Crops, Food, Biotechnology and Some Other Thoughts

Peggy G. Lemaux University of California, Berkeley http://www.lemaux 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?

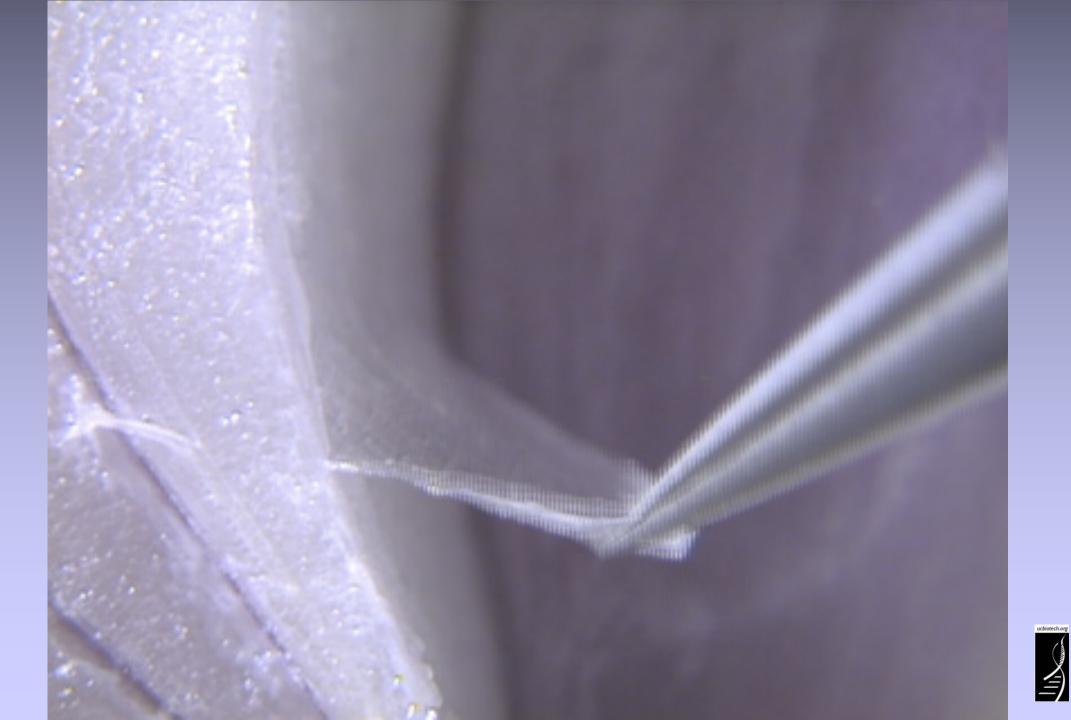
6. Some food for thought...

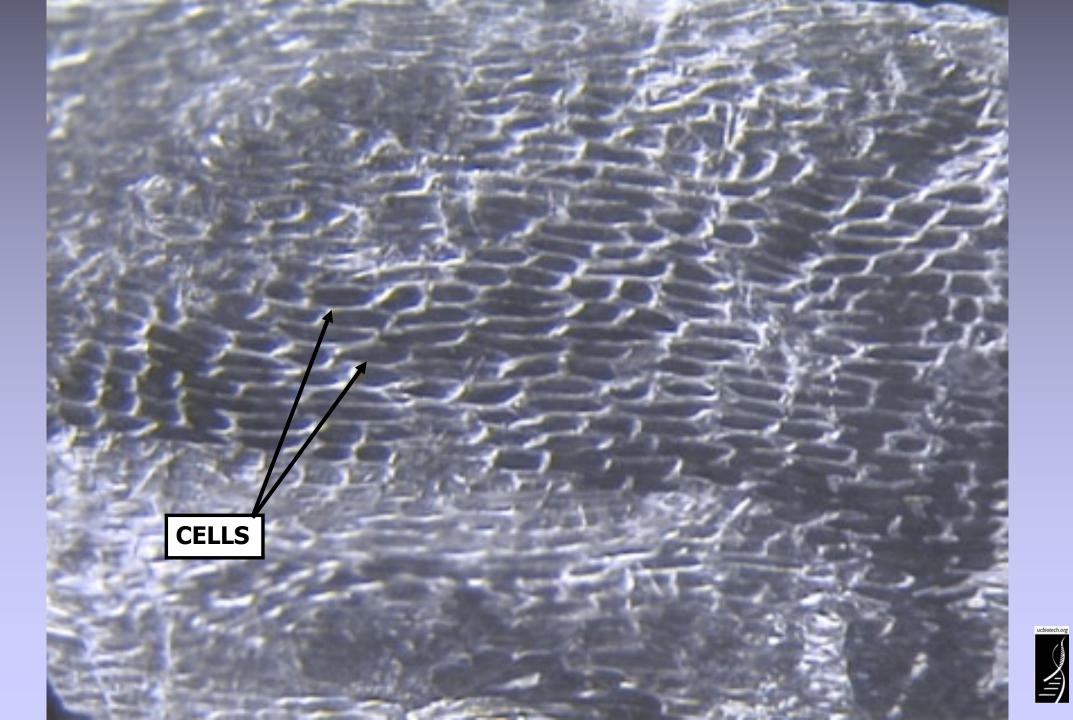


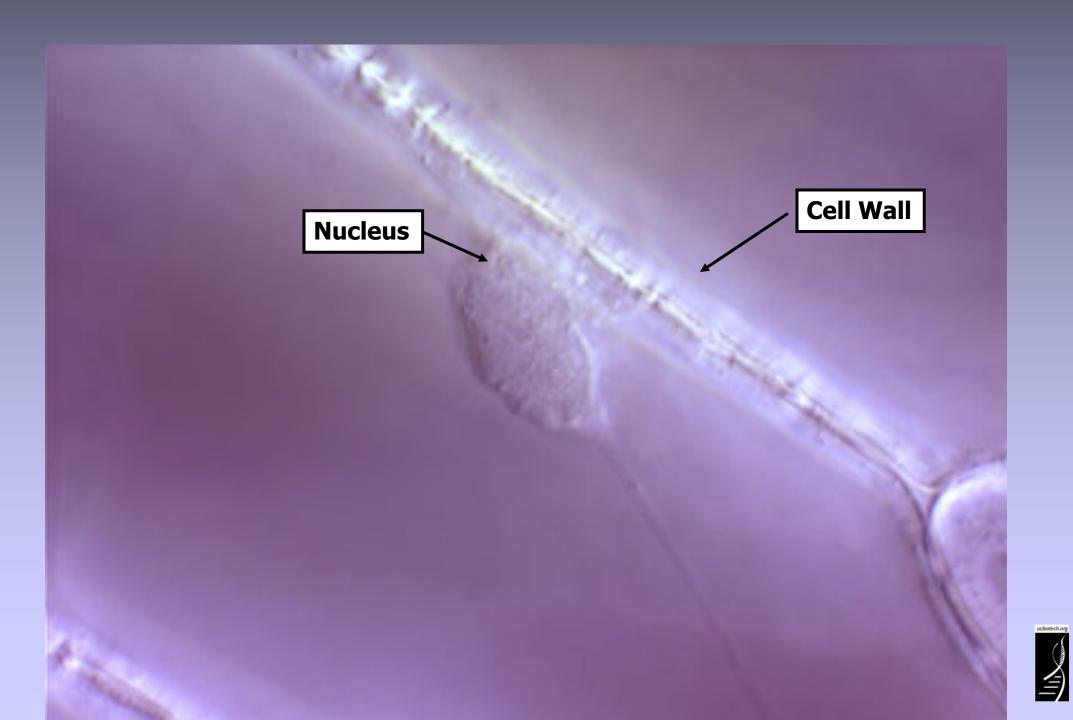
Four d'Onion

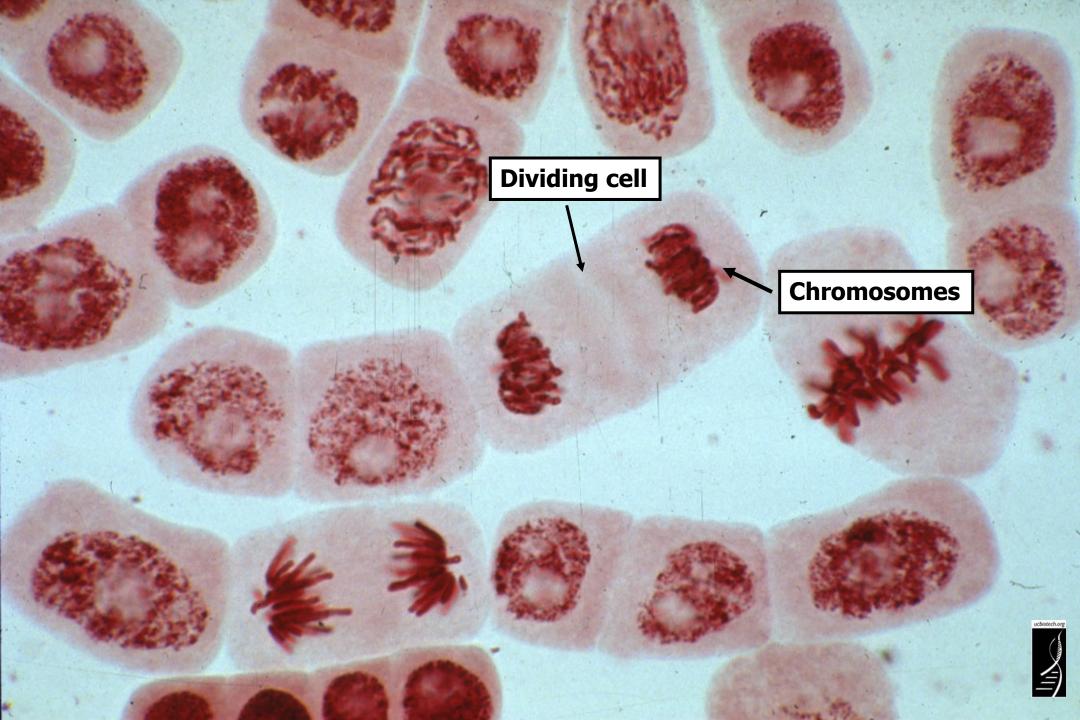
Or, what makes an onion and onion?

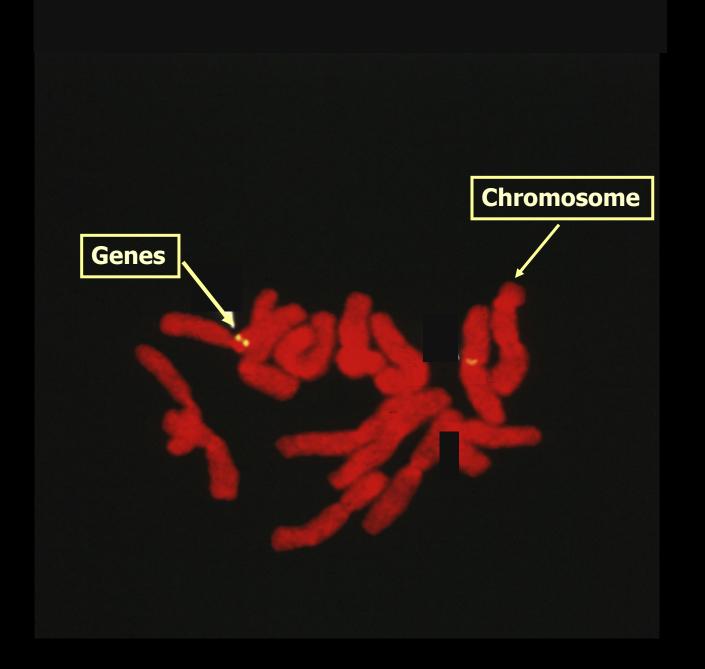














Genetic information in cell is responsible for traits

Chemical units in DNA represented by alphabetic letters

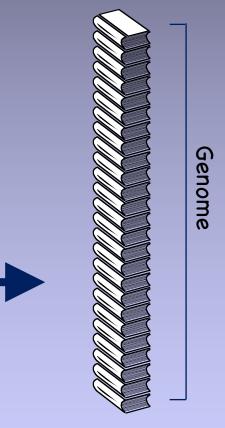
...CTGAACTAATGCCTTA...

...CTGACCTAATGCCGTA...

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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





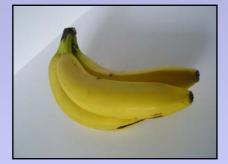




Eggplant



Broccoli, Kale, Cabbage



Banana





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.



Van Eenennaam 11/29/2016

Photo by Stephen Ausmus, USDA



Modern Example

Japanese Farmer Creates Mongee Banana With Softer, Digestible Skin



2/22/2018 A-peeling? Japanese farmers invent edible banana skin | World news | The Guardian

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

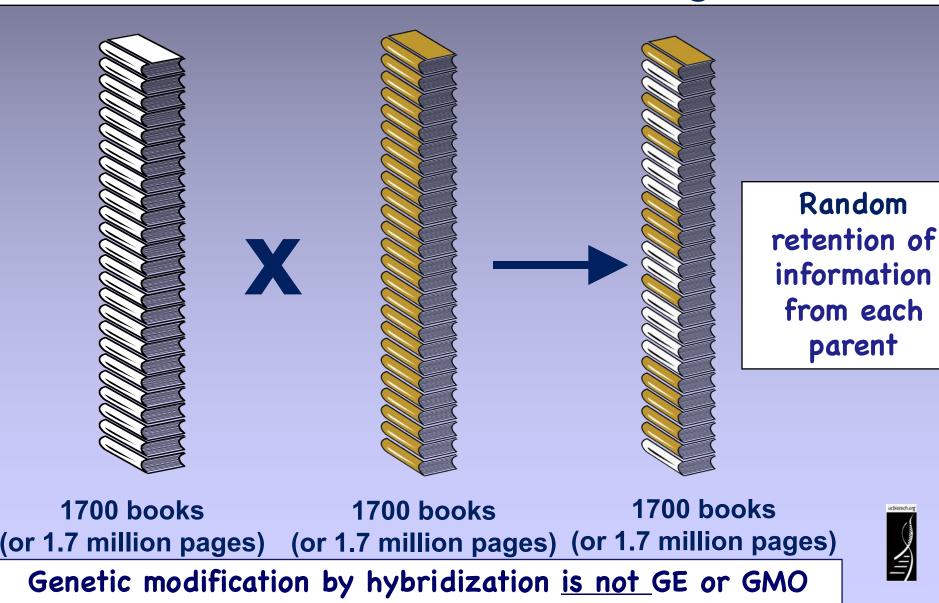




Triticum monococcumTriticum aestivumAncient varietyModern bread variety



Hybridization or Cross-breeding of Wheat



Example: Soybean variety with less allergenicity and anti-nutritional qualities after years of classical breeding efforts.



SOURCE: "Triple Null: New Genetically Modified Soybean A Big Benefit For Food http://www.science20.com/news_articles/on/le_null_new_genetically_modified_soybean_a_big_bene 2.0, 5/4/15.

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

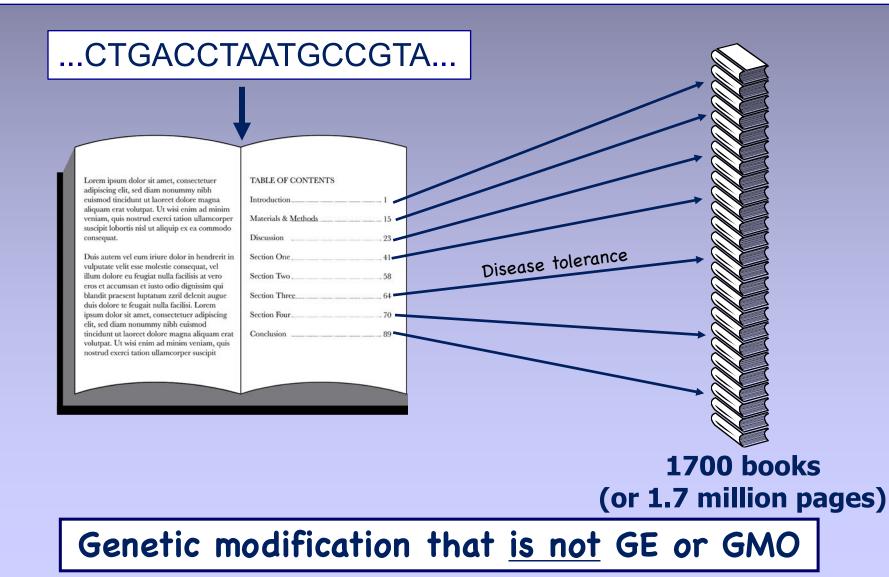
Product	2014 US acreage	US Acreage needed at 1950's rate	Additional Resources needed
Soybeans	82,591,000 acres	180,971,889 acres	~98 million acres (= size CA)
Corn	83,136,000 acres	372,134,346 acres	~289 million acres (= 3X size CA)
Broiler Chickens	8,544,100,000 head	16,679,545,455 head	~8 billion head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



New Breeding Method

Uses table of contents of genes for <u>marker assisted selection</u>

ucbiotech.org



Can't we just do all modifications this way?



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

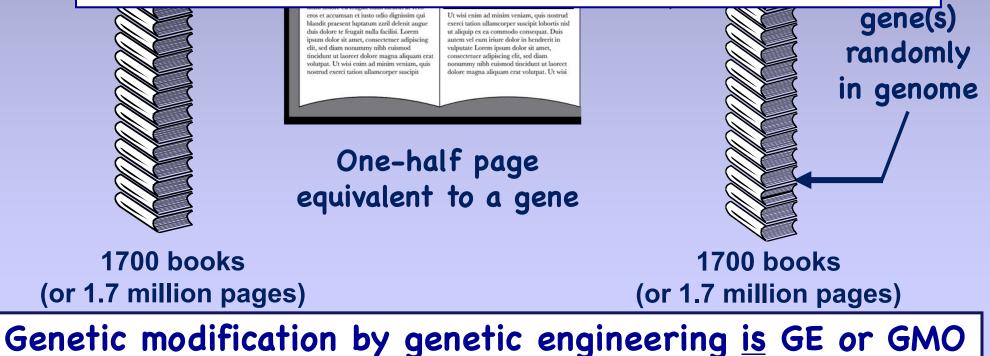
Protection limited to diversity in crop and compatible relatives



Also modify genomes with genetic engineering \rightarrow GMOs



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



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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



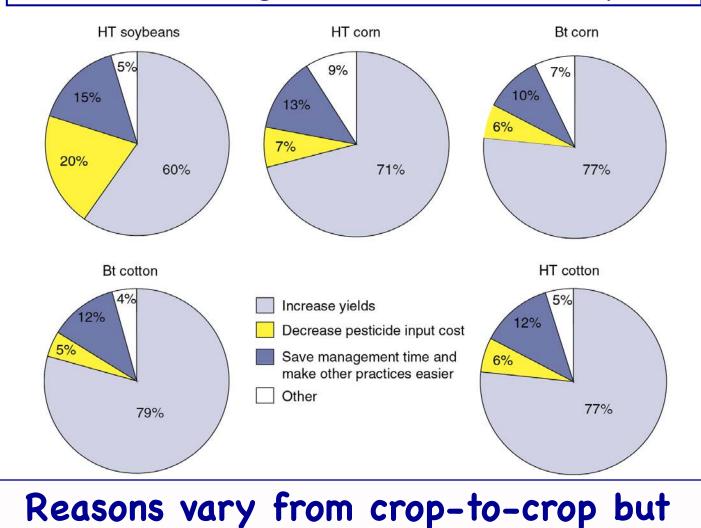


Herbicide-tolerant engineered with gene to tolerate herbicide application

Crops with stacked traits – Bt and HT – are available



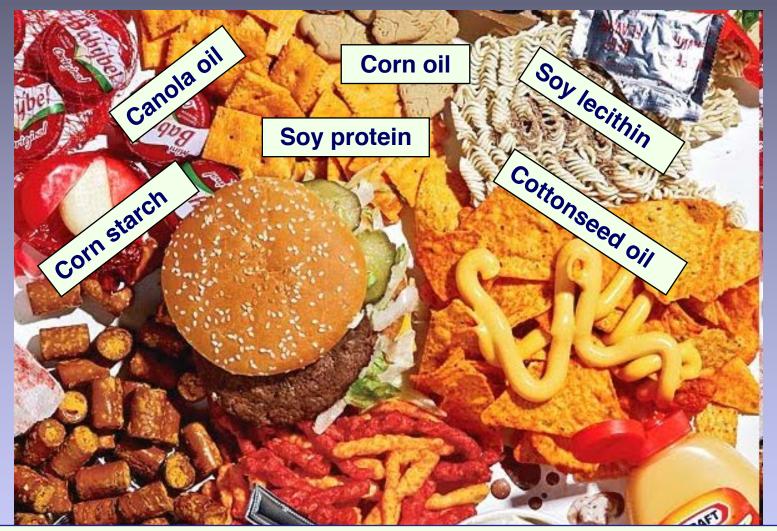
Why do U.S. growers use GE crops?



primary reason is improved yields

ucbiotech.org

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.

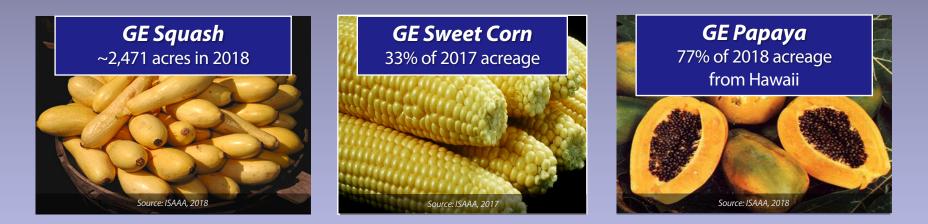


These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients – often only a minor ingredient



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

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



Two more are just being introduced



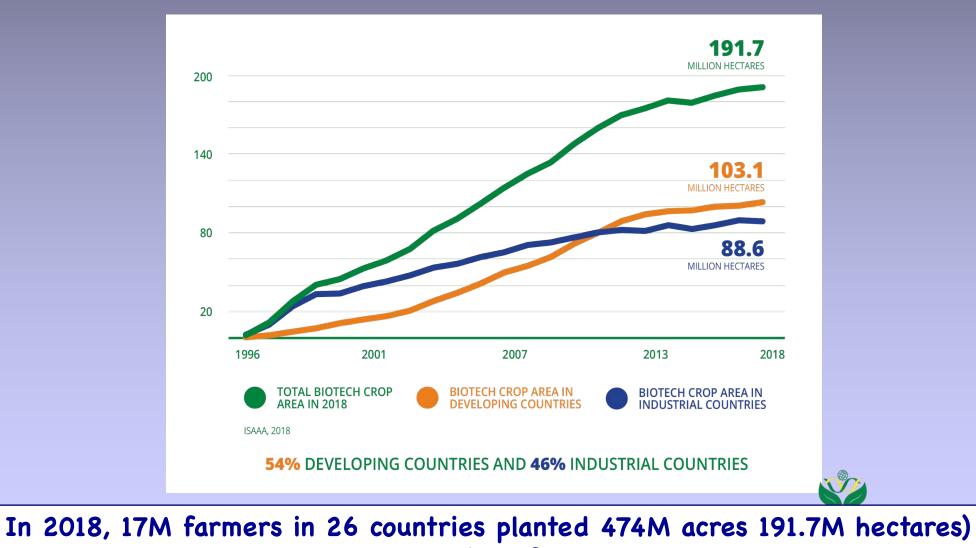
Innate[™] Potato

Generation 1: ,1977 acres in 2018 Generation 2: 2,224 acres in 2018



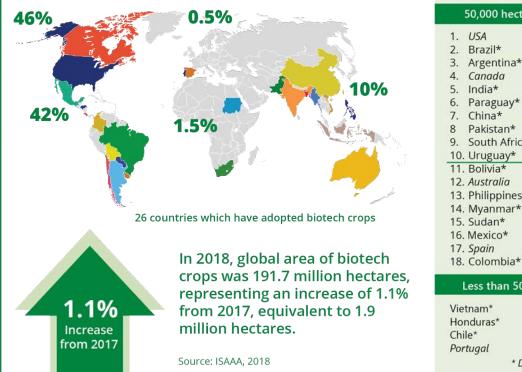


Despite limited U.S. crop and trait types, worldwide acreage is increasing in developing and developed countries



~4X size of CA

Here are the 26 countries where GE crops were planted in 2018



50,000 hectares, or more 1. USA 75.0 million Brazil* 51.3 million Argentina* 23.9 million Canada 12.7 million India* 11.6 million 3.8 million Paraguay* 2.9 million China* Pakistan* 2.8 million 9. South Africa* 2.7 million 1.3 million 10. Uruguay* 11. Bolivia* 1.3 million 0.8 million 12. Australia 13. Philippines* 0.6 million 0.3 million 14. Myanmar* 15. Sudan* 0.2 million 16. Mexico* 0.2 million 17. Spain 0.1 million 0.1 million

Less than 50,000 hectares

Vietnam*	Bangladesh*
Honduras*	Costa Rica*
Chile*	Indonesia*
Portugal	eSwatini*
	* Developing countries

10 Latin American, 9 Asia Pacific, 2 North American, 2 EU, and 3 African countries



WHAT'S IN THE PIPELINE?



Salinity and Drought Tolerance - UC Davis



Wild typeIPT gene15 days drought, 7 days re-watered

Drought-tolerance



Hanana M. 2011. Environ Rev 19: 121-140; Anjuman A et al. 2013 Mol. Biotechnol 54: 379-392

Salt-tolerance

200 mM NaCl (~1/2 sea water)

AtNHX1

Wild type

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







Field Trials in California with Grape Root Stocks Engineered for Resistance to Fanleaf Virus

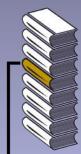




High anthocyanin purple GE tomatoes. Diets with 10% purple tomatoes increased lifespan of cancer-prone mice

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

New Genetic Method: Genome Editing-Mutation



Wheat is grown on more land area than any other food crop (220.4 million hexares, 2014). World made in wheat is proven the for production of the language of the language production of the language of the language making it the second moneproduced correal after mains: Bioteches 1980, world production of wheat and other grain crops has tripled and is expected to grow further through the middle of the 21 or century. When identical demand for viscolation and adhesive properties of gattern proteins, which facilitate the production of processed foods, whose consumption is increating as a result of the worldwise industrialization process and the westernization of the diet.

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

MUTATION

Wheat includes members like pasta and bread varieties.

Changing "includes" to "contains"

Wheat contains members like pasta and bread varieties.



EXAMPLES of edited products:

nature

NATURE | NEWS

Gene-edited CRISPR mushroom escapes US regulation



University

Dupont Develops Corn Using New CRISPR Technology

By KRISTOFOR HUSTED + APR 27, 2016

SHARE



EWEET, FLICKR CREATIVE COMMONS

A new genetically engineered corn variety developed by one of the world's largest seed companies won't undergo the same review by regulators as other GMO crops.

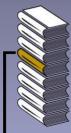
Company

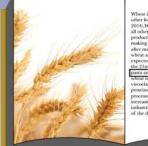


In 2016/2017, USDA said they can't regulate these edited crops because no DNA from plant pests or pathogens is introduced



Another Way of Genome Editing-Modification





When is grown on more land area than any older food crop (220.4 million bectares, 0.14), here are a set of the set of the set of the production of when with a set of the set of the production of when with a set of the set of the production of when with a set of the set of the production of when with a set of the set of the production of when with a set of the set of the set of the second most production of when and when a nod other grain crops has tripled and is operated to grow. Influent humang the middle of heat and thread varieties. [Clobal demand for wheat in thread varieties]. [Clobal demand for obtain intercentario due to the unique viscodatic; and adhesive properties of gluten processes foods, whose communication is incomarily an error and of the workbridt incomarily an error and of the workbridt processes of the set of the set of the set of the incomarily and process and the westerritization of the diet.

MODIFICATION

• Wheat includes members like pasta and bread varieties.

Changing "includes" to "may contain"

INSERTION

Inserts edits specifically in genome

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.

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

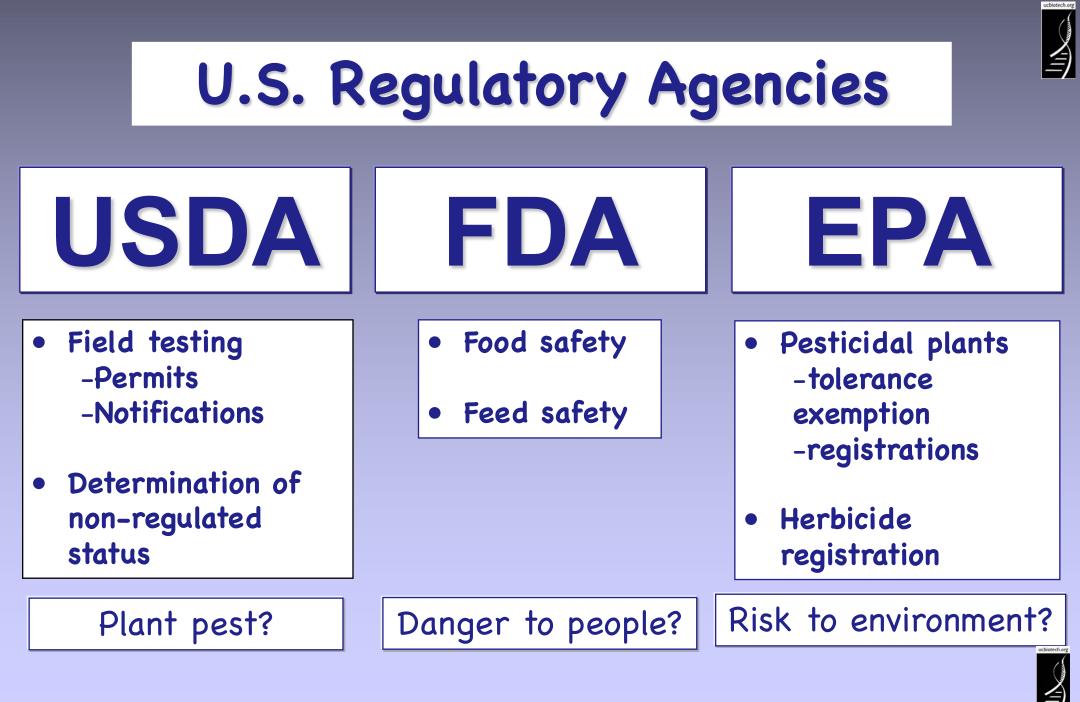


- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling
- Environmental issues
- Some additional food for thought...



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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

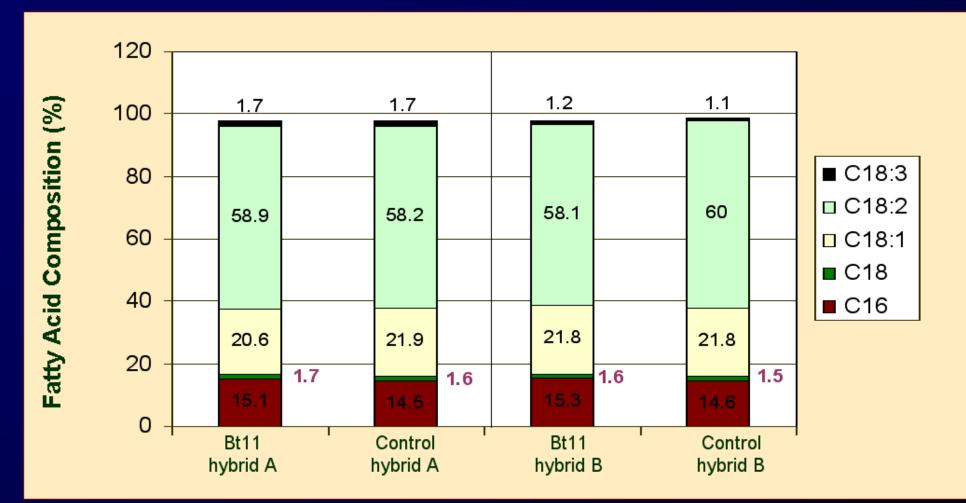
Product of introduced genetic information tested for safety separately

How is substantial equivalence tested?



SOURCE: Safety of Genetically Engineered Foods: Aproaches to Assessing Unintended Health Effects 2004. Natl Acad Press

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.



Trump streamlines ag biotech approval with executive order

SOURCE:Berezow A. "Trump's Executive Orders Move Biotech, Healthcare in right Direction". ACSH Weekend Highlights. July 5, 2019.

EU and other countries are making decisions on gene edited products – some accepting, some not.

- Canada, Australia and Brazil regulate GE and edited products by assessing the product itself, not the process used. Also Argentina.
- Countries, like those in the **European Union**, take a more process-oriented, or precautionary, approach.
- In **Chile**, GE crops are grown for seed production but not crop production.
- 2001 regulation in **China** states that every GE product must pass safety assessment and receive biosafety certificate and license before cultivation.
- In India, a GE Appraisal Committee makes regulatory decisions.
- Very mixed situation in Africa, varying from country to country



- 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?

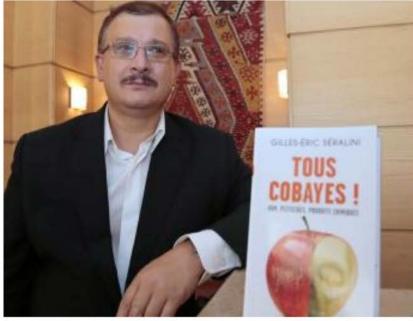
French academies trash GM corn cancer study

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

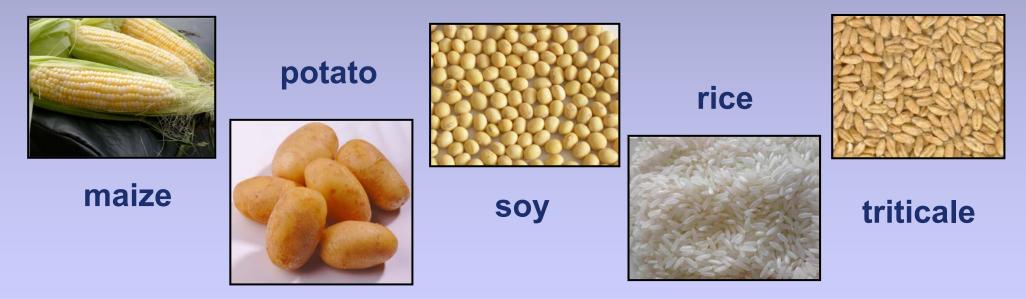
"This work does not enable any reliable conclusion to be drawn," they say, adding that the publicity surrounding the publication has "spread fear among the public."

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?

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





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.

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.





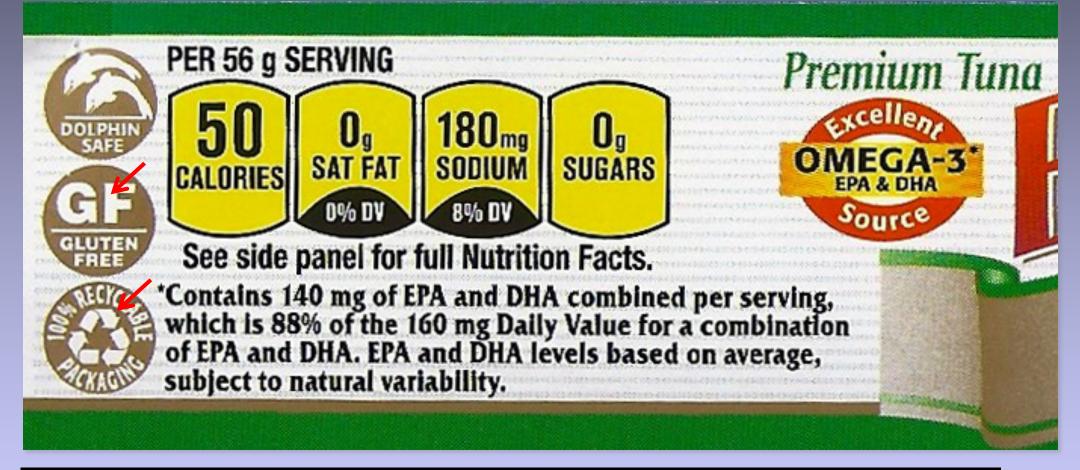




SOURCE: "Prevalence and impacts of genetically engineered feedstuffs on livestock populations" A. L. Van Eenennaam and A. E. Young, J. Animal Science September 2014

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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.



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

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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



What about Herbicide Tolerance?

Environmental impact of herbicide use, measured by 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

CAST[®] Issue Paper

Number 49 February 2012

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."

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.

Morning Ag Clips

friend/) 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!

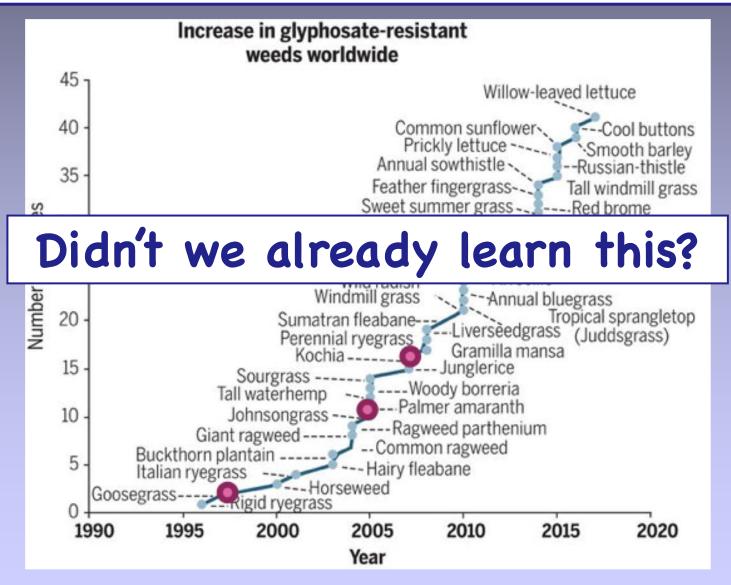


amaranth in some locations. (Patrick Tranel)

Davis AS, Frisvold GB. "Are herbicides a once in a century method of weed control?" 2017. Pest Management Science. DOI: 10.1002/ps4643



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



= SP Synthase gene amplification Science, 2018





And there are/were ways to avoid this

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



SOURCE: "Breeders working on new GM sugar beet variety", Capital Press, December 18, 2015 http://www.capitalpress.com/Idaho/20151218/breeders-working-on-new-gm-sugar-beet-variety

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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.







NEWS & OPINION MAGAZINE SU



Loss of diversity

n the past 250 years, 571 plant species have gone extinct, according to a

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

SOURCE: Akst, J. The Scientist June 11, 2019

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

CHANGE

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NPR "All Things Considered" interviewed CSW director Rick Piltz, 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. Sign Up for the Latest Whistleblower News q

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Climate Change?

climate change



Lynette Cook/Science

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.

► LISTEN · 4:23 + PLAYLIST 🛨 👀 🚍

Lastly this

THE FUTURE OF

Big mergers "could change food supplies and costs worldwide"

1.U.S.: Dow Chemical bought Dupont-Pioneer2.Germany: Bayer bought Monsanto3.China: ChemChina buys Syngenta

This \$170B in consolidations will profoundly affect future global agriculture

> biotech research center in Beijing, the first such foreign-funded h China.

hina's \$43Billion Bid for

And frankly this scares me!

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.

<i>Rortune

By Geoff Colvin

Food Securit

AGRICULTURE

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

http://ucbiotech.org

