of Republican members of Congress, and the vast majority of Republican candidates for Congress this year, are turning against the science of climate change and appearing to deny the evidence that human activity, our burning of fossil fuels, in causing global climate change.

Search ... Q

SIGN UP FOR THE LATEST WHISTLEBLOWER NEWS

Email Submit

CATEGORIES

RECENT POSTS

And this...

< Previous Next >

Climate Change?

climate change



Lynette Cook/Science Source

SCIENCE

The 'Great Dying' Nearly Erased Life On Earth. Scientists See Similarities To Today

It was the biggest extinction in Earth's history. A new Smithsonian exhibit notes that some of the same things that killed over 90% of ocean species 250 million years ago are happening now.











Where to get more information on issues and copies of my talks?

http://ucbiotech.org



ABOUT US NEWS ISSUES & RESPONSES GMO LABELING RESOURCES LINKS GLOSSARY

Select Language | W

This website provides educational resources focused broadly

on issues technologi tion relate tools and informed

THANKS!

FEATURED LECTURE VIDEO

Famine and

ire of Food"

Oregon State University January 25, 2012

BIOTECHNOLOGY INFORMATION



Informational resources available.

ANNUAL REVIEWS

Review articles:

Focused on food, environmental and socioeconomic issues of GE crops and

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 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 information to foster discussion

about agriculture, especially plant genetics and genetic engineering.

Animal Genomics &

Biotechnology Cooperative Extension



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

