

# The Science of GMOs and Related Issues



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



Want to ask questions?  
Follow these easy steps in Biotech information section of ucbiotech.org

ucbiotech.org - Science-Based Information and Resources on Agriculture, Food and Technology

ucbiotech.org - Science-Based I...

ucbiotech.org/index.html

Google




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

ABOUT US | IN THE NEWS | **BIOTECHNOLOGY INFORMATION** | RESOURCES | LINKS | GLOSSARY | SEARCH

Annual Review Articles | Issues & Responses

Select Language

**know GMOS**

*This website provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them. Science-based information related to these issues is available, as well as educational tools and information, which can be used to promote informed participation in discussions about these topics.*

**FEATURED PRESENTATION**



**How Much Did You Pay for Your Lunch Today?**

Center for Practical and Professional Ethics  
California State University, Sacramento  
February 7, 2012

**BIOTECHNOLOGY INFORMATION**

**ANNUAL REVIEWS**

**Review articles:**  
Focused on food, environmental and socioeconomic issues of GE crops and foods.  
[Part 1](#) | [Part 2](#)

**RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS**

**DNA for Dinner 4-H curriculum:**  
For grades 5-8, covers topics from plant diversity to genetic engineering. Each of the five lessons has 3 to 5 activities.





**New Game: Who's In Your Family?**  
A free educational game to teach participants about the diversity of fruits and vegetables, and how they are related.

**Slide Archive:**  
Extensive collection of PP slides on agriculture & biotechnology.

**Available on loan:**

**Teaching Aids:** Handouts and cards available, in both English and Spanish.



**Educational displays:** "Genetics and Foods" and "Genetic Diversity and Genomics" available with companion educational cards and teacher

**HELPFUL SITES**

**Academics Review**  
[Academics Review website](#)  
Testing popular claims against peer-reviewed science.

**Biofortified website**  
Provides factual information to foster discussion about agriculture, especially plant genetics and genetic engineering.

**Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis**



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



ucbiotech.org - Issues and Responses

ucbiotech.org - Issues and Res...

ucbiotech.org/search4.php

Google



**Go to Issues and Responses section on drop-down menu from Biotechnology Information section. Chose a category to see what issues are there or type your question in "search by phrase". Hit search.**

CES

[ABOUT US](#) | [IN THE NEWS](#) | [BIOTECHNOLOGY INFORMATION](#) | [RESOURCES](#) | [LINKS](#) | [GLOSSARY](#) | [SEARCH](#)

## ISSUES & RESPONSES

Common issues and responses, related to topics like agriculture, foods, food safety, bioenergy, agricultural practices and biotechnology, are covered and include scientific references. Content and choice of literature is the sole responsibility of Dr. Peggy G. Lemaux. Some issues are updated from two Annual Review of Plant Biology articles [Part I](#) | [Part II](#). Note our policy regarding [outside links](#).

### Search by Phrase

Enter a keyword such as "food".  
You can also search by combination of words such as "water and food".

bt corn safe to eat?

**SEARCH**

### List all by Category

Alternatively, you may list all of the questions related to a category.  
Select a category, and click "Display."

Agriculture

**DISPLAY**



Responses to the issue you raised will appear and you can click on the Response of the one issue that best addresses your question.

ucbiotech.org - Issues and Responses

ucbiotech.org - Issues and Res...

ucbiotech.org/search4.php

Google

ABOUT US | IN THE NEWS | BIOTECHNOLOGY INFORMATION | RESOURCES | LINKS | GLOSSARY | SEARCH

## ISSUES & RESPONSES

[Search Again?](#)

**Your search for *bt corn safe to eat?* returned the following results**

Results are given in order of relevance

---

**Are Food Safety Studies Conducted on GE Foods?** [Response](#)

**Besides Genetically Engineered Crops, Does Genetic Engineering Play a Role in Producing Food?** [Response](#)

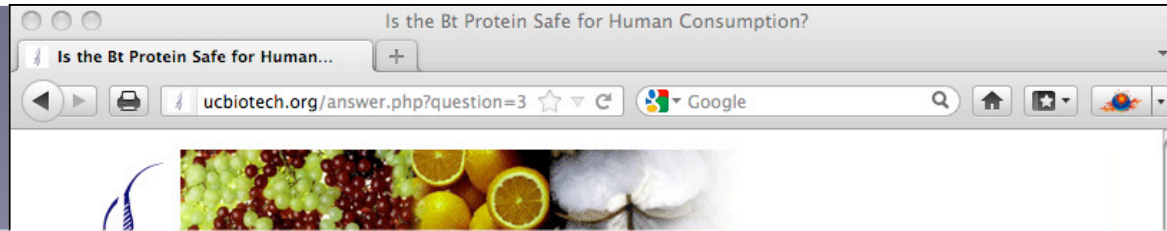
**Were Foods Made From Bt Corn Removed from the Market Because of Allergenicity Concerns?** [Response](#)

**Is the Bt Protein Safe for Human Consumption?**

Bt proteins, naturally occurring insecticides produced by the soil bacterium, *B. thuringiensis*, have been used to control crop pests since the 1920s (1), generally as microbial products. Many strains ... [Read more...](#)

Filed under [Food Risks] [Food Safety] [Pest Tolerance] [Regulation]

**Can Federal Regulatory Agencies Stop Planting of Genetically Engineered Crops That Pose Environmental Risks?** [Response](#)



**Response to the issue you raised will appear with links to the scientific literature. If that doesn't answer your question, go back to the responses and choose another.**

### Is the Bt Protein Safe for Human Consumption?

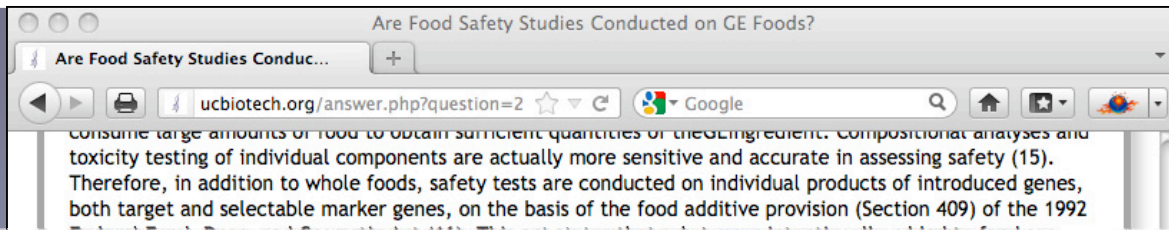
**Response:**

Bt proteins, naturally occurring insecticides produced by the soil bacterium, *B. thuringiensis*, have been used to control crop pests since the 1920s (1), generally as microbial products. Many strains of *B. thuringiensis* exist that produce different Bt proteins varying in the insects they target, e.g., larvae of butterflies and moths, beetles, and mosquitoes. The insecticidal Bt proteins form crystalline protein bodies inside the bacterium, hence the name Cry proteins. Full-sized Cry proteins are inactive until eaten by target insect larva, and inside the midgut they are cleaved and become active. The smaller, active peptides bind to specialized receptors, creating holes in the gut membrane that cause contents to leak and kill the larvae. The precision of different Bt proteins for their targets resides in the specificity of their tight binding to companion receptors in the insect gut (2).

Bt microbial products have a long history of safe use (~40 years) with only two reports prior to 1995 of possible adverse human effects, neither of which was due to exposure to Cry proteins (3). In a 1991 study that focused on exposure via inhalation of Bt sprays, results showed immune responses and skin sensitization to Bt in 2 of 123 farm workers (4). In a 2006 article, the Organic Consumers Association linked this observation to possible impacts of Bt in GE foods, warning that "Bt crops threaten public health" (5). But the respiratory sensitization observed in the farm workers does not provide validation that oral exposure to Bt would result in allergic responses.

In recent years a variety of safety studies were conducted specifically on native Bt proteins to show that they do not have characteristics of food allergens or toxins (See 6, 2, and 7 for reviews). In its review of Bt proteins, the EPA stated that, "several types of data are required for Bt plant pesticides to provide a reasonable certainty that no harm will result from the aggregate exposure of these proteins." The data must show that Bt proteins "behave as would be expected of a dietary protein, are not structurally related to any known food allergen or protein toxin, and do not display any oral toxicity when administered at high doses" (6).

The EPA does not require long-term studies because the protein's instability in digestive fluids makes such studies meaningless in terms of consumer health (8). In vitro digestion assays were used to confirm degradation characteristics of Bt proteins, whereas murine feeding studies were used to assess acute oral



Literature cited will appear with links when possible to the articles so that you can see them yourselves.

**References:**

1. Food Drug Adm. (FDA). 2005. Guidance for industry: Pharmacogenomic data submissions. <http://www.fda.gov/downloads/.../Guidances/ucm126957.pdf> Last accessed 2011-11-26. [PDF](#)

Now on to the topic at hand...

<http://www.epa.gov/scipoly/biotech/pubs/framework.htm>. Last accessed 2011-12-8. [PDF](#)

4. Kuiper HA, Kleter GA, Noteborn HPJM, Kok EJ. 2001. Assessment of the food safety issues related to genetically modified foods. *Plant J.* 27:503-28

5. Kessler DA, Taylor MR, Maryanski JH, Flamm EL, Kahl LS. 1992. The safety of foods developed by biotechnology. *Science* 256:1747-49

6. Berberich SA, Ream JE, Jackson TL, Wood R, Stipanovic R, et al. 1996. The composition of insect-protected cottonseed is equivalent to that of conventional cottonseed. *J. Agric. Food Chem.* 44:365-71

7. Sidhu RS, Hammond BG, Fuchs RL, Mutz J-N, Holden LR, et al. 2000. Glyphosate-tolerant corn: The composition and feeding value of grain from glyphosate-tolerant corn is equivalent to that of conventional corn (*Zea mays* L.). *J. Agric. Food Chem.* 48:2305-12

8. Taylor NB, Fuchs RL, MacDonald J, Shariff AR, Padgett SR. 1999. Compositional analysis of glyphosate-tolerant soybeans treated with glyphosate. *J. Agric. Food Chem.* 47:4469-73

9. Kahle K, Kraus M, Richling E. 2005. Polyphenol profiles of apple juices. *Mol. Nutr. Food Res.* 49:797-806

**10. Chassy B, Hlywka JJ, Kleter GA, Kok EJ, Kuiper HA, et al. 2004. Nutritional and safety assessments of foods and feeds nutritionally improved through biotechnology: An executive summary. *Compr. Rev. Food Sci. Food Saf.* 3:25-104  
*Provides scientific information and recommendations on safety and nutritional aspects of crops with improved nutritional qualities.***

11. Flachowsky G, Aulrich K, Böhme H, Halle I. 2007. Studies on feeds from genetically modified plants (GMP)—Contributions to nutritional and safety assessment; Table 3. *Anim. Feed Sci. Technol.* 133:2-30

12. König A, Cockburn A, Crevel RWR, Debruyne E, Grafstroem B, et al. 2004.





## **What will be covered?**

**1. Background on genes, genetics, genetic engineering**

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

**3. What is the regulatory structure for GE crops?**

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

**5. What are environmental issues with GE crops?**

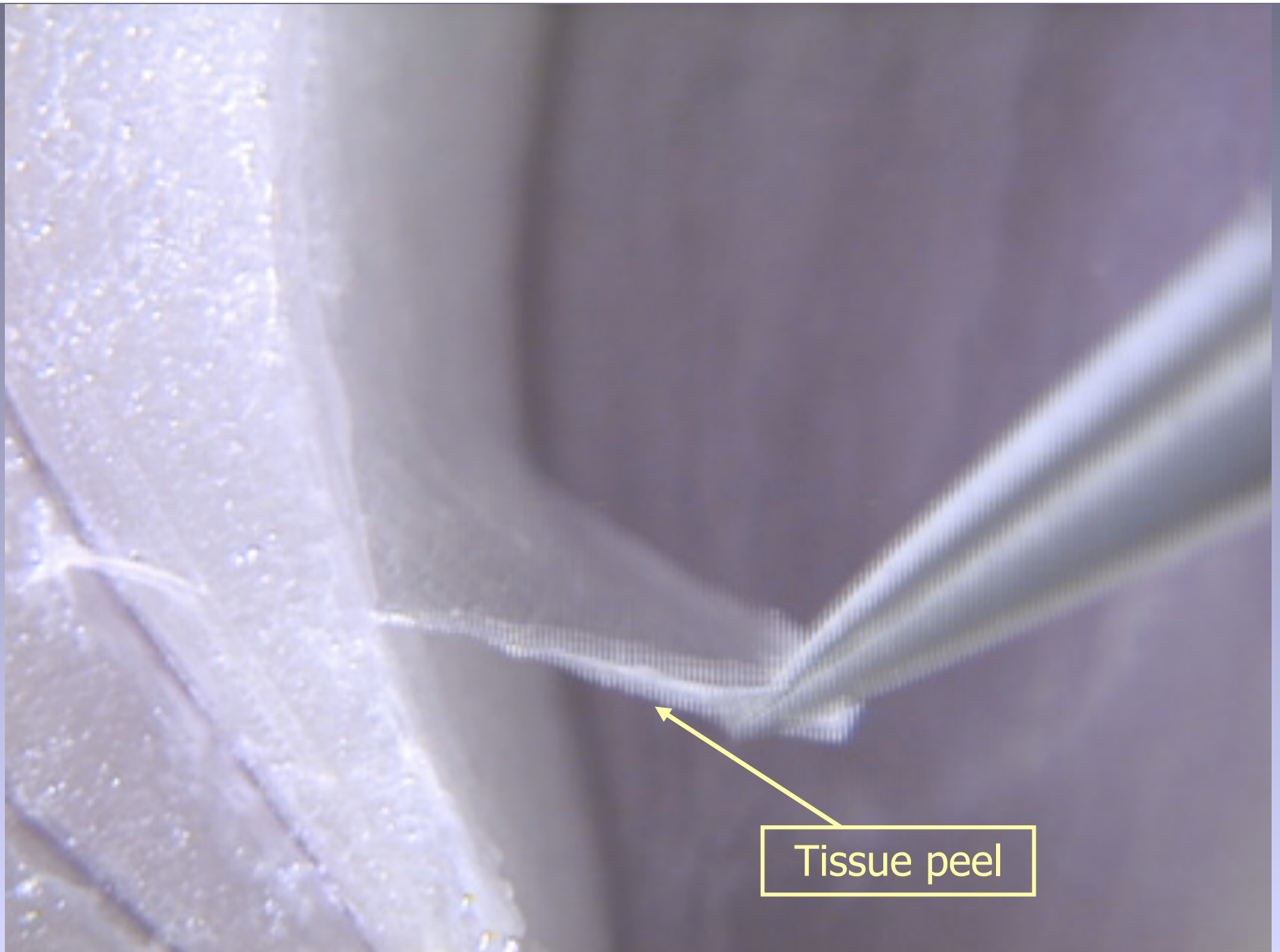
# *Tour d'Onion*



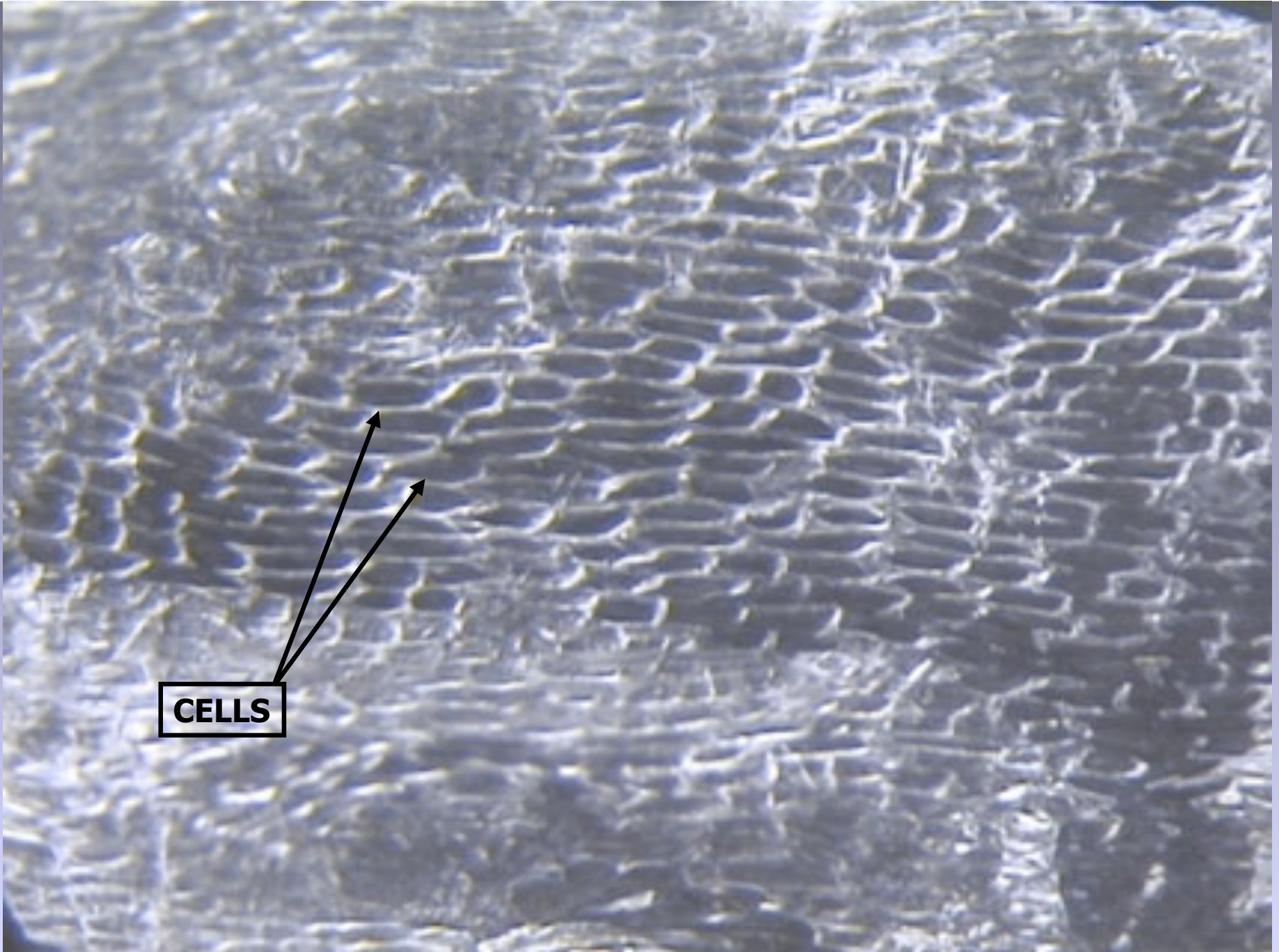
**Or what makes an onion, an onion?**



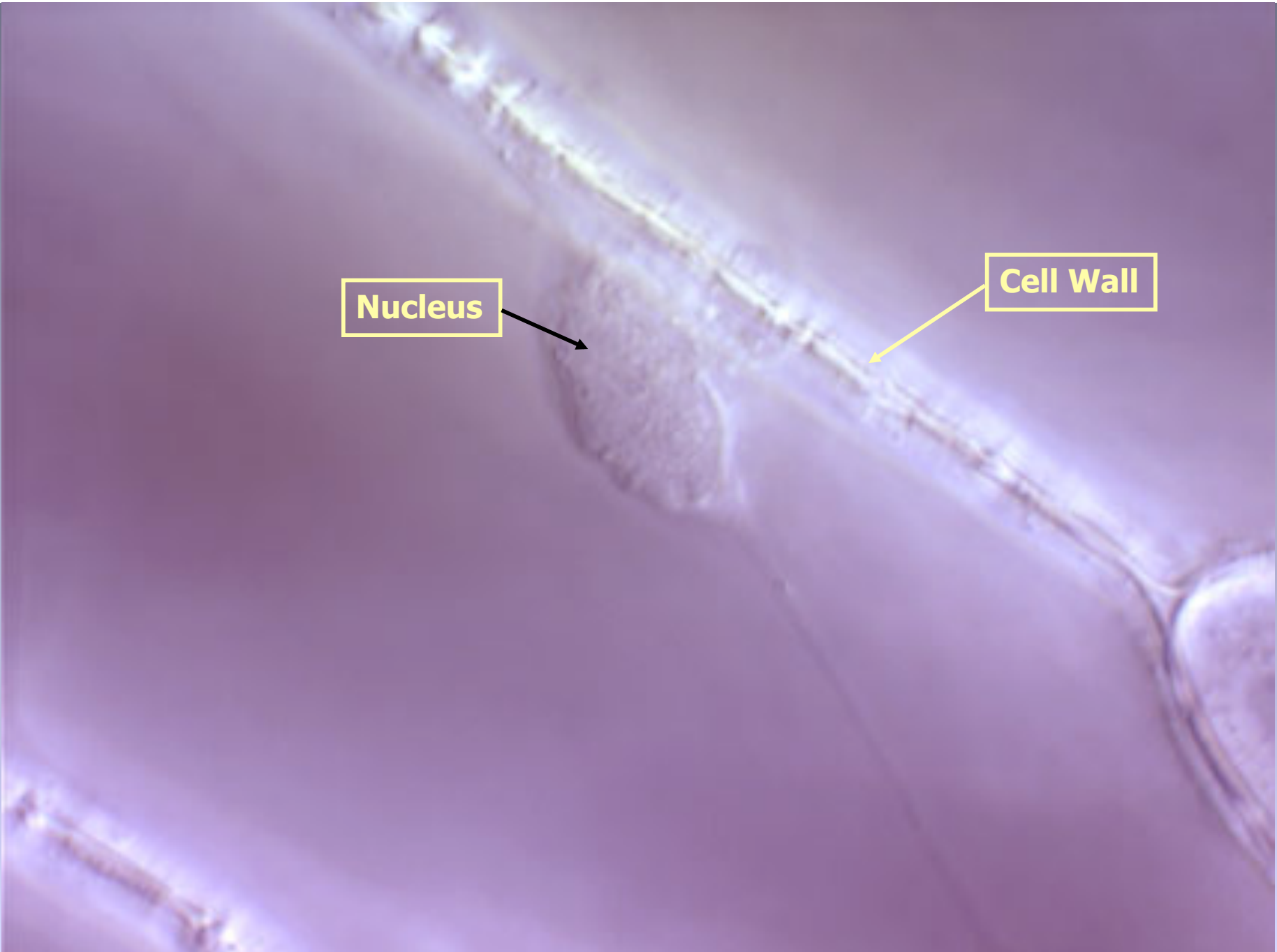




Tissue peel

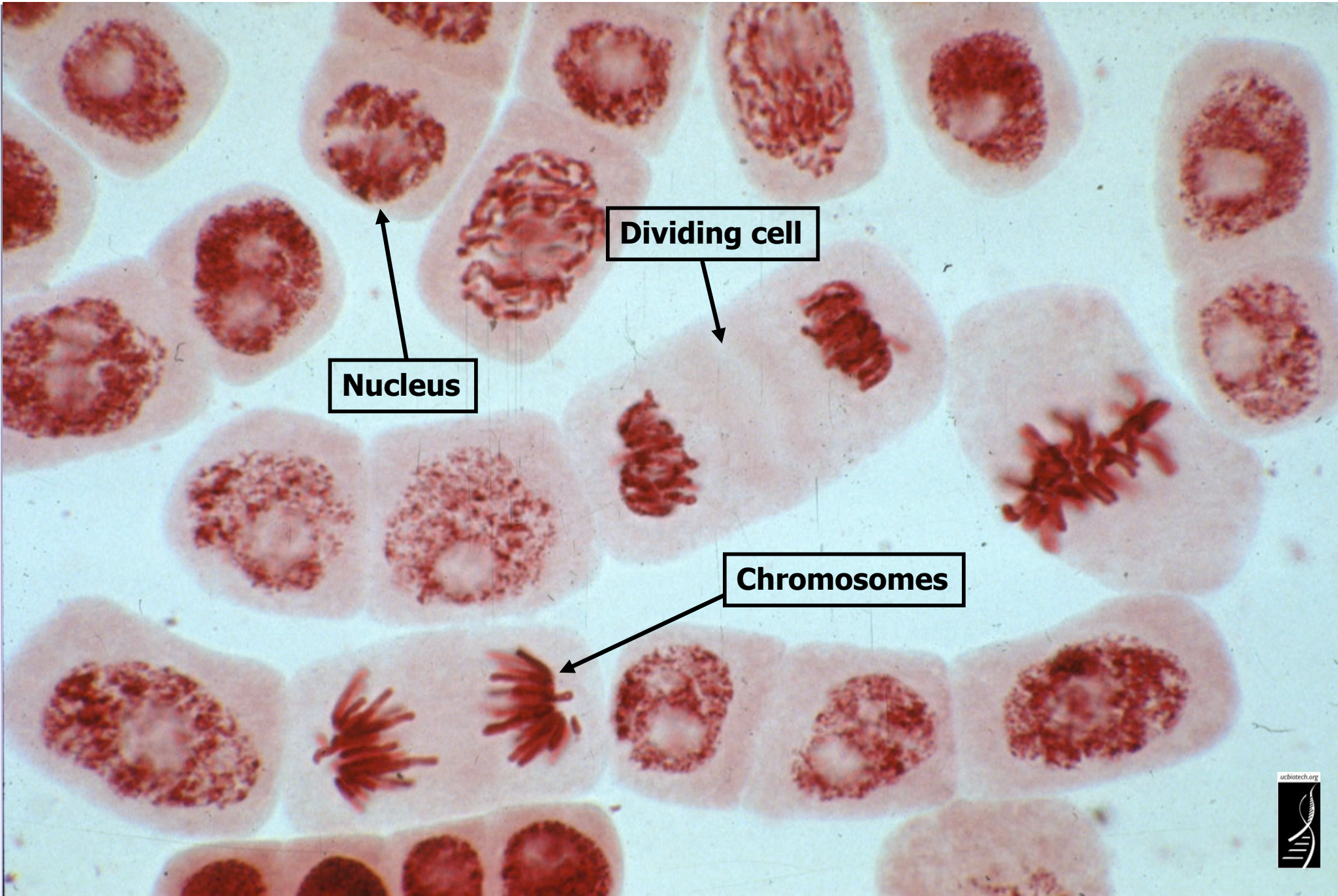


**CELLS**



**Nucleus**

**Cell Wall**



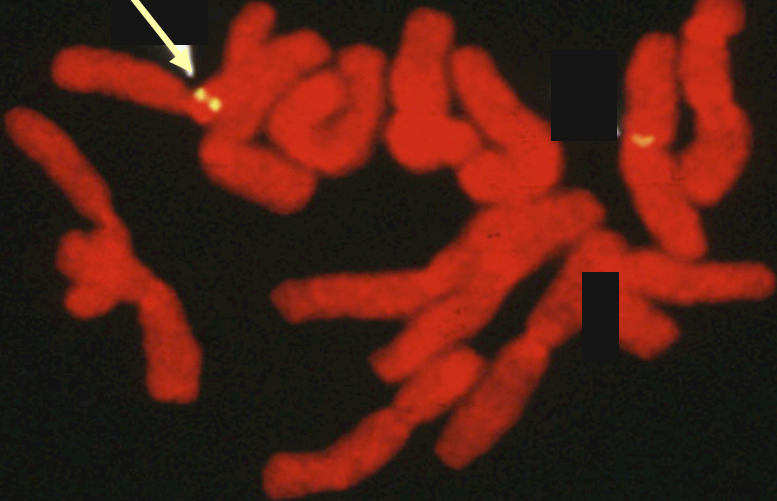
**Nucleus**

**Dividing cell**

**Chromosomes**

**Genes**

**Chromosome**



**How are the genes and chromosomes manipulated to create a new plant variety by classical breeding?**



*Triticum monococcum*



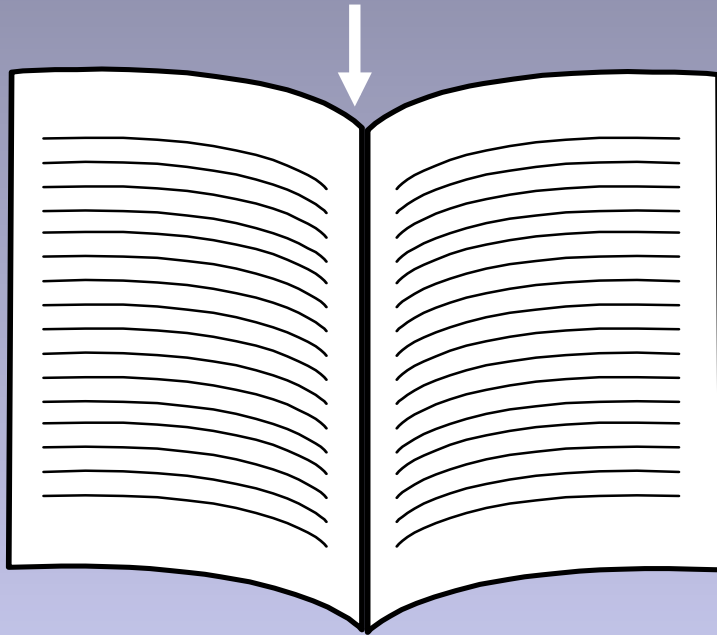
*Triticum aestivum*

**Ancient variety    Modern bread variety**

# Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

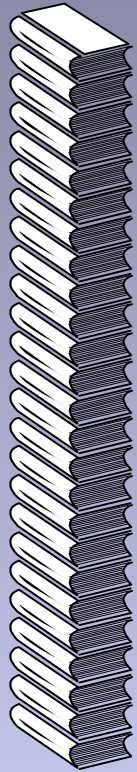


**1700 books**  
**1000 pages each**

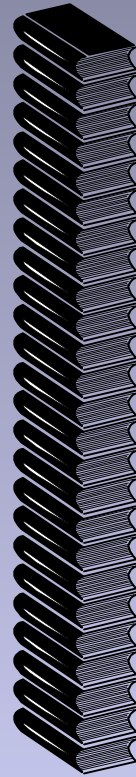


**1700 books**  
**(or 1.7 million pages)**

# Hybridization or cross breeding of wheat



**X**



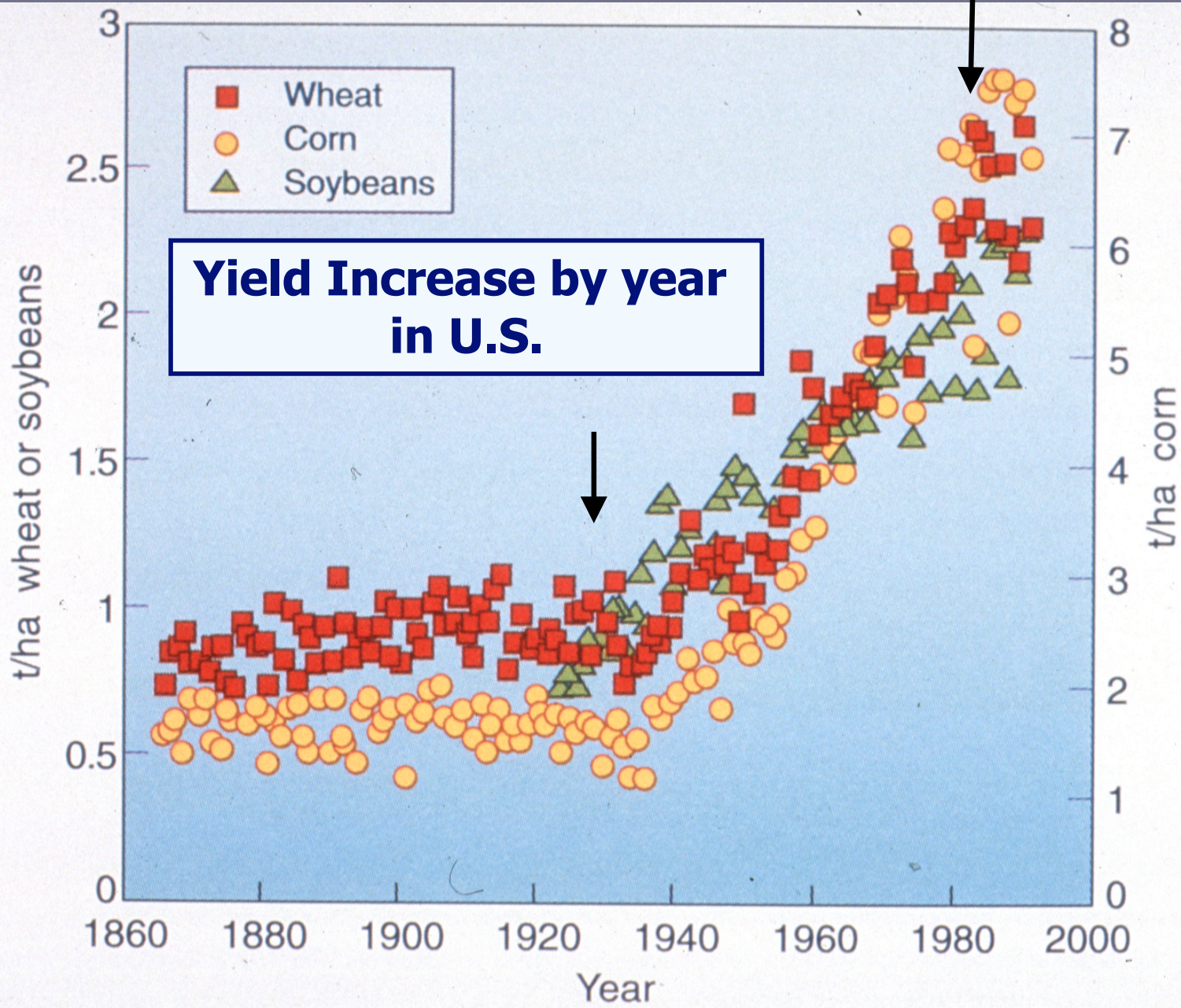
Random retention of information from each parent

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

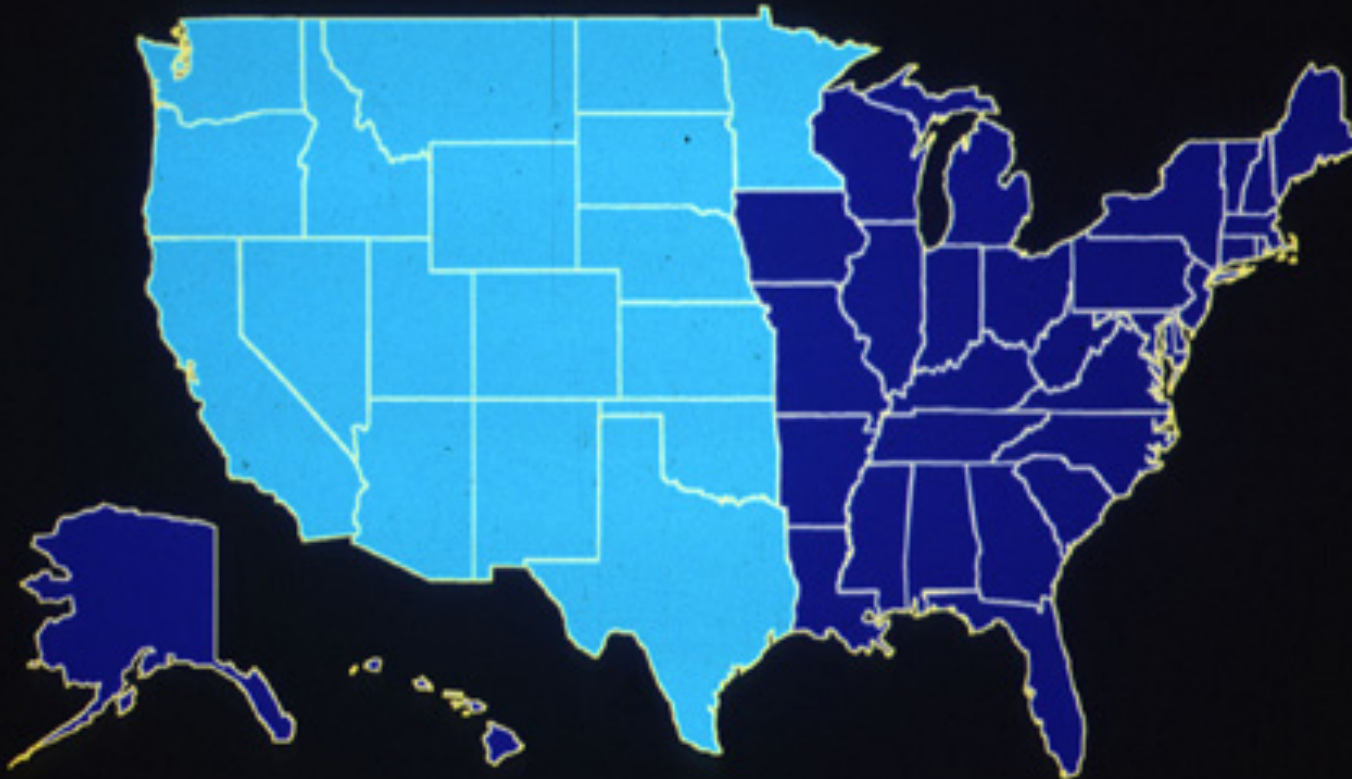
**1700 books  
(or 1.7 million pages)**

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



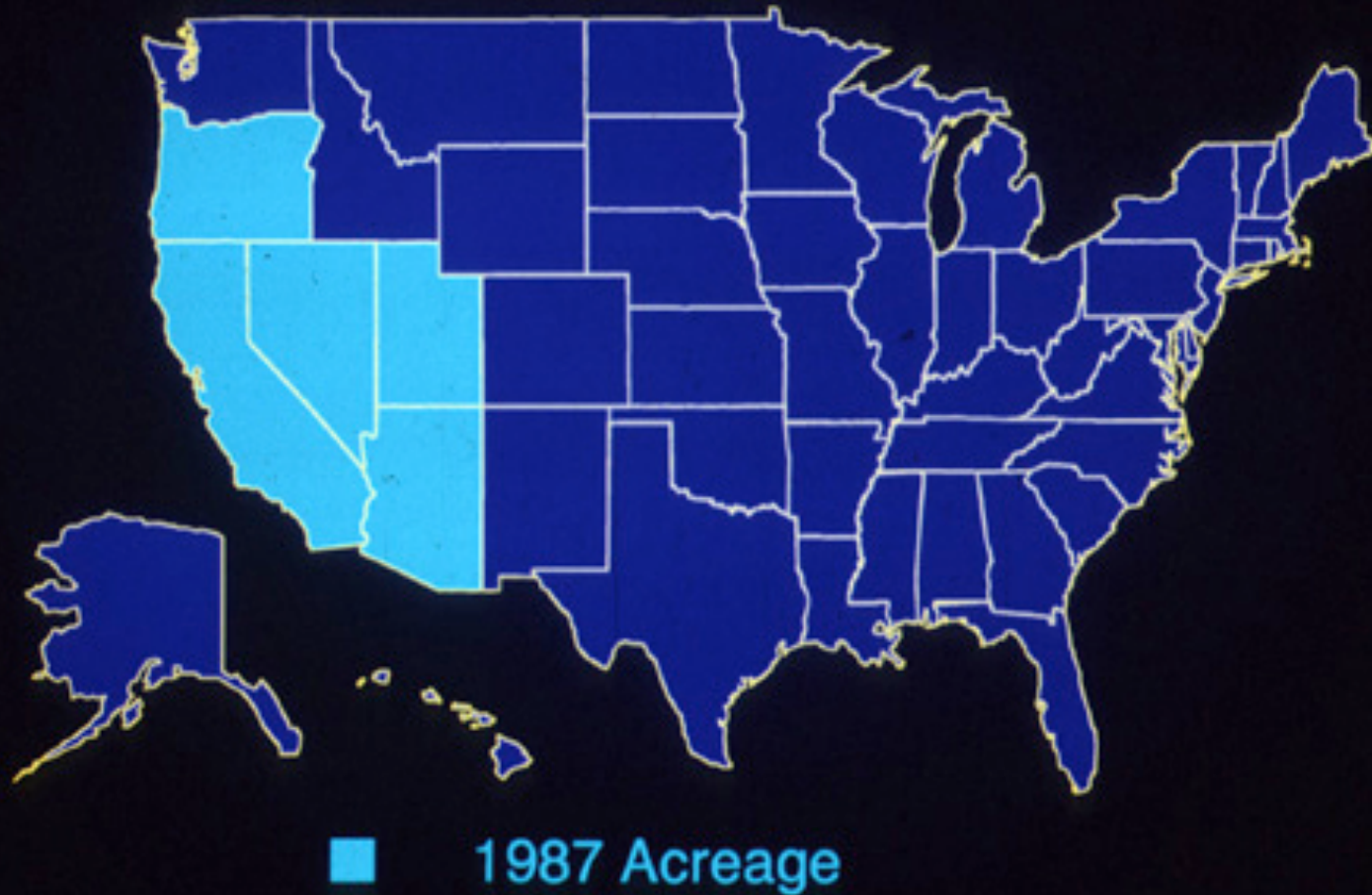


## U.S. Cultivated Land



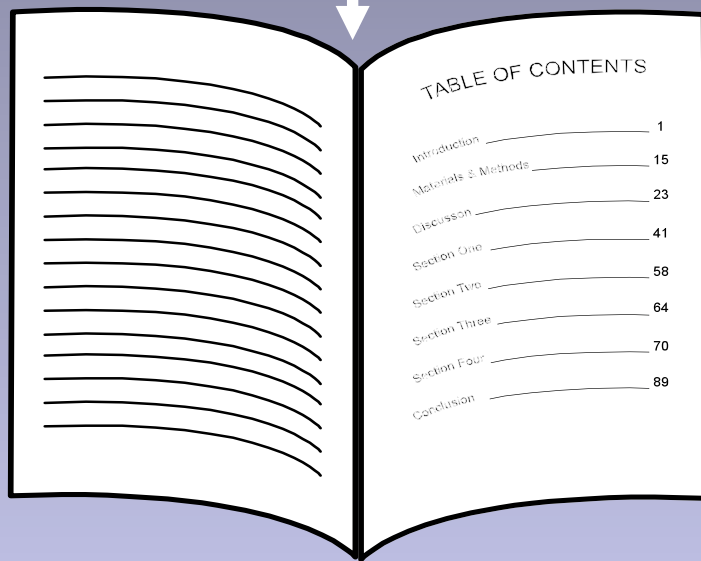
Acreage Needed at 1929 Production Levels

# U.S. Cultivated Land

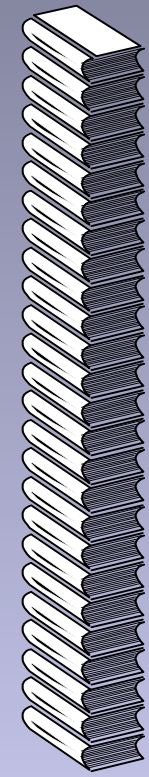


# Table of contents for genes in wheat

...CTGACCTAATGCCGTA...



**Genomics**



Used for  
Marker-  
Assisted  
Selection

1700 books  
(or 1.7 million pages)





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




**Marker-assisted selection used to protect potatoes against wireworms, but...**

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

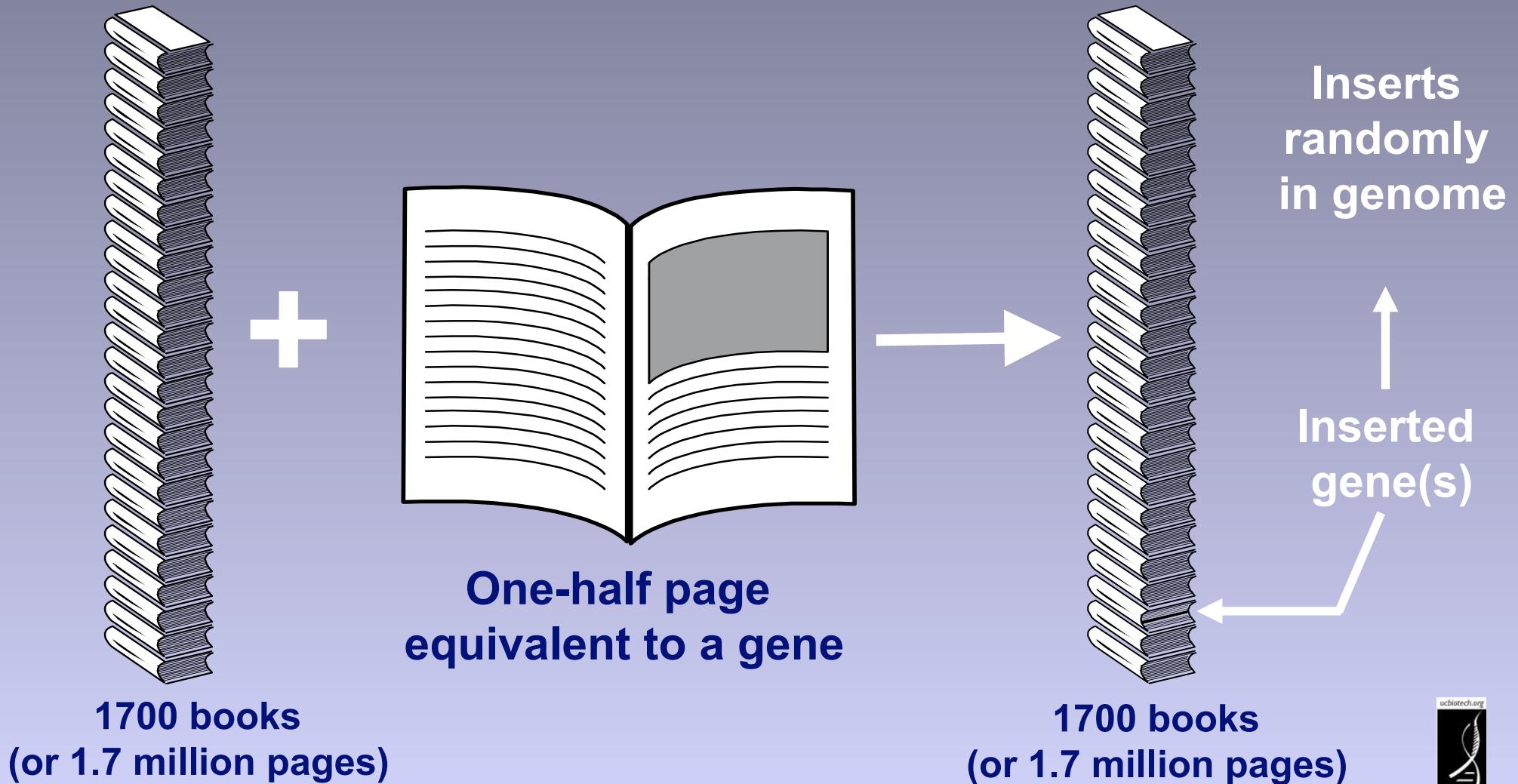
*SOURCE: "New Potatoes Withstand Destructive Wireworms", Agricultural Research Service, 9/20/11.  
<http://www.ars.usda.gov/is/AR/archive/sep11/wireworms0911.htm>*



A close-up photograph of a wheat field. The wheat stalks are green and appear to be in the early stages of grain development. The stalks are arranged in rows, and the background is filled with more wheat. A central text box with a yellow background and a dark blue border contains the text.

**But there are other ways to create  
new varieties using the modern  
tools of genetics**

# Genetic Engineering Methods





## ***Classical Breeding***

compared to

## ***Genetic Engineering***

Uses plant machinery in plant

Gene exchange is random  
involving whole genome

When/where gene expressed  
not controlled by breeder

Source of gene primarily within  
genera – not between kingdoms  
like plants & bacteria

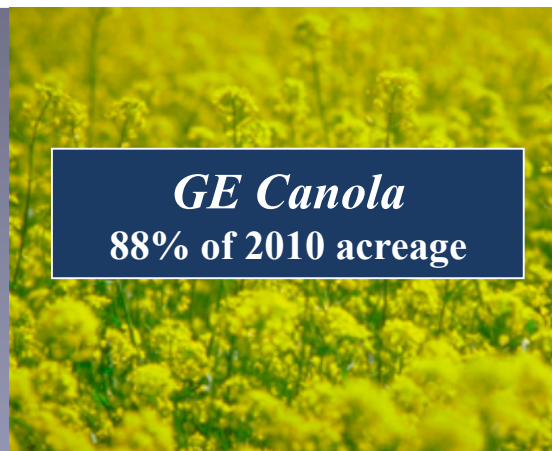
Uses plant machinery in laboratory

Gene exchange is specific  
involving single or few genes

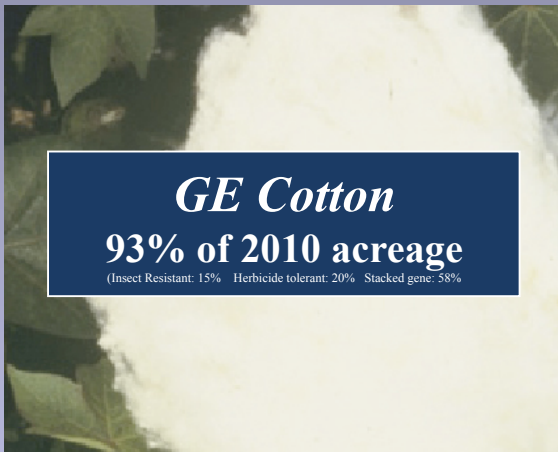
When/where gene expressed  
controlled precisely

Source of gene from any  
organism

**Number of  
different  
commercially  
available GE crops  
is limited**



***GE Canola***  
**88% of 2010 acreage**



***GE Cotton***  
**93% of 2010 acreage**  
(Insect Resistant: 15% Herbicide tolerant: 20% Stacked gene: 58%)



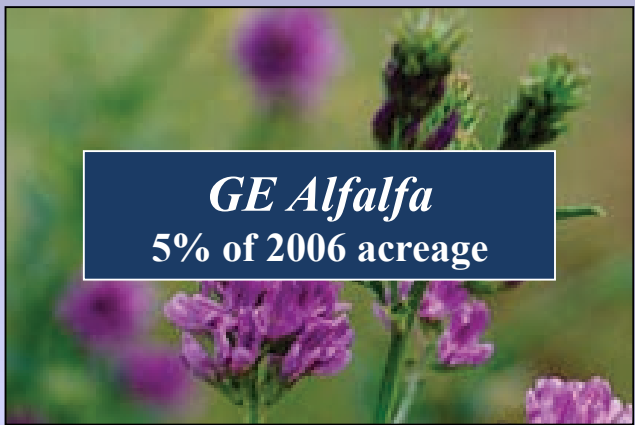
***GE Soybean***  
**93% of 2010 acreage**  
(Herbicide resistant: 93%)



***GE Corn***  
**86% of 2010 acreage**  
(Insect Resistant: 16% Herbicide resistant: 23% Stacked gene: 47%)  
1% of corn with Bt (ECB) + Bt (rootworm) + herbicide



***GE Sugarbeet***  
**96% of 2010 acreage**



***GE Alfalfa***  
**5% of 2006 acreage**

SOURCE: NCFAP; USDA ERS

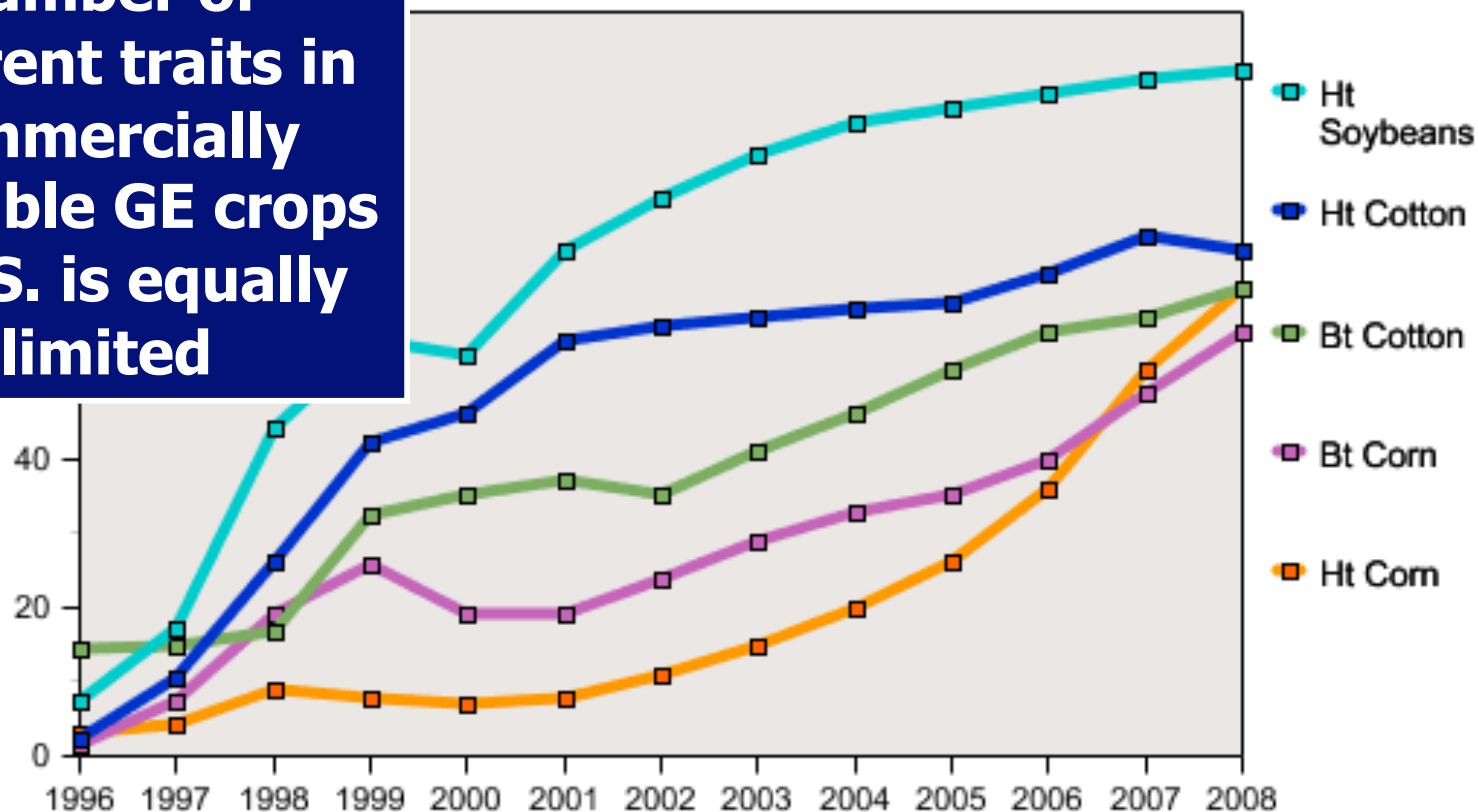




**Types of GE Crops Leads To Estimates that 75% of Processed Foods in U.S. Have GE Ingredients**

## Rapid growth in adoption of genetically engineered crops continues in the U.S.

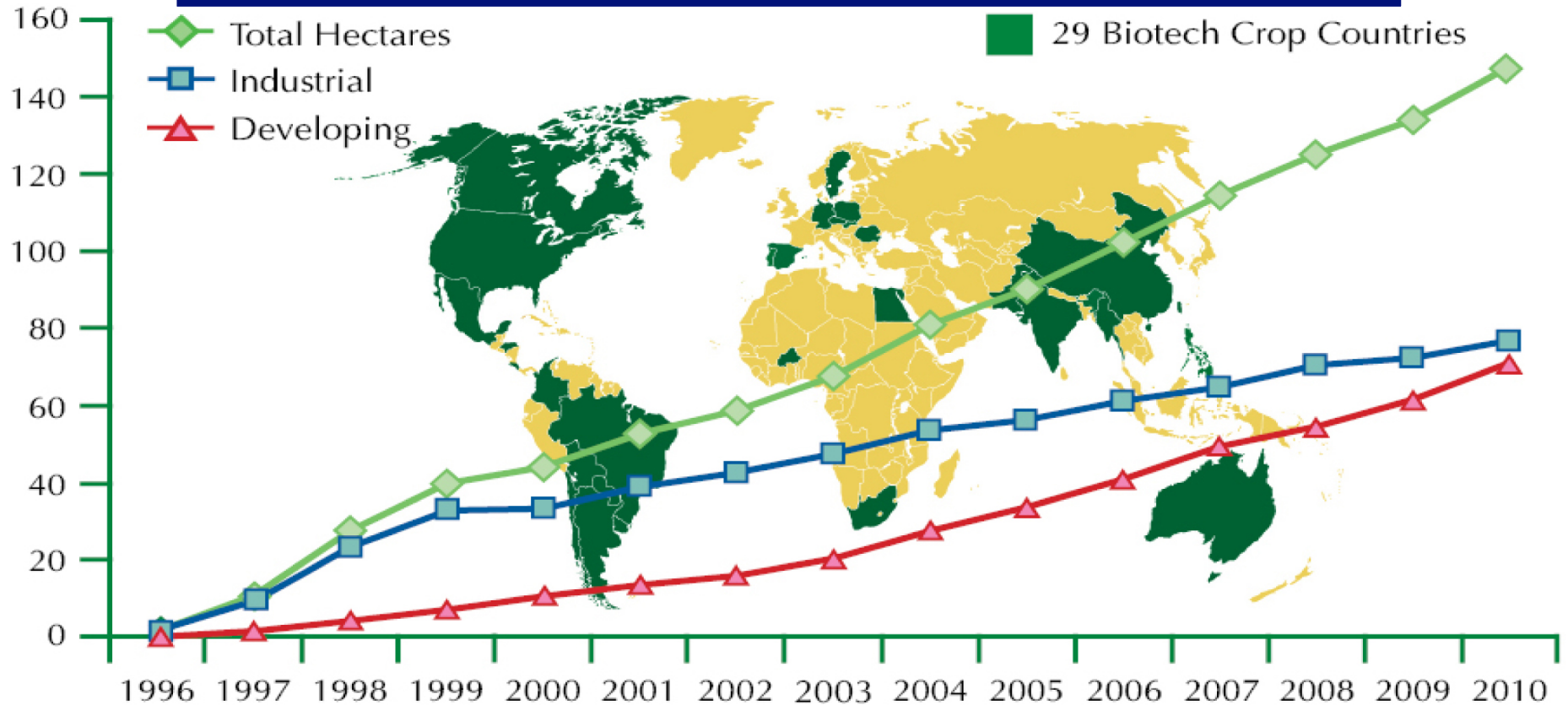
**Number of different traits in commercially available GE crops in U.S. is equally limited**



Data for each crop category include varieties with both HT and Bt (stacked) traits.

Source: 1996-1999 data are from Fernandez-Cornejo and McBride (2002). Data for 2000-08 are available in tables 1-3.

## Despite limited crop and trait types, worldwide acreage is increasing



**Total worldwide area cultivated = Areas of Texas + California + Colorado + South Carolina**

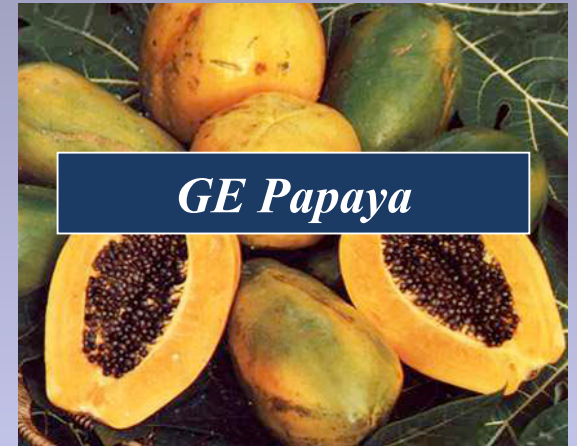
**There are a few whole,  
genetically engineered  
foods in the U.S market**



*GE Sweet Corn*

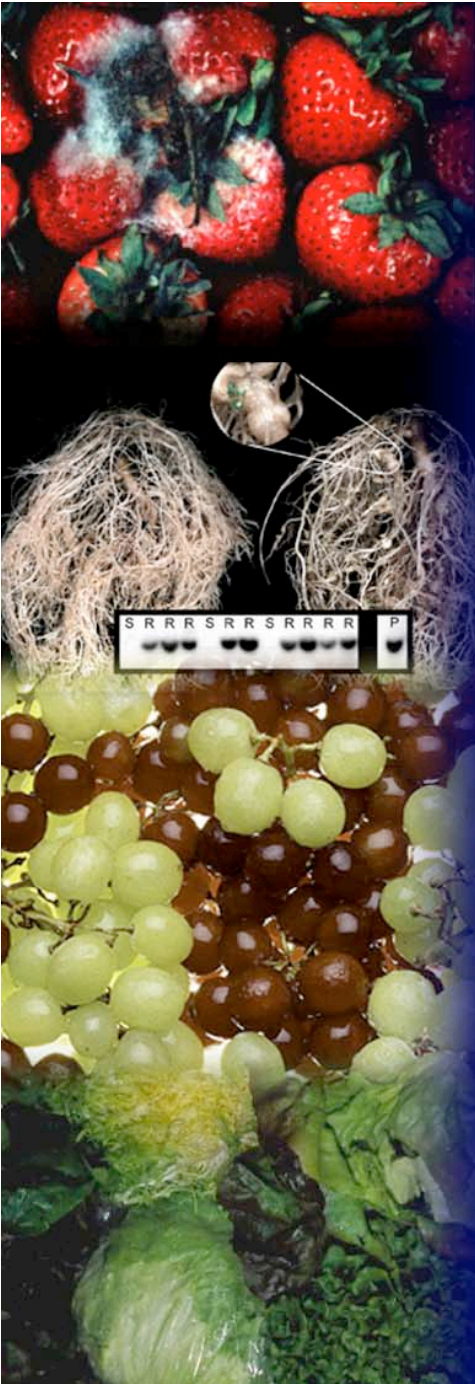


*GE Squash*



*GE Papaya*

# ***WHAT'S IN THE PIPELINE?***






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

SOURCE: <http://www.democratandchronicle.com/apps/pbcs.dll/article?AID=/20080806/BUSINESS/808060336/1001>







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

SOURCE: *Western Farm Press*, volume 26, number 16





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

SOURCE: [http://archives.foodsafety.ksu.edu/agnet/2007/4-2007/agnet\\_april\\_10.htm#story0](http://archives.foodsafety.ksu.edu/agnet/2007/4-2007/agnet_april_10.htm#story0)





*Yields in rice and maize increase  
under water-limiting conditions*

*SOURCE: Castiglioni, P. et al. 2008. Bacterial RNA Chaperones Confer Abiotic Stress Tolerance in Plants and Improved Grain Yield in Maize under Water-Limited Conditions. Plant Physiology 147: 446-455.*



# *Salt-tolerant Tomatoes*



*Engineered*

*Control*

SOURCE: Zeraim Gedera L.T.D., Israel



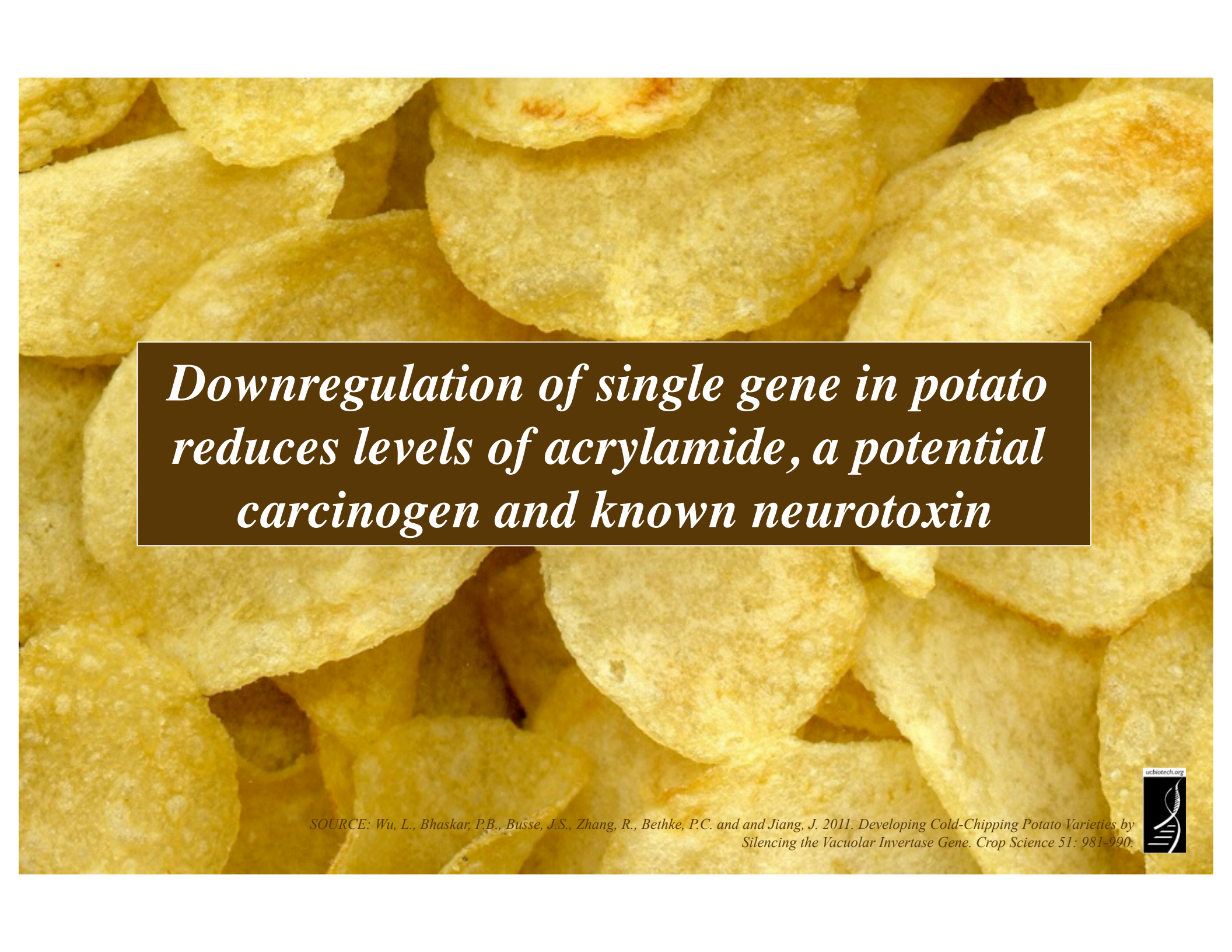
*“In a globalized economy, the control of fruit ripening is of strategic importance because excessive softening limits shelf life.”*

***Engineered tomatoes have ~30  
day extension of shelf life***



SOURCE: Meli, V.S., Ghosh, S., Prabha, T.N., Chakraborty, N., Chakraborty, S., and Datta, A. 2010. Enhancement of fruit shelf life by suppressing N-glycan processing enzymes. *Proceedings of the National Academy of Sciences USA*, doi/10.1073/pnas.0909329107.





*Downregulation of single gene in potato reduces levels of acrylamide, a potential carcinogen and known neurotoxin*

SOURCE: Wu, L., Bhaskar, P.B., Busse, J.S., Zhang, R., Bethke, P.C. and Jiang, J. 2011. Developing Cold-Chipping Potato Varieties by Silencing the Vacuolar Invertase Gene. *Crop Science* 51: 981-990.

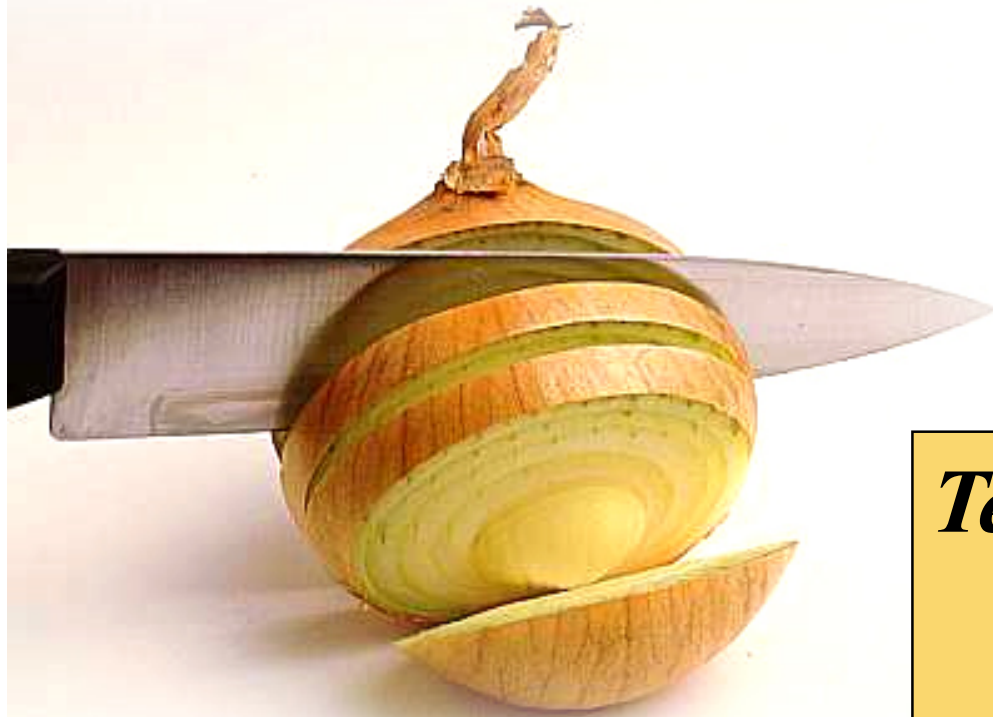




*Non-browning GE apple may not get to market; it is opposed by U.S. Apple Association due to possible negative impacts on export market*

SOURCE: "Stop Genetically Engineered Apples!", Organic Consumers Association, 3/24/11.  
<http://www.organicconsumers.org/bytes/ob269.htm#SEC3>





***Tear-free onion developed  
by turning off tear-  
inducing enzyme***

SOURCE: "Scientists create 'no tears' onions", Herald and Weekly Times, 2/1/08  
[http://www.checkbiotech.org/green\\_News\\_Genetics.aspx?Name=genetics&infoId=16834](http://www.checkbiotech.org/green_News_Genetics.aspx?Name=genetics&infoId=16834)







***Engineered corn:  
169-fold increase in Vitamin A  
precursor  
6-fold increase in Vitamin C  
2-fold increase in folate***



*SOURCE: Naqvi et al. 2009. Transgenic multivitamin corn through biofortification of endosperm with three vitamins representing three distinct metabolic pathways. Proceedings of the National Academy of Sciences USA, doi: 10.1073/pnas.0901412106.*





# *Engineered Pea Seeds Protect Chickens against Parasitic Coccidiosis*

*SOURCE: "Engineered pea seeds protect against parasites", BioMed Central, 9/10/09, [http://www.eurekalert.org/pub\\_releases/2009-09/bc-eps090909.php](http://www.eurekalert.org/pub_releases/2009-09/bc-eps090909.php)  
Zimmermann, J., Saalbach, I., Jahn, D., Giersberg, M., Haehnel, S., Wedel, J., Macek, J., Zoufal, K., Glunder, G., Falkenburg, D. and Kiprijanov, S.M. 2009. Antibody expressing pea seeds as fodder for prevention of gastrointestinal parasitic infections in chickens. BMC Biotechnology, in press.*





*Japanese scientists create blue rose  
with blue pigments from pansies*

*SOURCE: <http://www.japantimes.co.jp/cgi-bin/getarticle.pl5?nn20040701a2.htm>*



*Delayed senescence  
Moonshadow™ carnation*



[http://www.florigene.com/products/products.php?product\\_name=moonshadow](http://www.florigene.com/products/products.php?product_name=moonshadow)



*Slow-Mow grass addresses watering,  
maintenance and weed problems*



*SOURCE: "Engineering a mow-less lawn", New York Times, 4/22/06  
[http://www.nytimes.com/2006/04/22/business/22offline.html?\\_r=1&oref=slogin](http://www.nytimes.com/2006/04/22/business/22offline.html?_r=1&oref=slogin)*



***What is the U.S. regulatory process that governs these engineered plants?***

# 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?

# APHIS Determines Nonregulated Status – 75 granted

**Once nonregulated, organism  
no longer requires APHIS review  
for movement or release in U.S.**

**Alfalfa – HT –removed/  
reinstated**

- ✓ **Cotton - HT, IR**
- ✓ **Corn - HT, IR, AP**
- ✓ **Soybean - HT, PQ**
- ❖ **Potato - IR, VR**
- ❖ **Tomato - PQ**
- Squash - VR**
- ✓ **Canola – HT**

- ✓ **Large-scale production**
- ❖ **Not on market**

**Papaya - VR**

- ❖ **Rice - HT**
- Rapeseed - HT, AP, PQ**
- Sugar beet - HT**
- ❖ **Flax - HT**
- Chicorium - AP**
- Tobacco - PQ**

([http://www.aphis.usda.gov/brs/not\\_reg.html](http://www.aphis.usda.gov/brs/not_reg.html))





Where to  
get more  
information  
on the  
issues?

ucbiotech.org - Science-Based Information and Resources on Agriculture, Food and Technology

ucbiotech.org - Science-Based I...

ucbiotech.org/index.html

Google



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

ABOUT US | IN THE NEWS | **BIOTECHNOLOGY INFORMATION** | RESOURCES | LINKS | GLOSSARY | SEARCH

Annual Review Articles | Issues & Responses

Select Language

### know GMOS

This website provides educational resources focused broadly on issues related to agriculture, crops, animals, foods and the technologies used to improve them. Science-based information related to these issues is available, as well as educational tools and information, which can be used to promote informed participation in discussions about these topics.

### FEATURED PRESENTATION



#### How Much Did You Pay for Your Lunch Today?

Center for Practical and Professional Ethics  
California State University, Sacramento  
February 7, 2012

#### BIOTECHNOLOGY INFORMATION



**ANNUAL REVIEWS**

Review articles:  
Focused on food, environmental and socioeconomic issues of GE crops and foods.  
[Part 1](#) | [Part 2](#)

#### RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS

**DNA for Dinner 4-H curriculum:**  
For grades 5-8, covers topics from plant diversity to genetic engineering. Each of the five lessons has 3 to 5 activities.



**DNA FOR DINNER?**



**Who's in YOUR family?**

**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

#### HELPFUL SITES

**Academics Review**  
**Academics Review website**  
Testing popular claims against peer-reviewed science.

**Biofortified website**  
Provides factual information to foster discussion about agriculture, especially plant genetics and genetic engineering.

**Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis**  
Provides education on use of animal genomics & biotechnology in livestock production.



