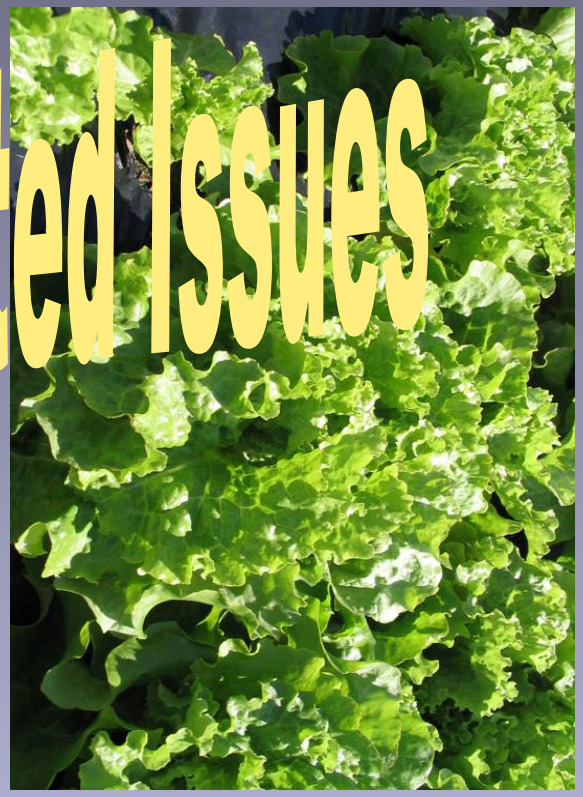
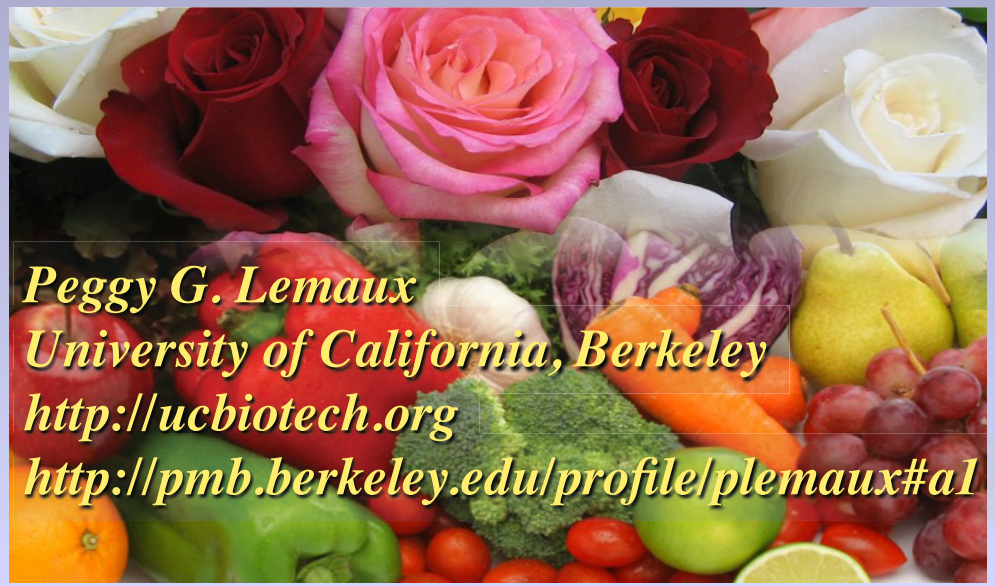
The Science of GMOs and Related Issues





Peggy G. Lemaux
University of California, Berkeley
http://ucbiotech.org
http://pmb.berkeley.edu/profile/plemaux#a1

ucbiotech.org

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?

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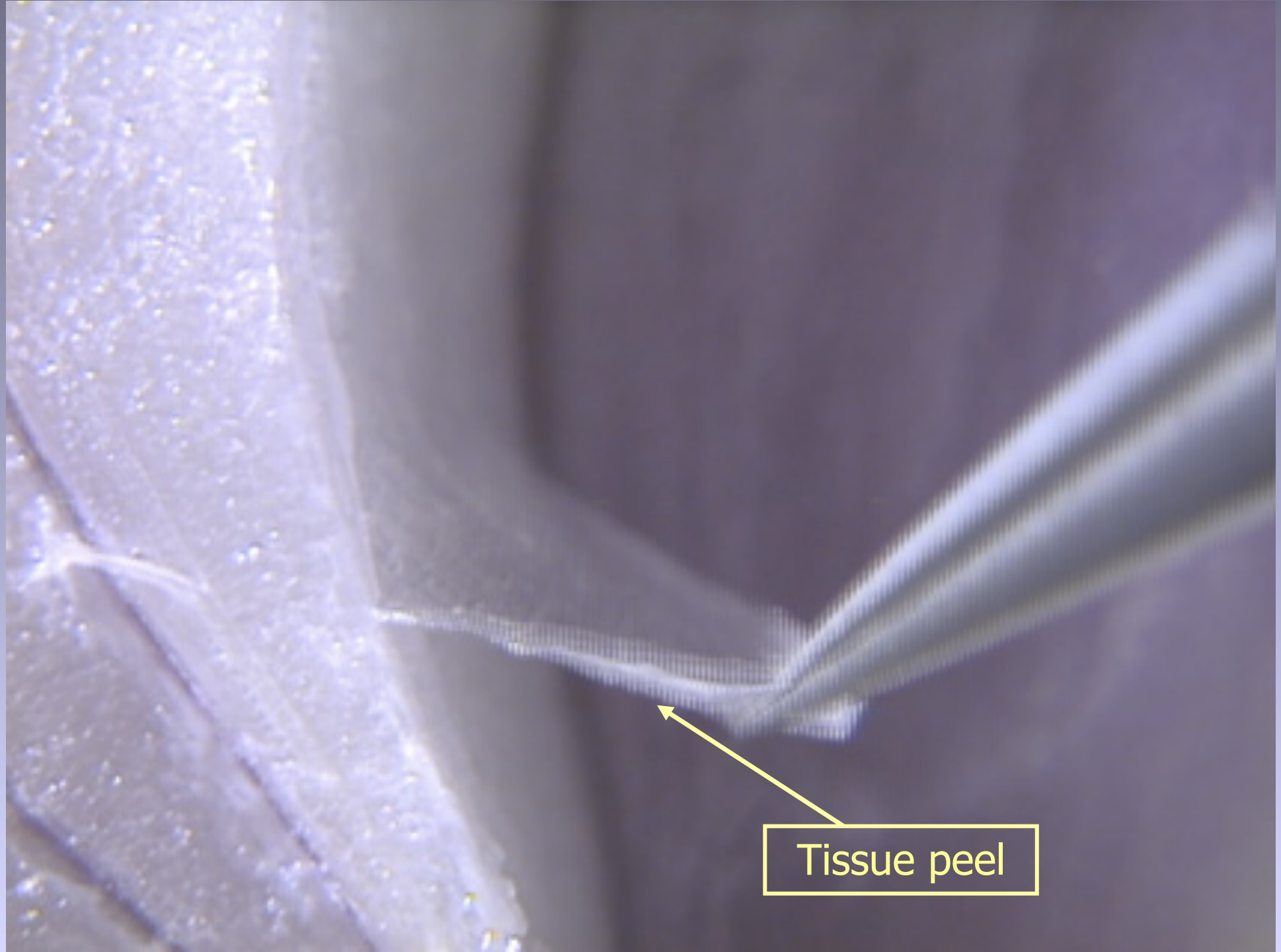
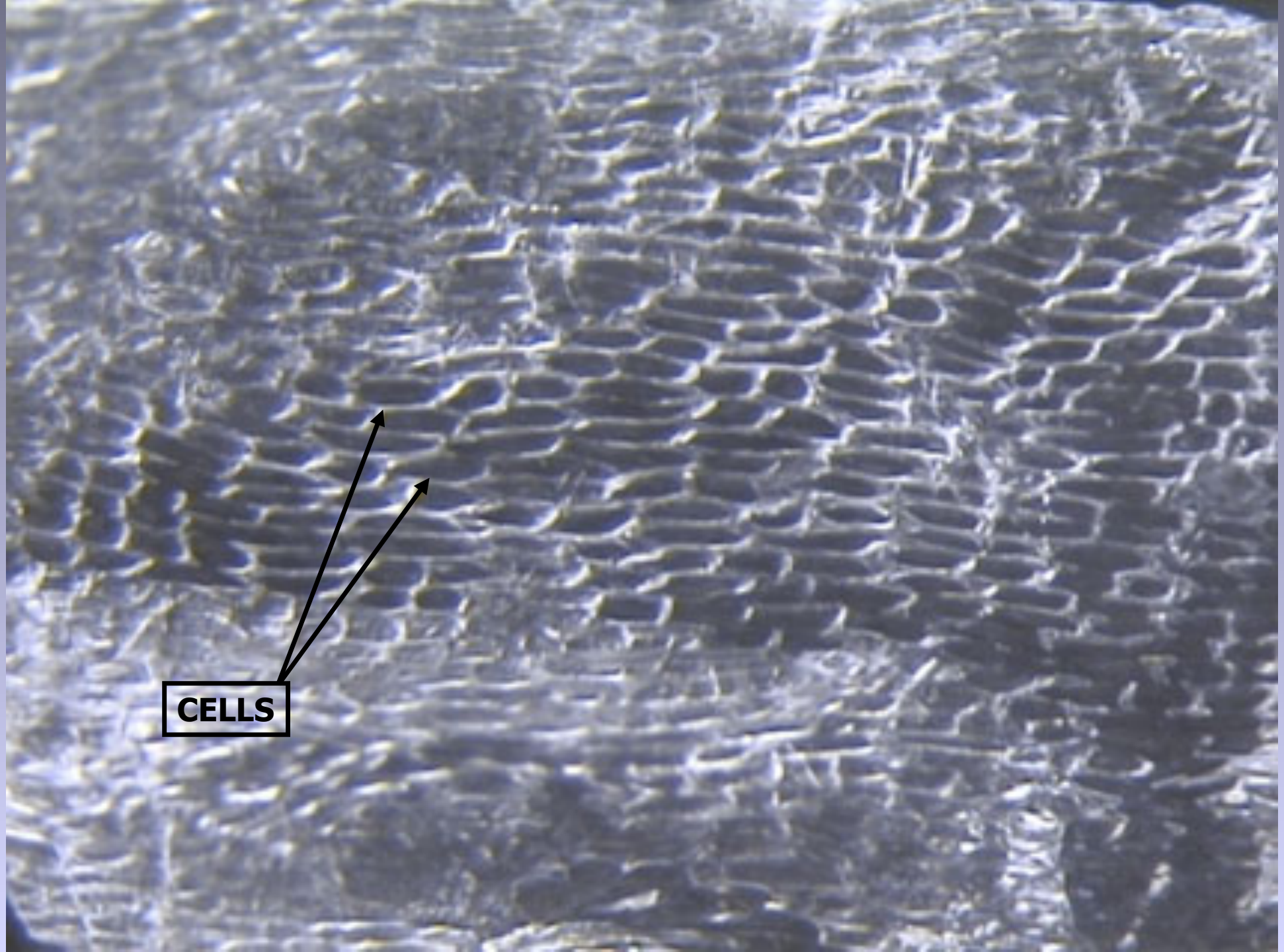
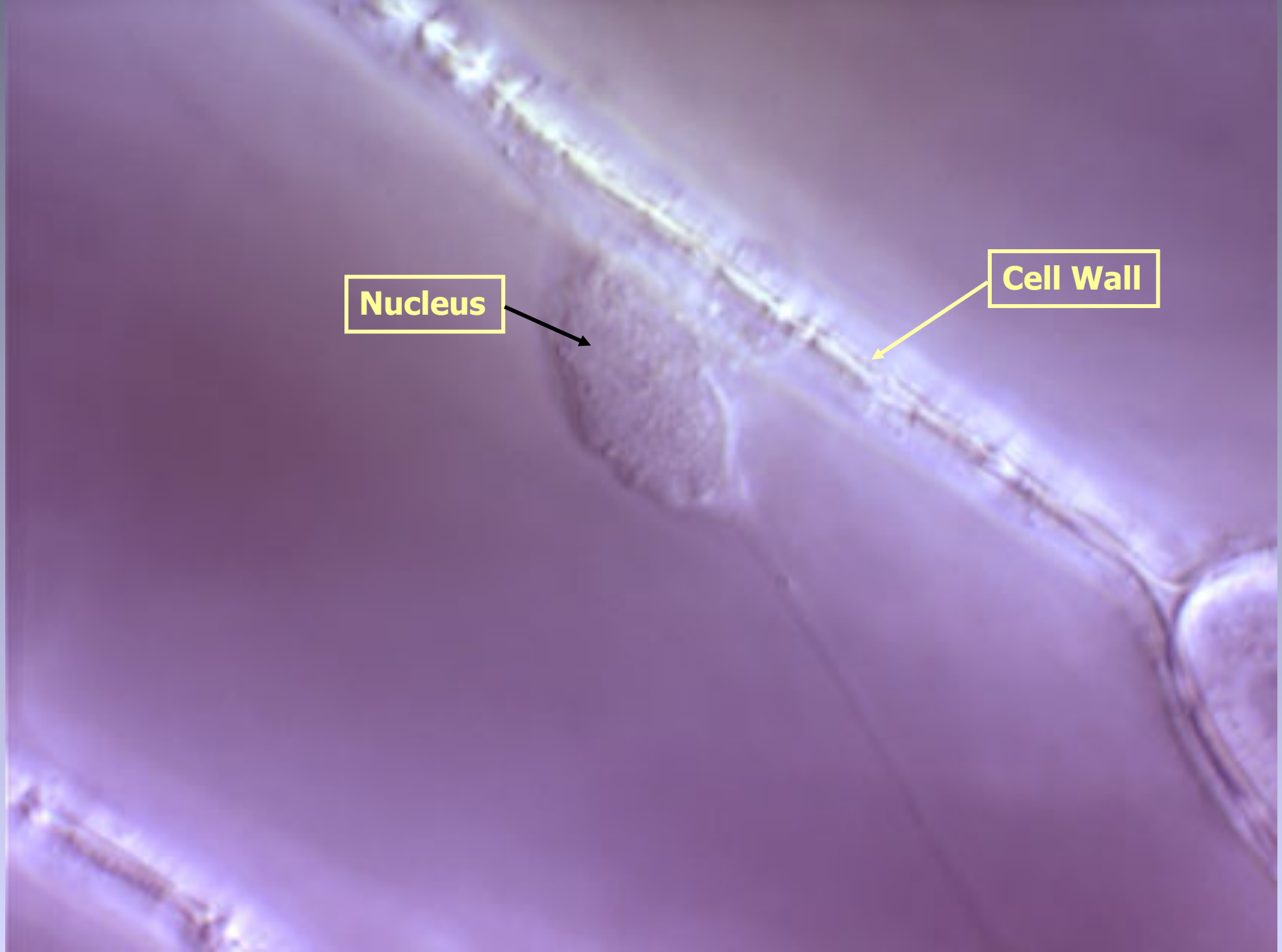
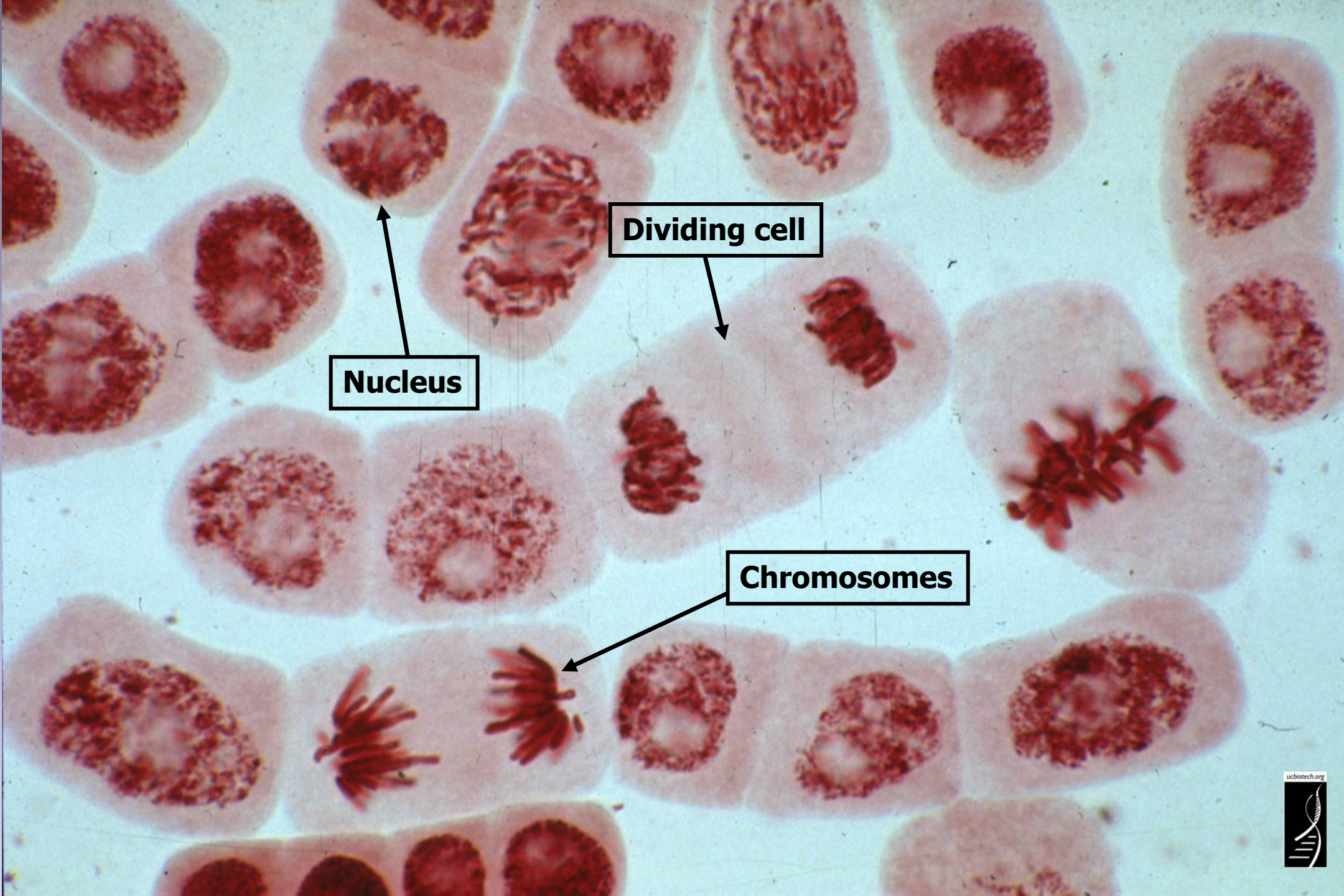

Tissue peel


CELLS


Nucleus
Cell Wall


Dividing cell
Nucleus
Chromosomes
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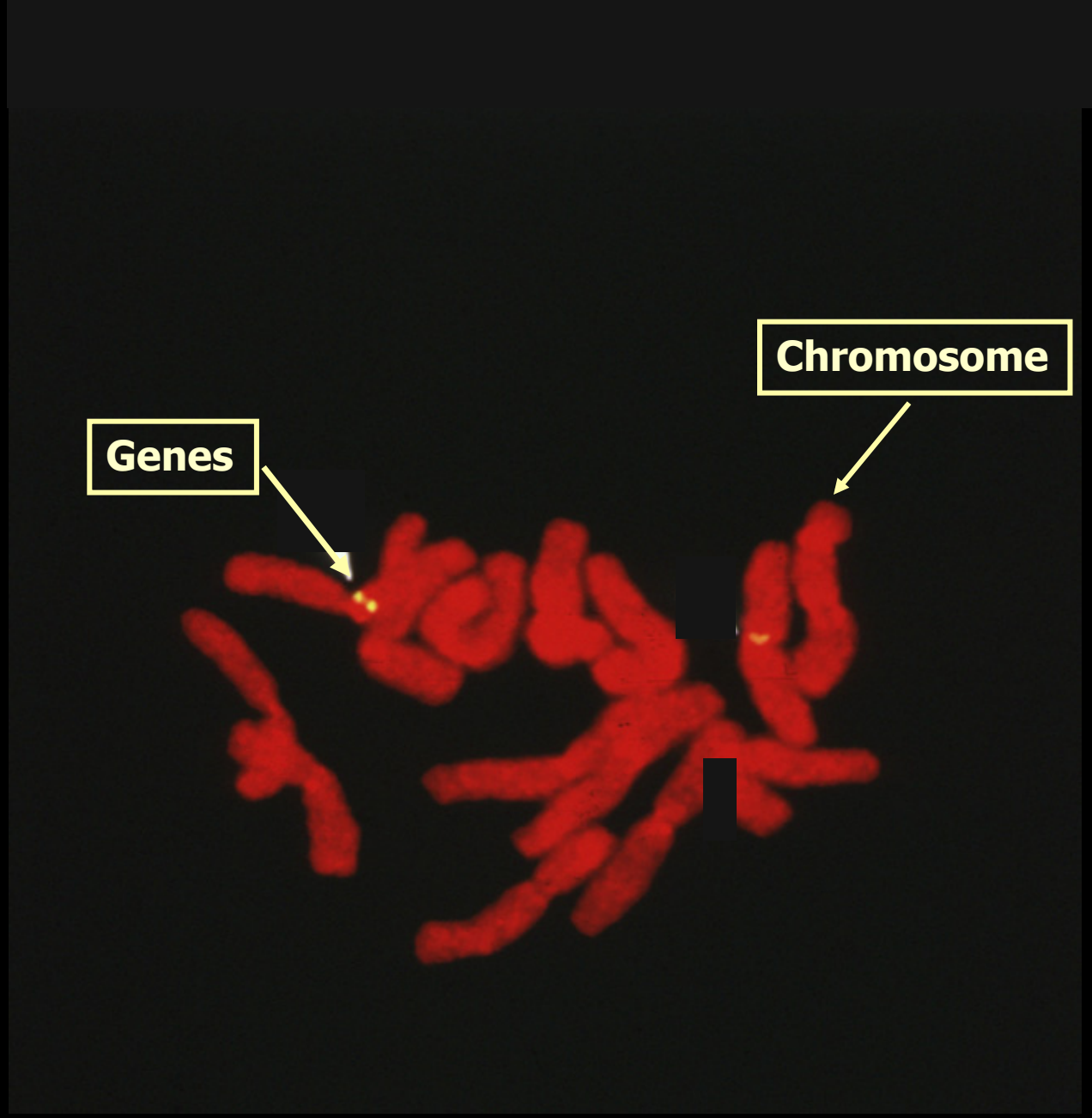

Chromosome
Genes

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

Triticum monococcum

Ancient variety

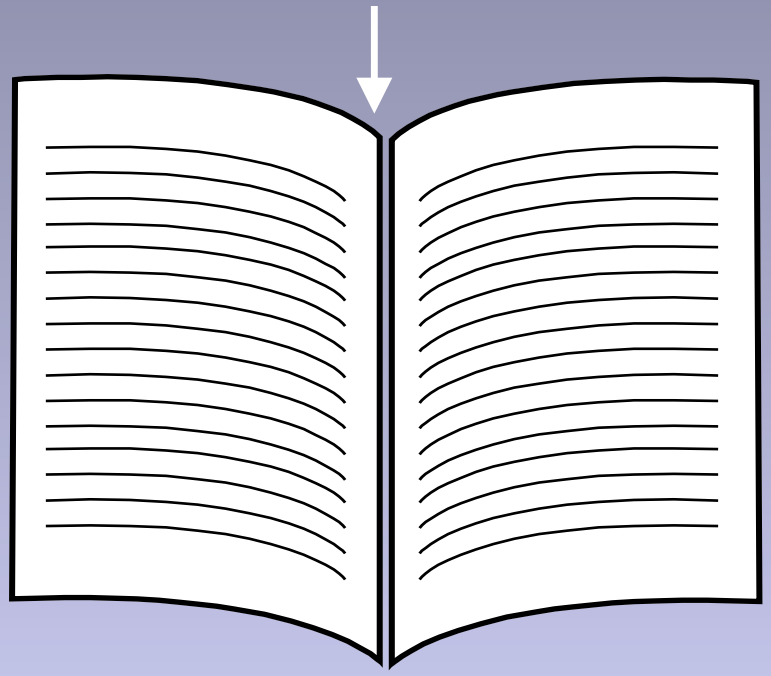
Triticum aestivum

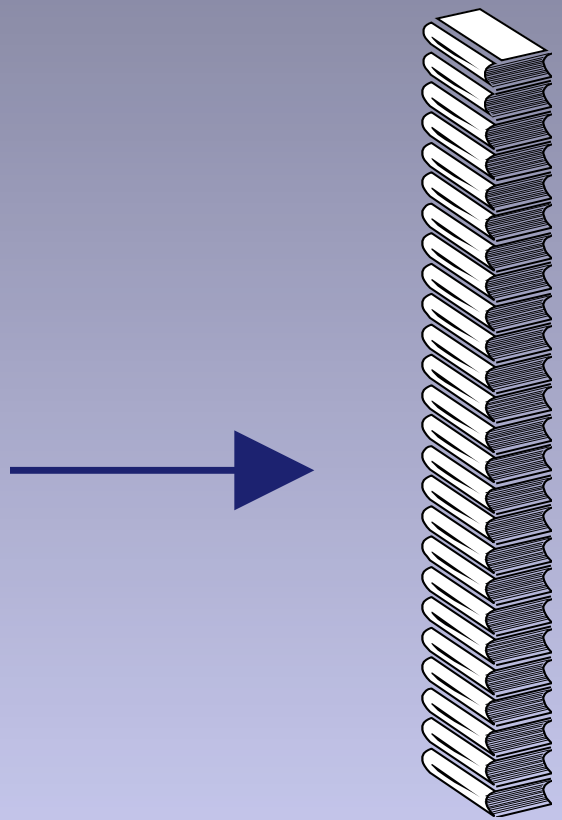
Modern bread variety

Information in the wheat genome

Chemical units represented by alphabetic letters

...CTGACCTAATGCCGTA...

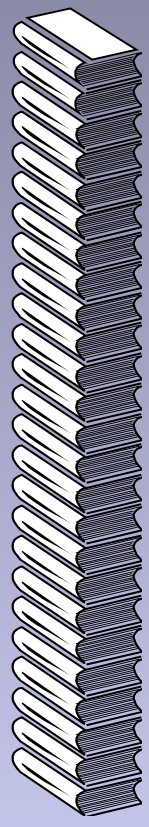




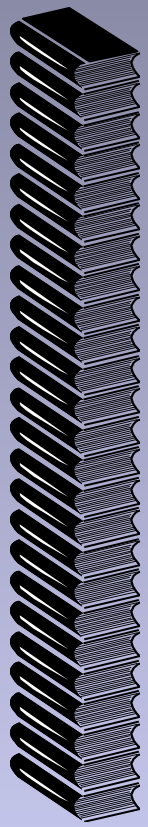
1700 books
1000 pages each

1700 books
(or 1.7 million pages)

Hybridization or cross breeding of wheat



X

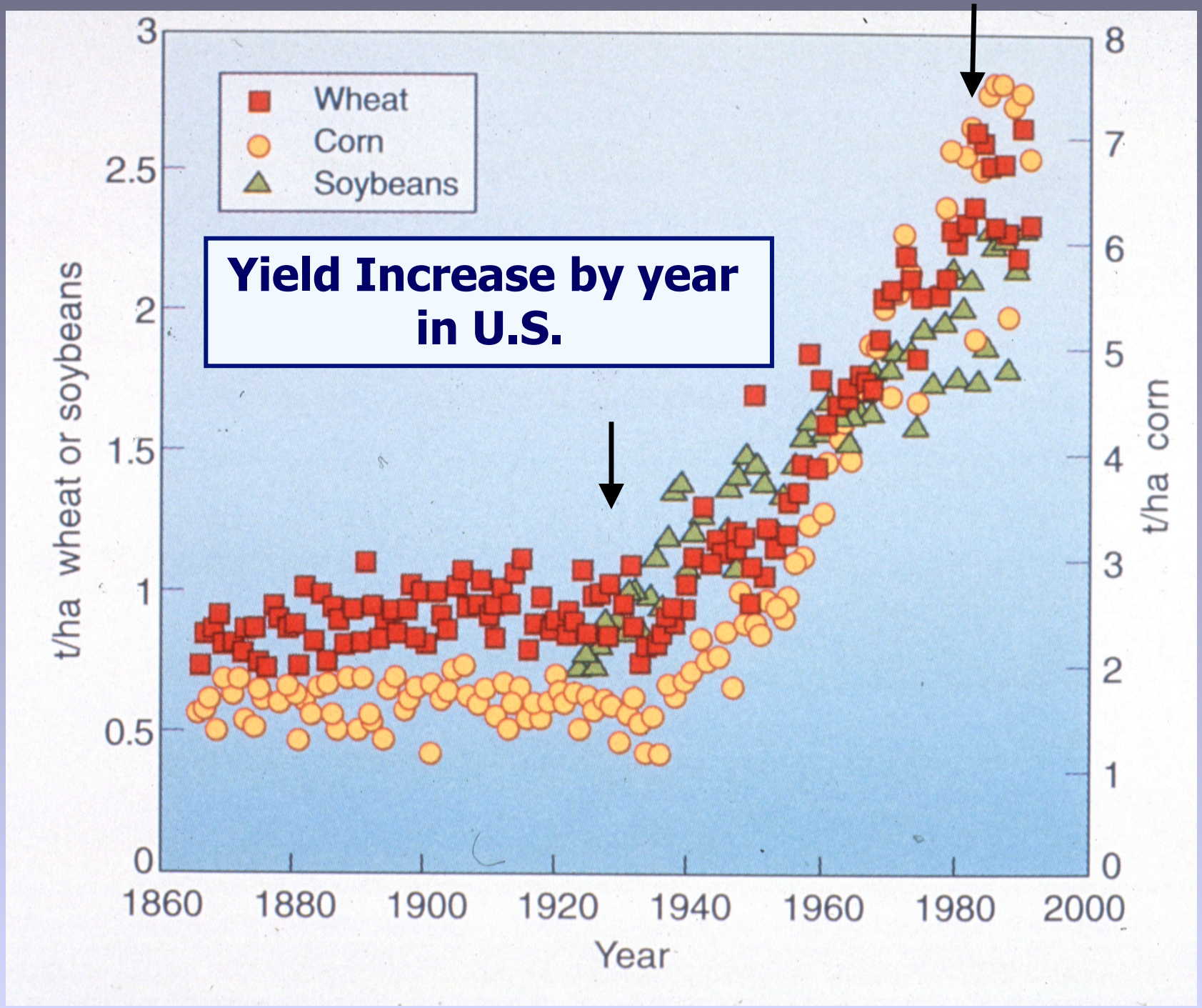


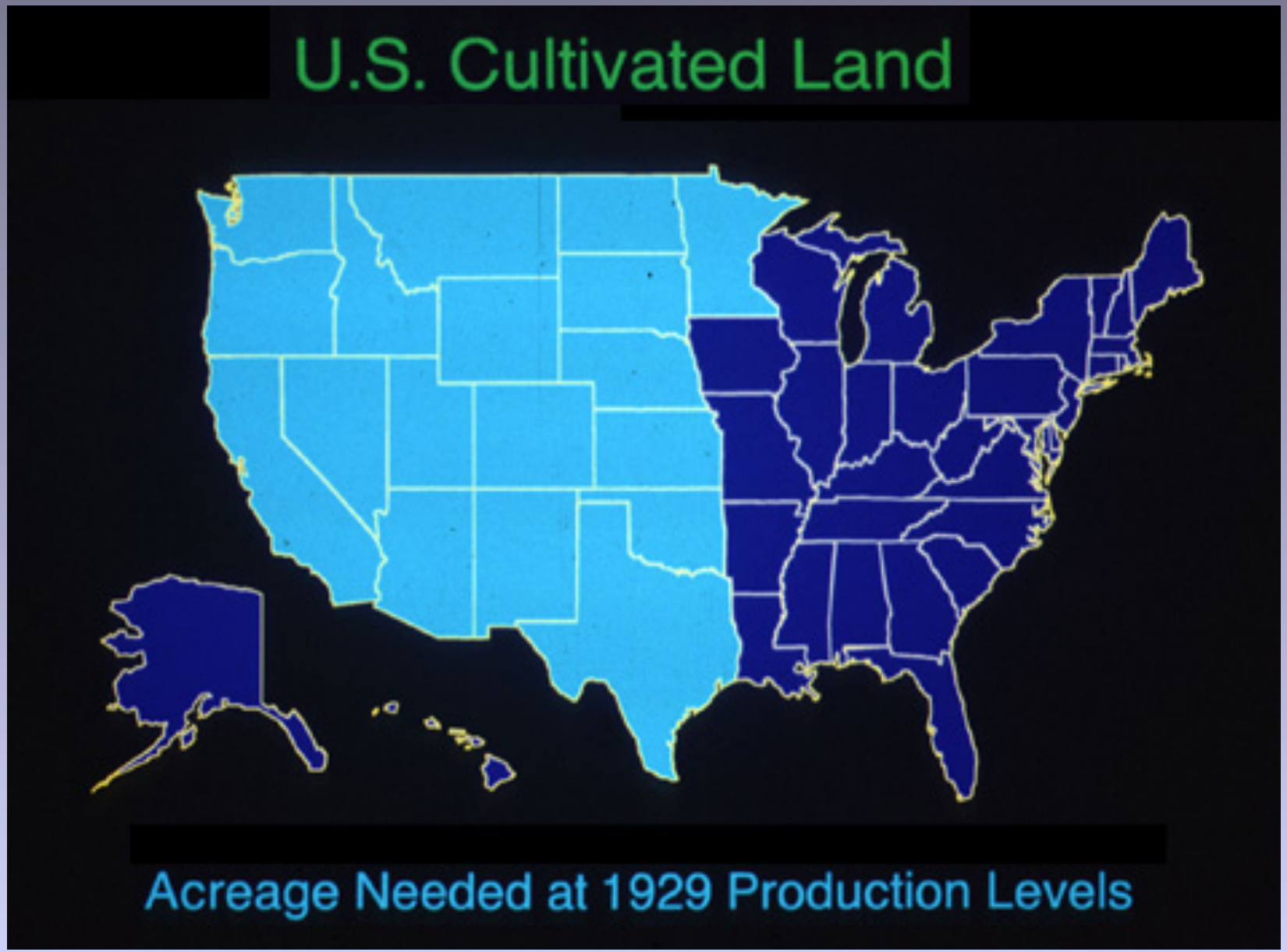
Random retention of information from each parent

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)

1700 books
(or 1.7 million pages)


Wheat
Corn
Soybeans
Yield Increase by year in U.S.
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



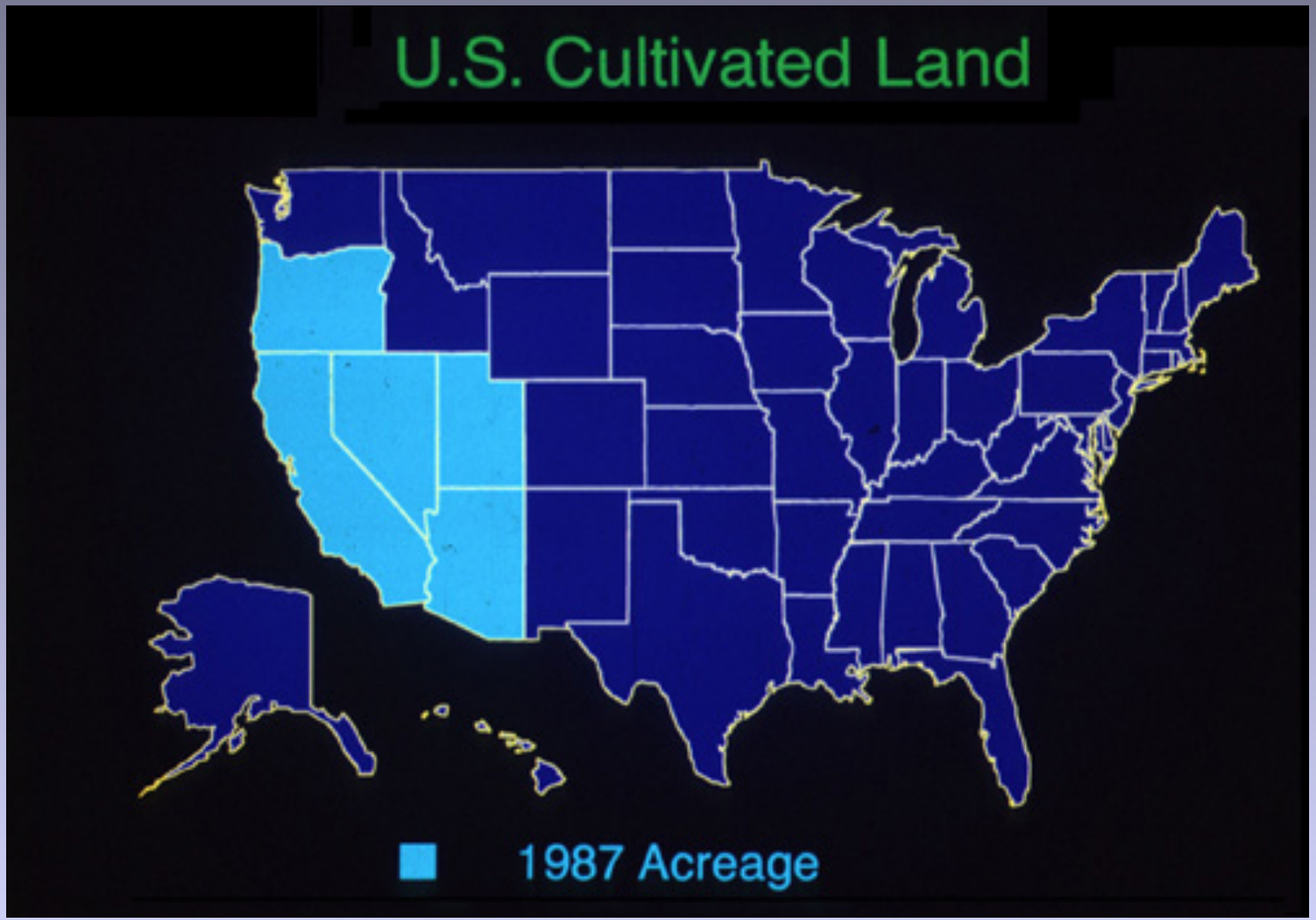
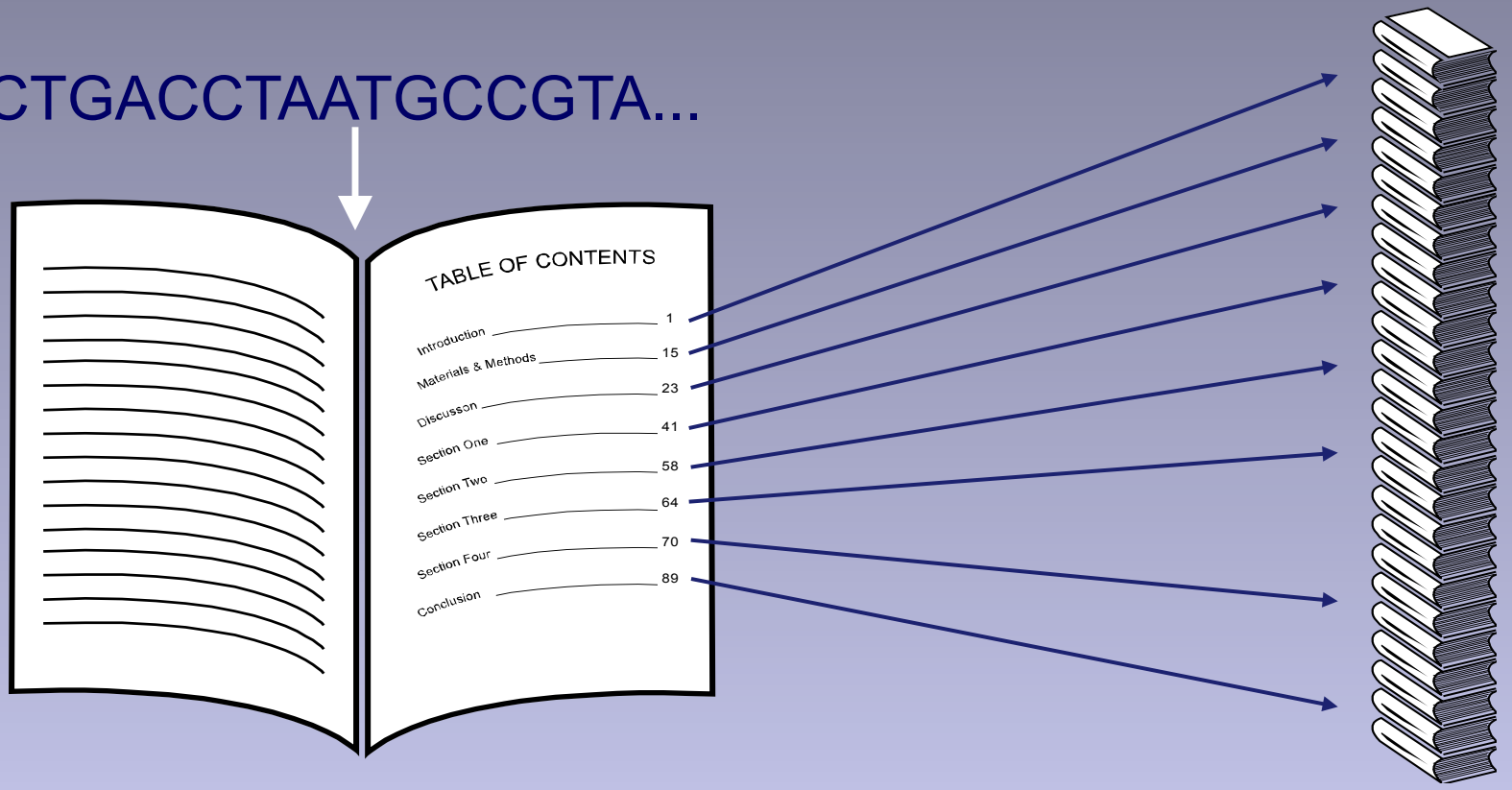


Table of contents for genes in wheat

...CTGACCTAATGCCGTA...



Genomics

Used for Marker-Assisted Selection

1700 books (or 1.7 million pages)

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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


But there are other ways to create new varieties using the modern tools of genetics
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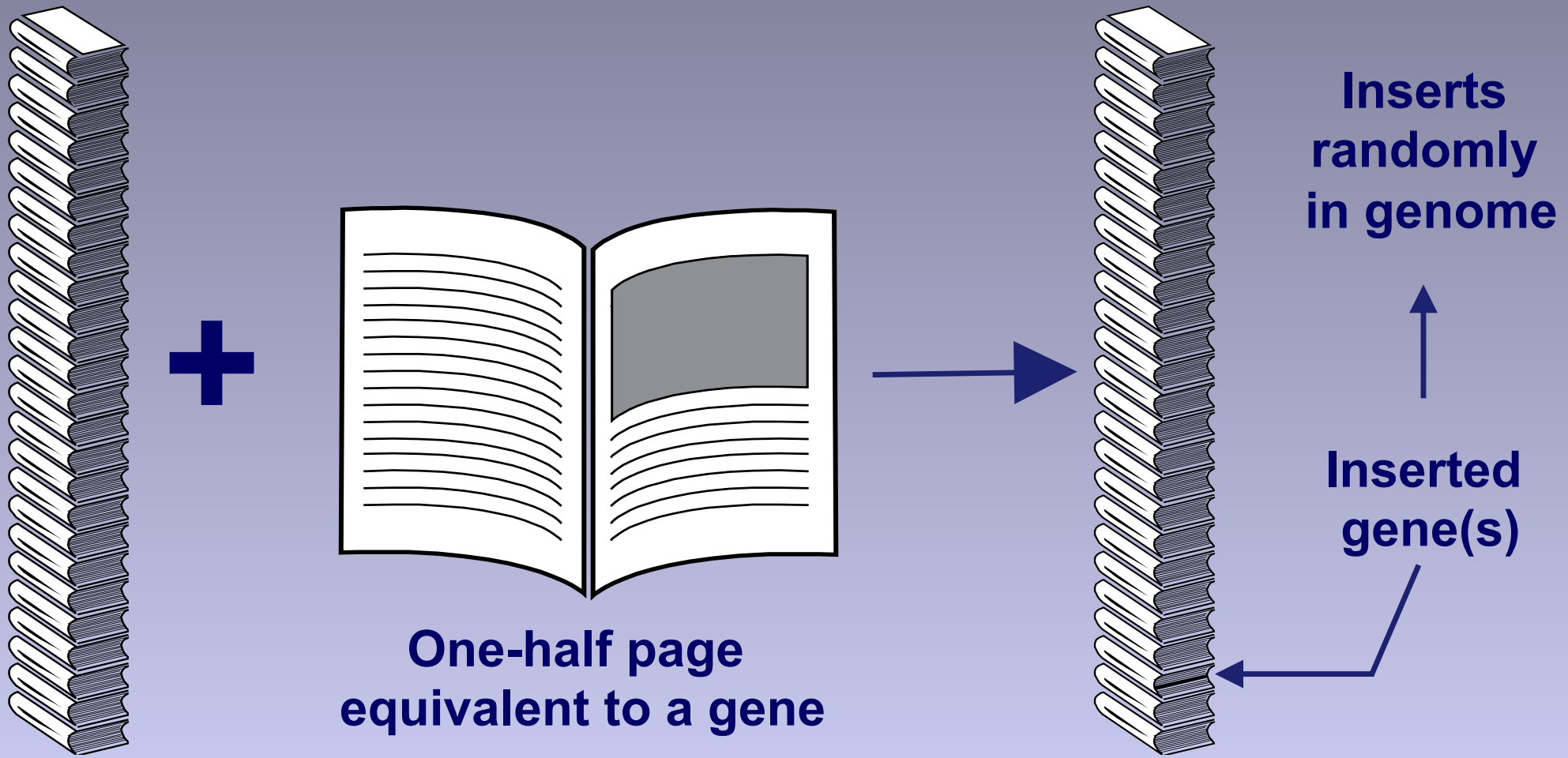
Genetic Engineering Methods

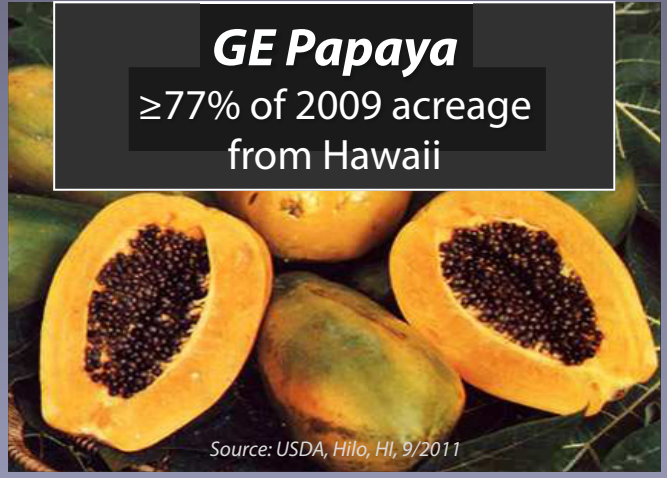


Classical Breeding compared to *Genetic Engineering*

Classical Breeding	*Genetic Engineering*
Uses plant machinery in plant	Uses plant machinery in laboratory
Gene exchange is random involving whole genome	Gene exchange is specific involving single or few genes
When/where gene expressed not controlled by breeder	When/where gene expressed controlled precisely
Source of gene primarily within genera – not between kingdoms like plants & bacteria	Source of gene from any organism

GE Papaya

≥77% of 2009 acreage from Hawaii



Source: USDA, Hilo, HI, 9/2011

GE Squash

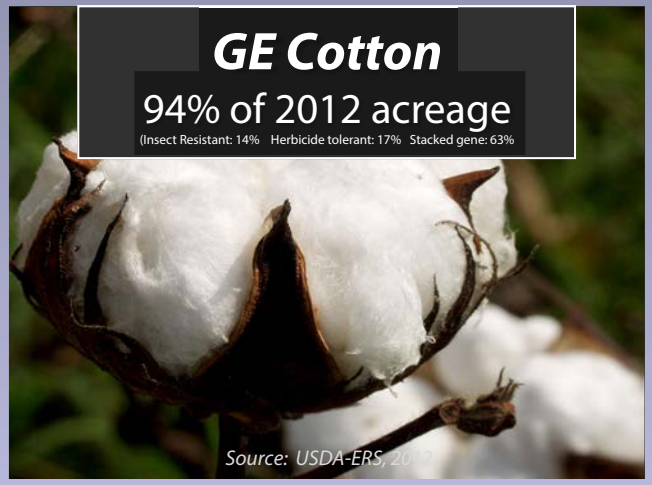
10% of 2004 acreage

Source: ISAAA, 2004

GE Cotton

94% of 2012 acreage

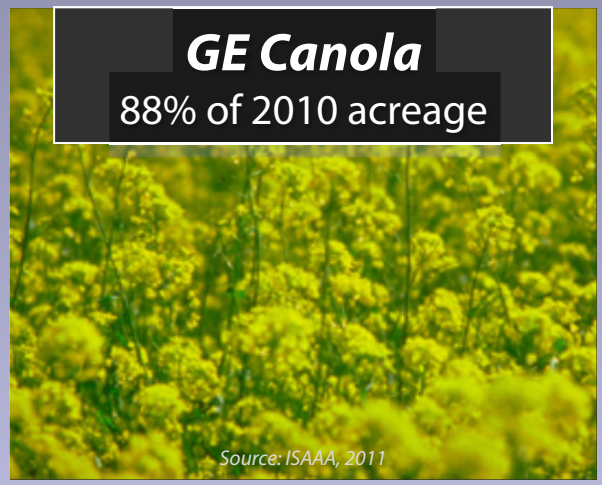
(Insect Resistant: 14% Herbicide tolerant: 17% Stacked gene: 63%



Source: USDA-ERS, 2012

GE Canola

88% of 2010 acreage

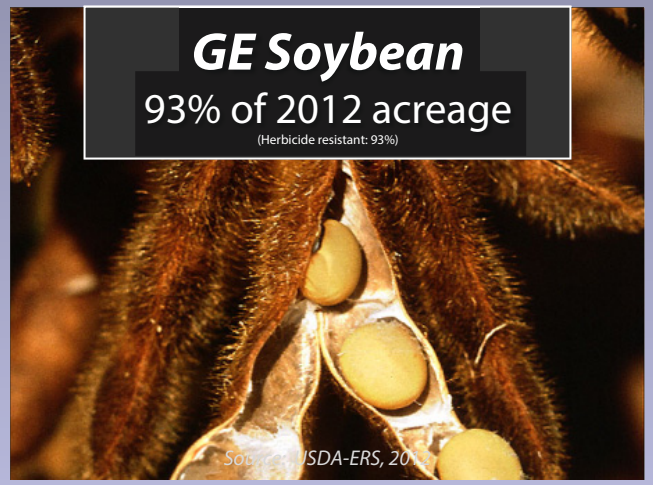


Source: ISAAA, 2011

GE Soybean

93% of 2012 acreage

(Herbicide resistant: 93%)

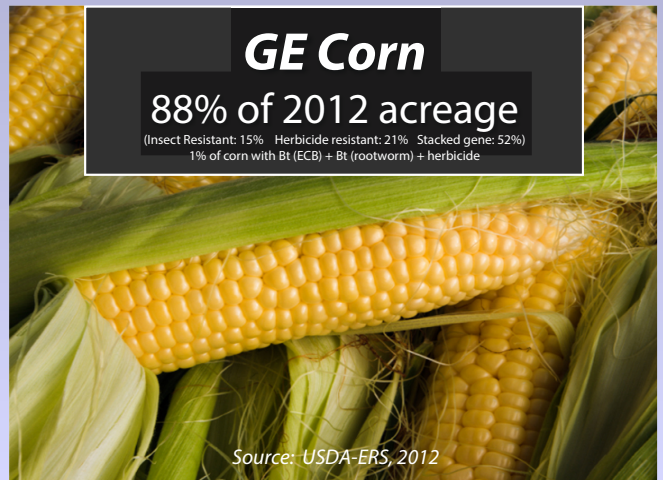


Source: USDA-ERS, 2012

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

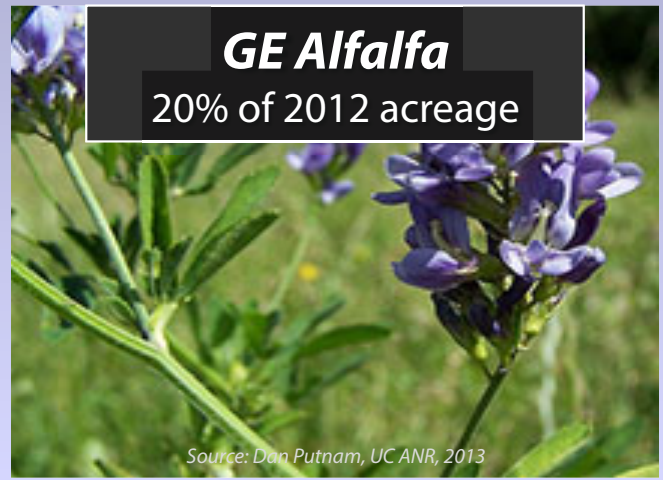
GE Sugarbeet

96% of 2010 acreage

Source: ISAAA, 2011

GE Alfalfa

20% of 2012 acreage



Source: Dan Putnam, UC ANR, 2013

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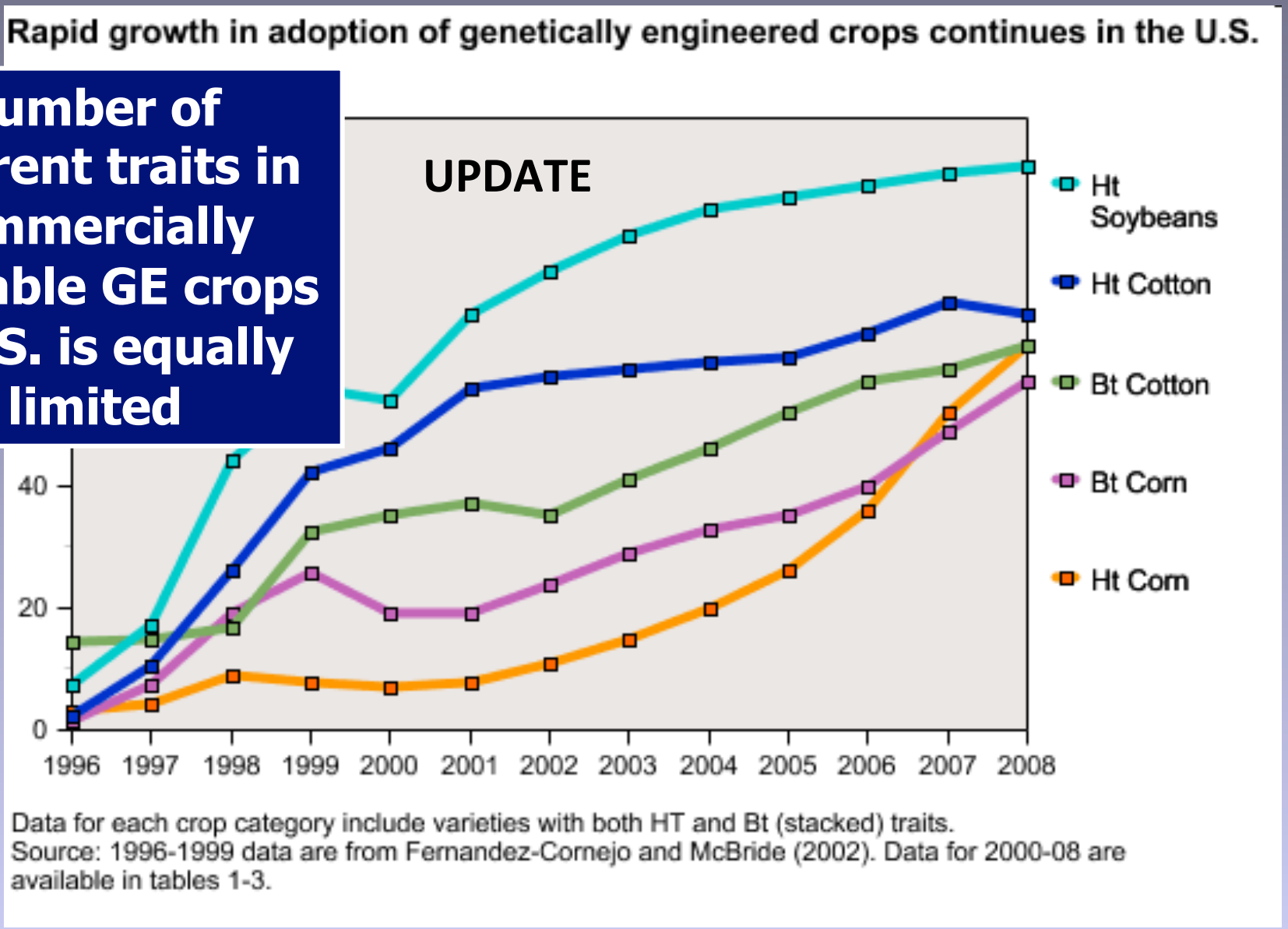
Types of GE Crops Leads To Estimates that 75% of Processed Foods in U.S. Have GE Ingredients

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



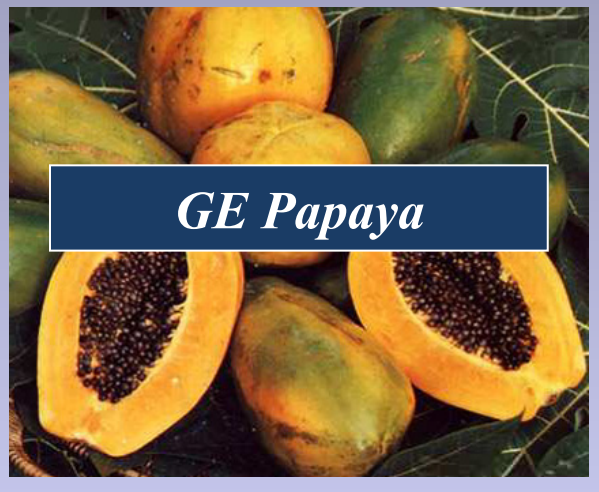
SOURCE: http://www.ers.usda.gov/Data/BiotechCrops/

Despite limited crop and trait types, worldwide acreage is increasing

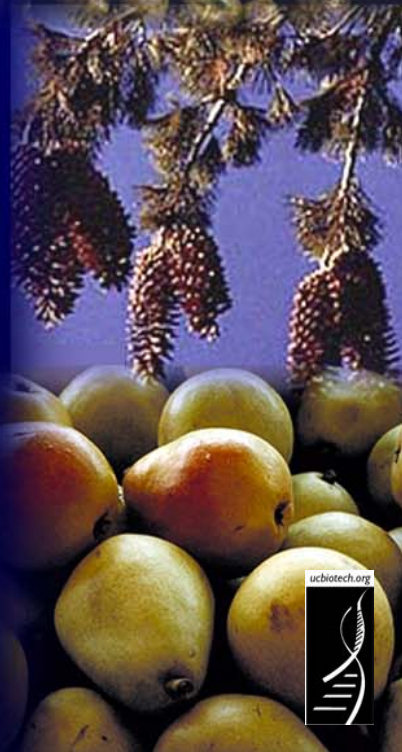
Total worldwide area cultivated = Areas of Texas + California + Colorado + Louisiana

Source: Clive James, 2011.

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



WHAT'S IN THE PIPELINE?



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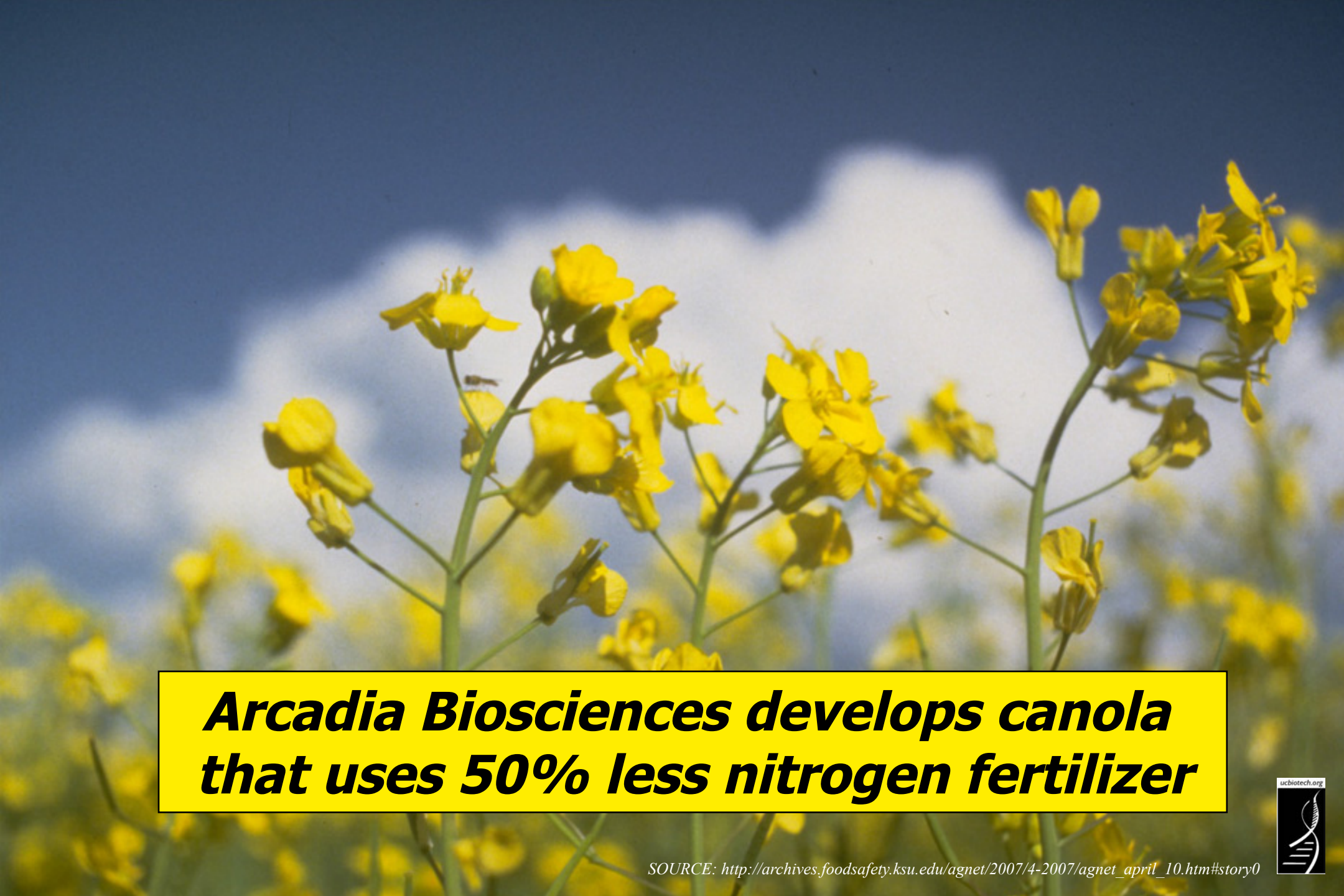
Field Trials Conducted in California with Grape Root Stocks Engineered for Resistance to Fanleaf Virus

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



SOURCE: http://archives.foodsafety.ksu.edu/agnet/2007/4-2007/agnet_april_10.htm#story0

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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.

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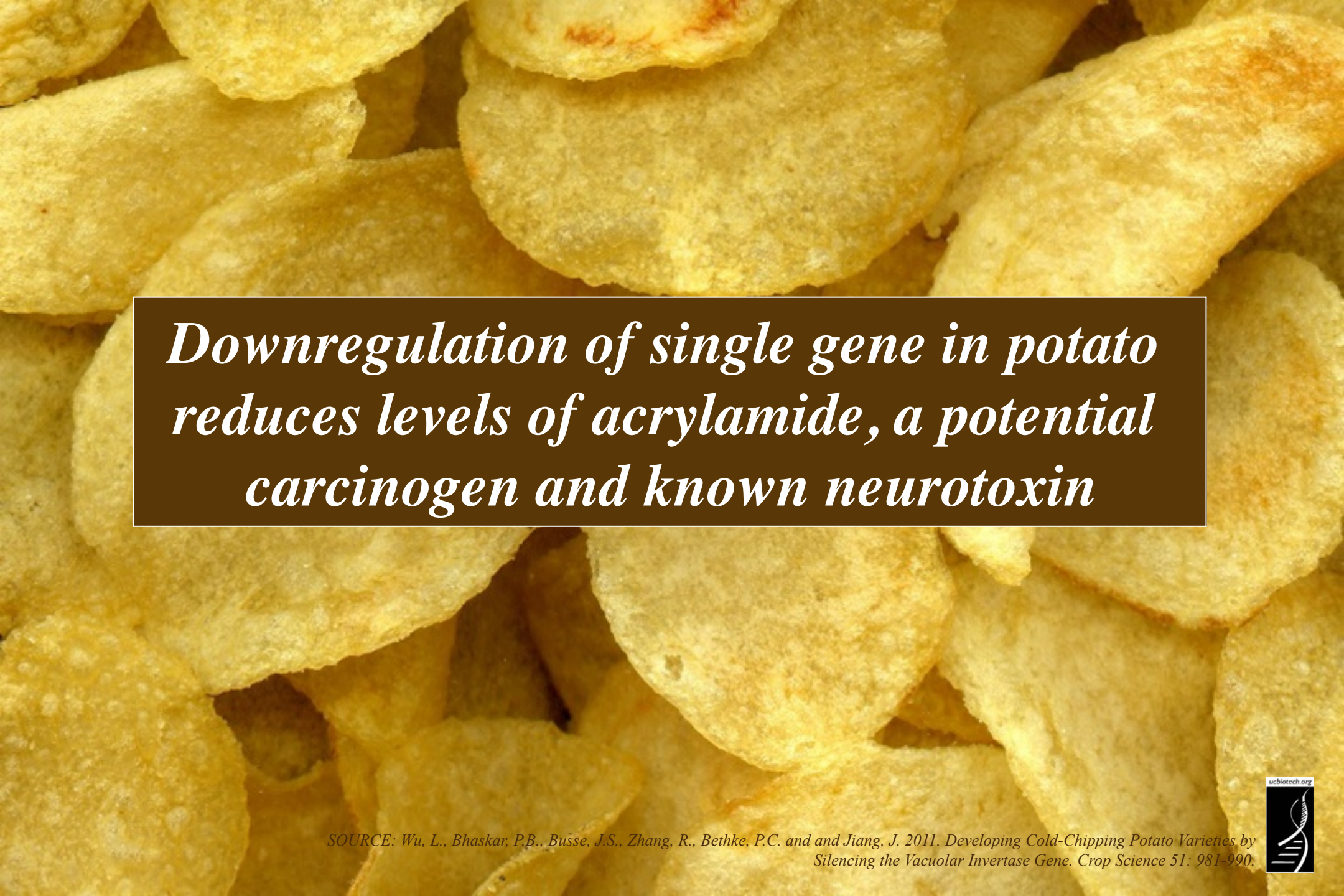

SOURCE: Wu, L., Bhaskar, P.B., Busse, J.S., Zhang, R., Bethke, P.C. and and Jiang, J. 2011. Developing Cold-Chipping Potato Varieties by Silencing the Vacuolar Invertase Gene. Crop Science 51: 981-990.

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

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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

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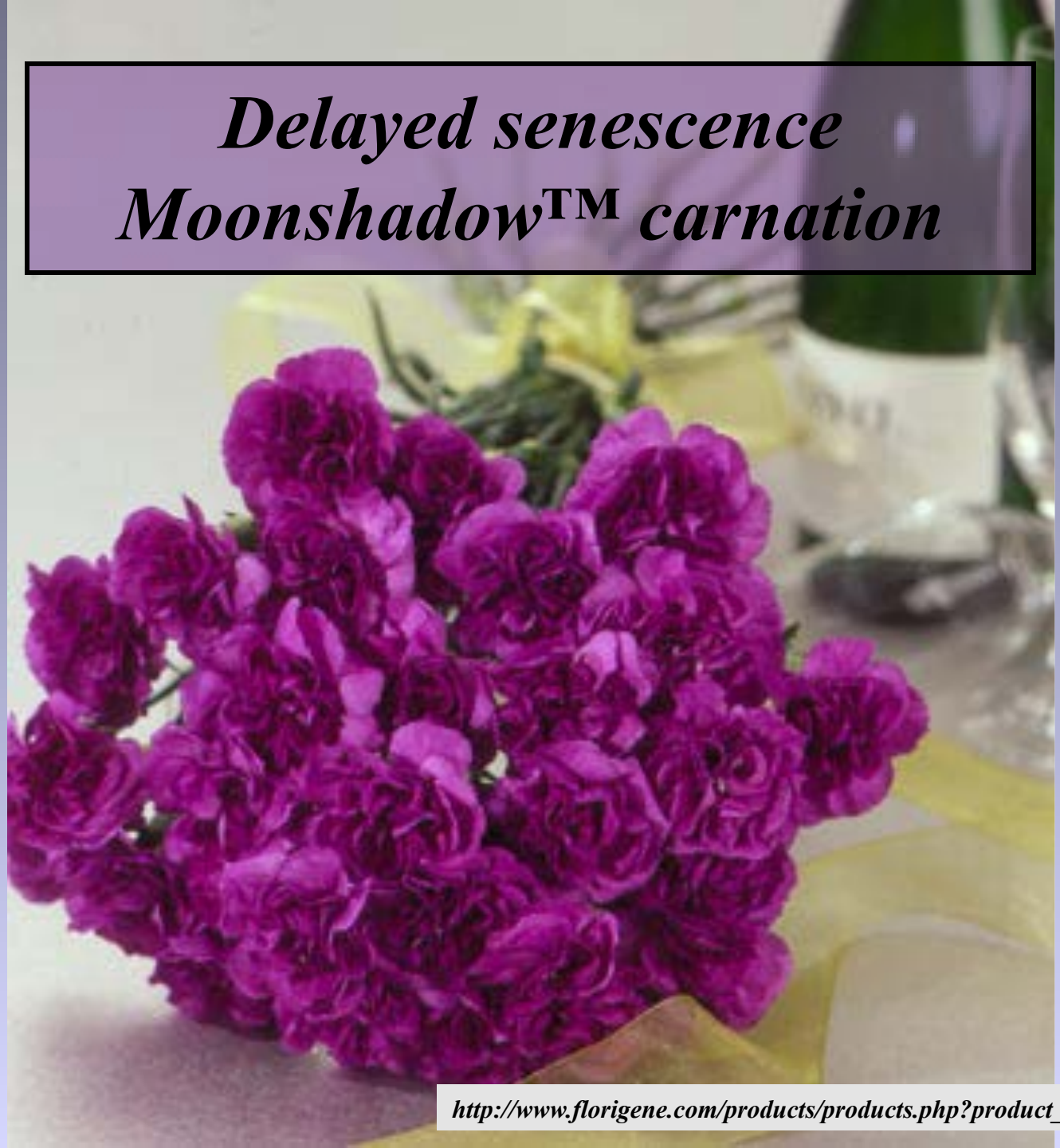
Engineered Pea Seeds Protect Chickens against Parasitic Coccidiosis

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 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

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

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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)

What Are Some of the Issues?

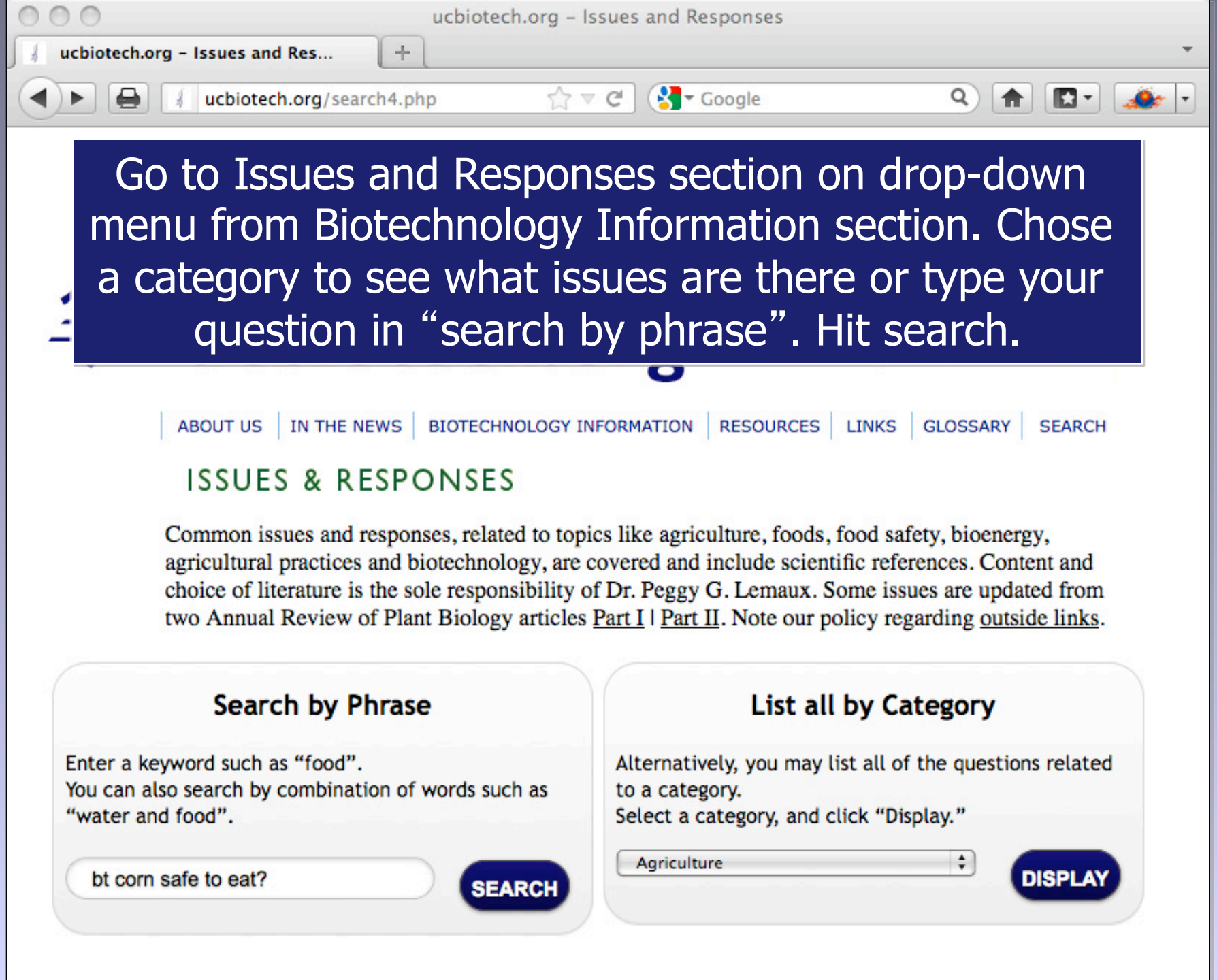
First, what are some food safety issues?

- 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

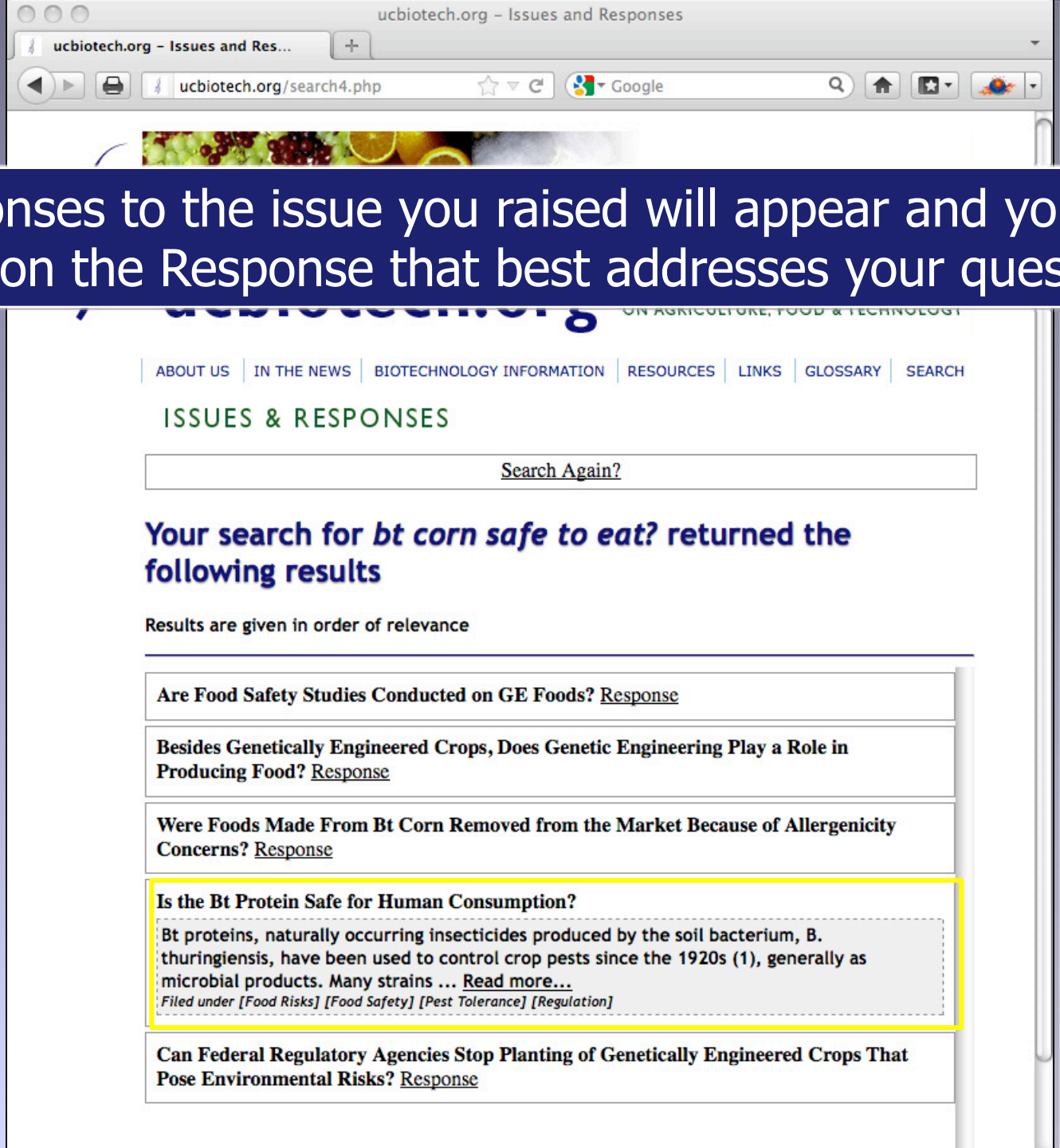
Now to some environmental issues?

- 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)?

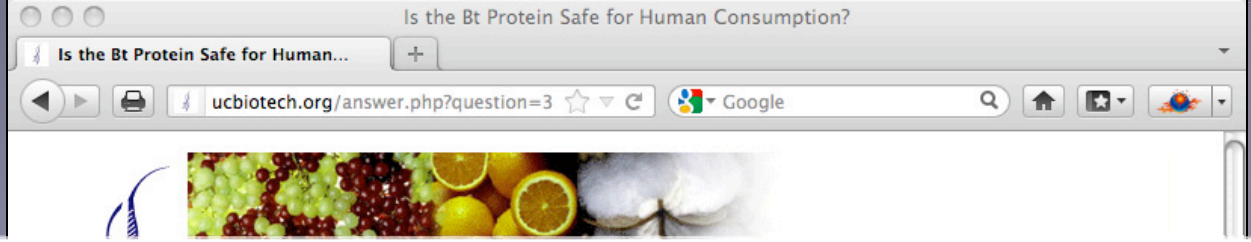
Want to ask questions? Follow these easy steps in Biotech information section of http://ucbiotech.org


ucbiotech.org – 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.
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 that best addresses your question.



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?

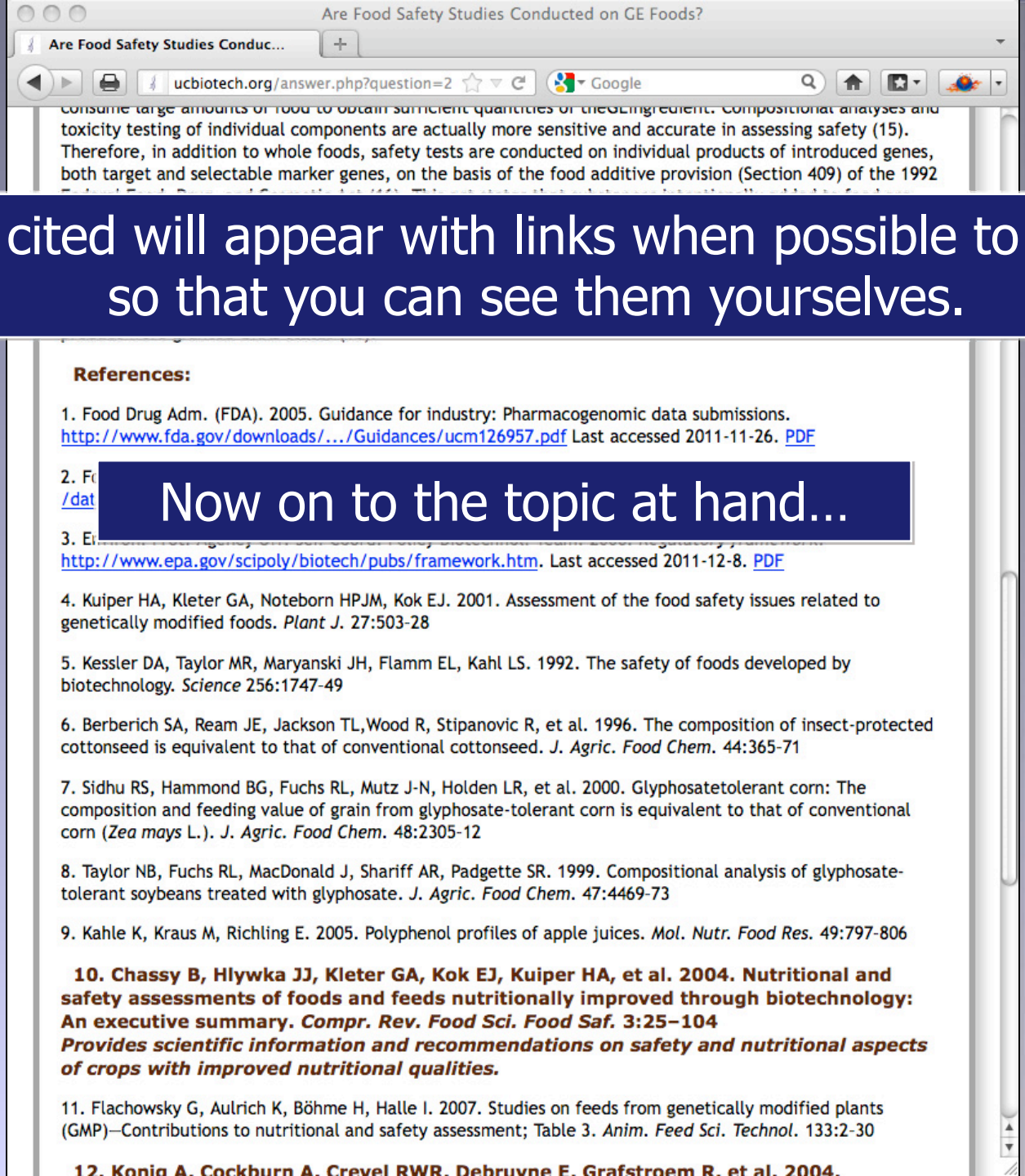
Response:

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.

Now on to the topic at hand…

Educational resources available on 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 Biotechnnology for Sustainability.

teaching tools

GENEie juice bar

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

afterschool curricula

DNA FOR DINNER?

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 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.

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

DNA FOR DINNER?

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.

BACKYARD mystery

Combined Lesson Leader Guide

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)
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.

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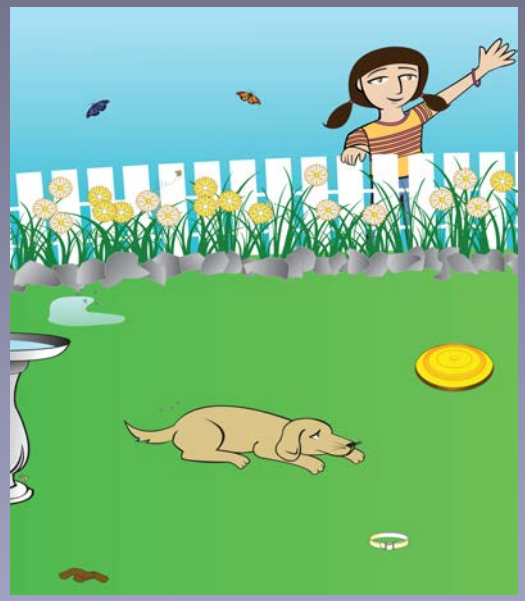
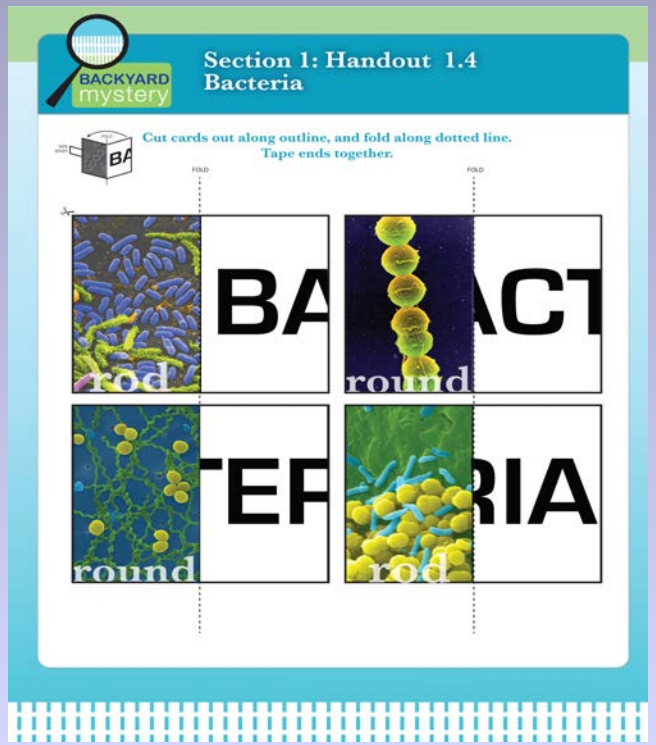
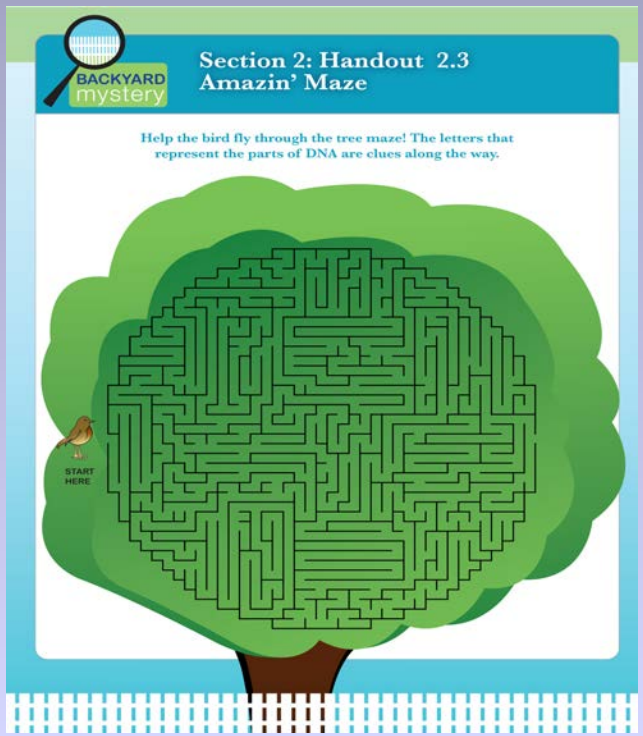
Middle school curriculum for 4-H and afterschool on diseases, detection and microbes





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



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!