Crops, Food, Biotechnology and Labeling

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http:/ucbiotech.org
http://pmb.berkeley.edu/lemaux

1. Background on genes, genetics, genetic engineering (aka biotechnology, GMOs), genome editing

2. What engineered (GE) crops have been commercialized? What's in the pipeline?

3. Why are GE crops & foods so controversial?

4. What are some regulatory, food safety, and environmental issues with GE crops & foods?

Tour d'Onion

Or what makes an onion, an onion?

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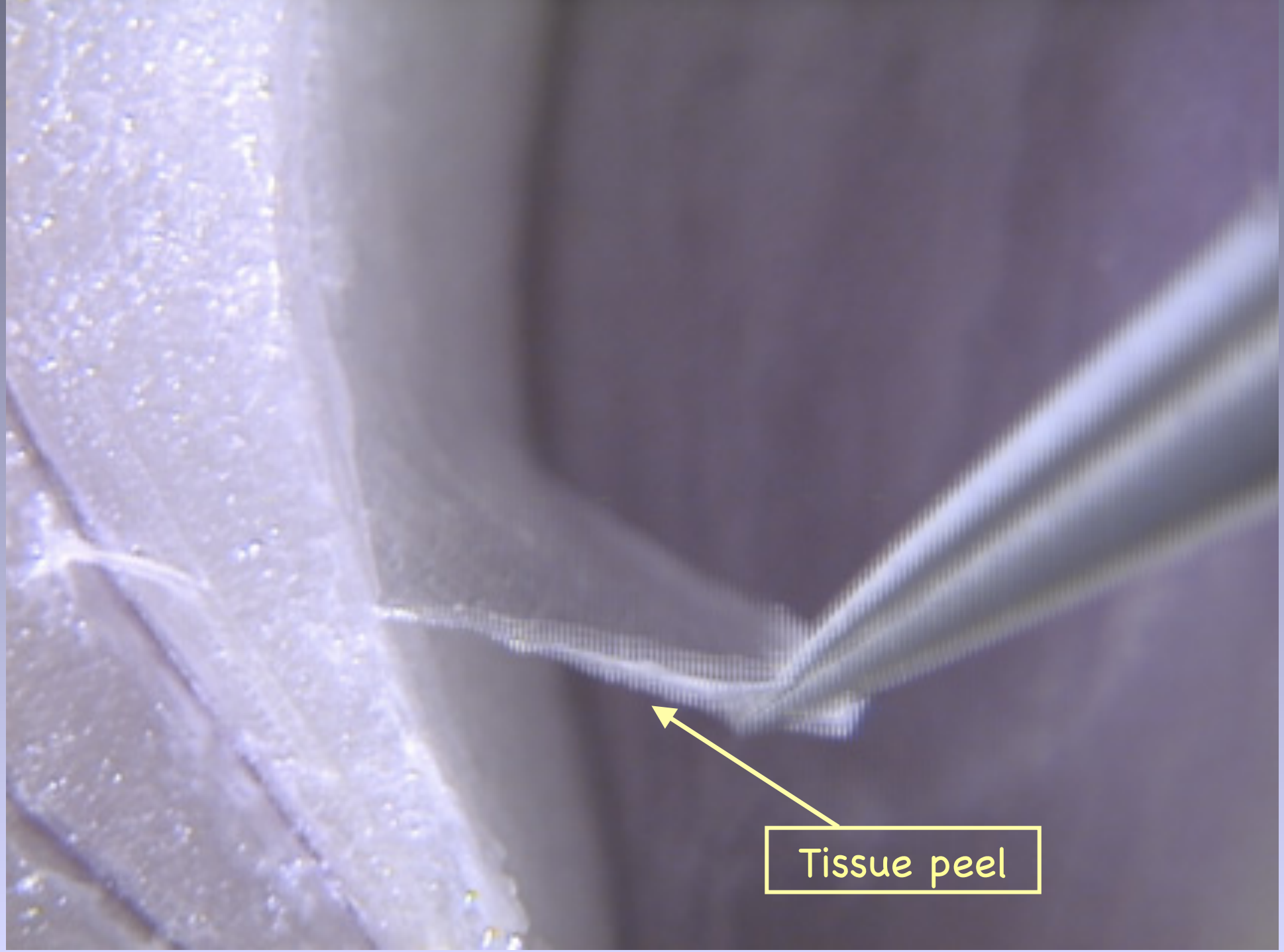
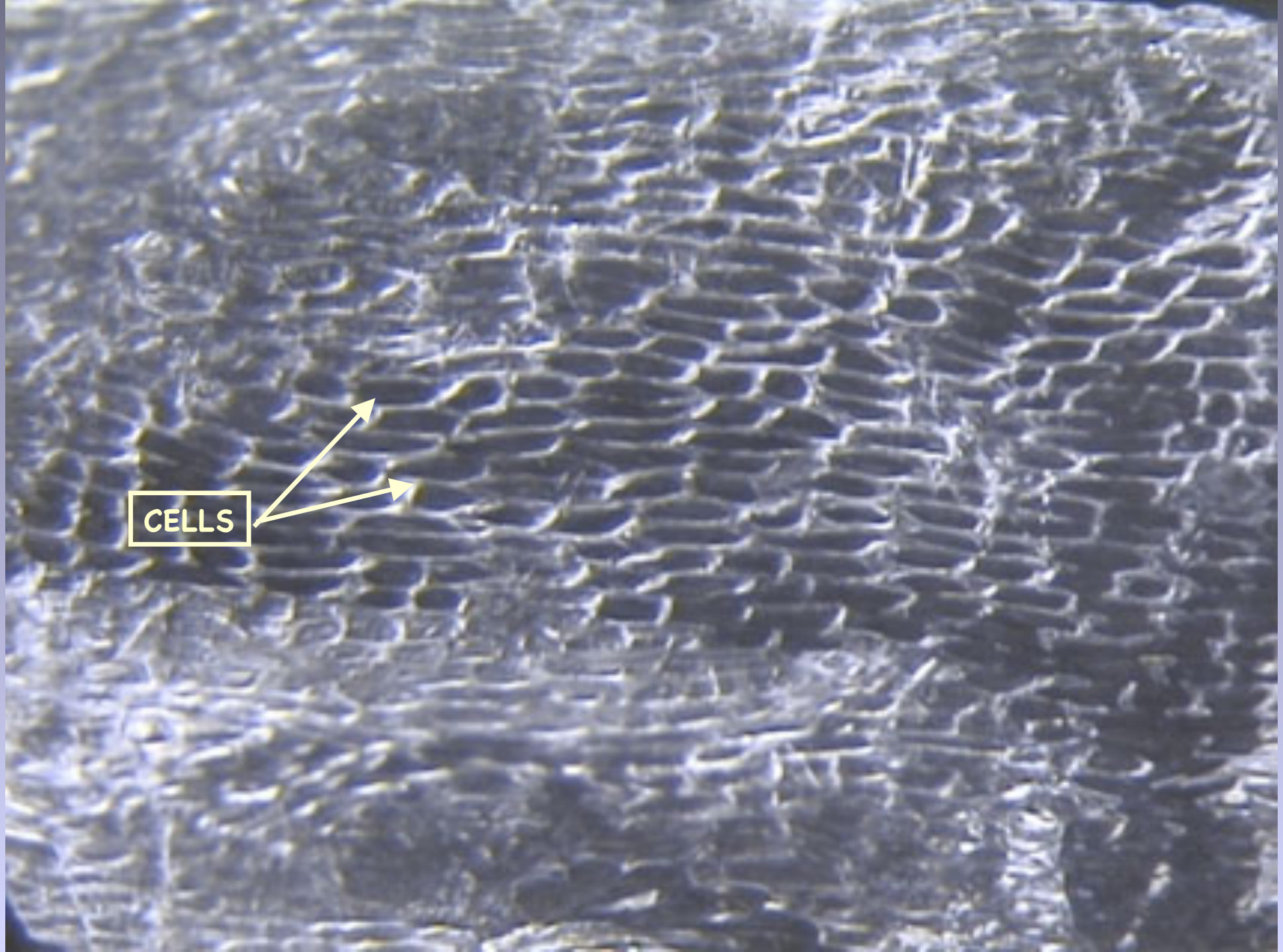
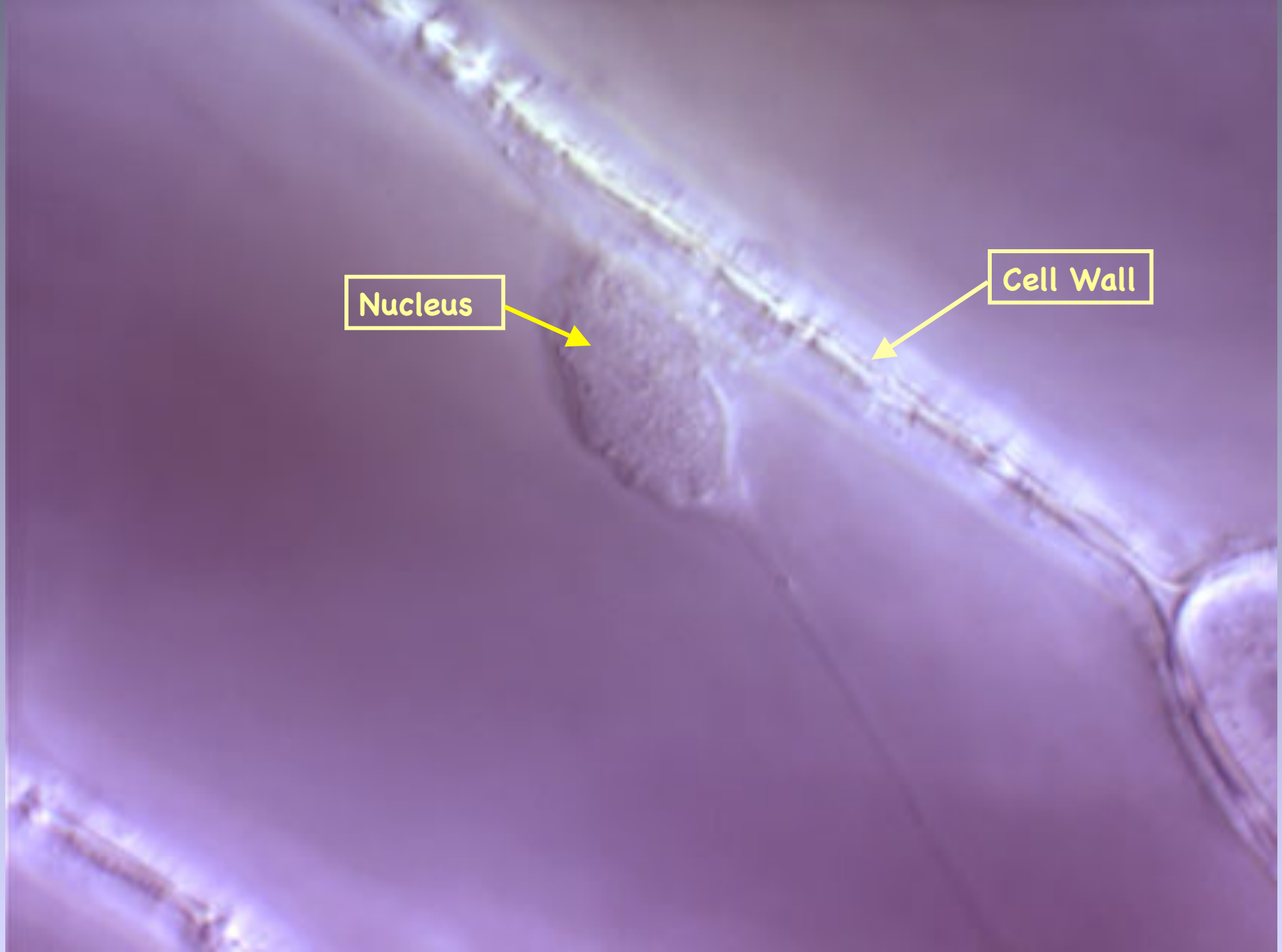
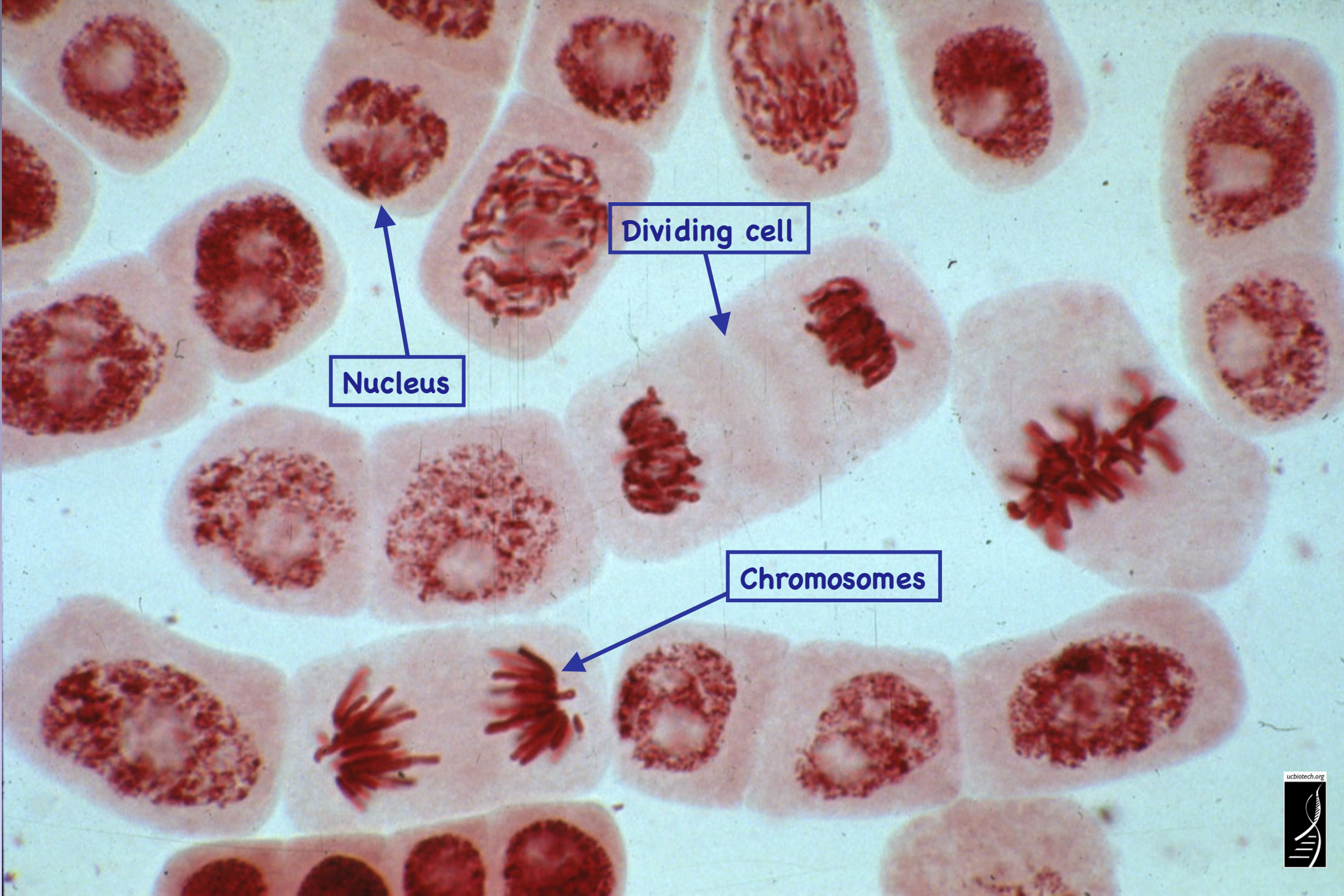
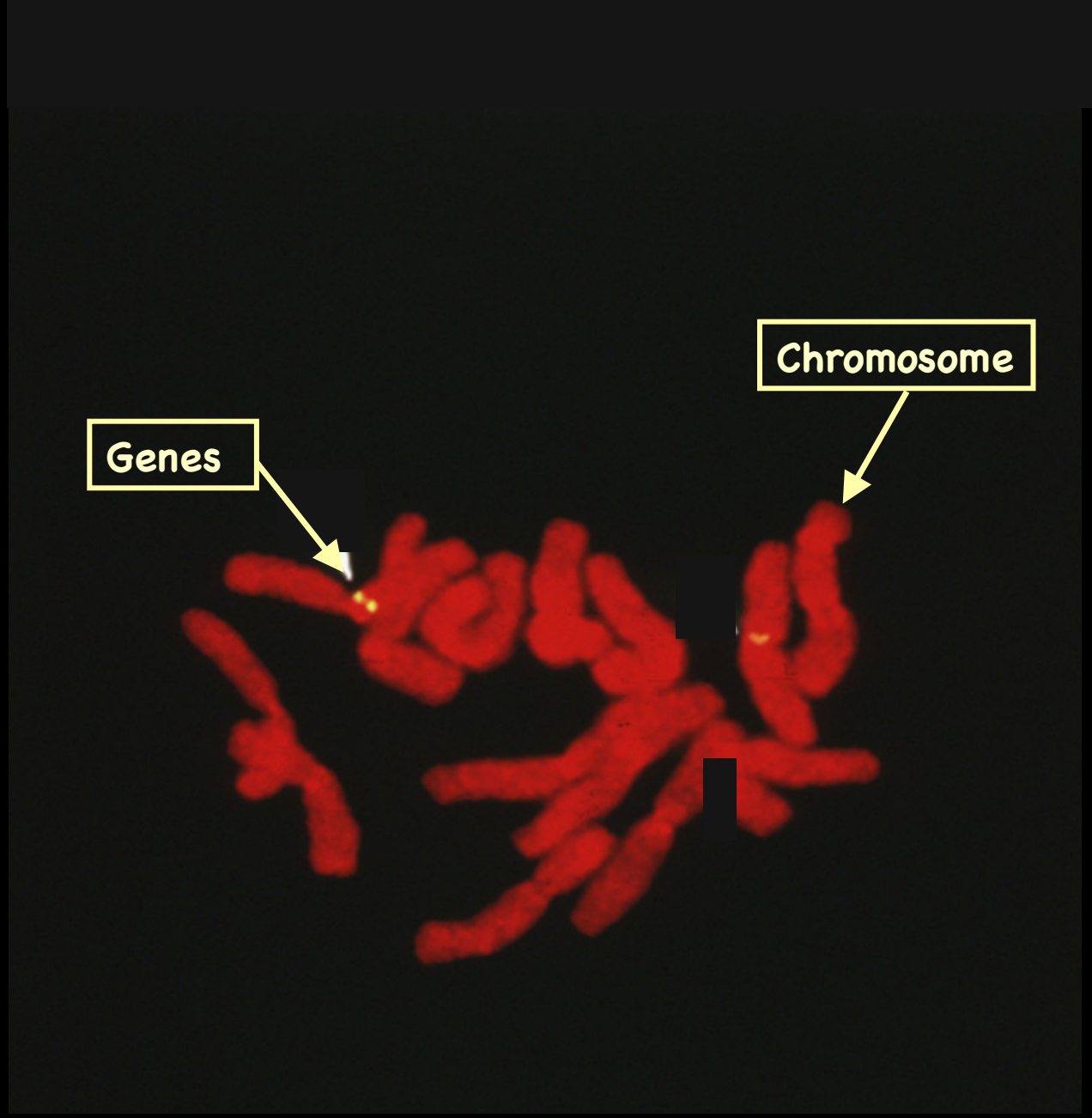

Tissue peel


CELLS


Nucleus
Cell Wall

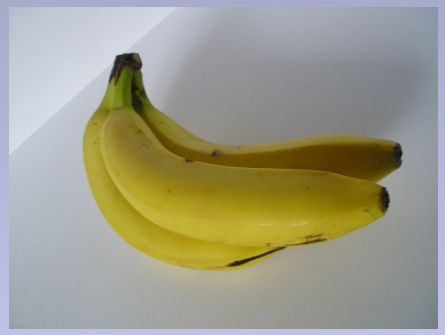

Dividing cell
Nucleus
Chromosomes


Chromosome
Genes

Has Anything Happened to All of the Genes and Genetic Information over Time?

Carrot

Eggplant



Modifications happened via spontaneous mutations, intercrossing and natural selection

What?

Broccoli, Kale, Cabbage

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

Triticum monococcum

Ancient variety

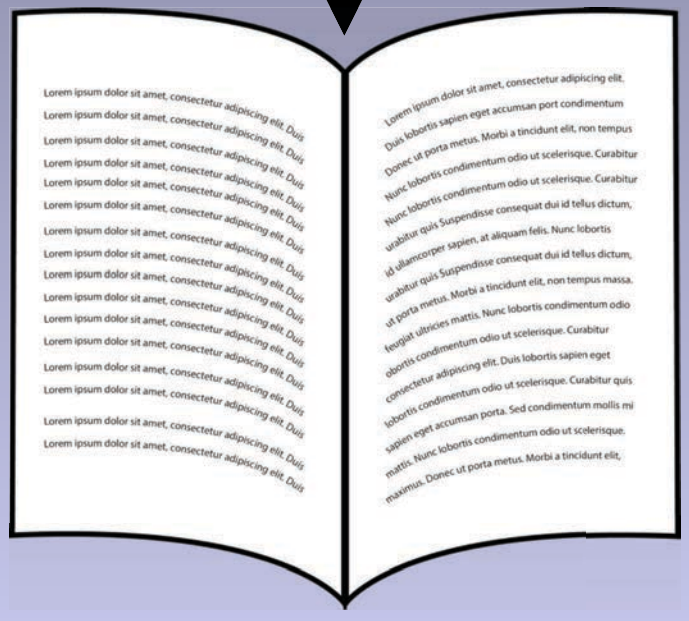
Triticum aestivum

Modern bread variety

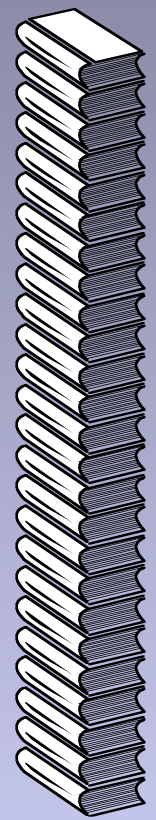
Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...



1700 books
1000 pages each



1700 books
(or 1.7 million pages)

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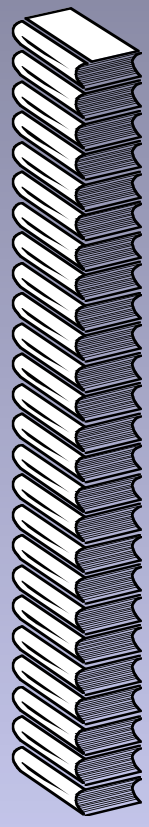
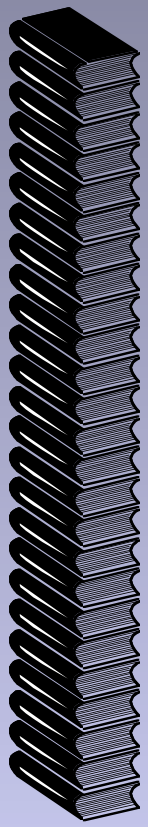
Hybridization or cross breeding of wheat



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)

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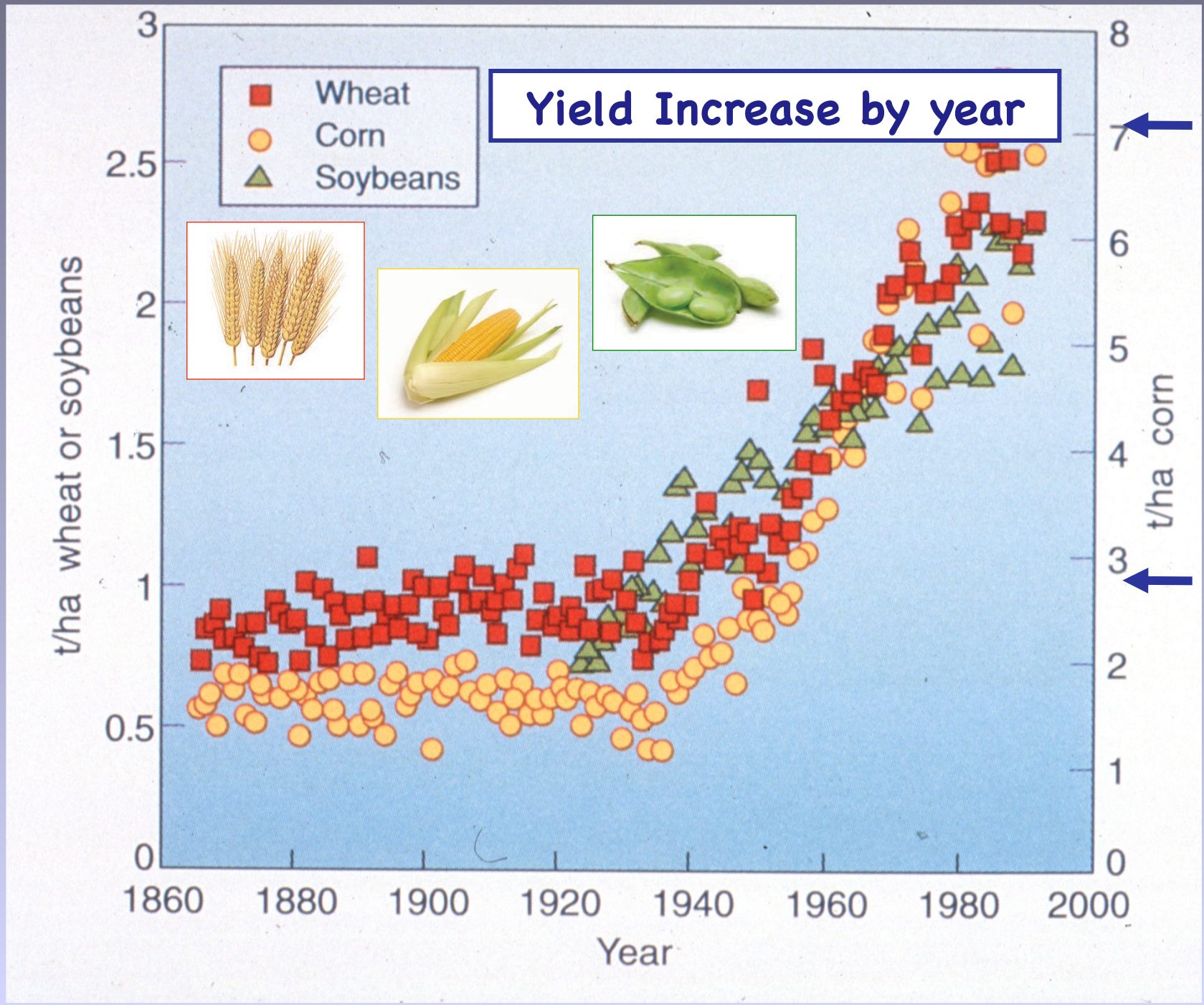
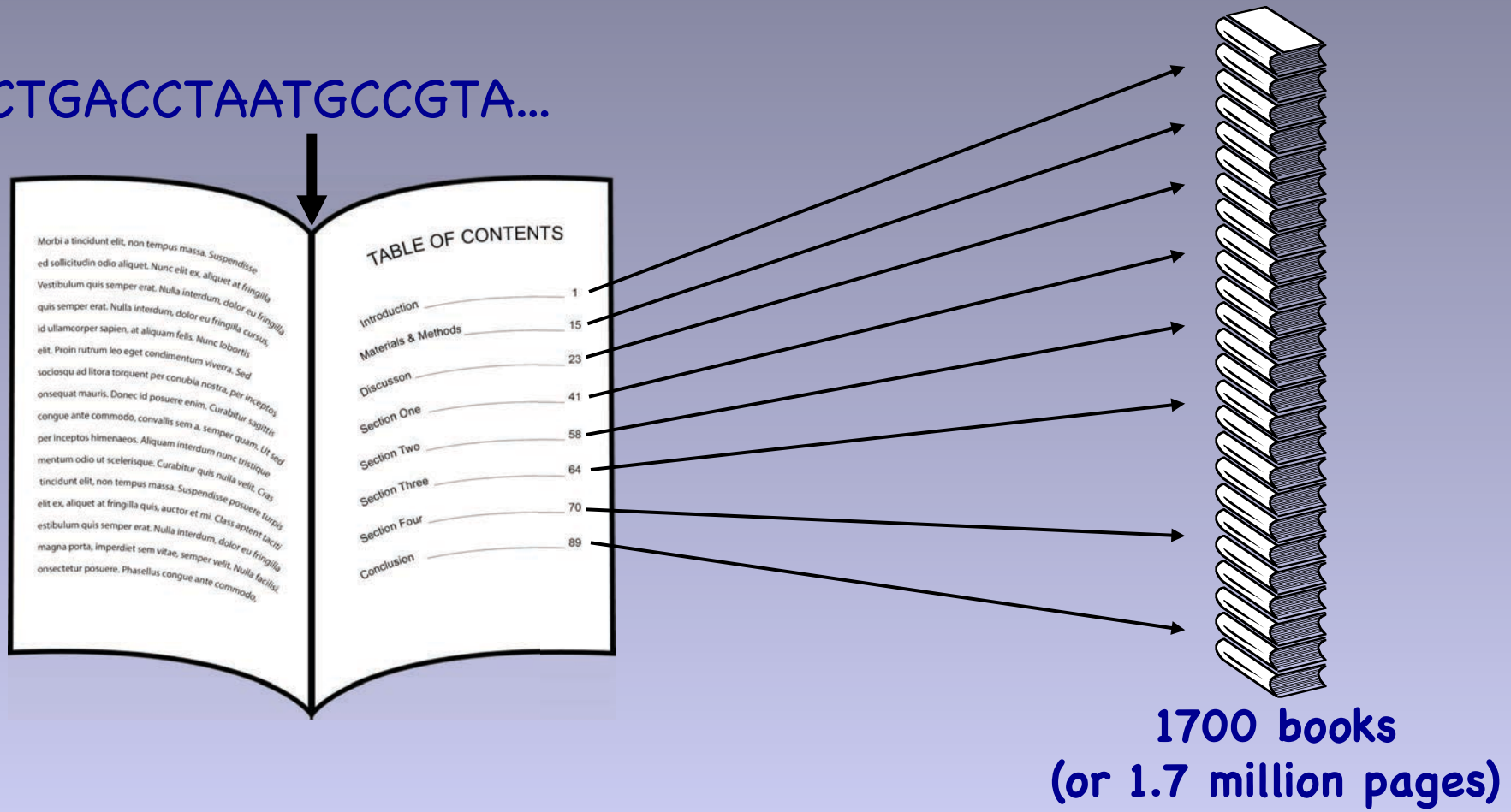
Genetic modification by hybridization <u>is not</u> GE or GMO


Yield Increase by year
Wheat
Corn
Soybeans
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000

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

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Can't We Just Do All Modification This Way?

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

Limited to diversity in crop and compatible relatives


If the trait is from an incompatible plant or other organism, there are ways to create new varieties using the modern tools of genetics
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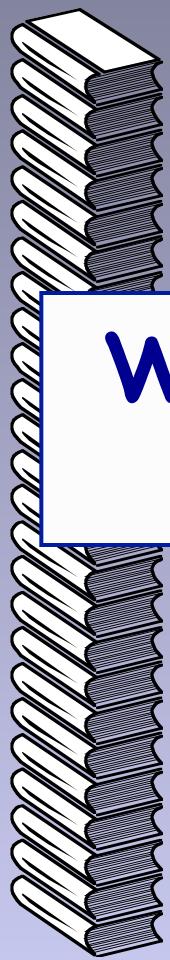
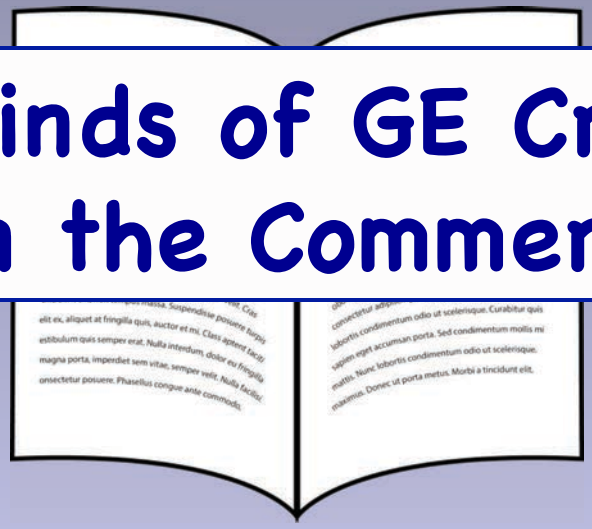
Genetic Engineering



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



One-half page
equivalent to a gene

Inserts randomly in genome

Inserted gene(s)

1700 books
(or 1.7 million pages)

Genetic modification that is GE and GMO

1700 books
(or 1.7 million pages)

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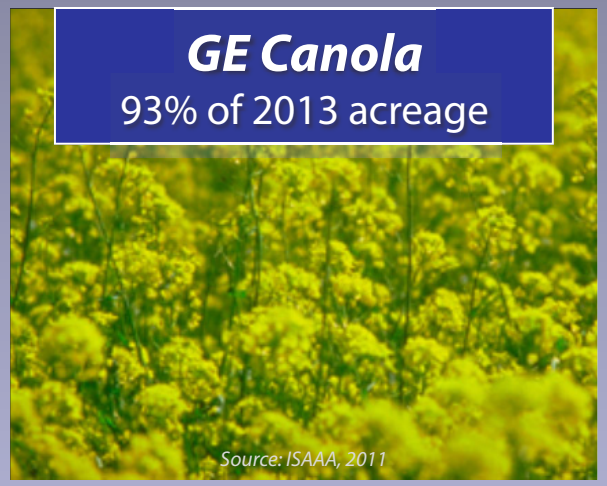
Number of different commercially available, large acreage GE (GMO) crops is limited

GE Cotton

96% of 2014 acreage

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

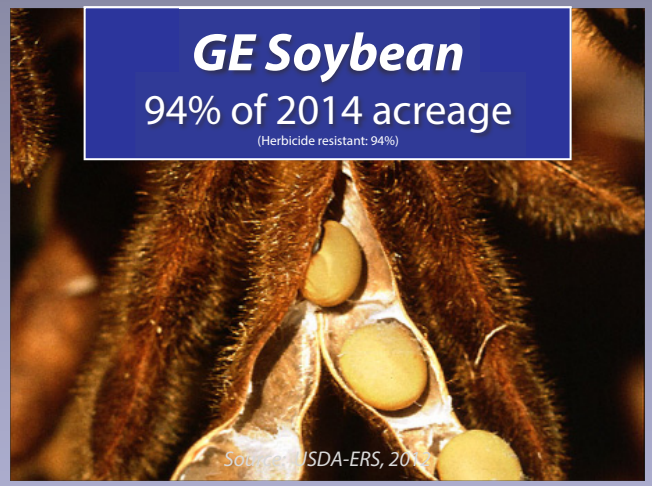
Source: USDA-ERS, 2014



GE Canola

93% of 2013 acreage

Source: ISAAA, 2011

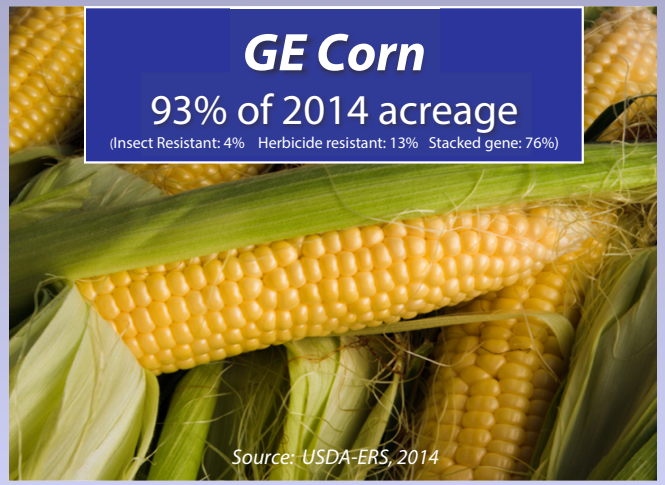


GE Soybean

94% of 2014 acreage

(Herbicide resistant: 94%)

Source: USDA-ERS, 2014



GE Corn

93% of 2014 acreage

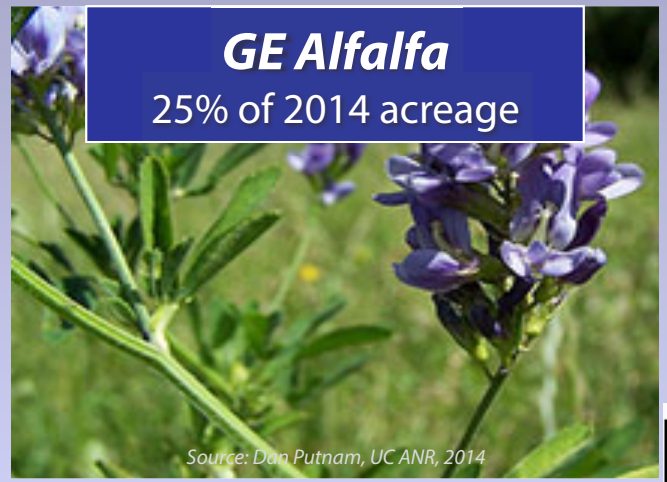
(Insect Resistant: 4% Herbicide resistant: 13% Stacked gene: 76%)

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

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

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

Herbicide-tolerant - engineered with gene to tolerate herbicide application

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

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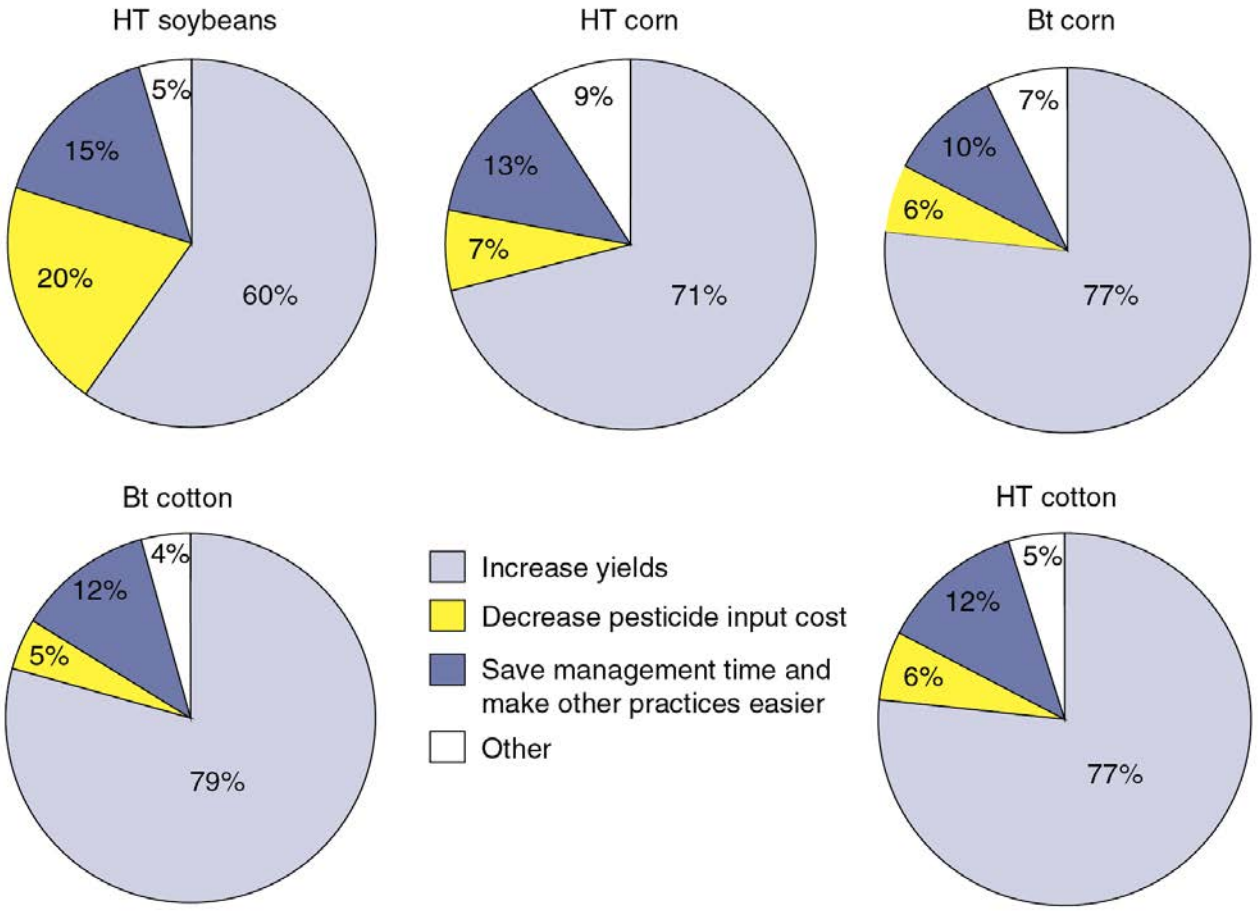
These types of large-acreage GE crops lead to estimates that 75% of processed foods in U.S. have GE ingredients

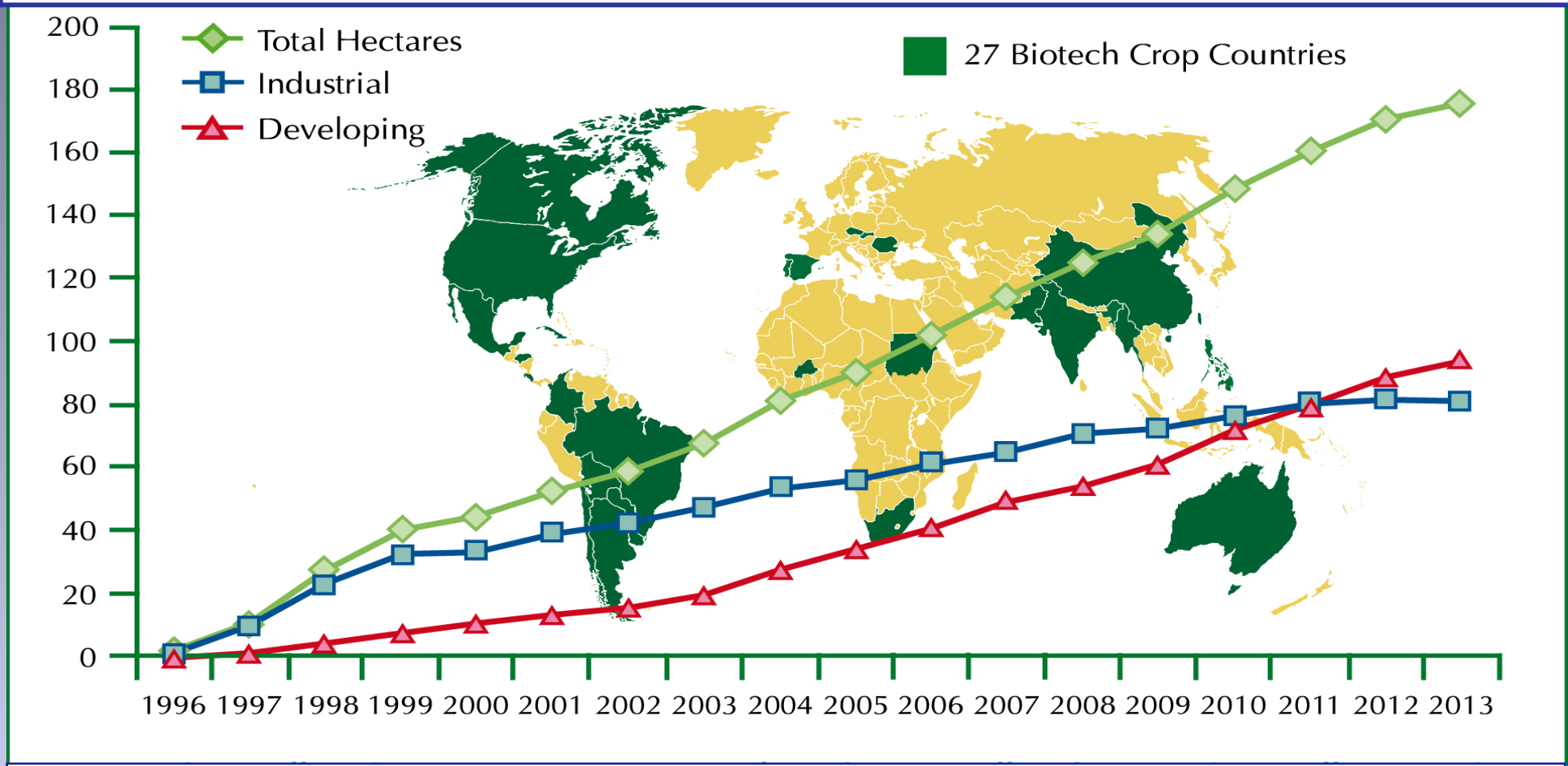
Why do U.S. growers use GE crops?



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.

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

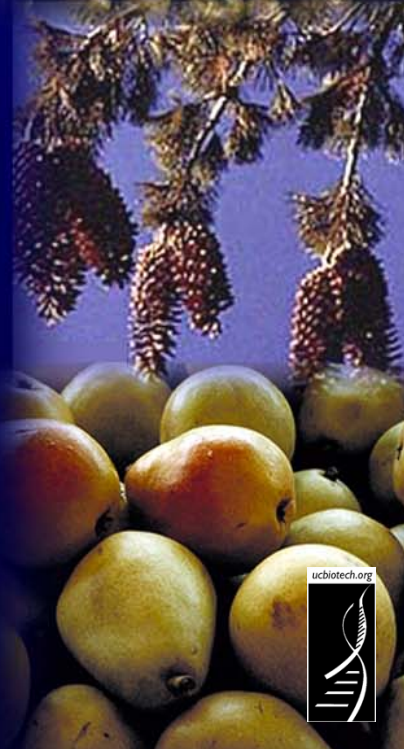


2014: 18 million farmers in 28 countries
448 M acres planted: >3X size of California
>90% were small acreage farmers

There are only a few whole, GE foods that have been commercialized

Two more are just being introduced

WHAT'S IN THE PIPELINE?



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Australian researchers identify grape genes that provide resistance to powdery mildew

SOURCE: Western Farm Press, volume 26, number 16

UCD researcher engineers drought tolerance: results in vigorous growth after prolonged drought

Tobacco after 2 weeks without water then 1 week watered

Control, non-GE

GE tobacco

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

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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

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

teagasc
Agriculture and Food Development Authority

WAGENINGEN UR
For quality of life

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About 80% of tomatoes under certain conditions suffer blossom end rot. Tomatoes engineered for high solids resist this disease

SOURCE: "Transgenic processing tomato also resists blossom end rot", The Grower, 5/24/12
http://www.thegrower.com/e-newsletters/fresh-from-the-field/Transgenic-processing-tomato-also-resists-blossom-end-rot-152327065.html

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

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

High anthocyanin purple GE tomatoes. 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

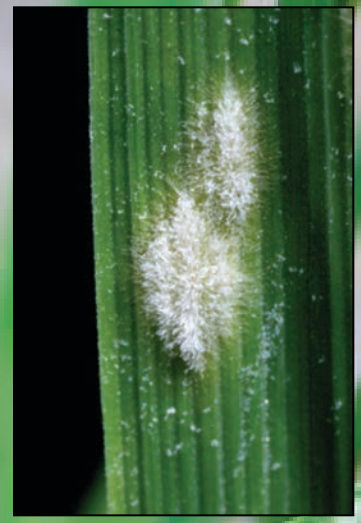
MIT Technology Review

Chinese Researchers Stop Wheat Disease with Gene Editing

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

By David Talbot on July 21, 2014

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



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

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

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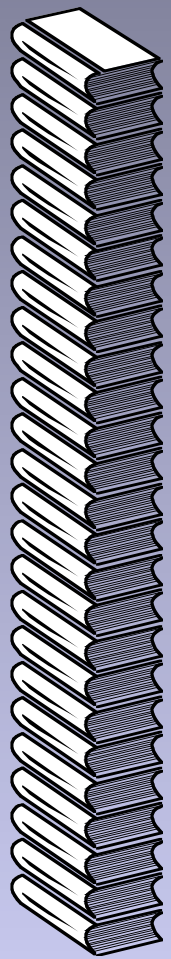
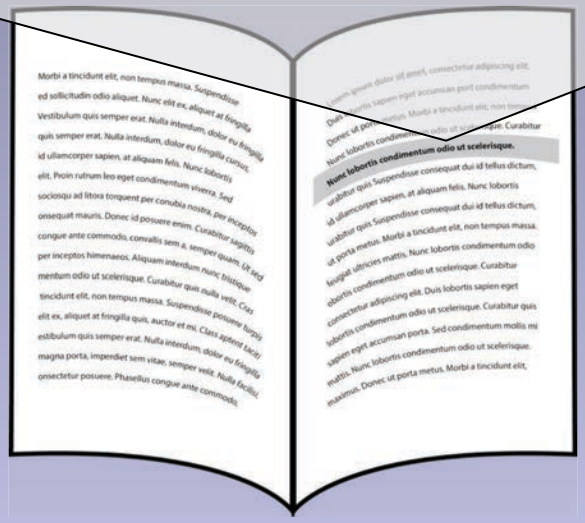
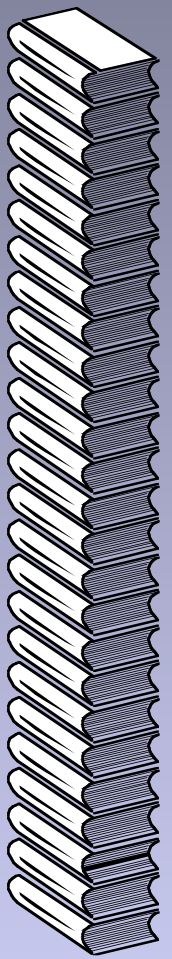
What is Genome Editing?



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





Inserts specifically in genome

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

1700 books (or 1.7 million pages)

Genome editing is not GE or GMO (?)

1700 books (or 1.7 million pages)

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

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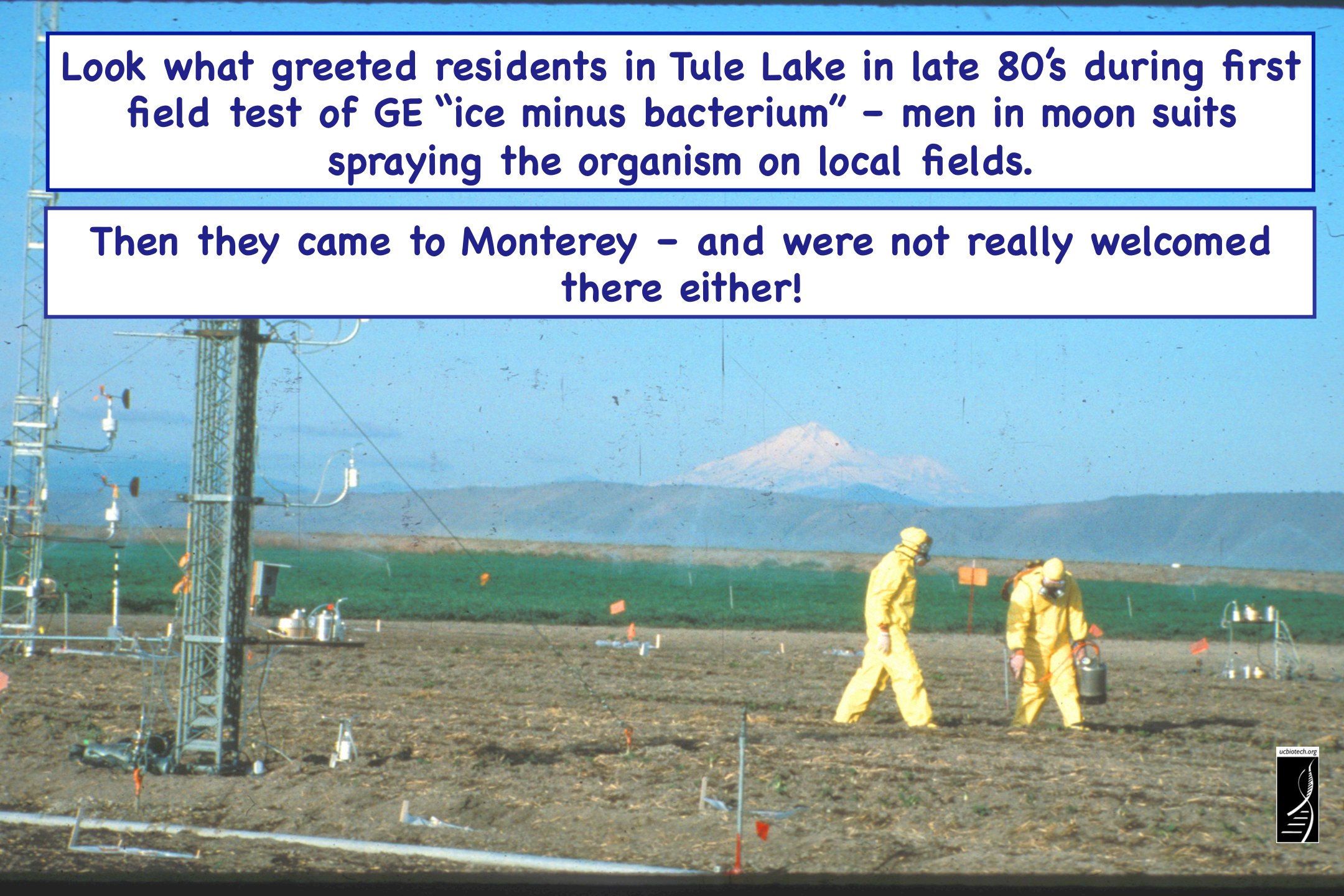
Look what greeted residents in Tule Lake in late 80's during first field test of GE "ice minus bacterium" – men in moon suits spraying the organism on local fields.

Then they came to Monterey – and were not really 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

2014
GM maize protest in Germany

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

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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?

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:


nature

NATURE | NEWS

Gene-edited CRISPR mushroom escapes US regulation

Jose A. Bernat Bacete/Getty Images


Dupont Develops Corn Using New CRISPR Technology

By KRISTOFOR HUSTED • APR 27, 2016

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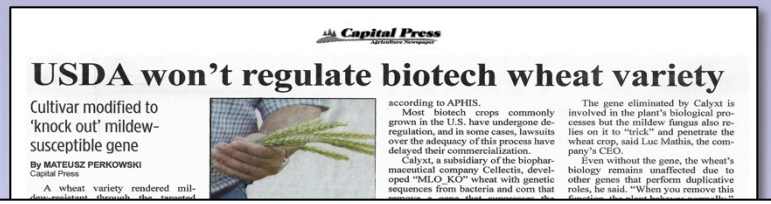
LIZ WEST, FLICKR CREATIVE COMMONS

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.


Capital Press

USDA won't regulate biotech wheat variety

Cultivar modified to 'knock out' mildew-susceptible gene

By MATEUSZ PERKOWSKI
Capital Press

A wheat variety rendered mil-

according to APHIS.

Most biotech crops commonly grown in the U.S. have undergone de-regulation, and in some cases, lawsuits over the adequacy of this process have delayed their commercialization.

Calyxt, a subsidiary of the biopharmaceutical company Cellectis, developed "MLO_KO" wheat with genetic sequences from bacteria and corn that

The gene eliminated by Calyxt is involved in the plant's biological processes but the mildew fungus also relies on it to "trick" and penetrate the wheat crop, said Luc Mathis, the company's CEO.

Even without the gene, the wheat's biology remains unaffected due to other genes that perform duplicative roles, he said. "When you remove this

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

the scope of its regulations several genetically

Coordinated Framework is on the one hand

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

of entities seeking nonregulated status for

US regulatory framework for GE crops and

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

as null segregants, novel delivery systems,

small companies and public sector institutions.

Camacho et al. 2014. Nature Biotech. 32:1087-1091

What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling
- Environmental issues

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

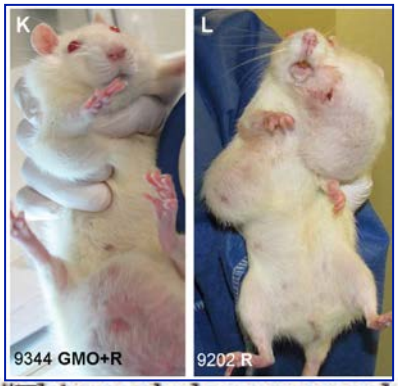
But did you ever hear that on Dr. Oz?

French academies trash GM corn cancer study

By **RFI**

A controversial study that linked genetically modified maize to cancer in la... six ... in a...

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 th... names of the national academies of agriculture, medicine, pharmacy, science, technology and... veterinary studies.

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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

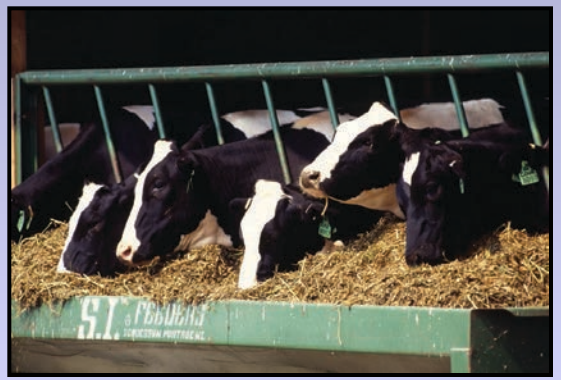
SOURCE: Snell C, Bernheim A, Berge J-P, Kuntz M, Pascal G, Paris A, Ricroch AE. 2012. Assessment of the health impact of GM plant diets in long-term and multigenerational animal feeding trials: A literature review. Food and Chemical Toxicology 50: 1134-1148.

2014 study

- 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

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What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling
- Environmental issues

Over the past few months, what food or ingredients did you avoid or eat less of?

	Jan. 2001	July 2006	Apr. 2010	Apr. 2014
• Sugars	31%	50%	51%	55%
• Fats/cholesterol	41%	33%	32%	26%
• Animal products	28%	28%	18%	25%
• Other	9%	11%	14%	N/A
• Snacks/Fast food	N/A	16%	16%	20%
• Salt/spices	11%	12%	20%	18%
• Caffeine	4%	N/A	N/A	N/A
• Soda	4%	N/A	N/A	N/A
• Genetically engineered	0%	0%	0%	2%

SOURCE: IFIC, April 2014.
*http://www.foodinsight.org/Press-Release/Detail.aspx?topic=Survey_Finds_Continued_Support_for_FDA_s_Biotech_Foods_Labeling_*

Can you think of any information that is not currently included on food labels that you would like to see on food labels? And what types of information would that be?

	Jan. 2001	Apr. 2003	July 2006	Apr. 2010	Apr. 2014
• Yes	26%	17%	18%	18%	26%
– Ingredients (i.e., fats, salt)	6%	4%	3%	20%	23%
– Other	11%	9%	5%	25%	4%
– Genetically altered	2%	2%	1%	0	0
• No	74%	77%	82%	82%	74%
• Don't know/refused	--	6%	--	--	14%

Open-ended poll that doesn't use term, GMO

SOURCE: IFIC, April 2014.
*http://www.foodinsight.org/Press-Release/Detail.aspx?topic=Survey_Finds_Continued_Support_for_FDA_s_Biotech_Foods_Labeling_*

What if you ask people directly about labeling of GMO foods?

May 2016 Harris Poll
When asked if they supported labeling legislation for GMO's:

75% of respondents, yes
9% no
16% didn't know

SOURCE: Harris Poll Finds Support for Federal G.M.O. Labeling. Food Business News May 26, 2016

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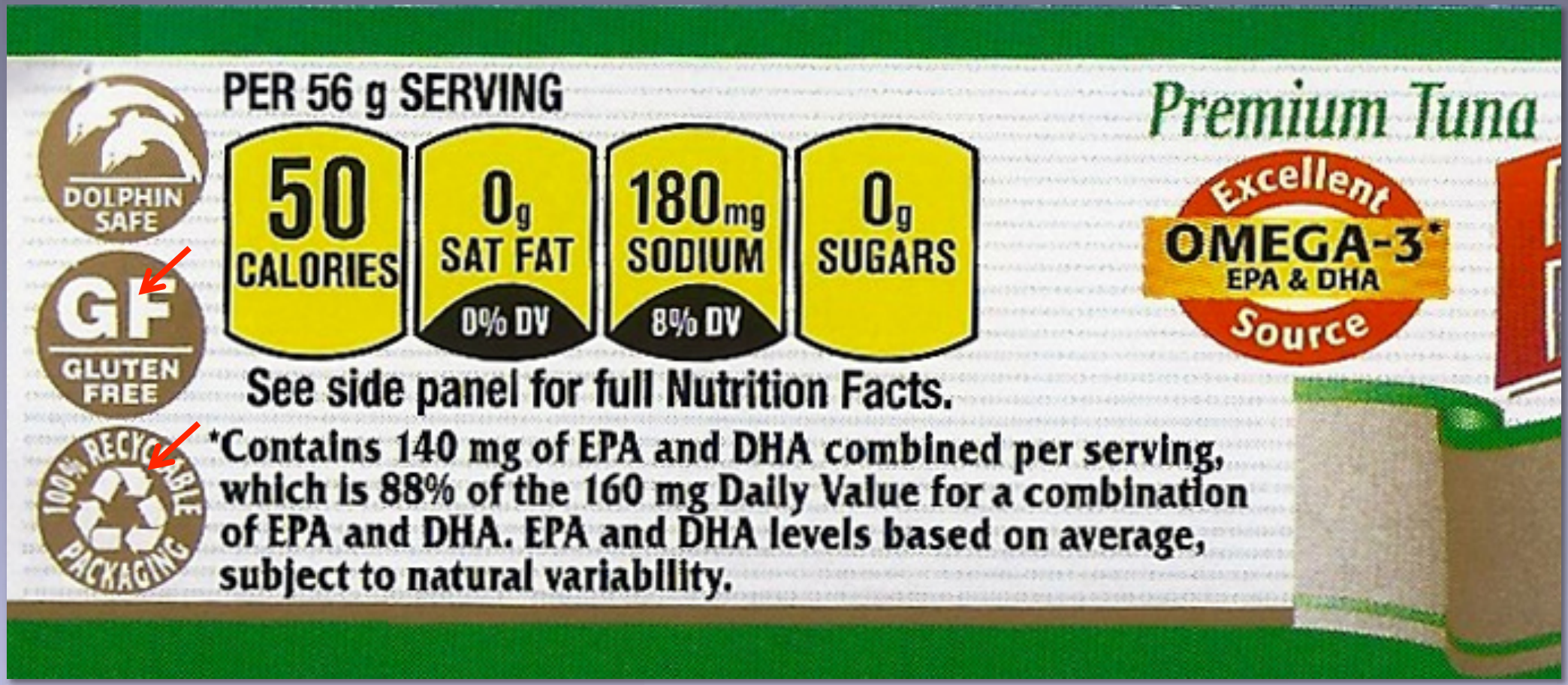

But, there are many labels on foods- from gluten-free to dolphin-safe - none are mandated. And, up to now, there were no federally mandated labels on foods with GE ingredients.

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

While waiting for federal laws, non-legislative labeling efforts, like the popular Non-GMO Project label, arose

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

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

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With the Vermont labeling law taking effect July 1, companies had to decide.

SFGATE

General Mills to add GMO labeling on its products

By Tara Duggan Updated 4:36 pm, Friday, March 18, 2016

In a striking reversal for big food manufacturers, which have spent millions fighting state efforts to require mandatory labeling of genetically engineered food, General Mills announced Friday that it would voluntarily add that information to its labels.

General Mills' move is a reaction to a law due to go into effect July 1 in Vermont that will require mandatory labeling of foods with genetically modified organisms. On Wednesday, the Senate blocked efforts by Sen. Pat Roberts, R-Kan., to preempt Vermont's law by making that labeling voluntary nationwide. Jeff Harmening, executive vice president and chief operating officer for U.S. retail at General Mills, explained the Minneapolis company's move in a blog post.

"We can't label our products for only one state without significantly driving up costs for our consumers, and we simply will not do that." General Mills

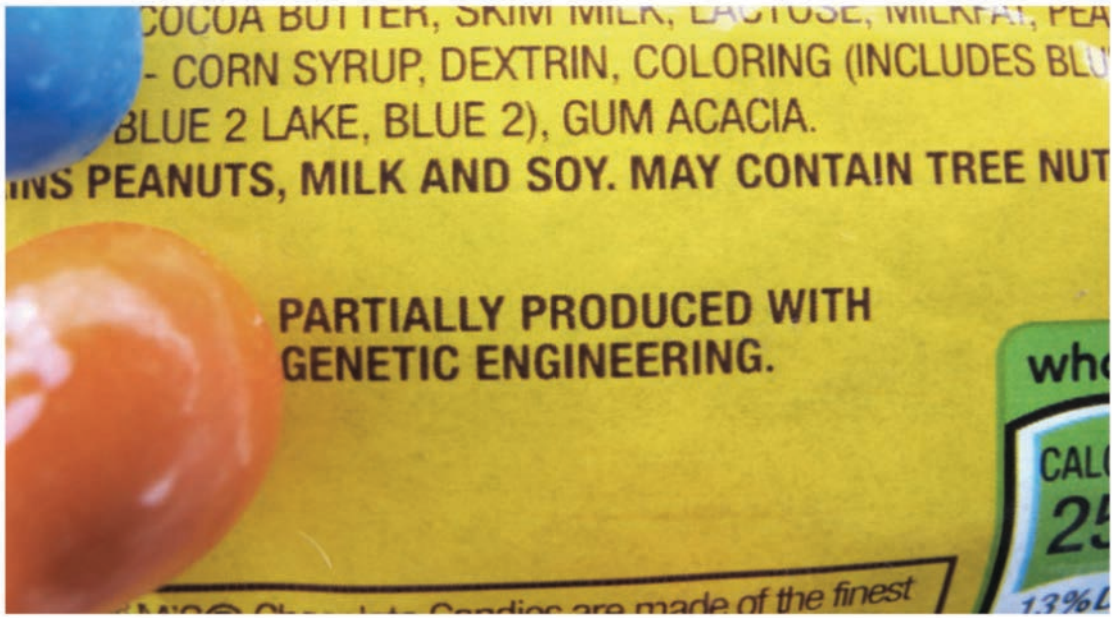
Others: Campbell's Soup Co., Mars, Kellogg's and ConAgra Foods said they would label food with GMOs in time to comply with Vermont's deadline and compatible with the law's standards.

SOURCE: "General Mills to add GMO labeling on its products", SF Gate, 3/18/16
http://www.sfgate.com/food/article/General-Mills-to-add-GMO-labeling-on-its-products-6922250.php

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&Ms 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

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What are some issues with GE crops & foods?

- Regulatory oversight
- Lack of peer-reviewed food safety tests
- Consumer attitudes and labeling
- Environmental issues

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

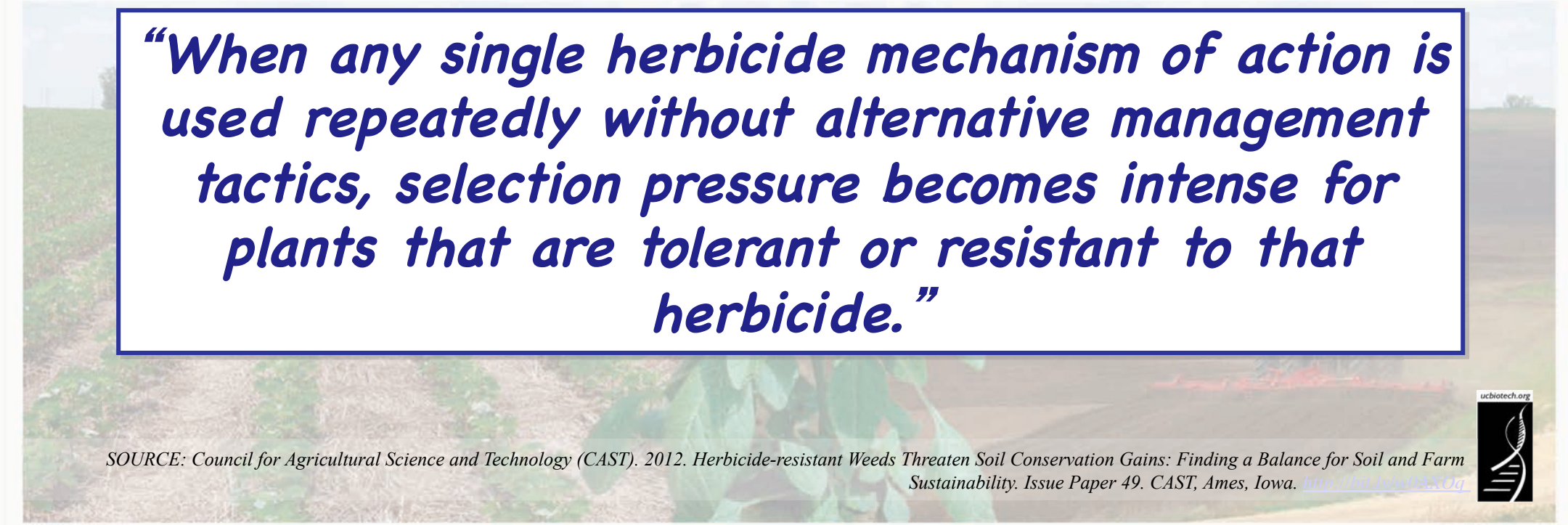
But is there a consequence?

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

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 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/wDXOq

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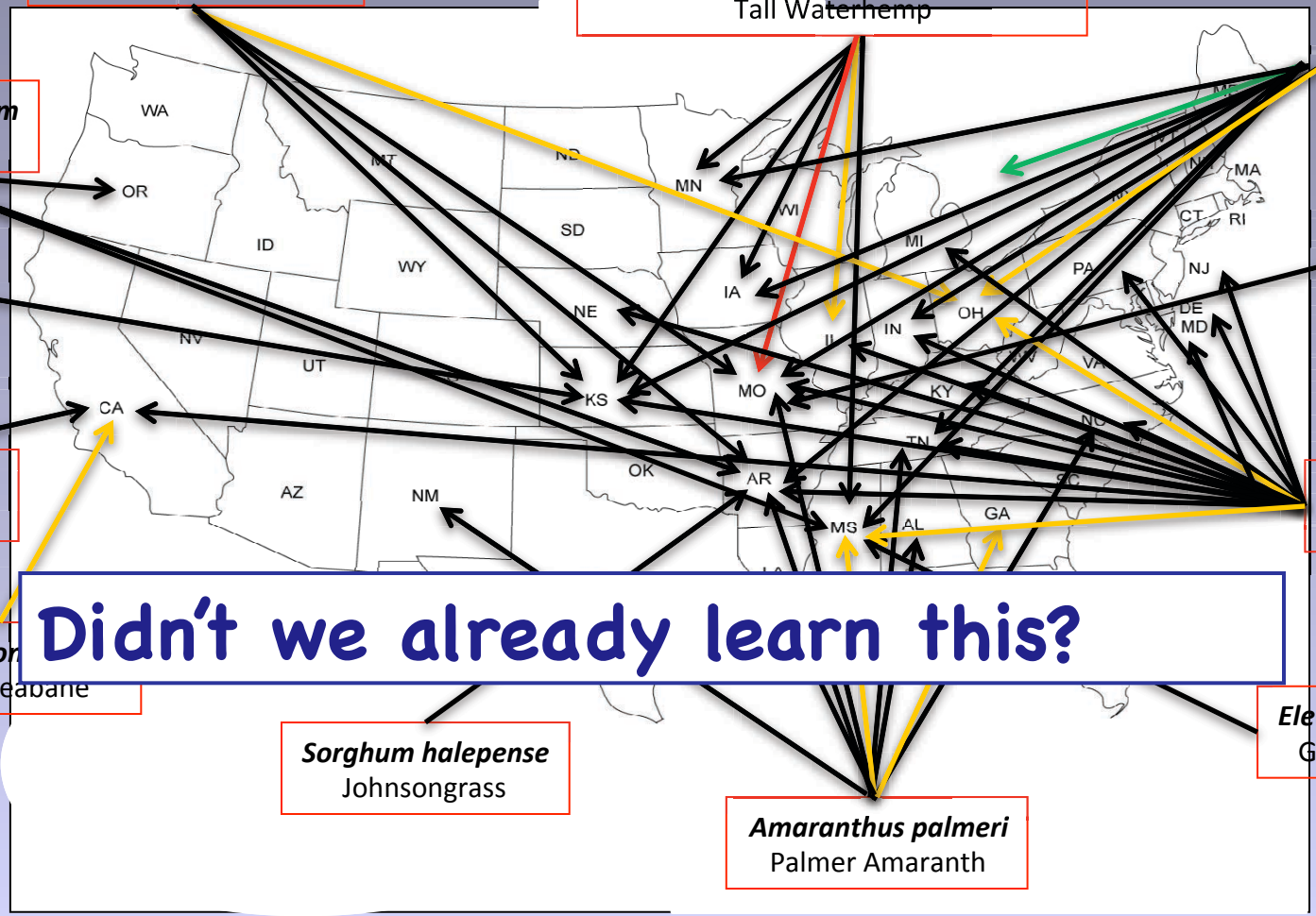
Glyphosate-resistant weeds due to mutation, gene flow, weed shift – exacerbated when same herbicide is used repeatedly

Glyphosate- Resistant Weeds – USA

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



Ambrosia artemisiifolia
Common Ragweed

Amaranthus tuberculatus (syn. rudis)
Tall Waterhemp

Ambrosia trifida
Giant Ragweed

Lolium multiflorum
Italian Ryegrass

Poa annua
Annual Bluegrass

Kochia scoparia
Kochia

Lolium rigidum
Rigid Ryegrass

Conyza canadensis
Horseweed

Didn't we already learn this?

Conyza bon
Hairy Fleabane

Eleusine indica
Goosegrass

Sorghum halepense
Johnsongrass

Amaranthus palmeri
Palmer Amaranth

K. Neil Harker
AAFC - Lacombe, AB

Where to get more information on the issues?

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