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<http://ucbiotech.org>  
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# 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?**

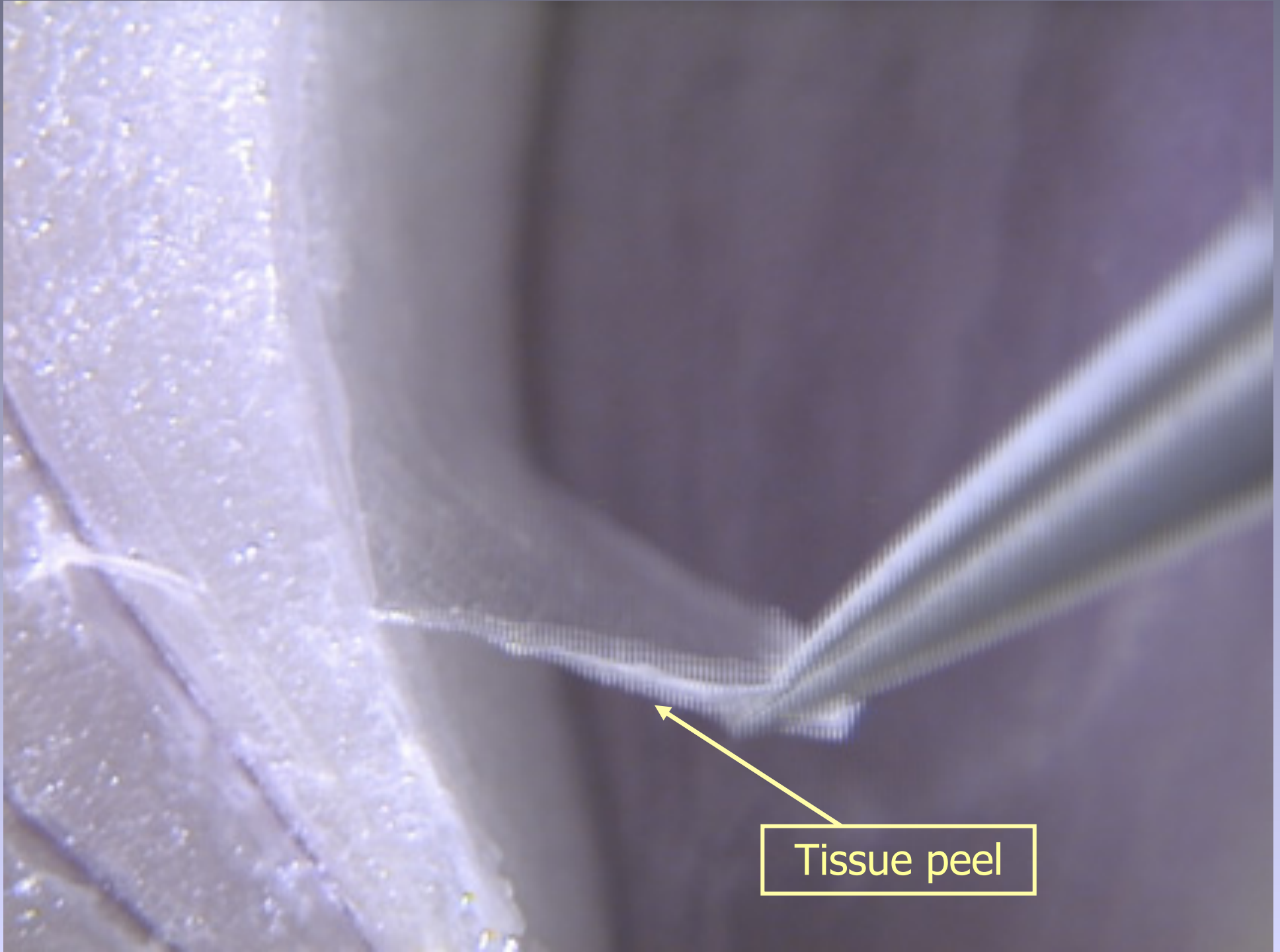
**5. What are environmental issues with GE crops?**



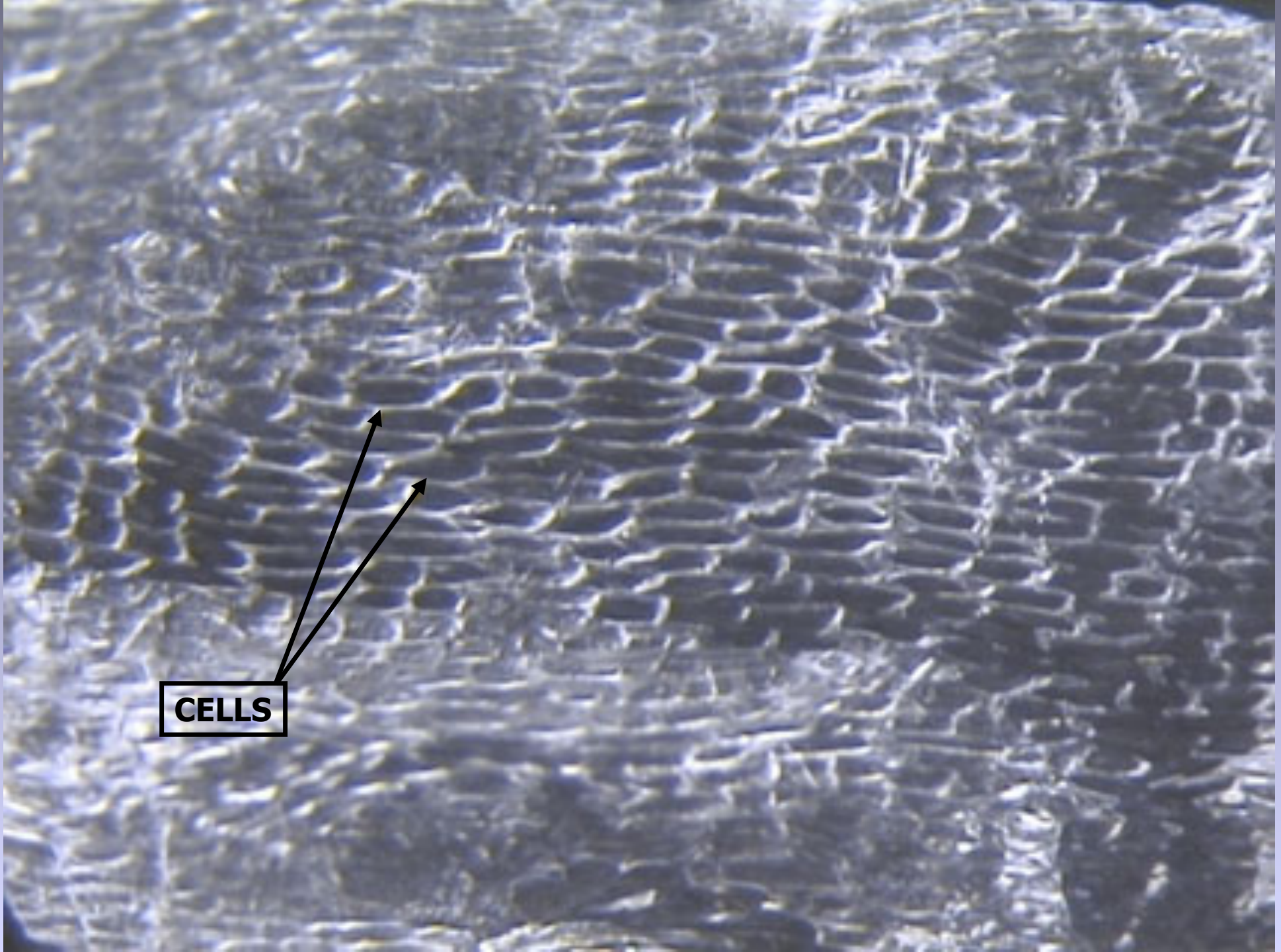
# *Tour d'Onion*



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



Tissue peel

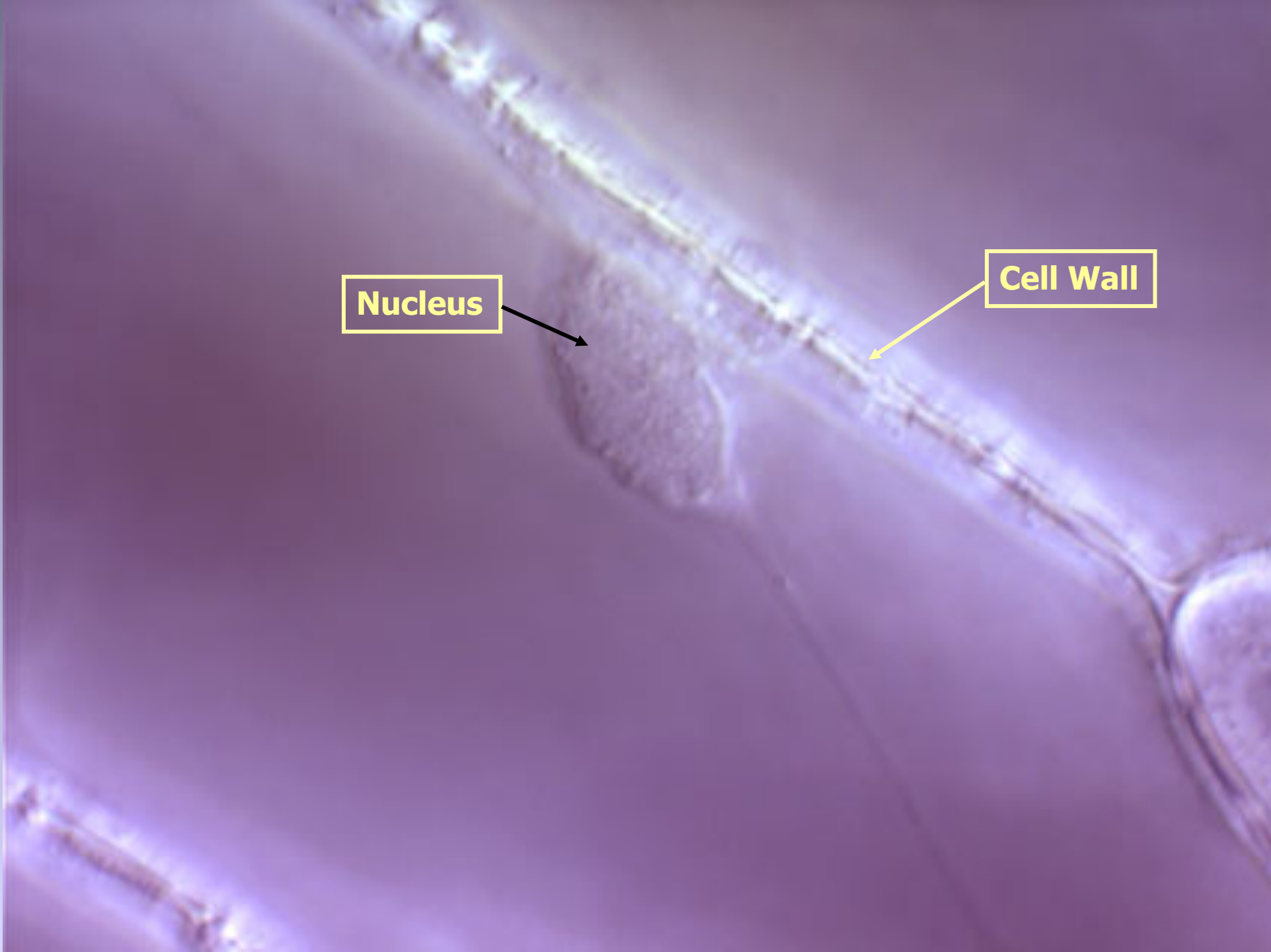


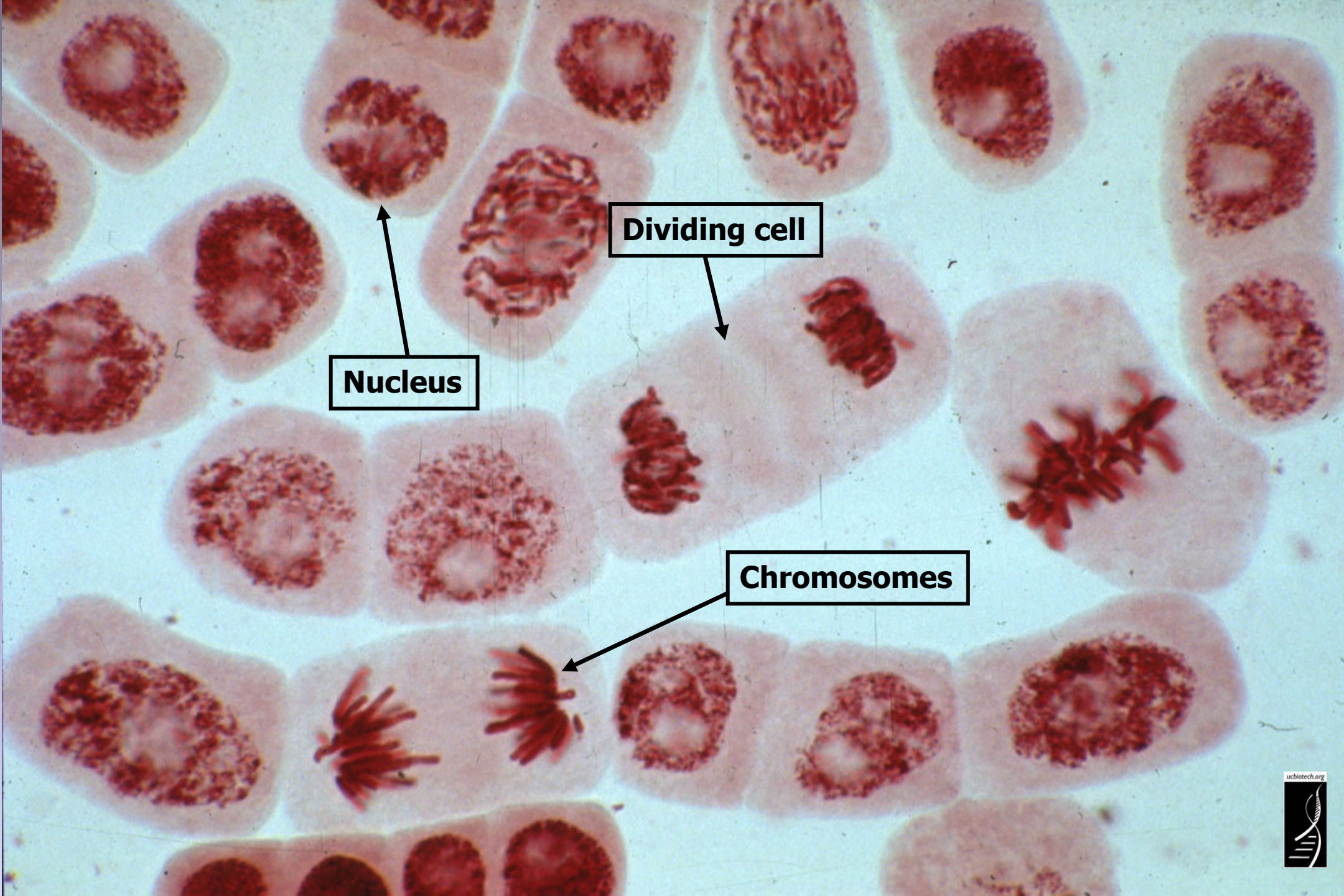
**CELLS**

**Nucleus**



**Cell Wall**





**Nucleus**

**Dividing cell**

**Chromosomes**



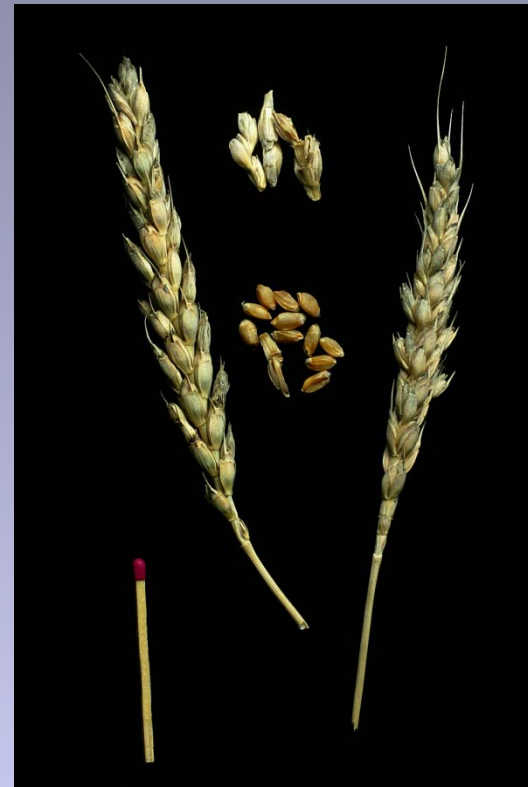


# How are the genes and chromosomes manipulated to create a new plant variety by classical breeding?



*Triticum monococcum*

**Ancient variety**



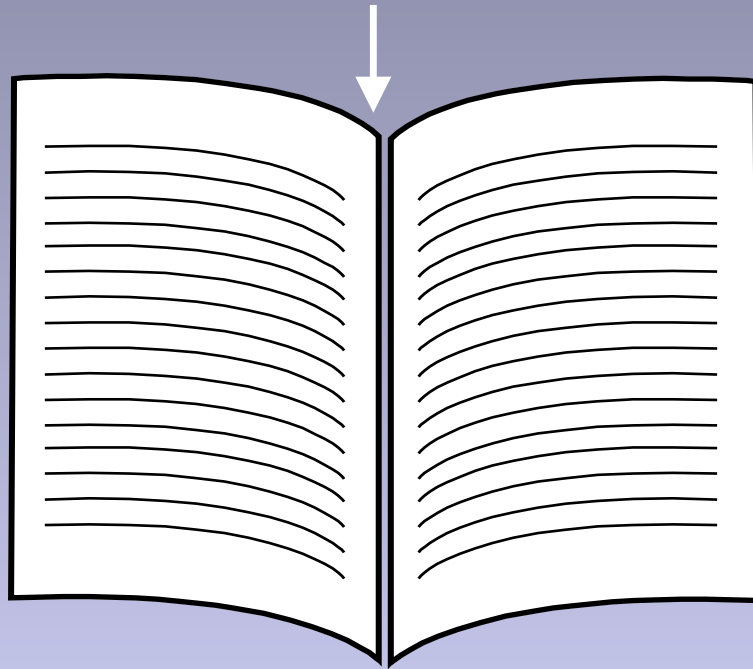
*Triticum aestivum*

**Modern bread variety**

# Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

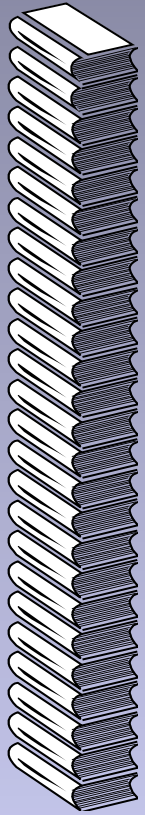


**1700 books**  
**1000 pages each**

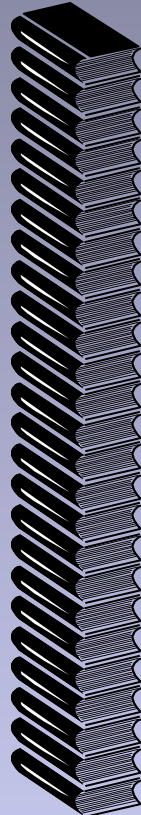


**1700 books**  
**(or 1.7 million pages)**

# Hybridization or cross breeding of wheat



**X**

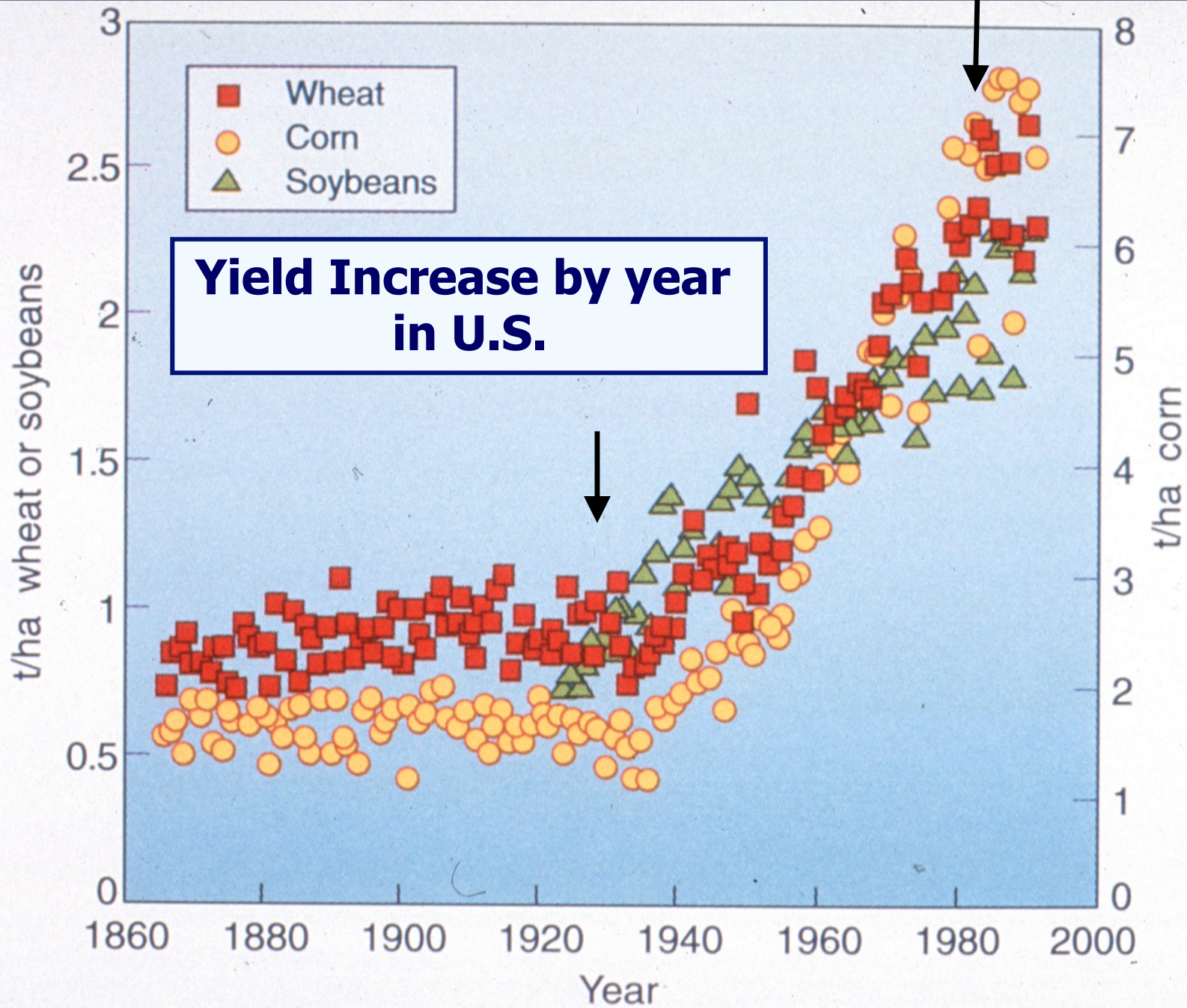


Random  
retention of  
information  
from each  
parent

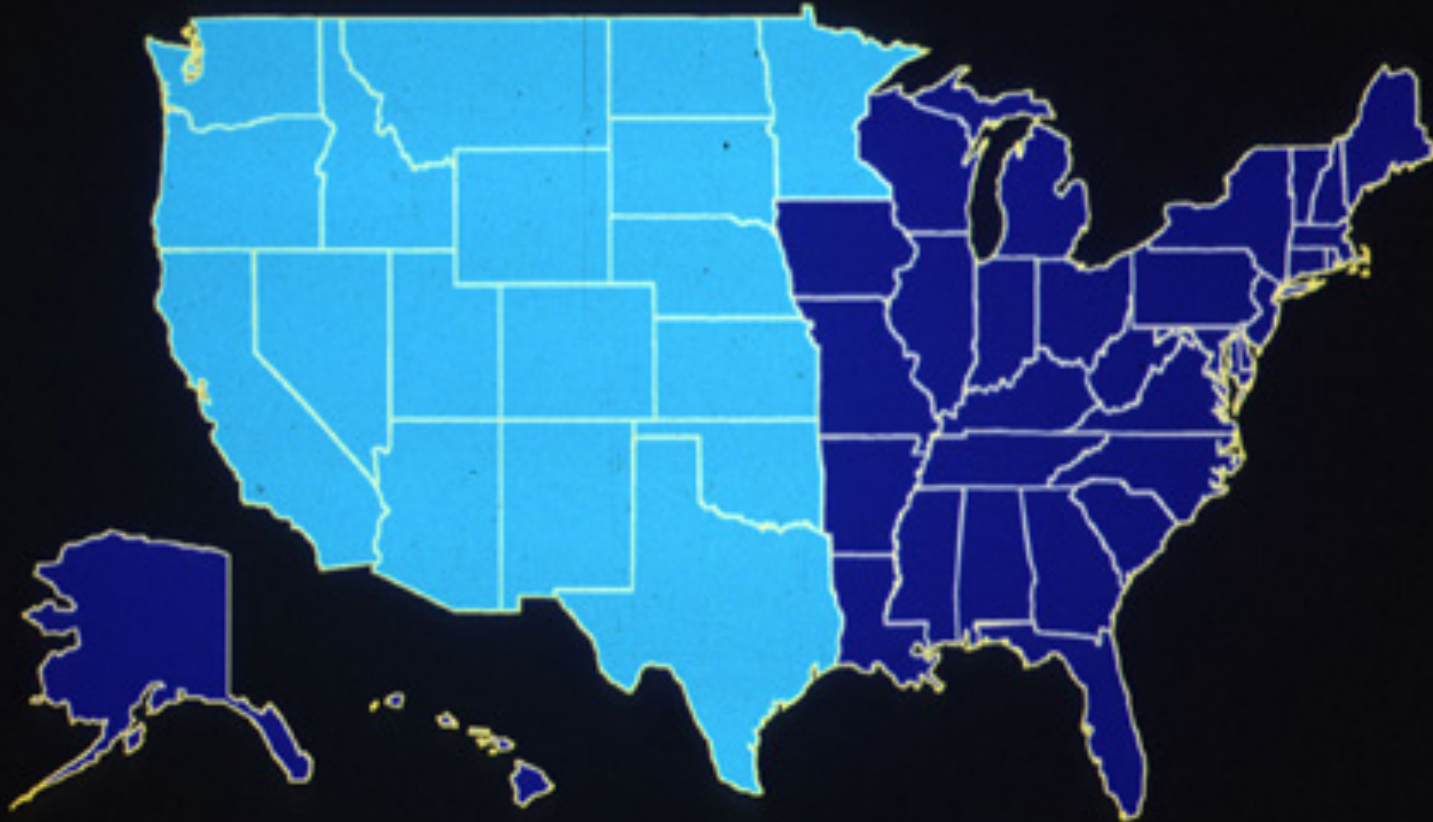
1700 books  
(or 1.7 million pages)

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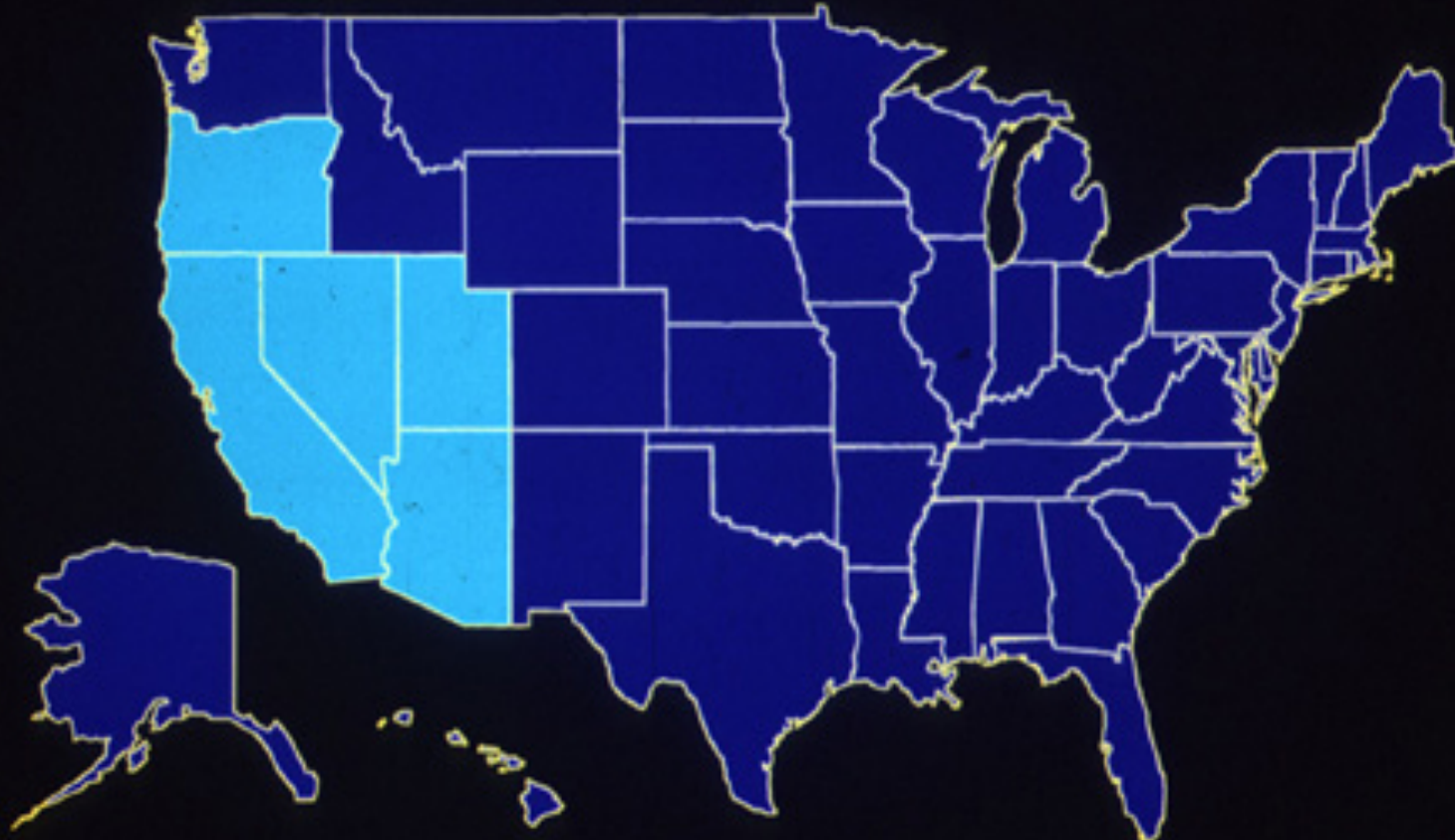


# U.S. Cultivated Land



Acreage Needed at 1929 Production Levels

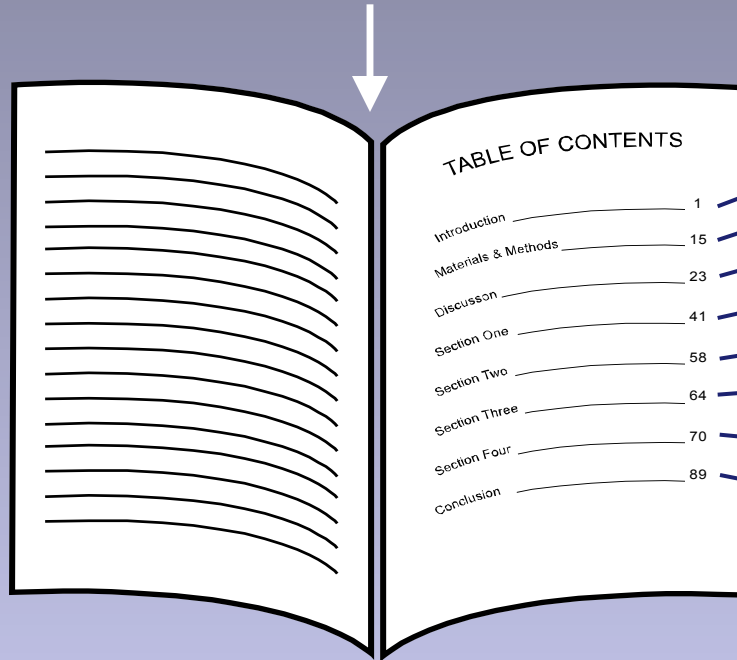
# U.S. Cultivated Land



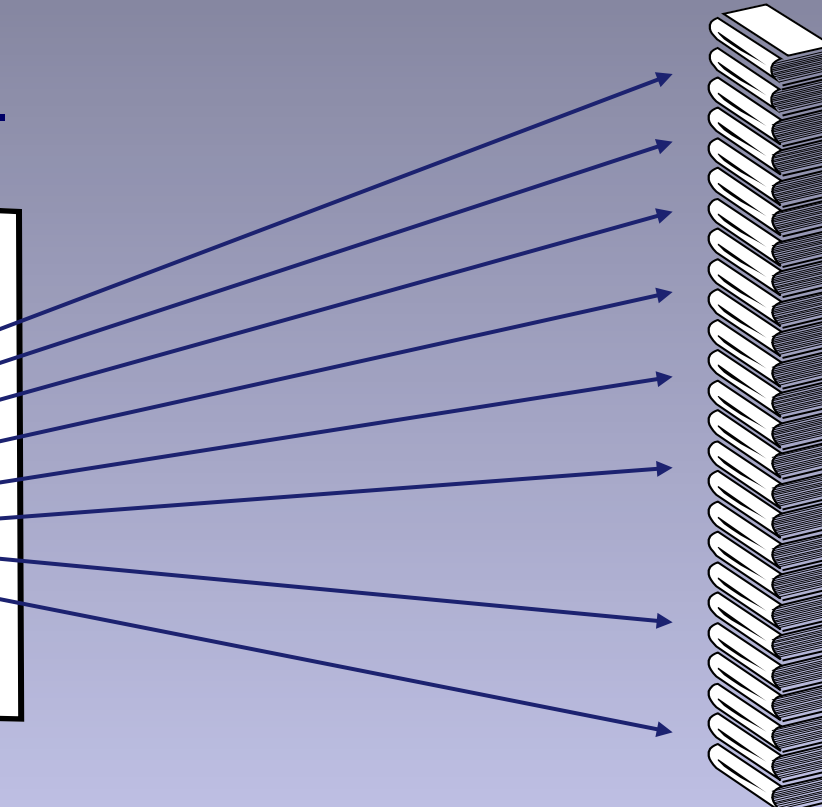
■ 1987 Acreage

# 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...**

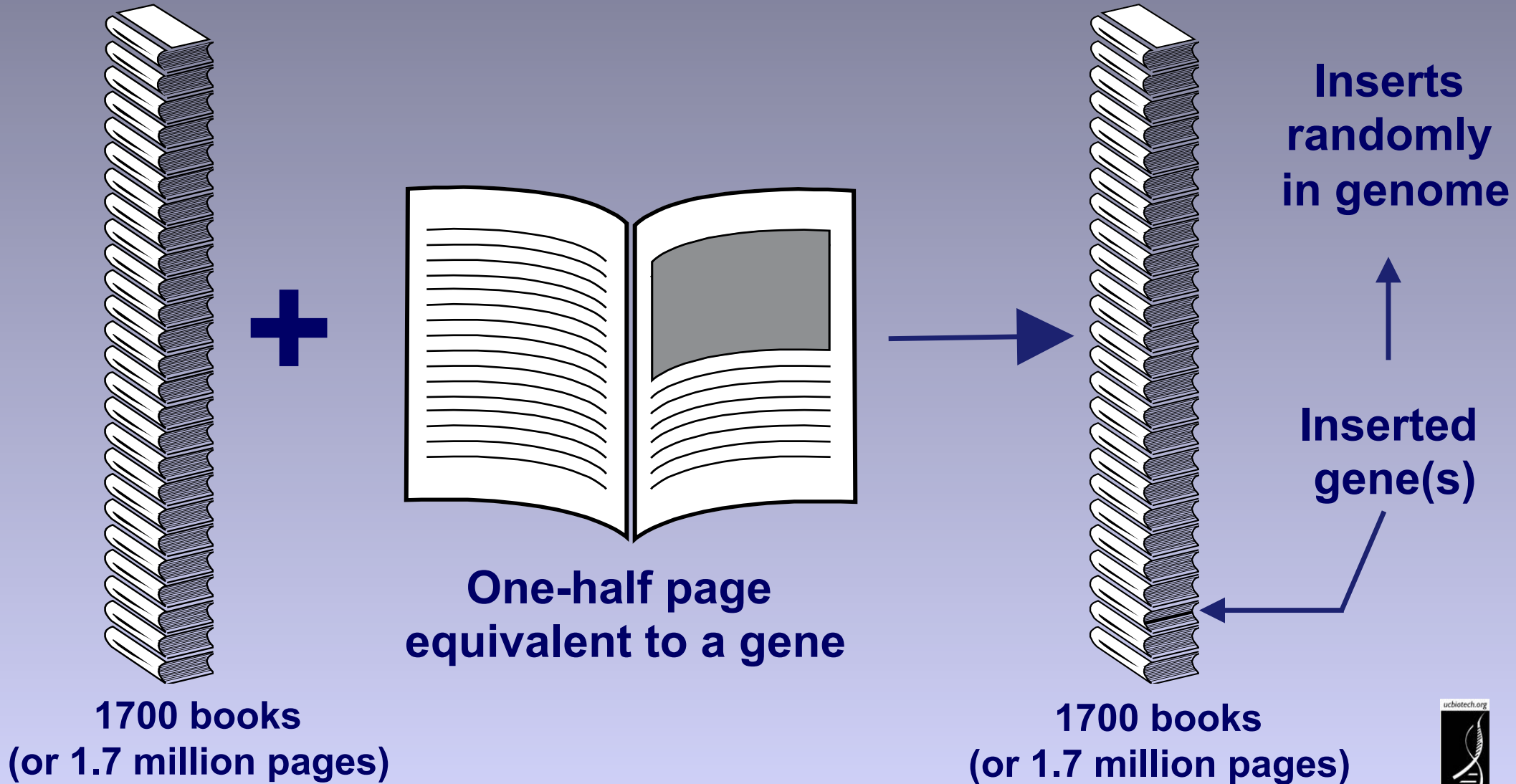
**Protection limited to diversity in crop and compatible relatives**

*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

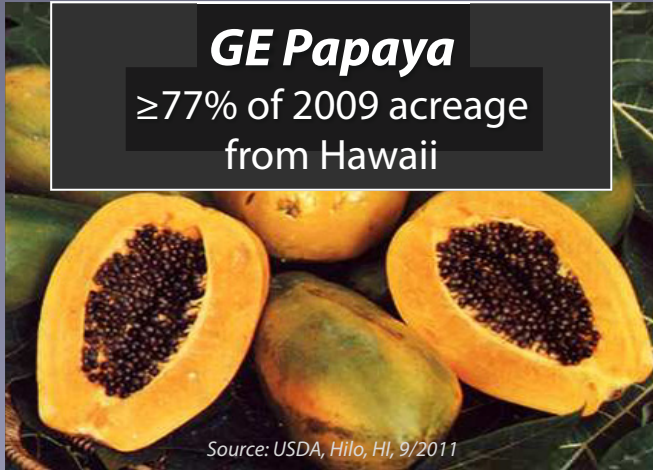
Uses plant machinery in laboratory

Gene exchange is specific  
involving single or few genes

When/where gene expressed  
controlled precisely

Source of gene from any  
organism





## GE Papaya

≥77% of 2009 acreage  
from Hawaii

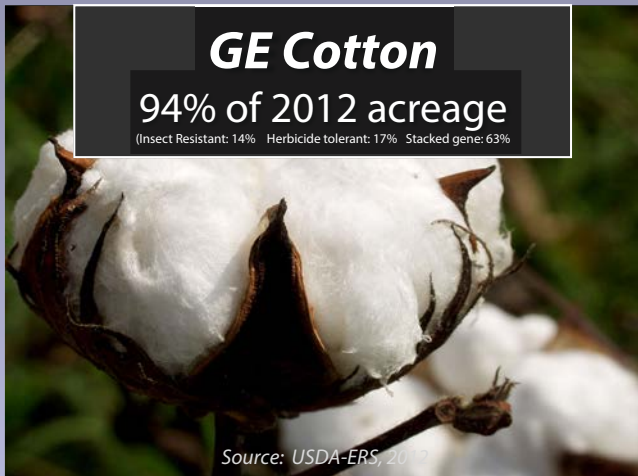
Source: USDA, Hilo, HI, 9/2011



## GE Squash

10% of 2004 acreage

Source: ISAAA, 2004

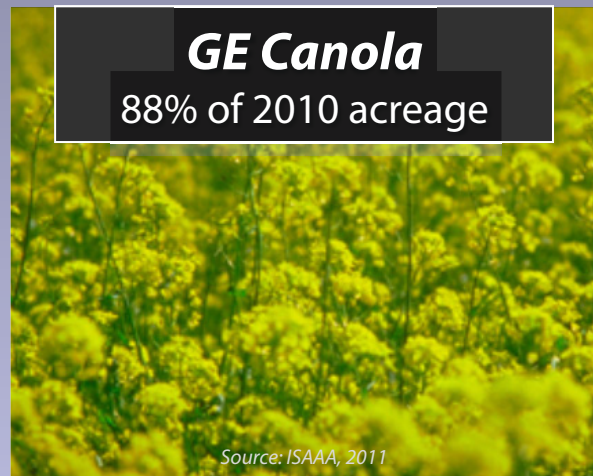


## GE Cotton

94% of 2012 acreage

(Insect Resistant: 14% Herbicide tolerant: 17% Stacked gene: 63%)

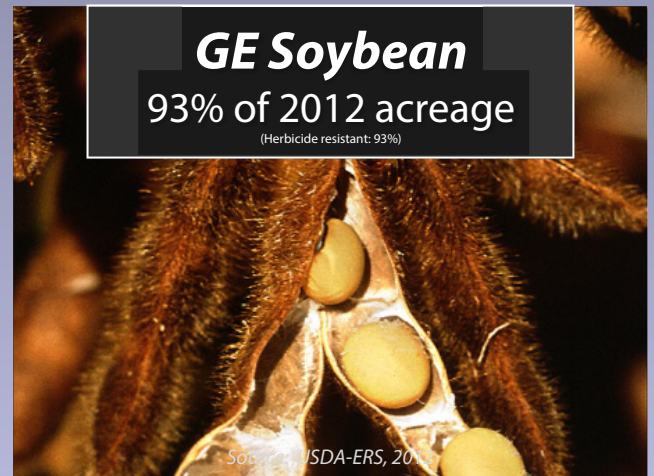
Source: USDA-ERS, 2012



## GE Canola

88% of 2010 acreage

Source: ISAAA, 2011

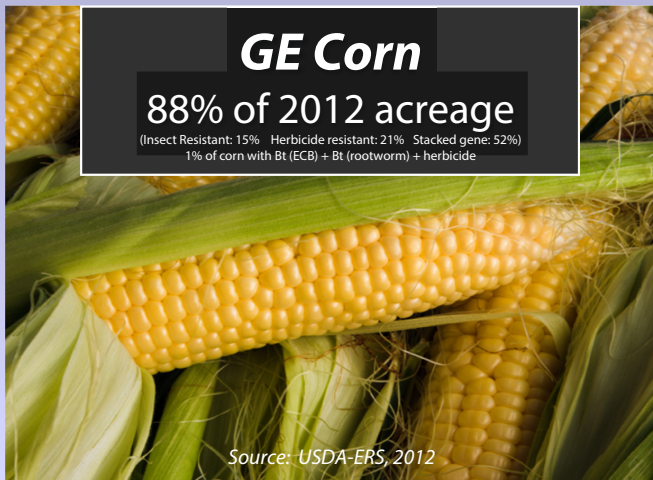


## GE Soybean

93% of 2012 acreage

(Herbicide resistant: 93%)

Source: USDA-ERS, 2012



## GE Corn

88% of 2012 acreage

(Insect Resistant: 15% Herbicide resistant: 21% Stacked gene: 52%)  
1% of corn with Bt (ECB) + Bt (rootworm) + herbicide

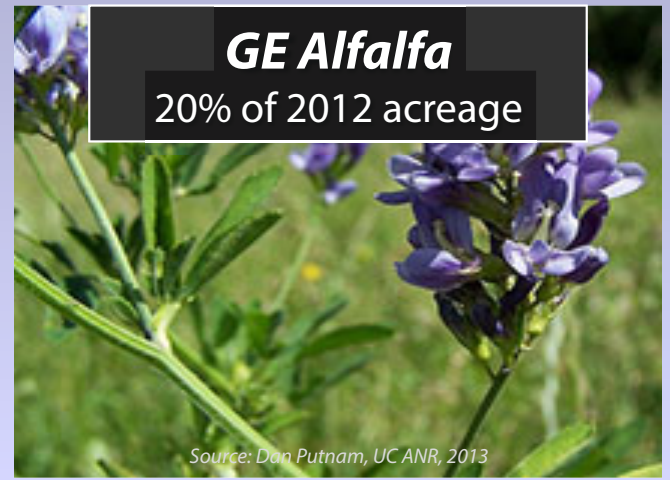
Source: USDA-ERS, 2012



## GE Sugarbeet

96% of 2010 acreage

Source: ISAAA, 2011



## GE Alfalfa

20% of 2012 acreage

Source: Dan Putnam, UC ANR, 2013

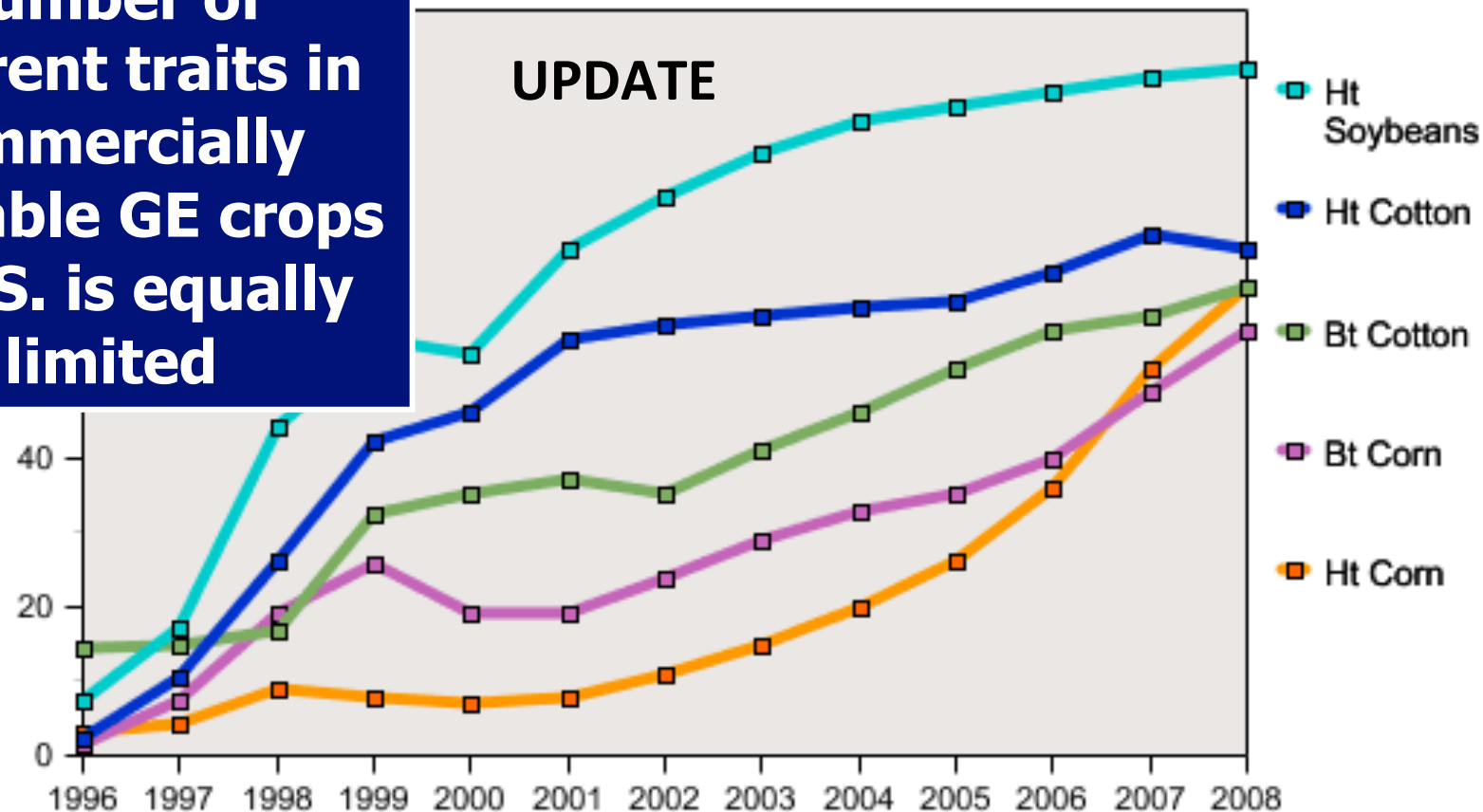




**Types of GE Crops Leads To Estimates that 75% of Processed Foods in U.S. Have GE Ingredients**

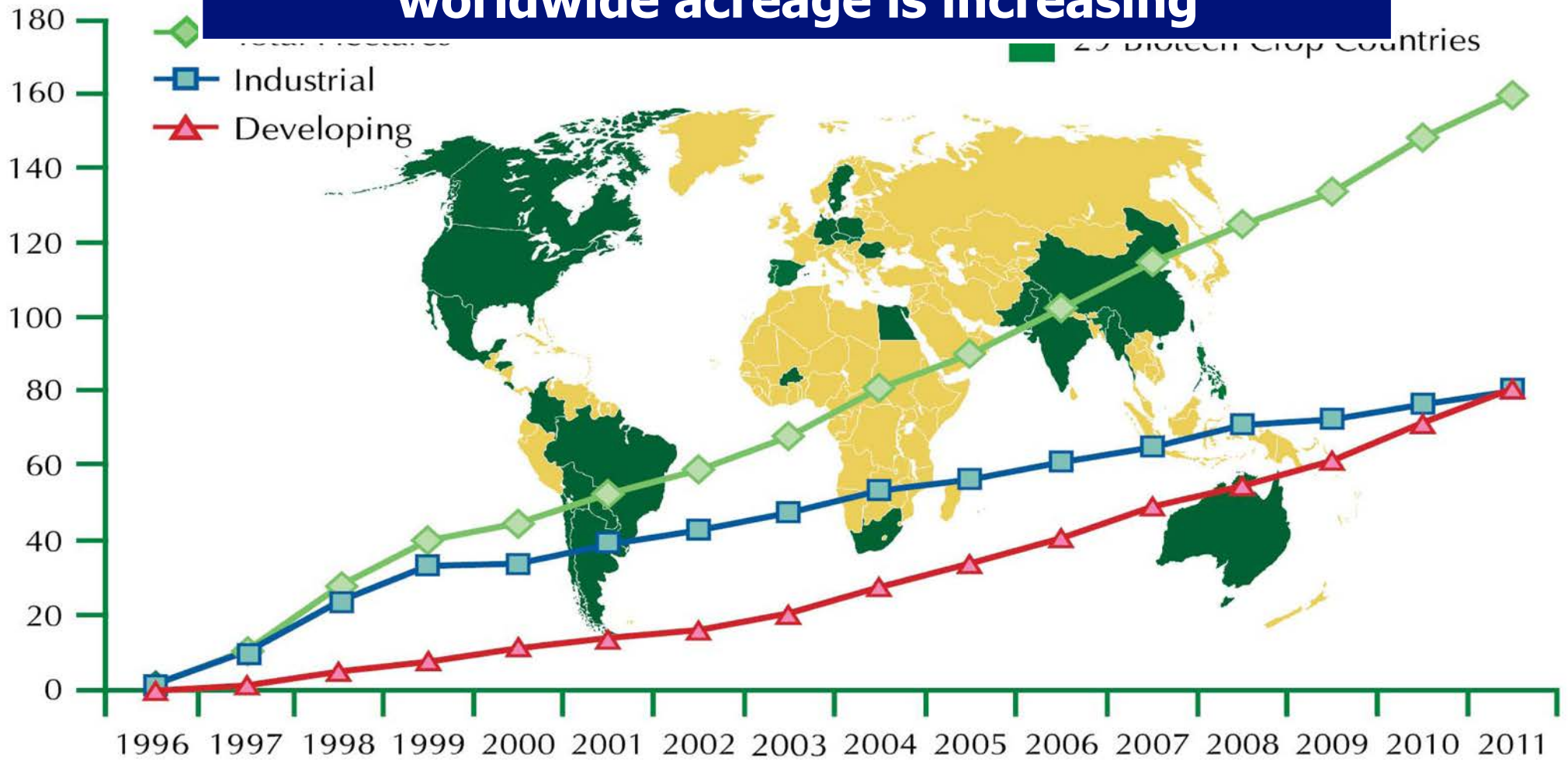
## Rapid growth in adoption of genetically engineered crops continues in the U.S.

**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 + Louisiana**

Source: Clive James, 2011.





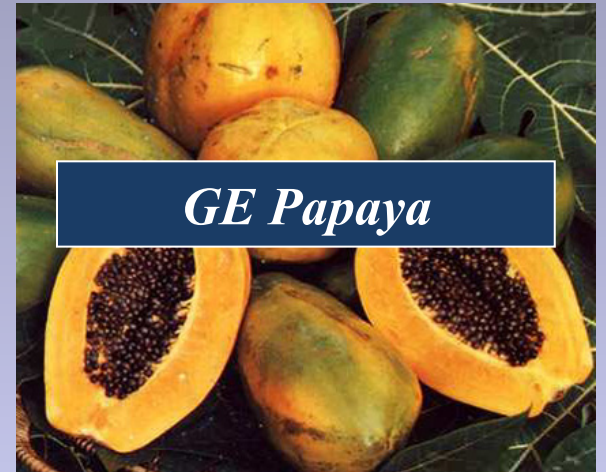
**There are a few whole,  
genetically engineered  
foods in the U.S market**



*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>



A close-up photograph of several green grapes. The grapes are covered in a fine, white, powdery substance, which is powdery mildew. The background is dark, making the green grapes and the white powder stand out.

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



***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.*



*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.



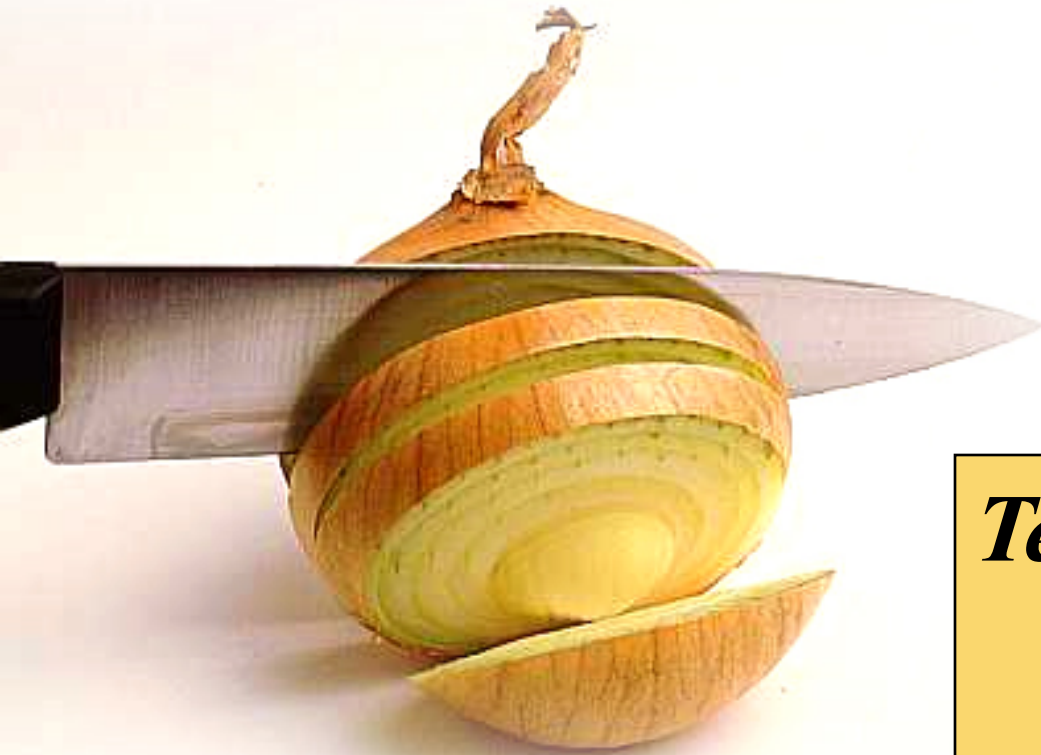
A photograph of a whole green apple at the top center and two slices of a green apple below it, all resting on a white marble surface. The apple slices are cut horizontally, showing the core and seeds. A dark green rectangular box is overlaid on the image, containing white text.

*Non-browning GE apple will be marketed in U.S. and labeled as genetically modified by Okanagan Specialty Fruits*

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 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?

# USDA 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))





# *What Are Some of the Issues?*



# First, what are some food safety issues?

- Changes in nutritional content
- No peer-reviewed food safety tests
- Creation of allergens or activation of toxins
- Pharma crops contaminating food supply
- Labeling
- Gene flow from food to intestinal bacteria increasing antibiotic resistance

# Now to some environmental issues?

- Gene flow to generate “superweeds” (herbicide tolerance to wild/weedy species)
- Transfer of transgenes to organic crops?
- Spread of pharmaceutical genes into commercial crops?
- Loss of genetic diversity?
- Property rights (gene patents)?

Want to ask questions?  
Follow these easy steps in Biotech information section of <http://ucbiotech.org>

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

ucbiotech.org/index.html

ucbiotech.org

SCIENCE-BASED INFORMATION & RESOURCES ON AGRICULTURE, FOOD & TECHNOLOGY

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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?**

**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.

**Who's in YOUR family?**

**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**  
[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.

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

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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”.

### List all by Category

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

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

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## 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](#)

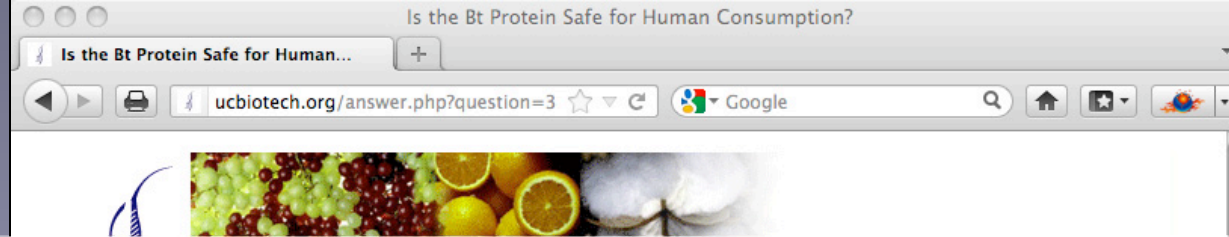
**Were Foods Made From Bt Corn Removed from the Market Because of Allergenicity Concerns?** [Response](#)

**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

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](#)
2. Food Drug Adm. (FDA). 2005. Guidance for industry: Safety testing of individual products of introduced genes. [/dat](#)
3. EPA. 2005. Safety testing of individual products of introduced genes. <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 R, et al. 2004.

Now on to the topic at hand...



**Educational resources available on  
[ucbiotech.org](http://ucbiotech.org)**

# educational resources

AVAILABLE ON LOAN FOR FREE, ANYWHERE IN THE U.S.!

These educational displays, cards, handouts and games can be borrowed for use at venues, like state and county fairs, student and teacher meetings, and other professional events.

## games



Educational games for all ages to help make connections between seeds, plants and food.

## displays



Three colorful, tactile displays available on loan for free: Biotech and Foods, Genetics and Diversity and Biotechnology for Sustainability.

## GENEie juice bar



## teaching tools



Cards and teacher handouts accompany displays - in both English and Spanish. GENEie juice bar makes DNA extraction from food easy.



## afterschool curricula

4-H/afterschool curriculum for grades 5 to 8 with five lessons covering topics from plant diversity to genetics.

PLEASE VISIT

<http://ucbiotech.org>

TO VIEW & RESERVE ANY OF THESE RESOURCES

For more information, contact Barbara Alonso  
(email: [balonso@berkeley.edu](mailto:balonso@berkeley.edu) or phone: 510-642-1589)

**Educational Resources section has information on games, displays, teaching tools and afterschool curricula with details on how to access the materials for free.**



# DNA FOR DINNER?

<http://ucbiotech.org/dnafordinner>

**Middle school curriculum for 4-H and afterschool on genetics and diversity**



## FIVE LESSONS AVAILABLE FOR DOWNLOAD ONLINE!

<http://ucbiotech.org/dnafordinner>

### LESSON 1

#### Dare to Be Different

- All living things, **organisms**, are made up of **cells**.
- The variation in organisms reflects their **diversity**.
- The variety comes from the different **genes** and the characteristics they encode.
- Organisms with many similar traits, and thus with similar genetic information, may be **related**.

### LESSON 2

#### Language of Life

- All of an organism's genes are called a **genome**.
- Some genes from every organism are the same; some are different.
- The genome is written with a set of rules called the **genetic code**; that code is the same for all organisms.
- Genetic code is made up of different arrangements of four chemical units that together are arranged in a sequence called **DNA**.

### LESSON 3

#### DNA for Dinner

- Every organism is made up of **cells** containing a genome that has all of the genetic information that determines its characteristics.
- During reproduction, the next generation gets half of its genetic information or genes from one parent, half from the other.
- The genome and genes are written in a **chemical language** called DNA, which is made up of individual chemical units abbreviated with A, C, G and T.
- DNA is present in the cells of any organism, including foods like fruits, vegetables, cereals, meat, eggs, and fish.

### LESSON 4

#### Building Blocks to Organisms

- The order of A's, C's, G's and T's in the DNA sequences of genes is the code for specific **amino acids** that result in specific proteins.
- The order of amino acids determines the function of the particular protein.
- Different proteins do different jobs in the organism.
- Some proteins, called **enzymes**, have functions that speed reactions in the cell.
- Certain DNA sequences are "on" switches to start proteins; others are "off" switches to end proteins.

### LESSON 5

#### From Bread to Biotech

- Literally **biotechnology** means using organisms to do a job, like using yeast to make bread.
- Modern biotechnology uses new genetic tools to modify genomes and speed crop development.
- In the past humans modified genomes by crossing plants with different traits and selecting ones with improved traits.
- A part of modern biotechnology, called **genetic engineering**, involves isolating genes, linking them to on and off switches and introducing them into the same or different organisms.
- Special enzymes are used to cut (restriction enzymes) and paste (ligase) DNA, in a process called **recombinant DNA**.

# ACTIVITIES

## M&M Codes

### 4 COLORS TO USE



Examples of combinations:

A =  

B =  

C =    
 

This counts as 1 combination

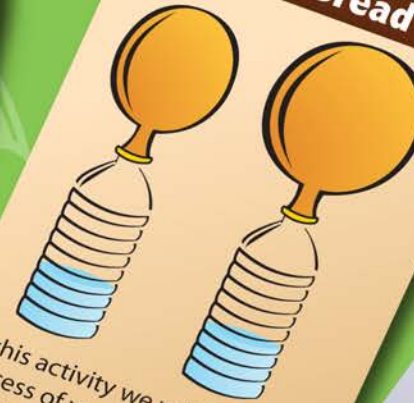
Create a unique "M&M" code to describe a fruit or vegetable; let others guess the identity.

## Live and Play DNA



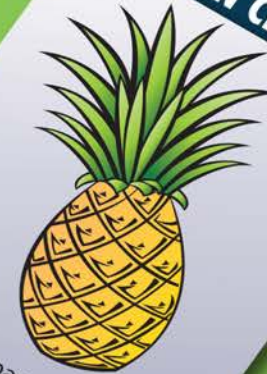
Each participant is one base in a DNA strand that they will form. They will then pair with their complementary base in another DNA strand. They will live and play as DNA!

## Balloons, Bottles and Bread



In this activity we will see the process of yeast producing carbon dioxide after being fed sugar – the same activity that occurs when making bread.

## Mellow Jell-O® and Spit 'N Crackers



In this activity, participants will learn what kinds of jobs proteins can do. Start with the gelatin and pineapple activity, so the gelatin can set while you do the Spit 'n Crackers activity.

This curriculum, geared to middle school students, has five lessons covering plant biology topics from diversity to genetic engineering. Each lesson has both computer-based and hard-copy activities.

# AFTERSCHOOL CURRICULUM GRADES 5-7

## What we will learn

- There are millions of living things on earth, called **organisms**.
- Organisms can have many cells, like plants and animals, or just single cells, like **microbes**.
- Each organism has specific **characteristics** dictated by its **genes**.
- Genes are specified in the **DNA** of its cells.
- Certain organisms, called **pathogens**, have genes that cause disease in other organisms.
- Microbes that can be pathogens are **fungi, parasites, viruses, or bacteria**.
- **Special tools** are used to determine what organisms cause disease and what don't.
- Certain **careers** prepare you to use those tools to identify disease-causing organisms.

## Science Standards

**Scientific Concepts Addressed**  
Discovery-based research and the scientific method

**National Science Education Standards in Life Sciences**  
([http://www.educationworld.com/standards/national/science/5\\_8.shtml#ns.5-8.3](http://www.educationworld.com/standards/national/science/5_8.shtml#ns.5-8.3))  
Grades 5-7, Structure and function in living systems;  
Reproduction and heredity;  
Diversity and adaptation of organisms

**Scientific Process Skills Used**  
Categorize/order/classify;  
compare/contrast/hypothesize;  
observe; organize/order/classify

## Time needed

Length of lesson: 1 to 1.25 hours.



# BACKYARD mystery

## Combined Lesson Leader Guide

Prepared and designed by Dr. Peggy G. Lemaux & Barbara Alonso & Jenne Stonaker\*  
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**Middle school  
curriculum for 4-H  
and afterschool on  
diseases, detection  
and microbes**



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**BACKYARD mystery** Section 1: Handout 1.4  
Bacteria

Cut cards out along outline, and fold along dotted line.  
Tape ends together.

 rod	<b>BA</b>	 round	<b>ACT</b>
 round	<b>EF</b>	 rod	<b>RIA</b>

**Lessons help students solve a disease mystery in the backyard using modern genetic tools to identify the culprit**

**BACKYARD mystery** Section 2: Handout 2.3  
Amazin' Maze

Help the bird fly through the tree maze! The letters that represent the parts of DNA are clues along the way.

**Middle school  
curriculum on plant  
biology for the mixed  
classroom of sighted  
and sight-limited  
students**

**Learning Plant Biology**

***It's All in the Touch!***

