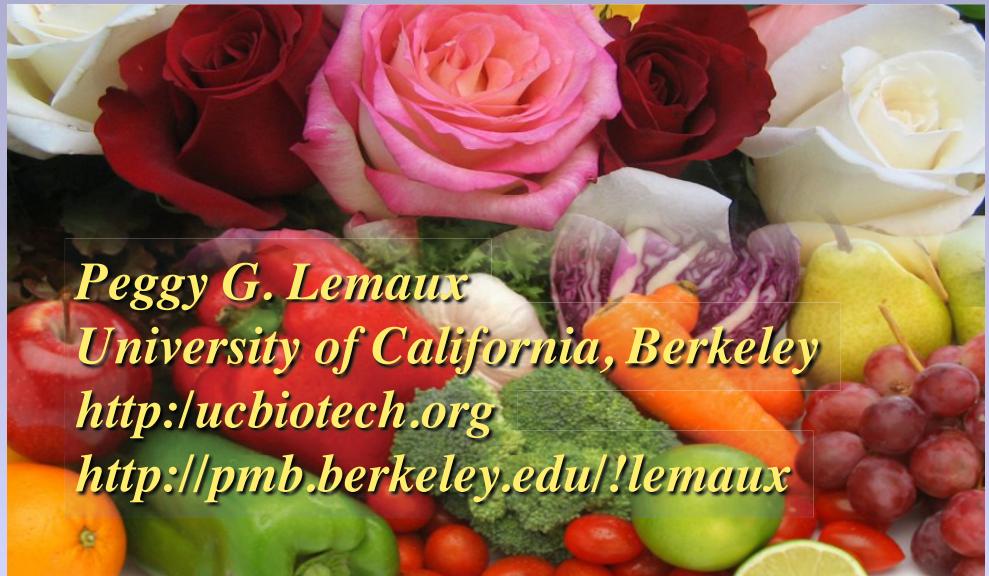


The Science of GMOs and Related Issues



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

**Want to ask
questions?
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Annual Review Articles | Issues & Responses Select Language ▾


knowGMOS
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

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
[biofortified.org](#)
Provides factual information to foster discussion about agriculture, especially plant genetics and genetic engineering.


Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis
[animalgenomics.ucdavis.edu](#)
Provides education on use of animal genomics & biotechnology in livestock production.





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

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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.

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](#)





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

consume large amounts of food to obtain sufficient quantities of the GE ingredient. Compositional analyses and toxicity testing of individual components are actually more sensitive and accurate in assessing safety (15). Therefore, in addition to whole foods, safety tests are conducted on individual products of introduced genes, both target and selectable marker genes, on the basis of the food additive provision (Section 409) of the 1992

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

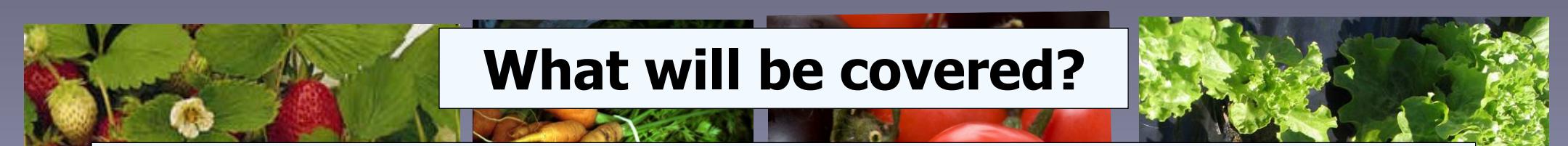
References:

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, Padgette 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. Konig A, Cockburn A, Crevel RWR, Debruyne F, Grafstroem R, 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?



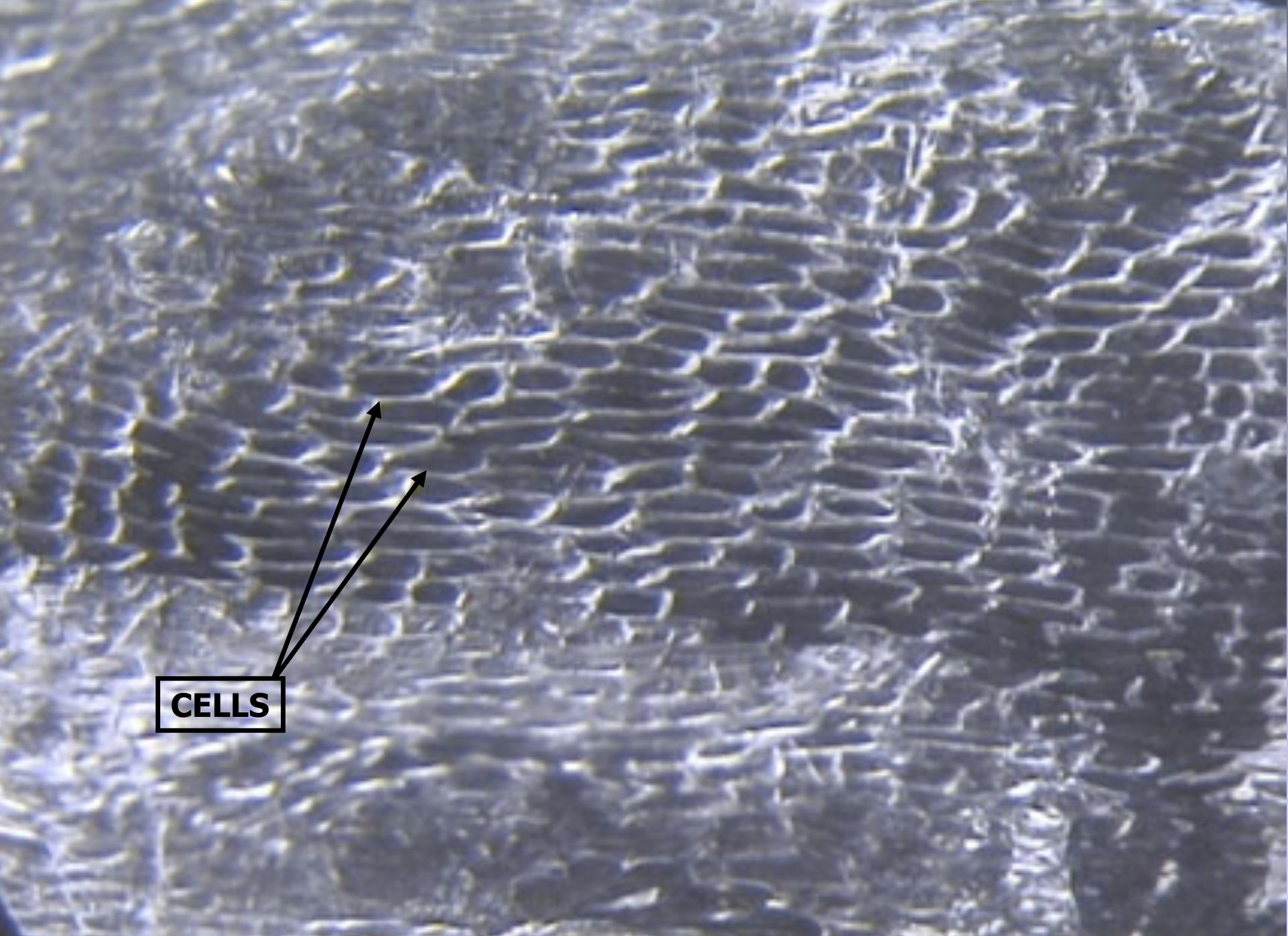
Tour d'Onion



Or what makes an onion, an onion?

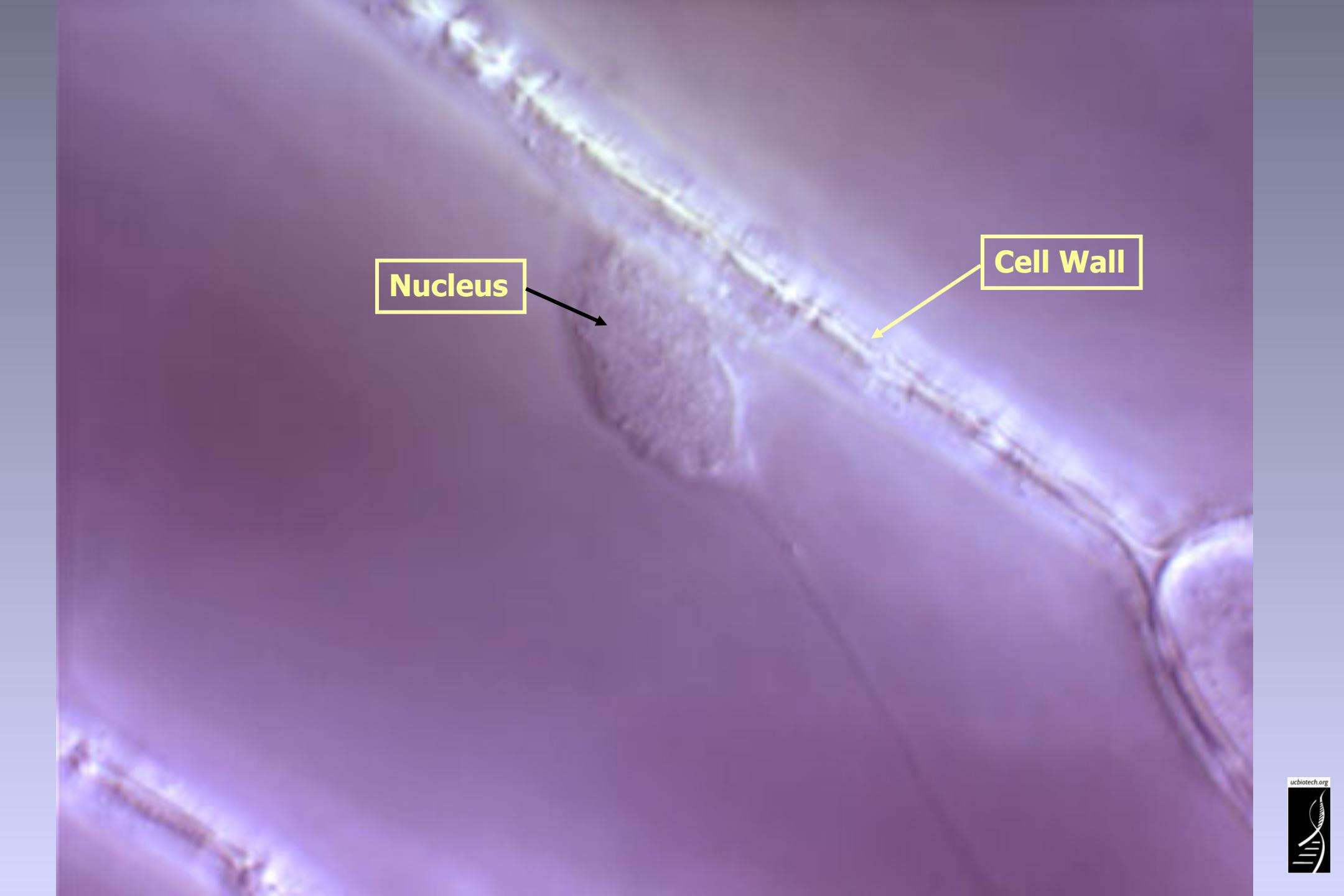


Tissue peel



CELLS

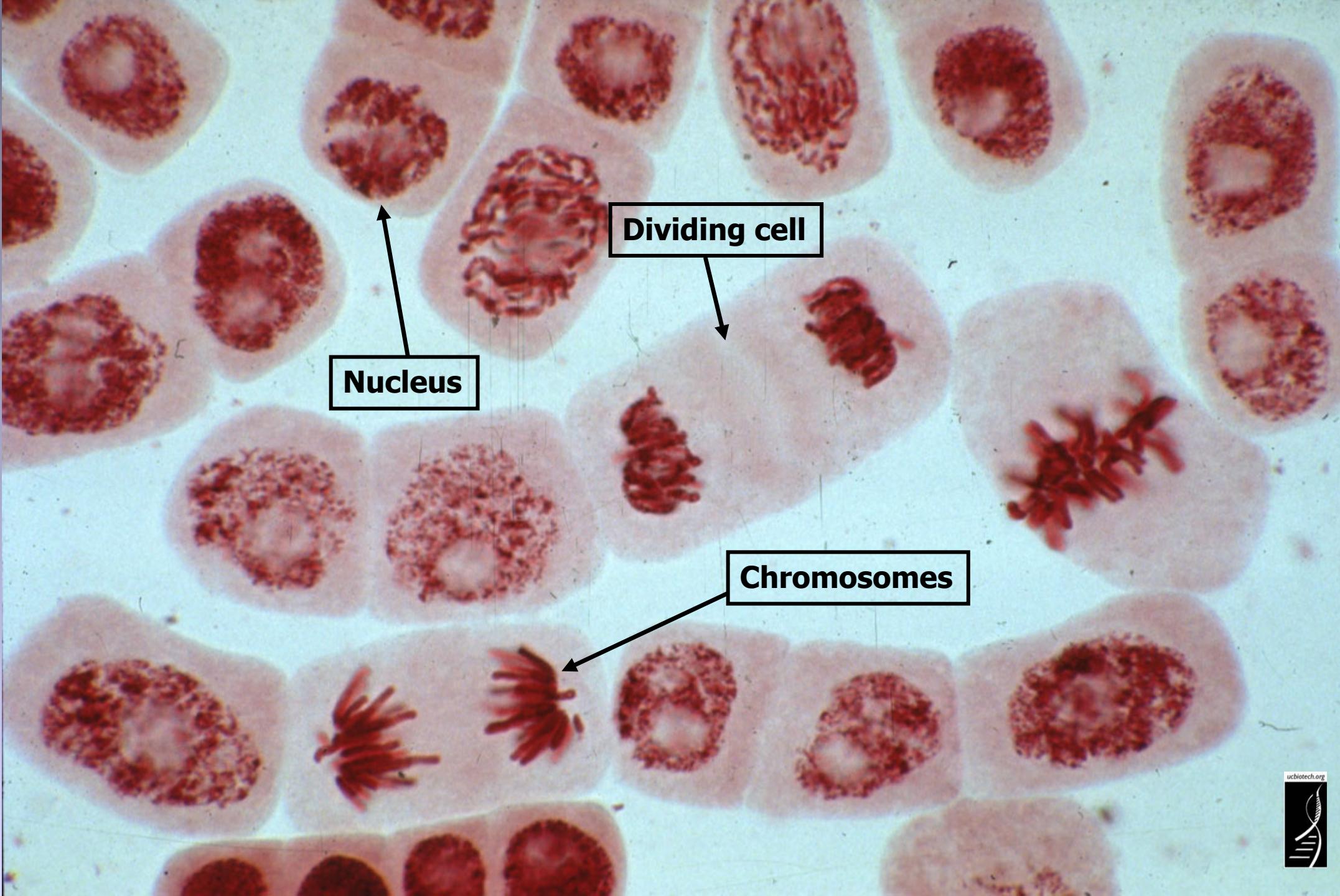
A high-magnification light micrograph showing a dense arrangement of cells. The cells are roughly rectangular and organized into a regular, overlapping pattern. Some cells appear slightly larger or more prominent than others. Two black arrows point from a white rectangular box containing the word "CELLS" towards the center of the image, indicating the location of individual cells within the tissue structure.



A micrograph showing a single cell with a prominent nucleus and a visible cell wall. The cell is stained with a purple hue. A black arrow points from a yellow-bordered box labeled "Nucleus" to the central, darker purple region of the cell. A yellow arrow points from another yellow-bordered box labeled "Cell Wall" to the thin, light-colored boundary of the cell.

Nucleus

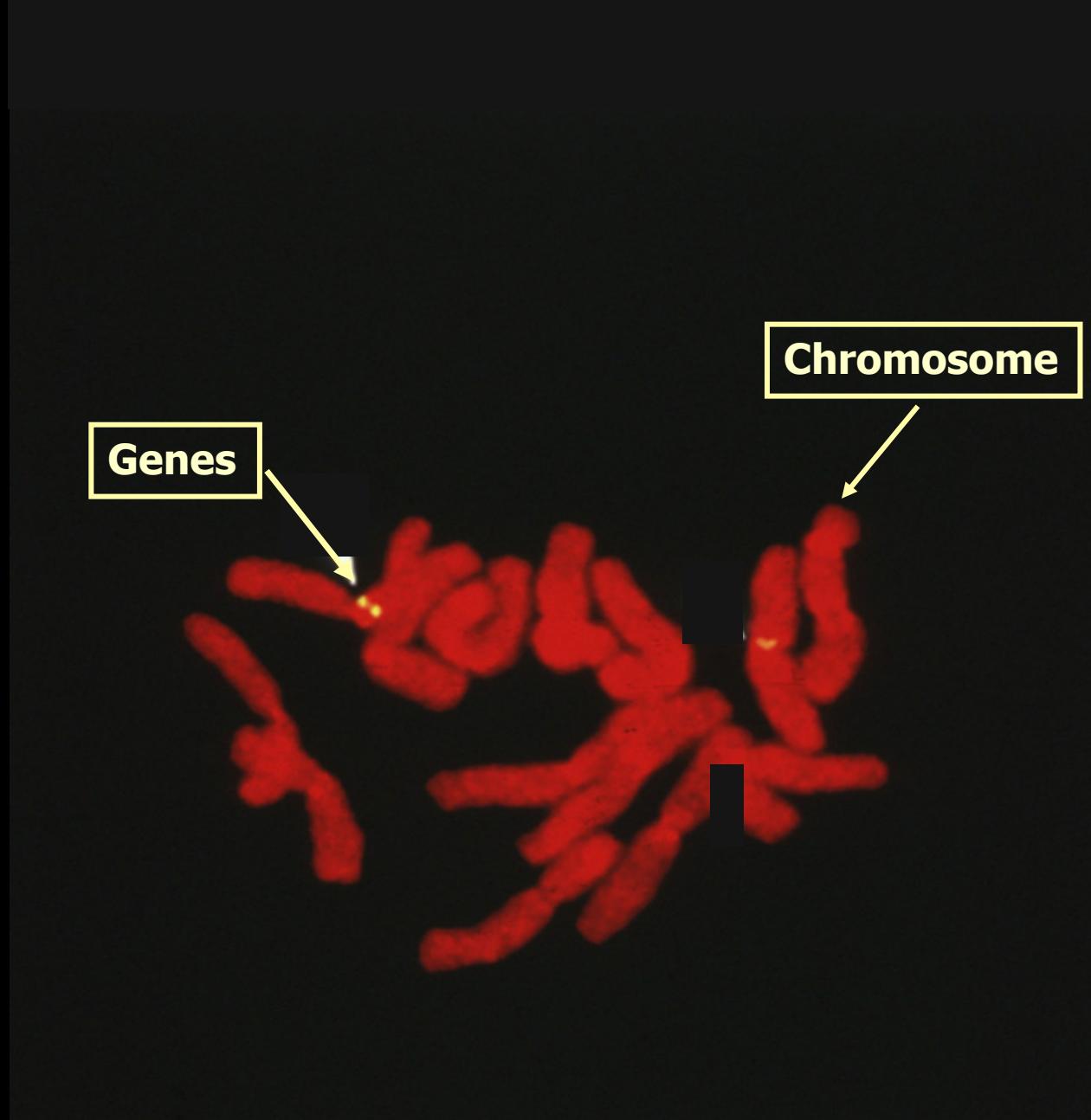
Cell Wall



Nucleus

Dividing cell

Chromosomes



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



Triticum monococcum

Ancient variety



Triticum aestivum

Modern bread variety

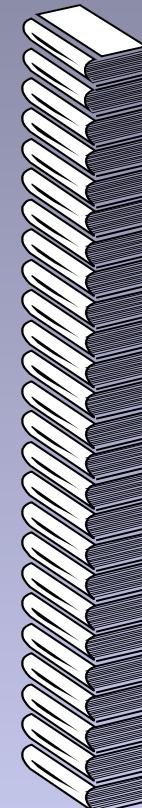
Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...



1700 books
1000 pages each



1700 books
(or 1.7 million pages)

Hybridization or cross breeding of wheat

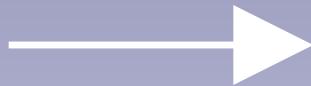


X

1700 books
(or 1.7 million pages)

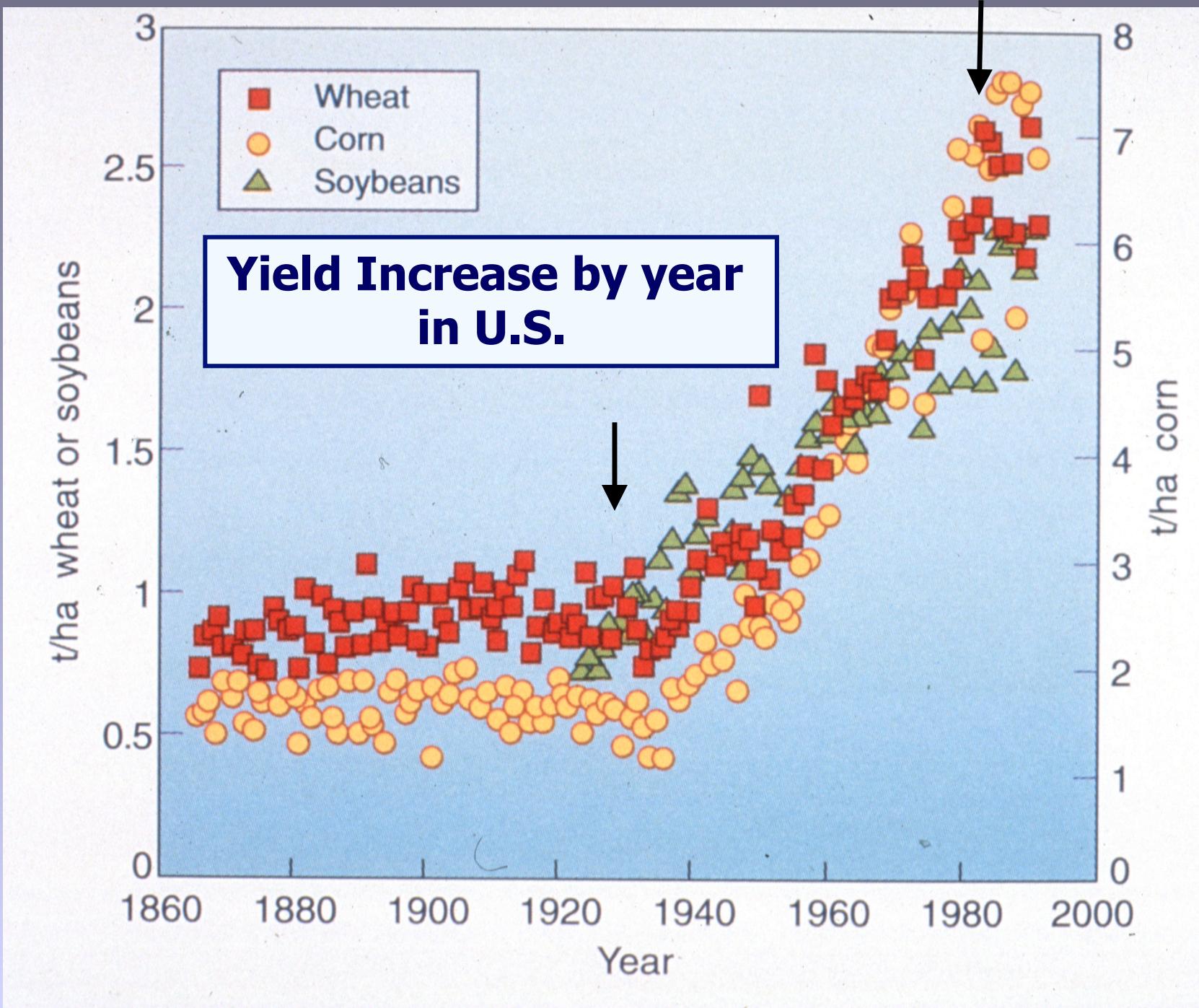


1700 books
(or 1.7 million pages)

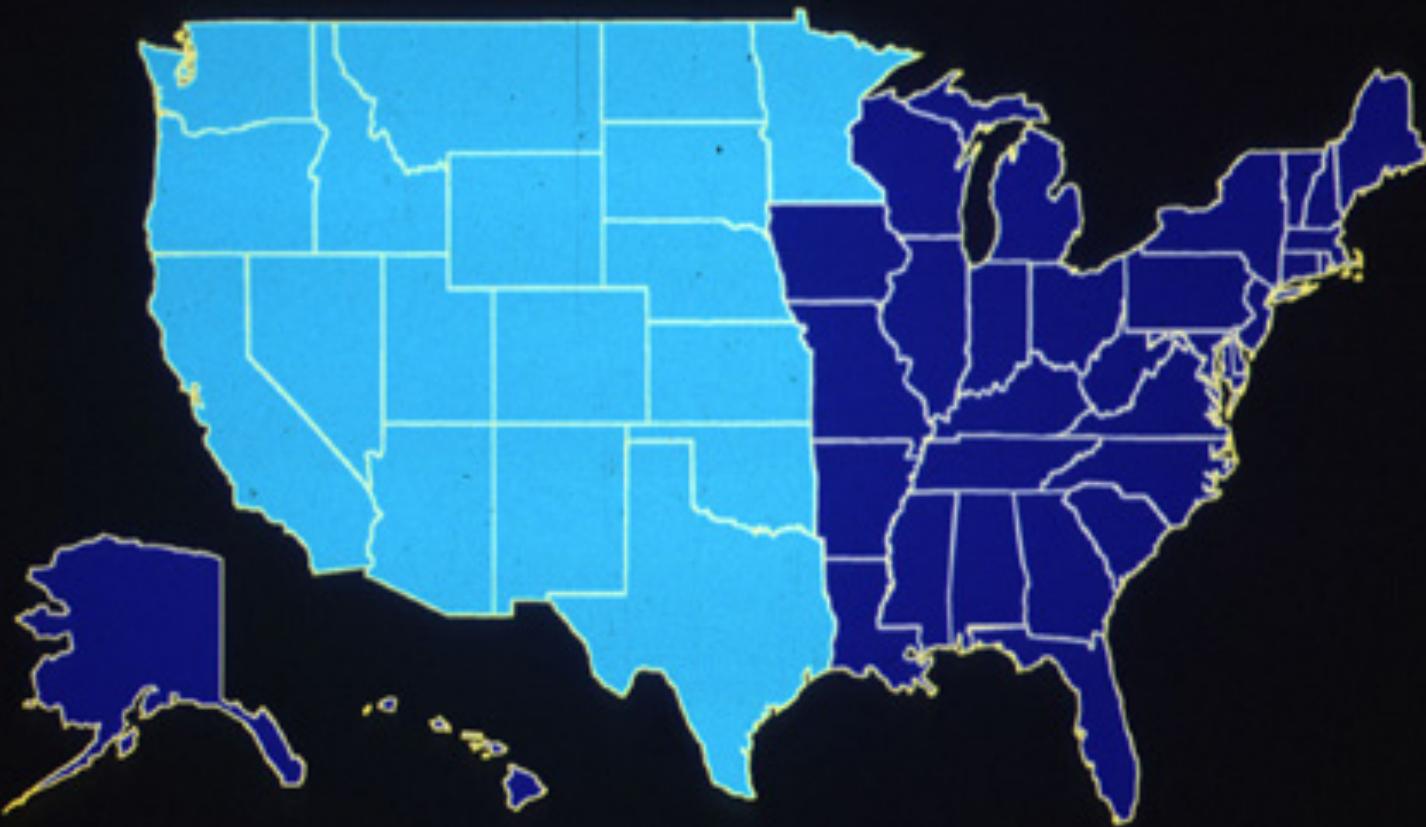


1700 books
(or 1.7 million pages)

Random
retention of
information
from each
parent



U.S. Cultivated Land



Acreage Needed at 1929 Production Levels



U.S. Cultivated Land

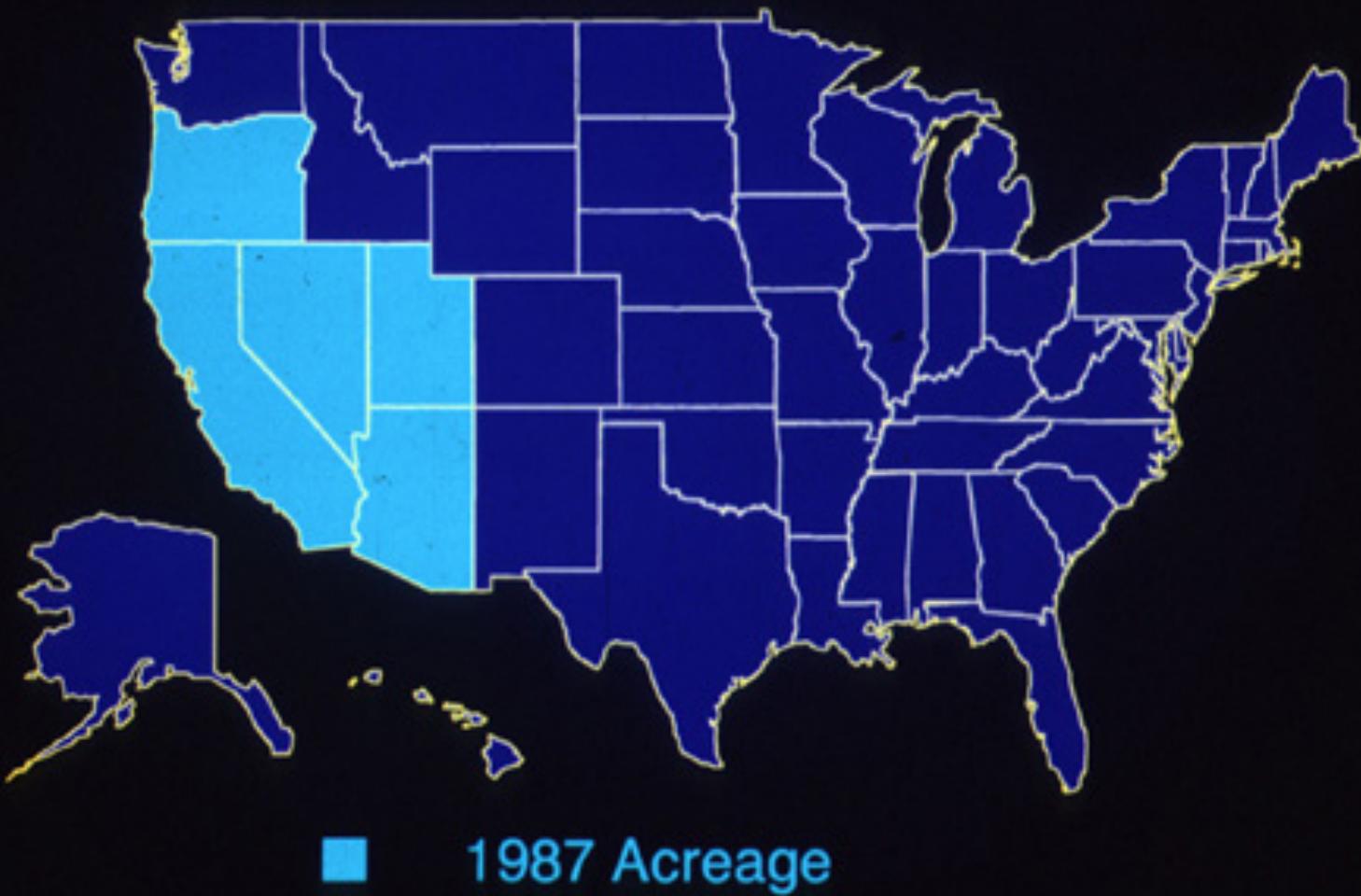
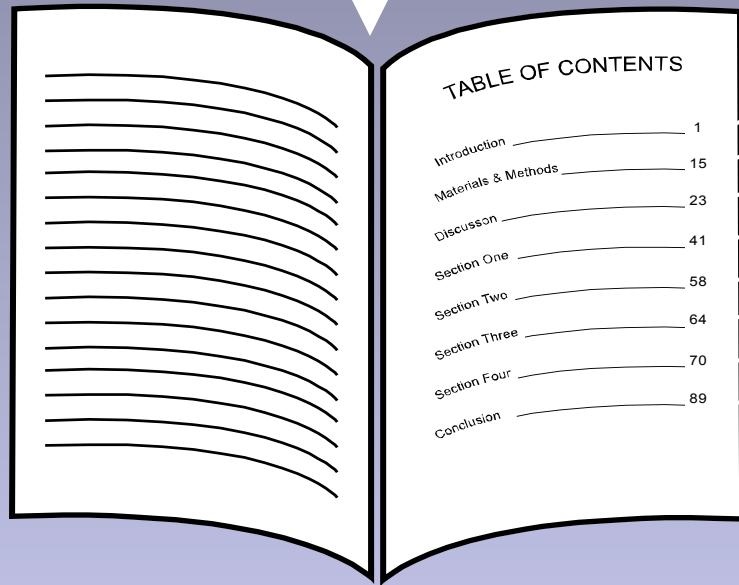


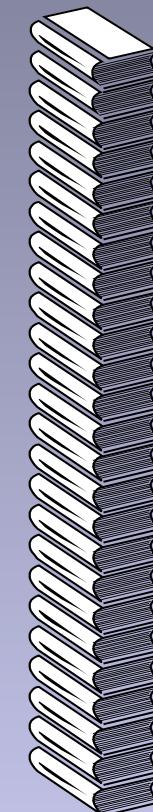
Table of contents for genes in wheat

...CTGACCTAATGCCGTA...



Genomics

1700 books
(or 1.7 million pages)



Used for
Marker-
Assisted
Selection



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



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

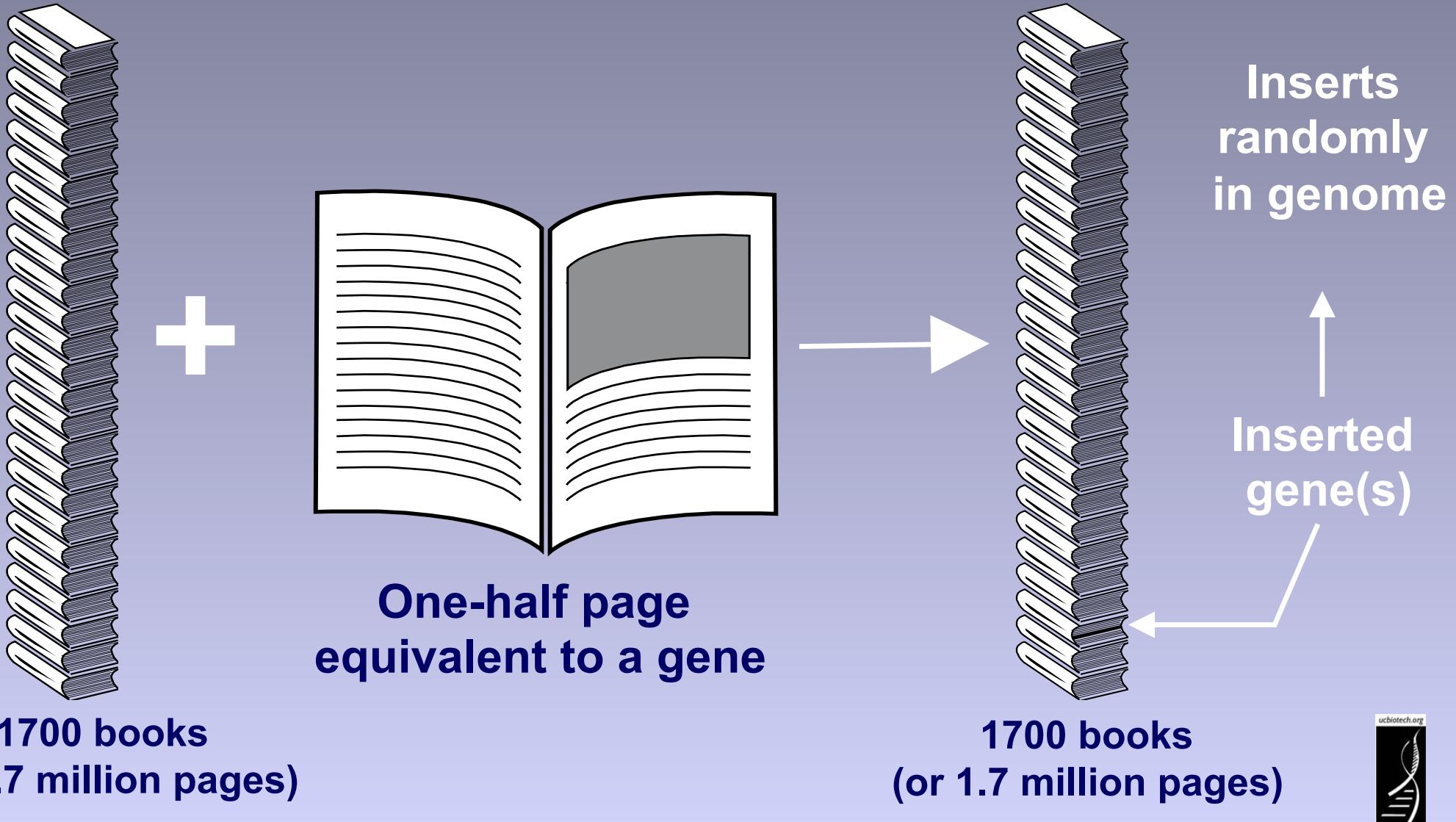
Protection limited to diversity in crop and compatible relatives

SOURCE: "New Potatoes Withstand Destructive Wireworms", Agricultural Research Service, 9/20/11.
<http://www.ars.usda.gov/is/AR/archive/sept11/wireworms0911.htm>



**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

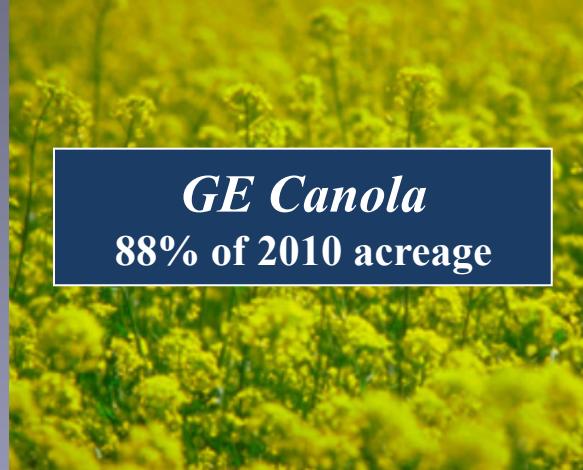
Uses plant machinery in laboratory

Gene exchange is specific involving single or few genes

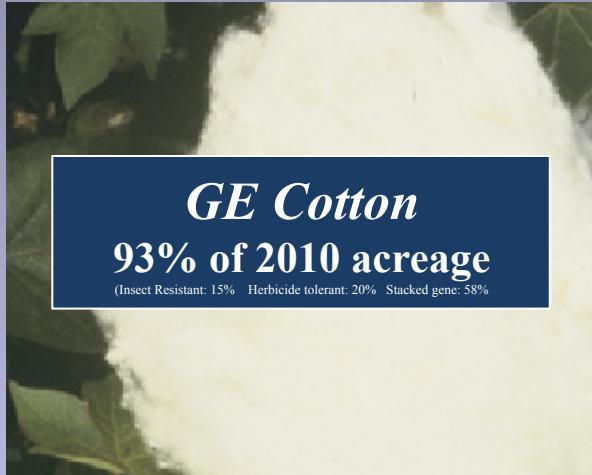
When/where gene expressed controlled precisely

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



GE Soybean
93% of 2010 acreage

(Herbicide resistant: 93%)

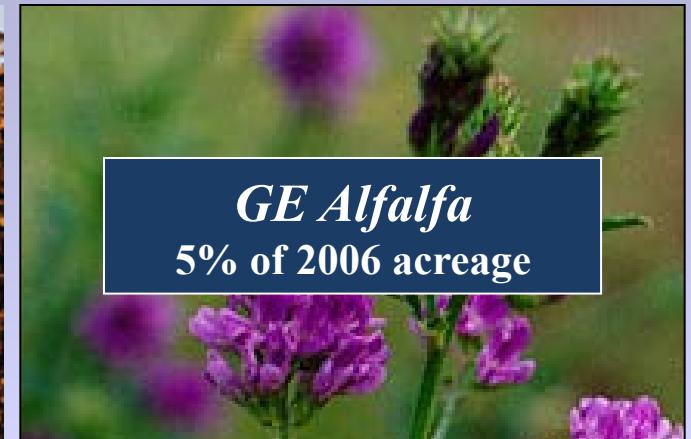


GE Corn
86% of 2010 acreage

(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

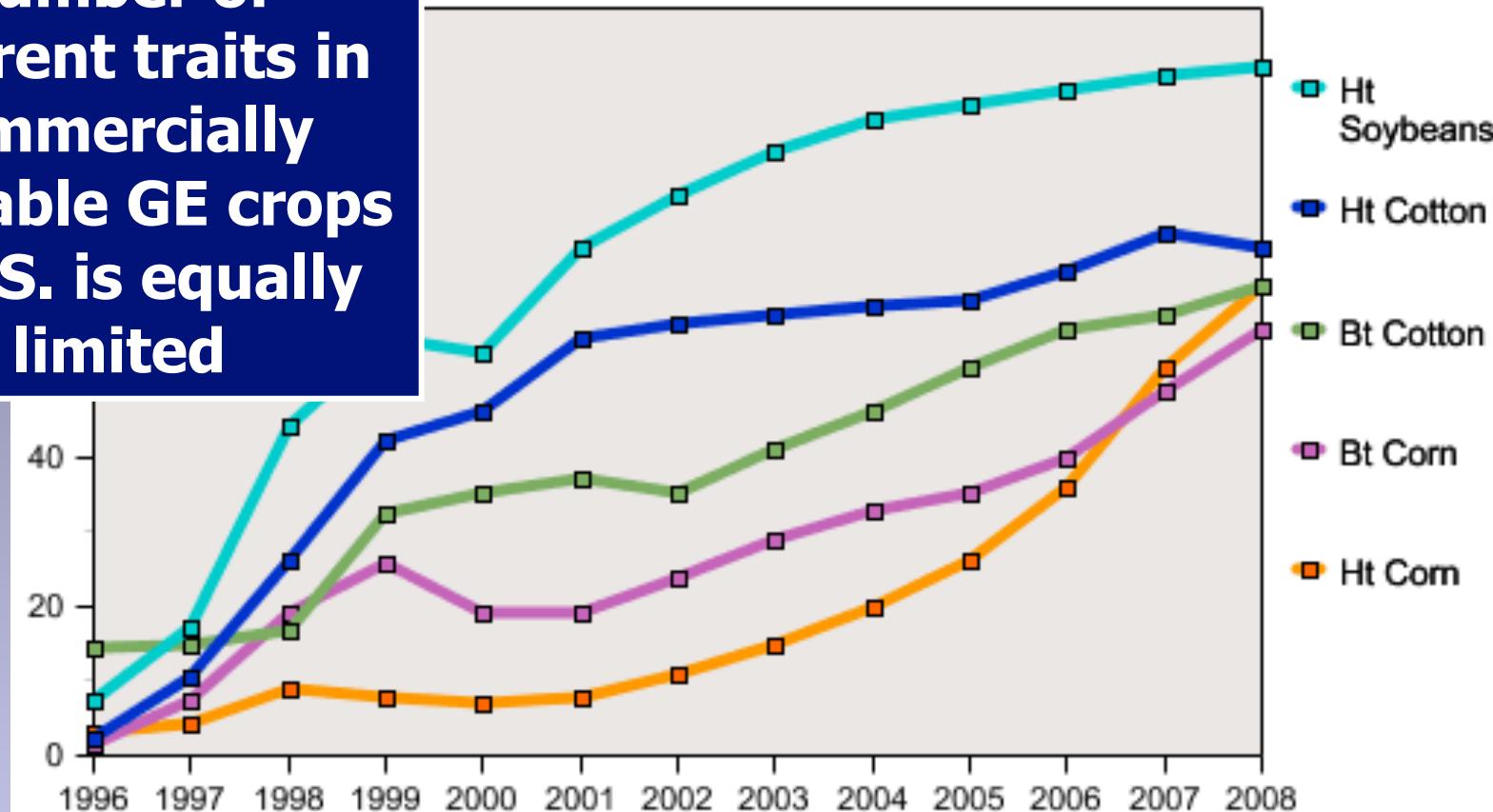


These types of large-acreage GE crops lead to estimates that 60-80% of processed foods in U.S. have GE ingredients

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

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

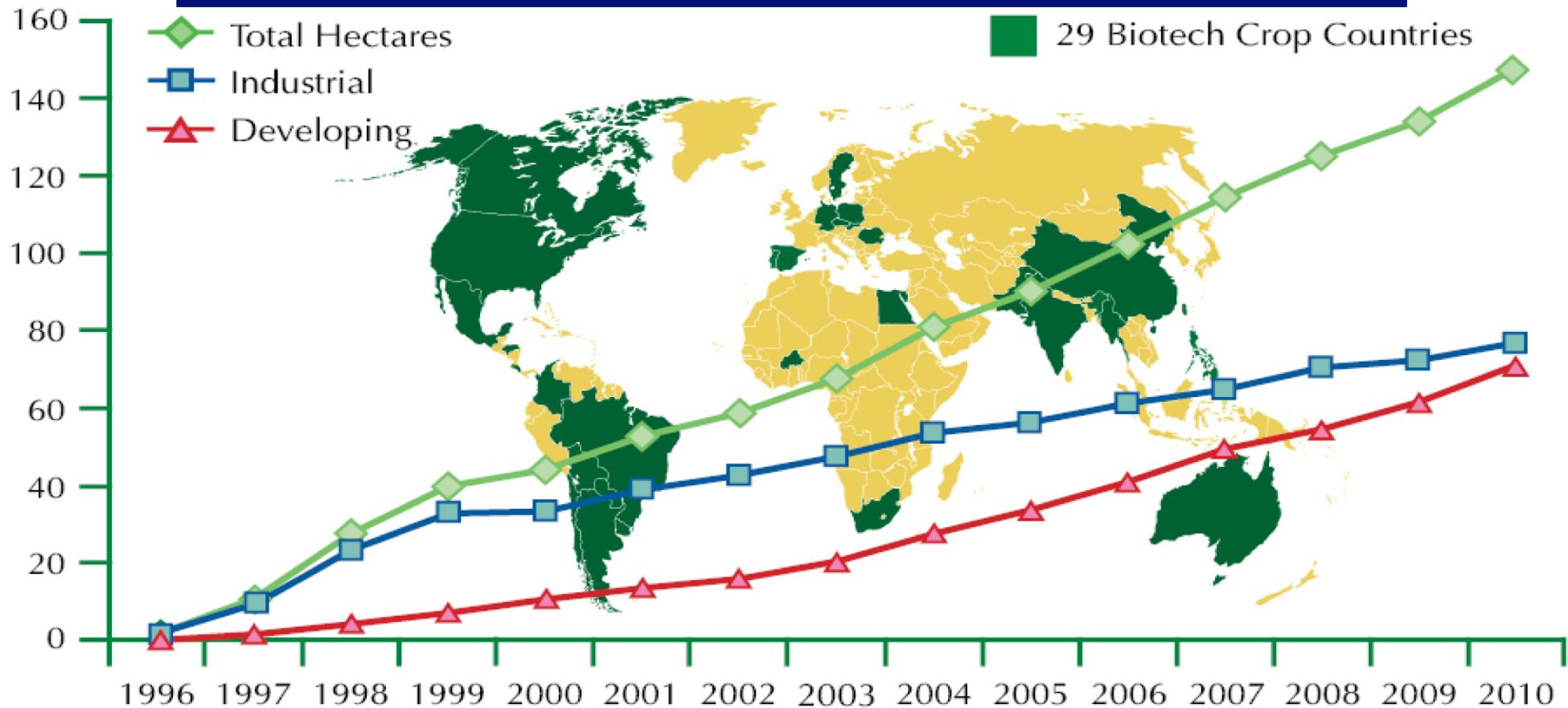


Data for each crop category include varieties with both HT and Bt (stacked) traits.

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**

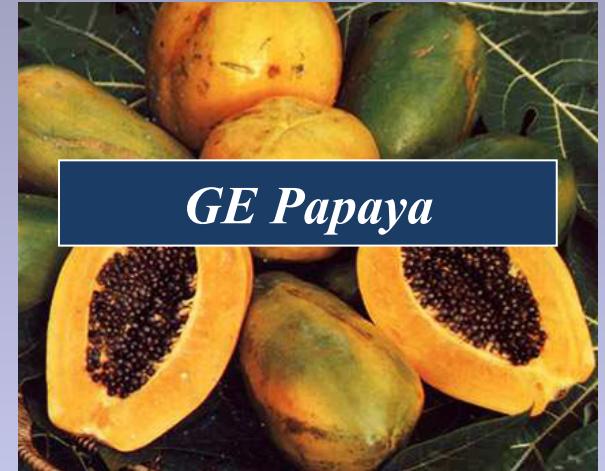
**There are a few whole,
genetically engineered
foods in the U.S market**



GE Sweet Corn



GE Squash



GE Papaya



WHAT'S IN THE PIPELINE?



S R R R S R R S R R R R P



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>

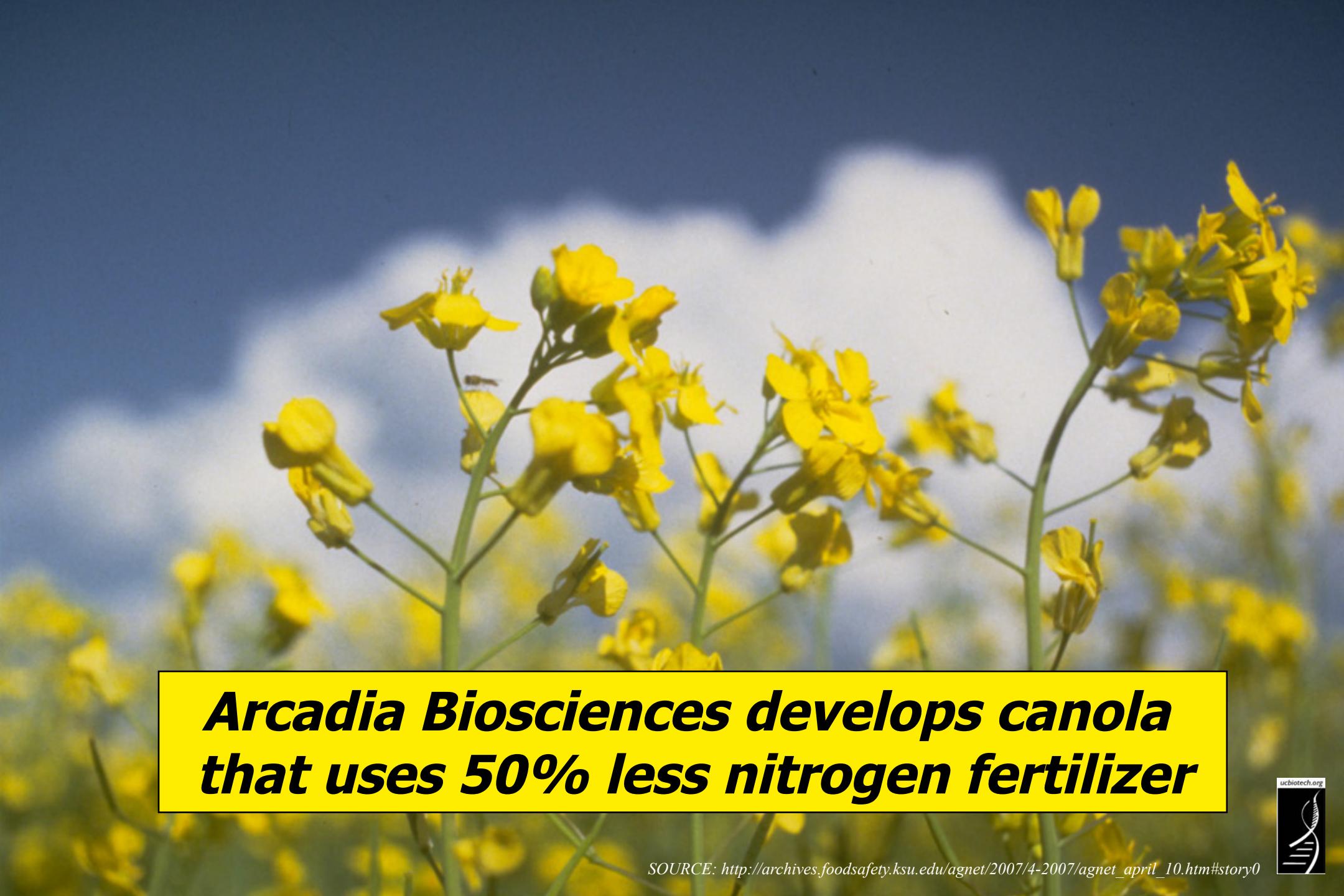




*Australian researchers identify
grape genes that provide resistance
to powdery mildew*

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





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

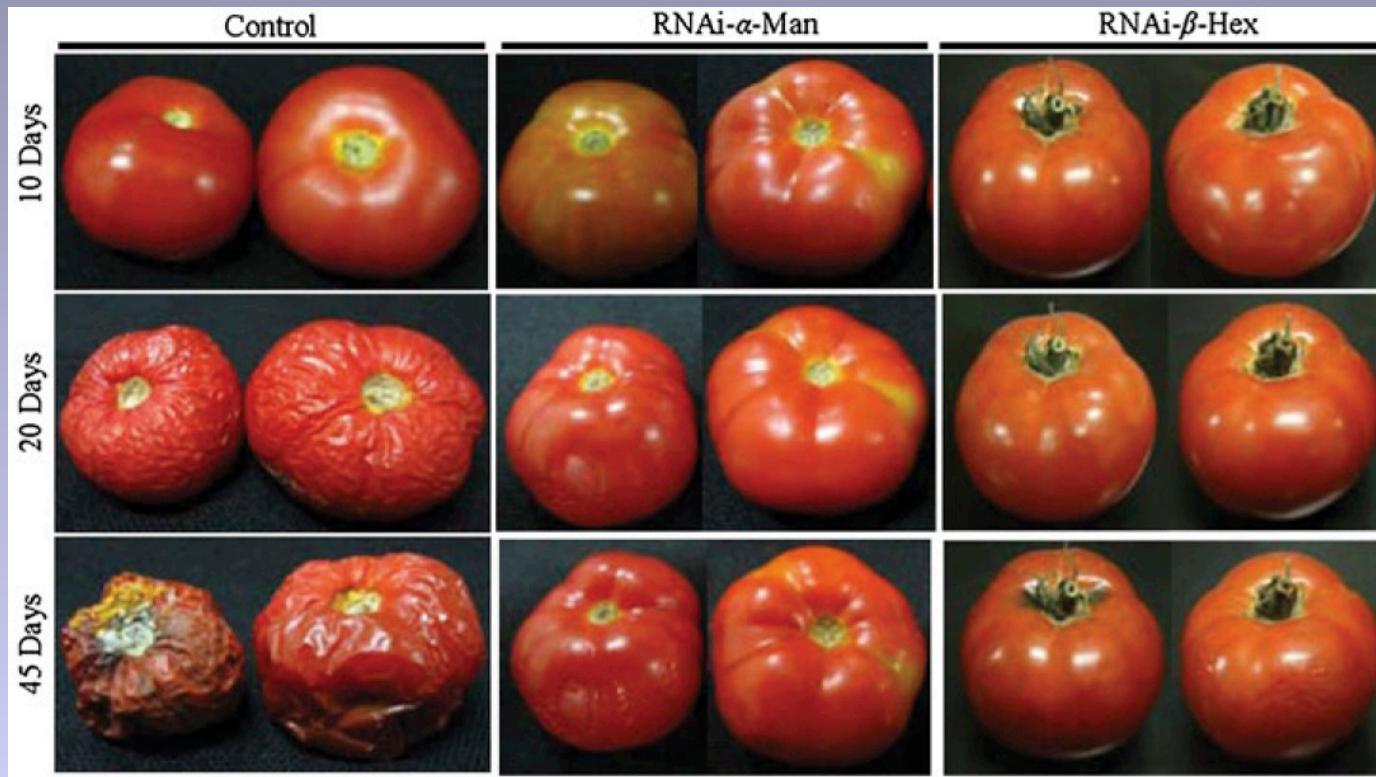
Control

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





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
Zimmermann, J., Saalbach, I., Jahn, D., Giersberg, M., Haehnel, S., Wedel, J., Macek, J., Zoufal, K., Glunder, G., Falkenburg, D. and Kipriyanov, S.M. 2009. Antibody expressing pea seeds as fodder for prevention of gastrointestinal parasitic infections in chickens. *BMC Biotechnology*, in press.

A close-up photograph of a blue rose flower with its green stem and leaves. The rose is a vibrant shade of blue, with many layers of petals. The stem is green and has several leaves attached to it.

*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



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

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.**

- | | |
|--|---|
| <p>Alfalfa – HT –removed/
reinstated</p> <ul style="list-style-type: none">✓ Cotton - HT, IR✓ Corn - HT, IR, AP✓ Soybean - HT, PQ❖ Potato - IR, VR❖ Tomato - PQSquash - VR✓ Canola – HT <p>✓ Large-scale production</p> <p>❖ Not on market</p> | <p>Papaya - VR</p> <ul style="list-style-type: none">❖ Rice - HTRapeseed - HT, AP, PQSugar beet - HT❖ Flax - HTChicorium - APTobacco - PQ |
|--|---|



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

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

BIOTECHNOLOGY INFORMATION

ANNUAL REVIEWS
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[Part 1](#) | [Part 2](#)

RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS

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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  [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