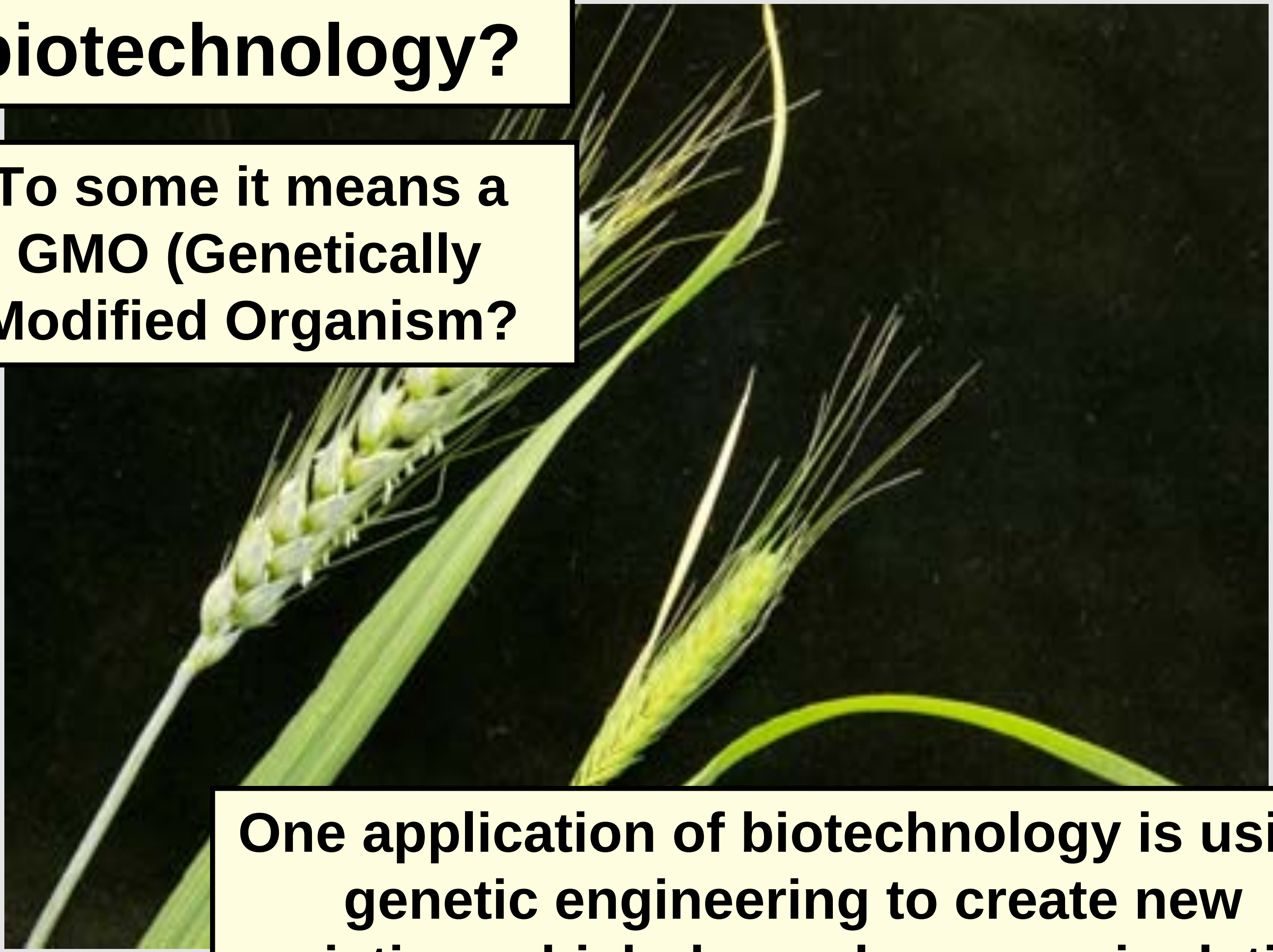
SCIENCE BEHIND BIOTECH IN AGRICULTURE

Resources for Teaching Ag Biotech

Peggy G. Lemaux
http:/ucbiotech.org
http://pmb.berkeley.edu/~lemaux

What is biotechnology?

To some it means a GMO (Genetically Modified Organism?



One application of biotechnology is using genetic engineering to create new varieties, which depends on manipulating the organism's DNA

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How have we created new varieties in the past ?

Classical breeding involves mixing DNA of female cells from one wheat variety with DNA from male cells of another…

Triticum aestivum *Triticum monococcum*

Modern bread variety **Ancient variety**

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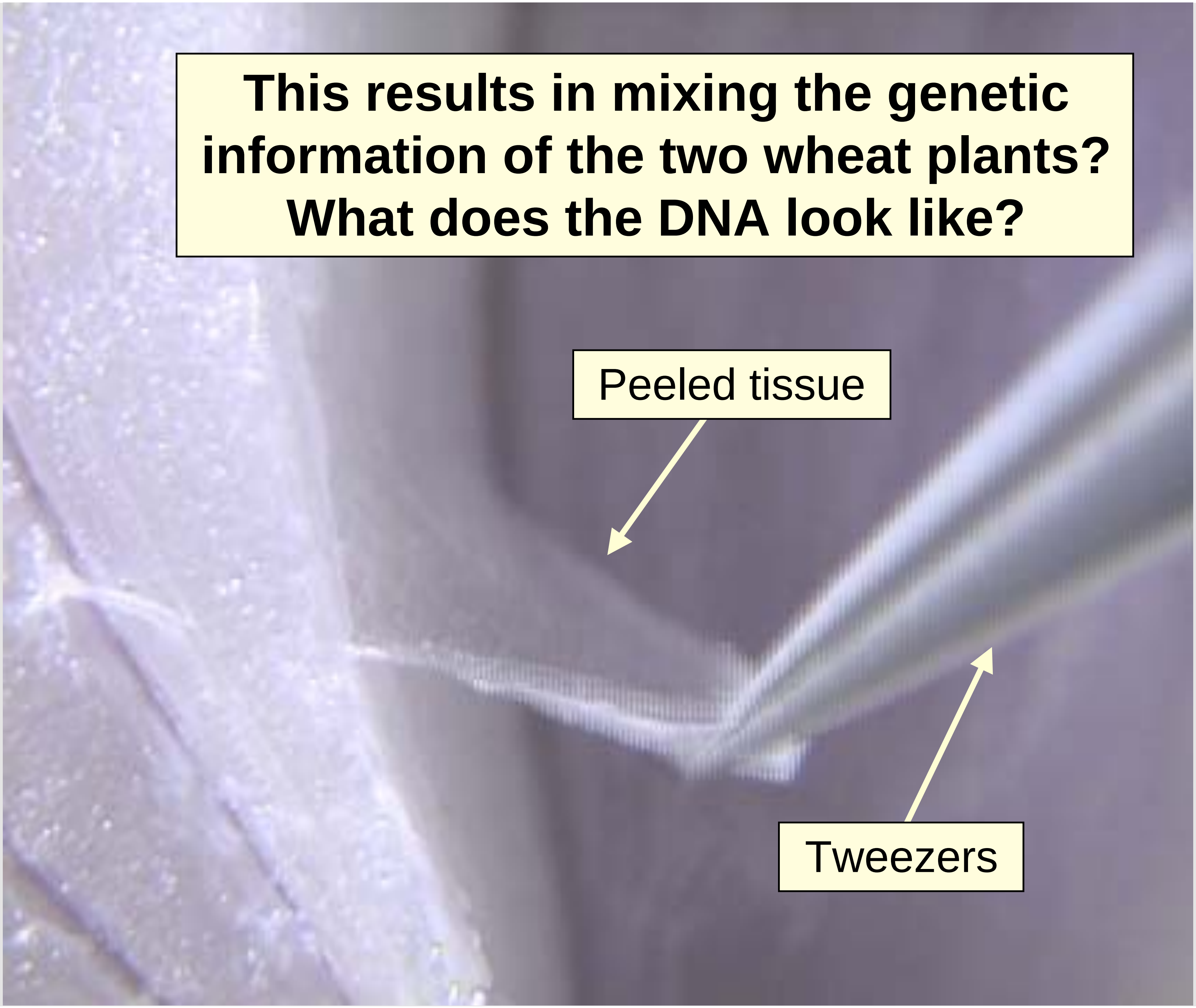
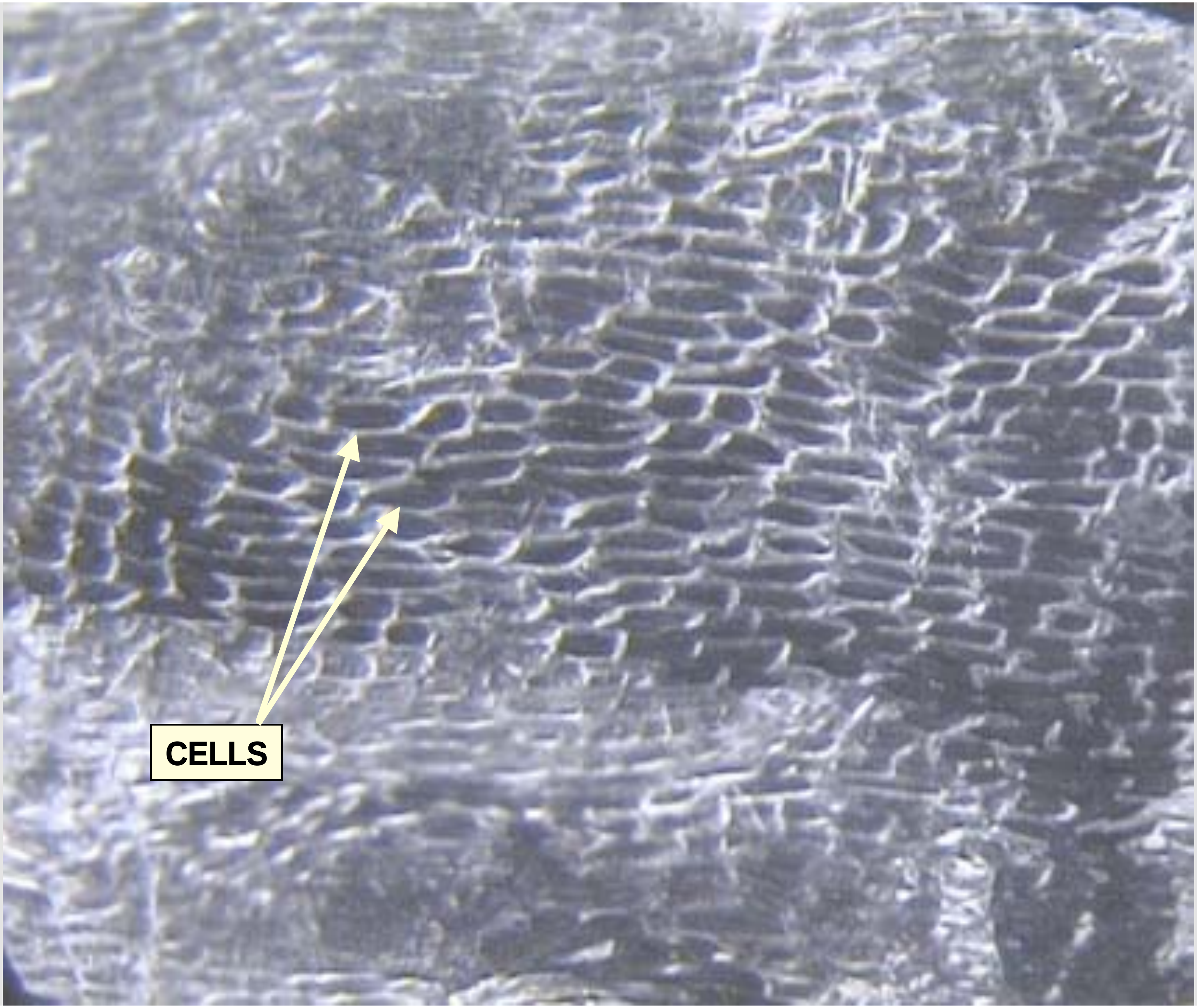
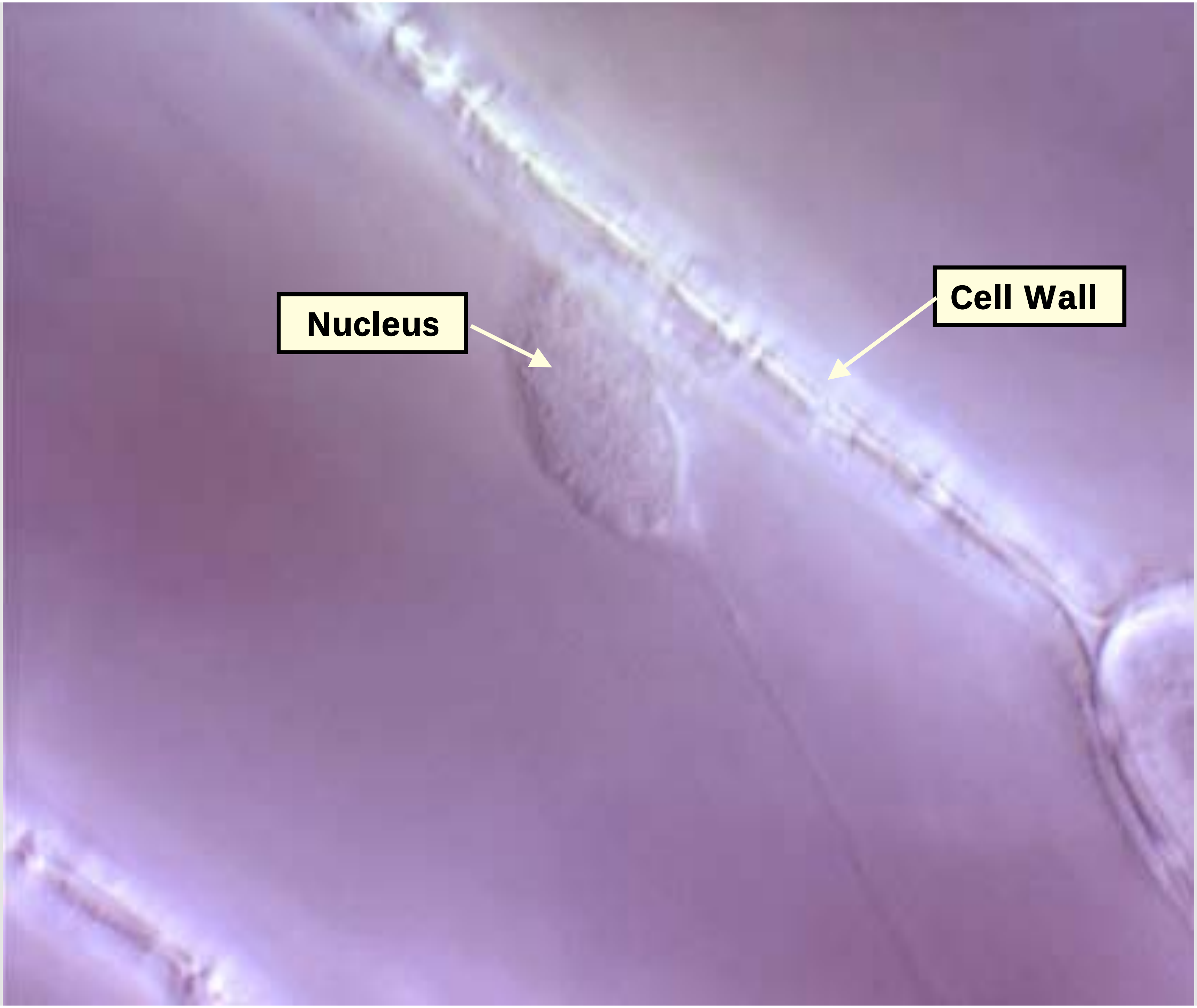
This results in mixing the genetic information of the two wheat plants? What does the DNA look like?




CELLS



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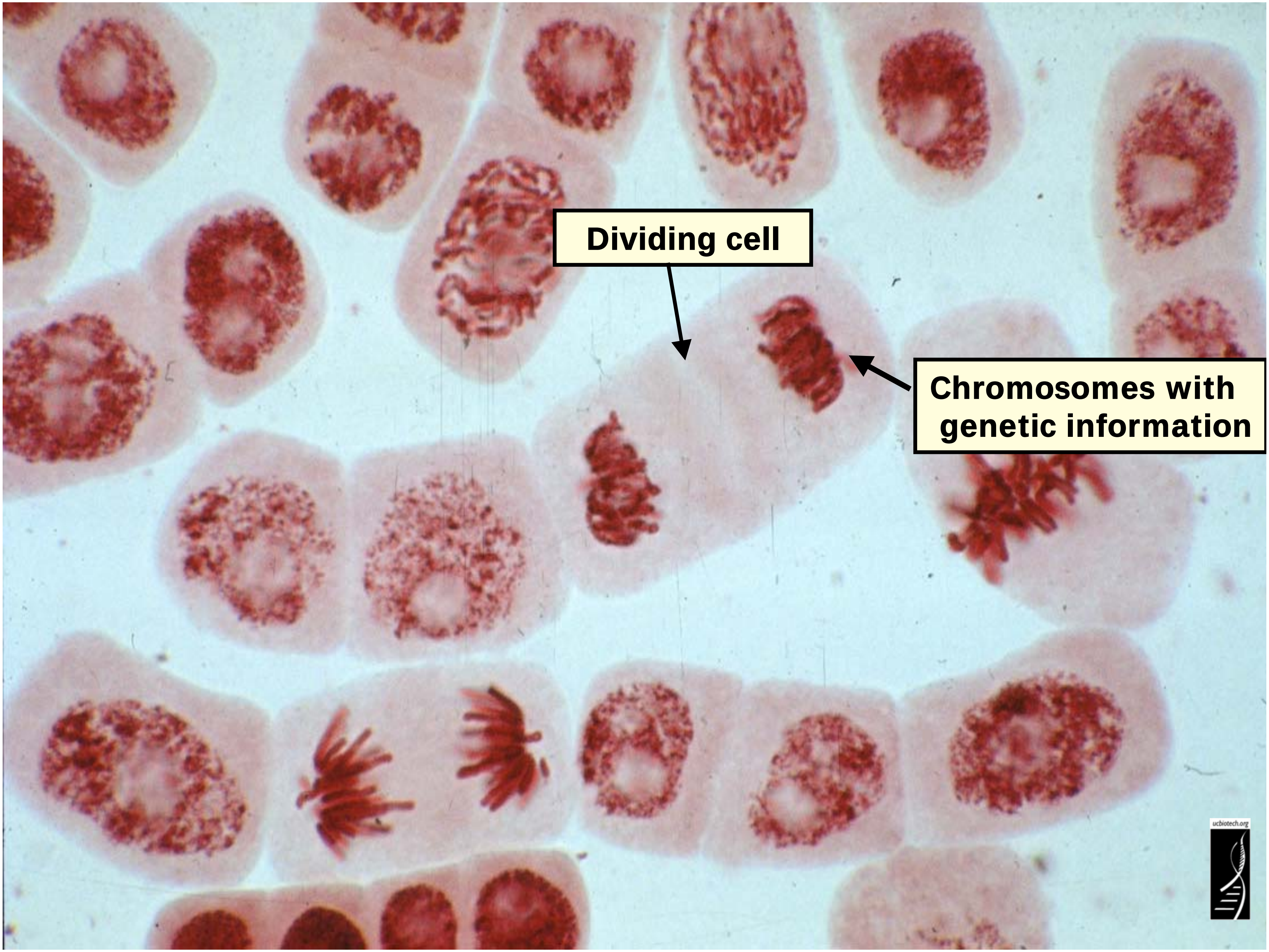
Dividing cell
Chromosomes with genetic information
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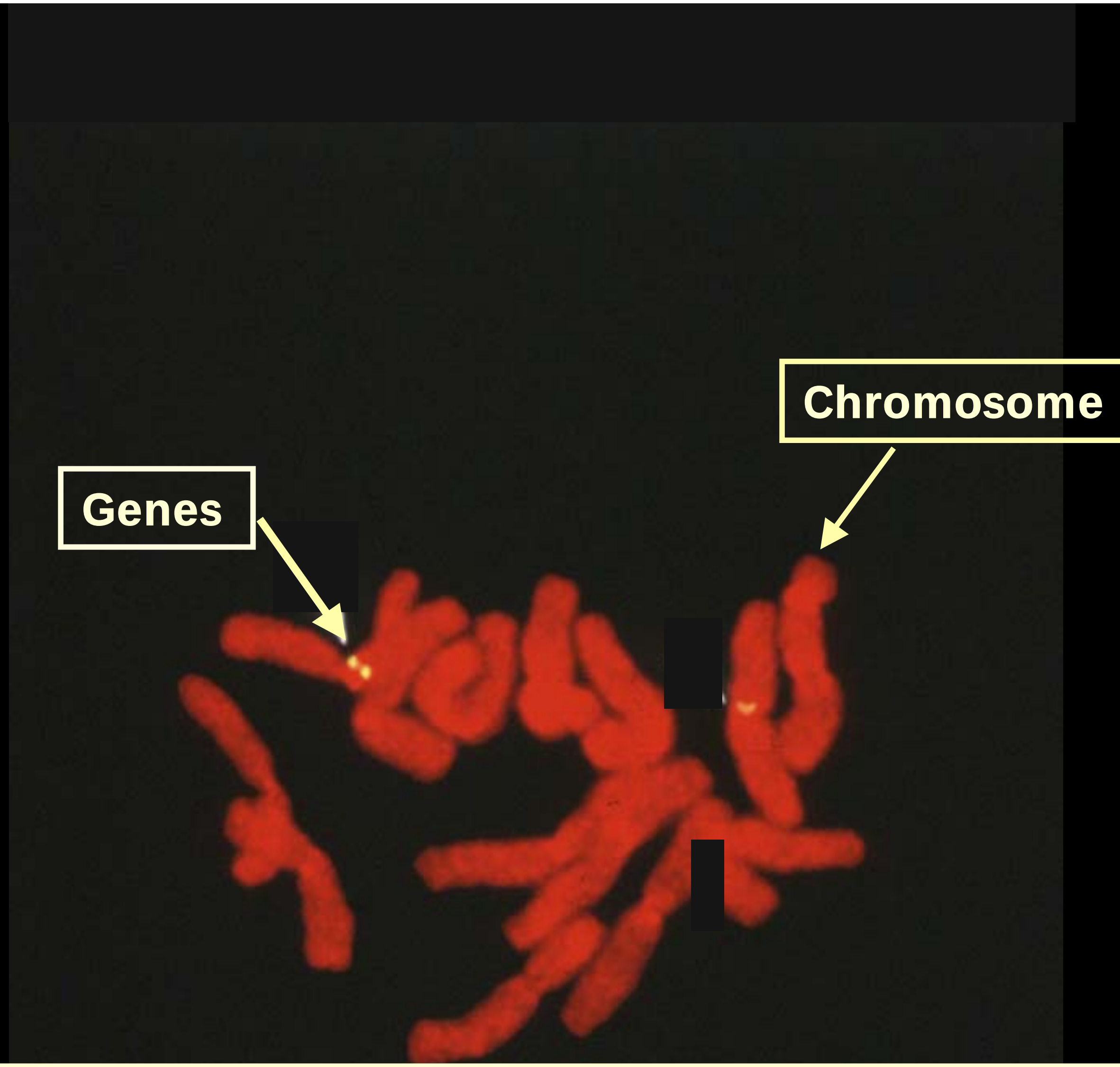
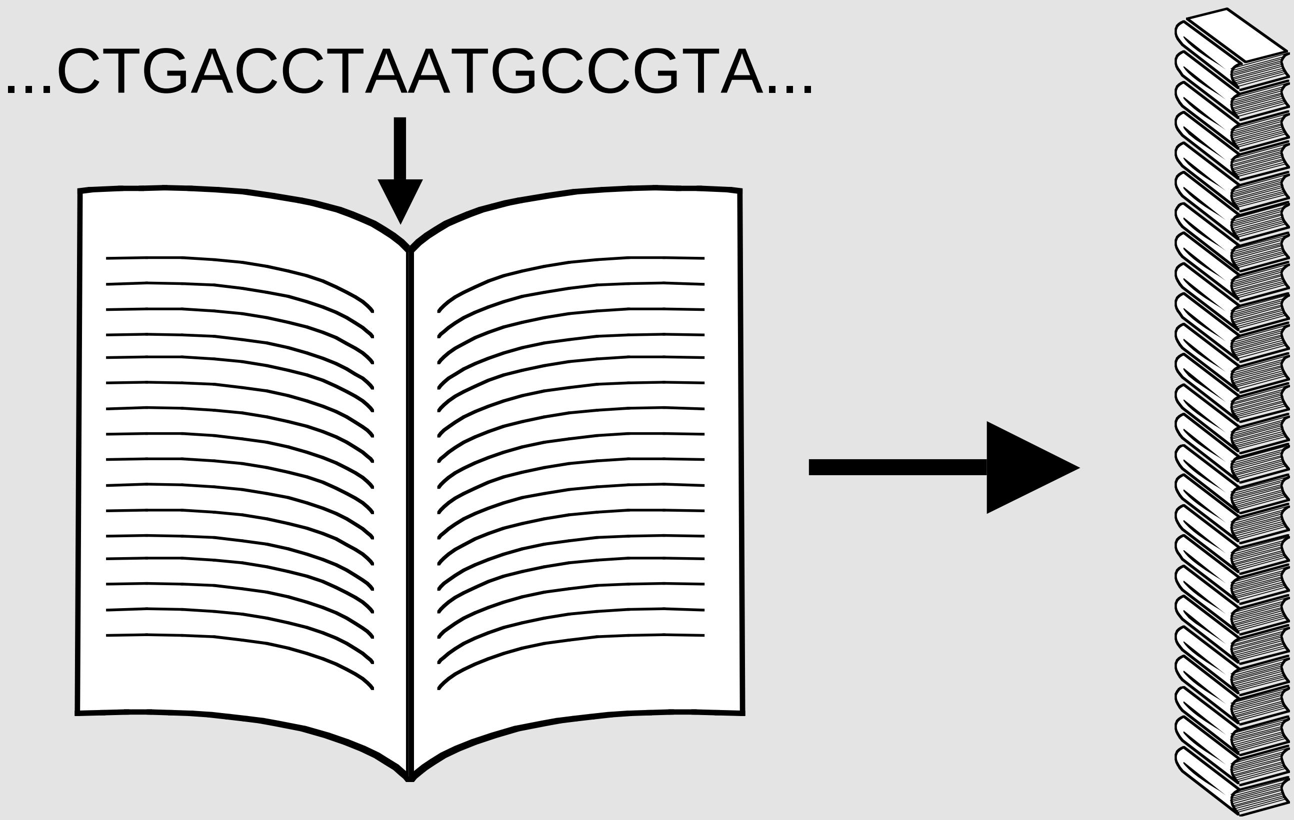


Now what happens to all of the DNA and genes when we cross two plants?

Genetic information in wheat genome

Made of chemical units represented by alphabetic letters

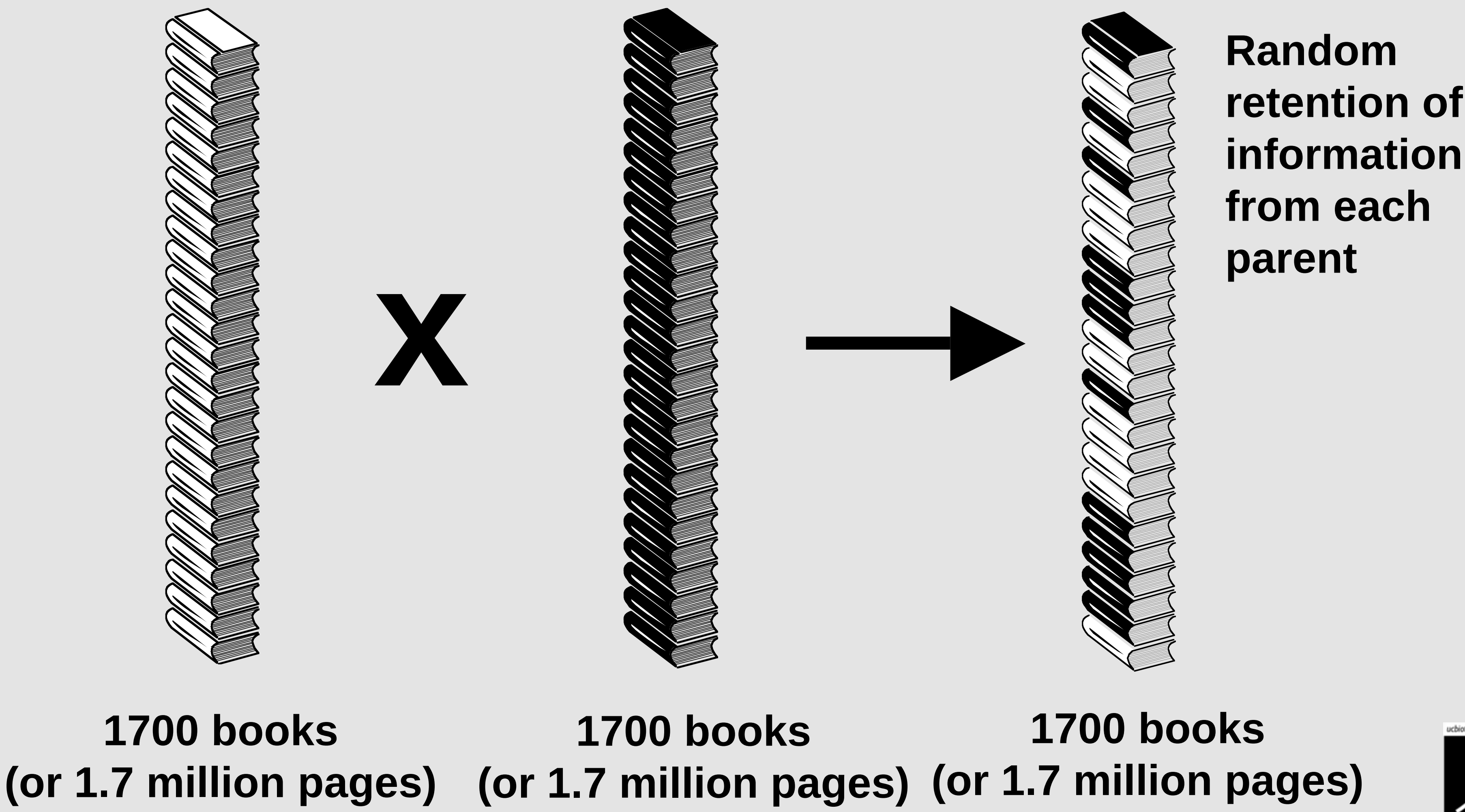


1700 books
1000 pages each

1700 books
(or 1.7 million pages)


How can the genetic information in the cells of the wheat plant be modified to create new varieties?

Hybridization or cross breeding of wheat



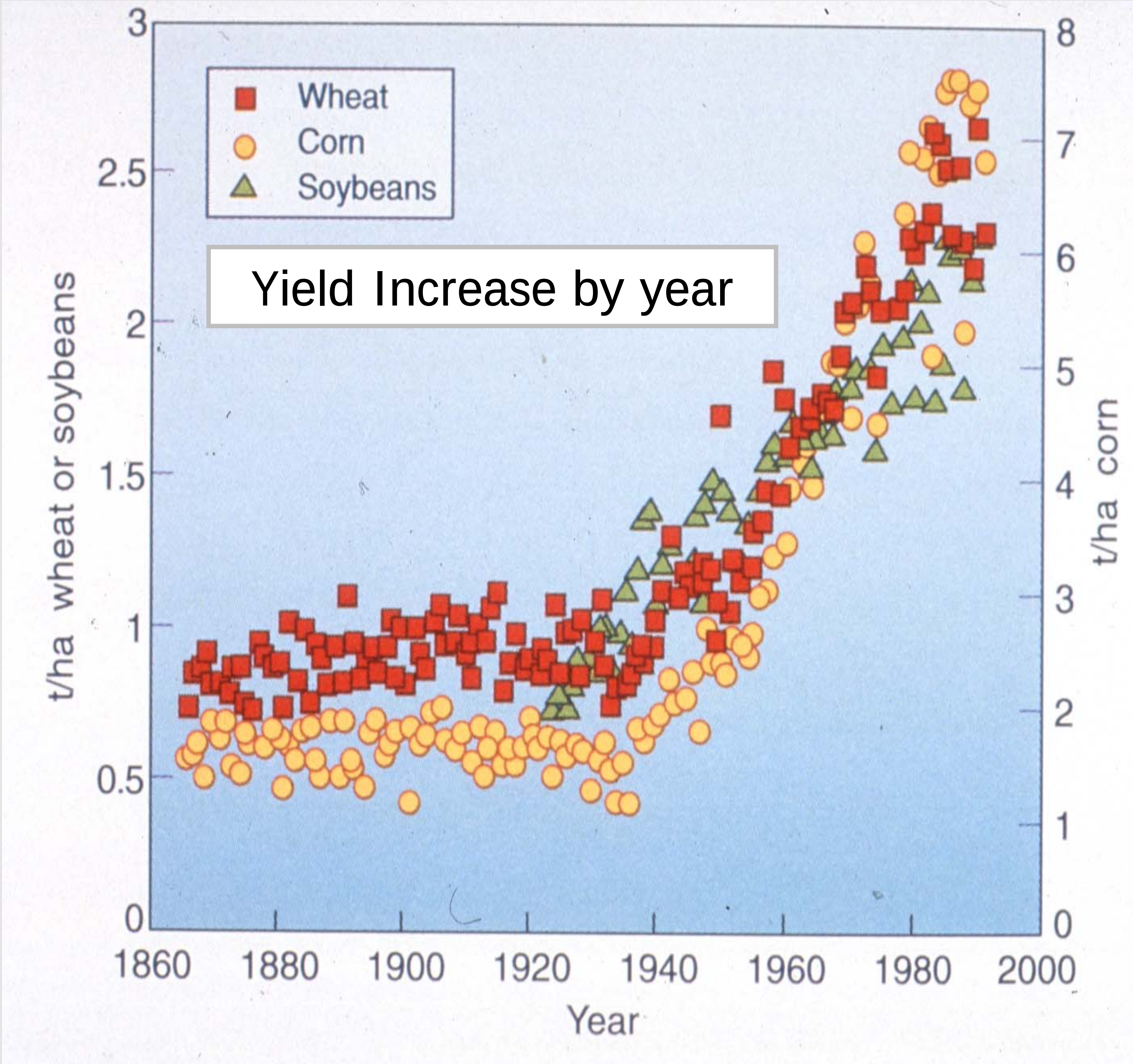
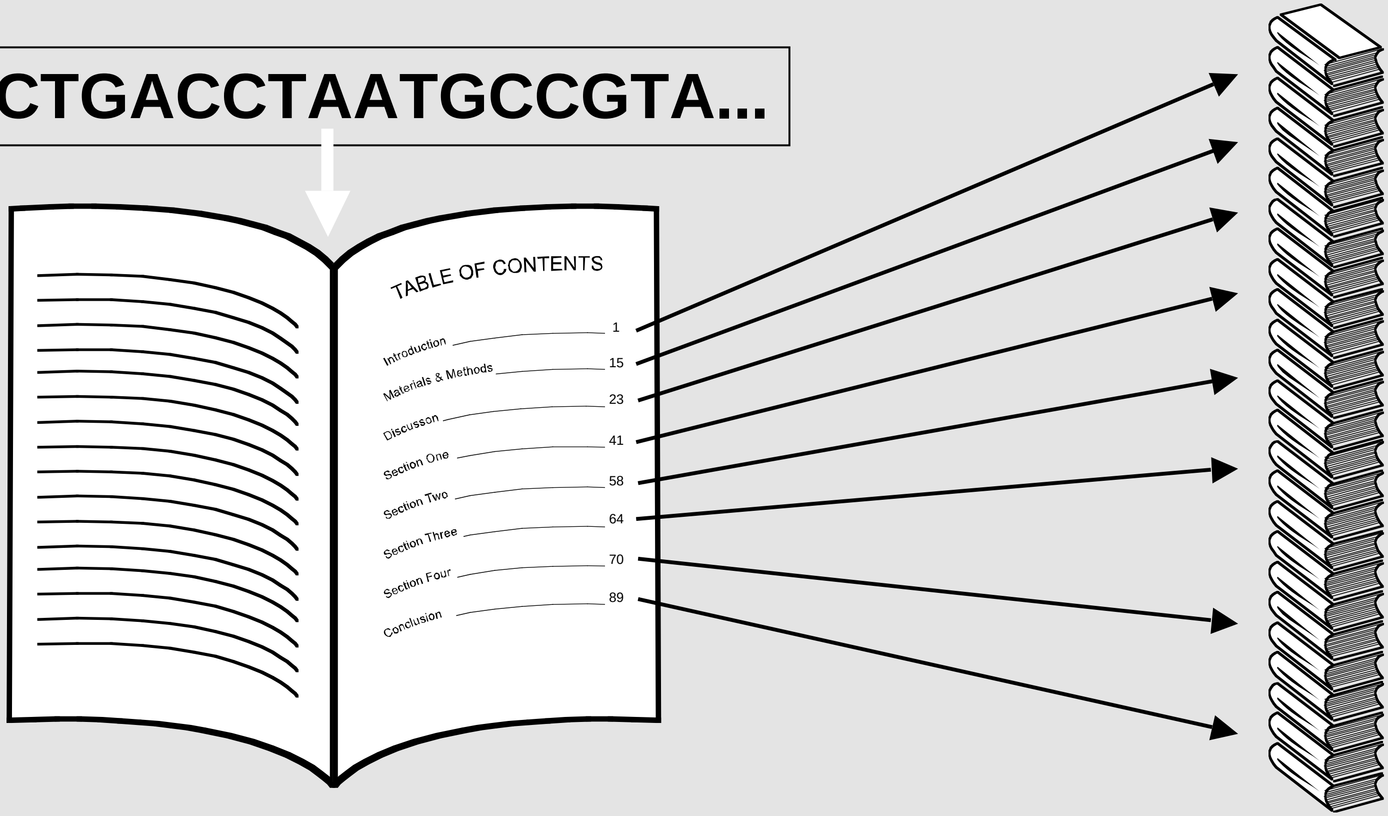

Yield Increase by year
Wheat
Corn
Soybeans
t/ha wheat or soybeans
t/ha corn
Year
0
0.5
1
1.5
2
2.5
3
0
1
2
3
4
5
6
7
8
1860
1880
1900
1920
1940
1960
1980
2000

Table of contents for genes in wheat

...CTGACCTAATGCCGTA...



Used for Marker-Assisted Breeding

Genomics

1700 books (or 1.7 million pages)

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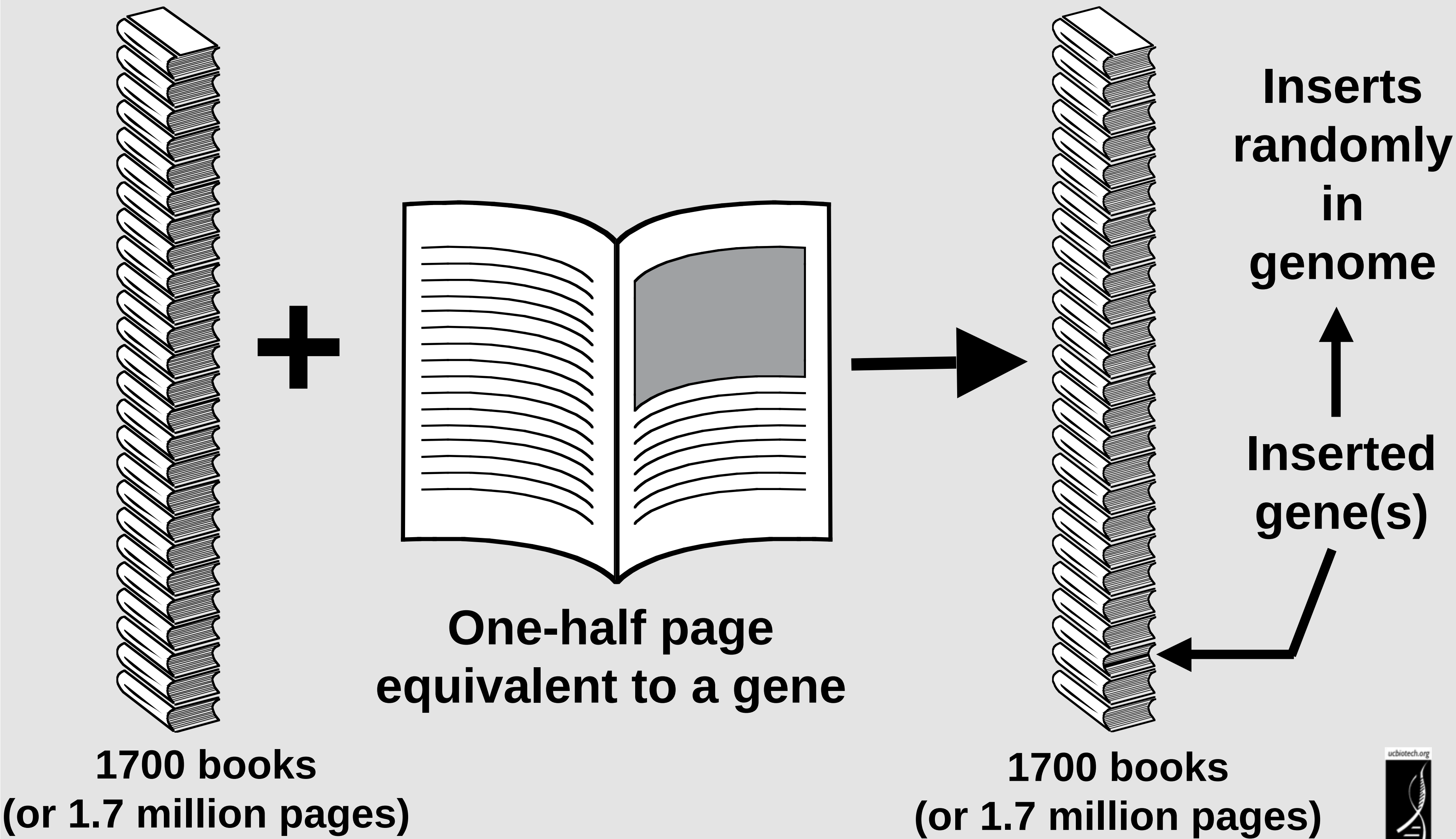
Marker Assisted Selection for Leaf Rust Resistance in Wheat

Plant Protection Science 39: 13-17

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

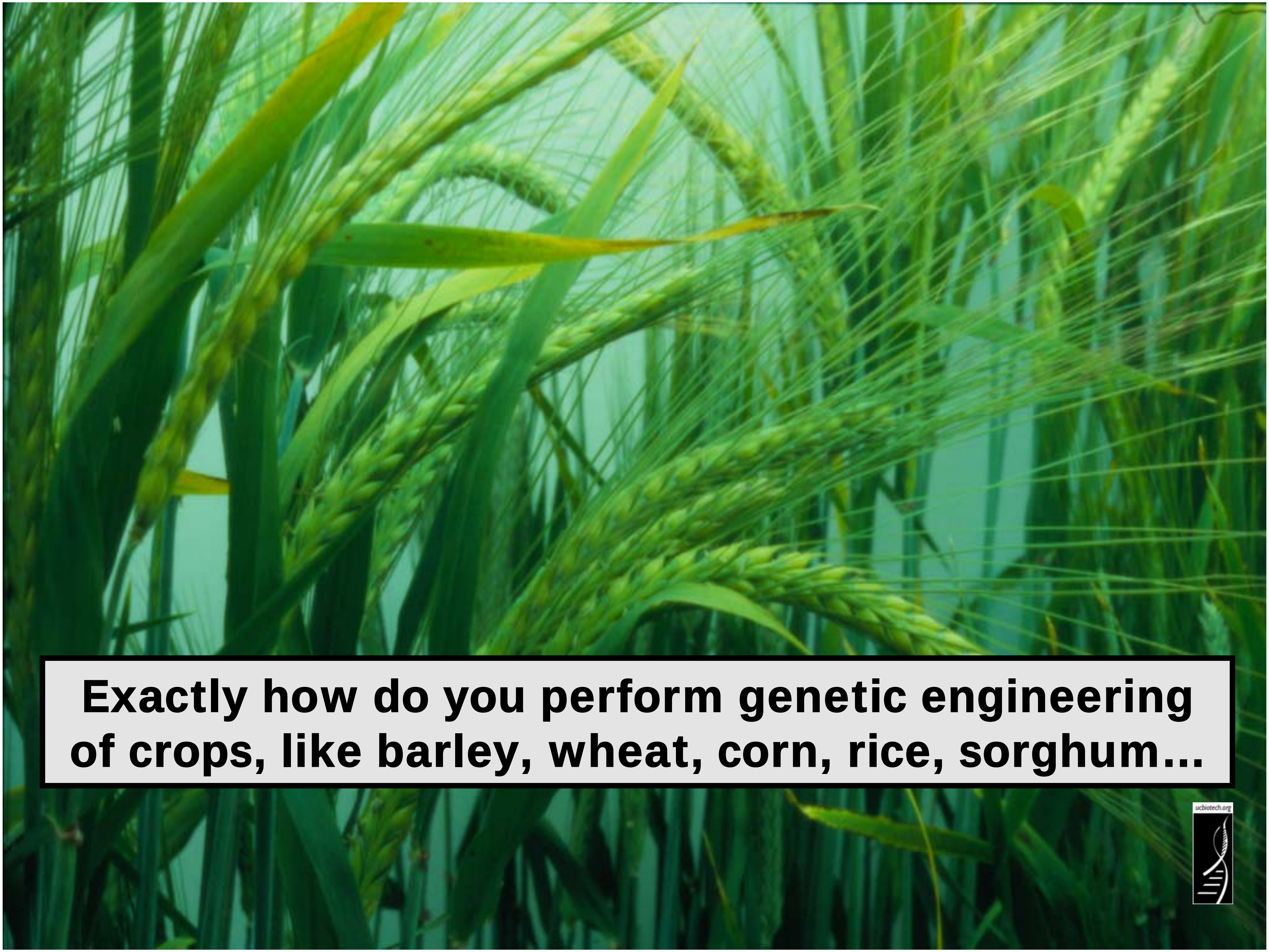
Genetic Engineering Methods

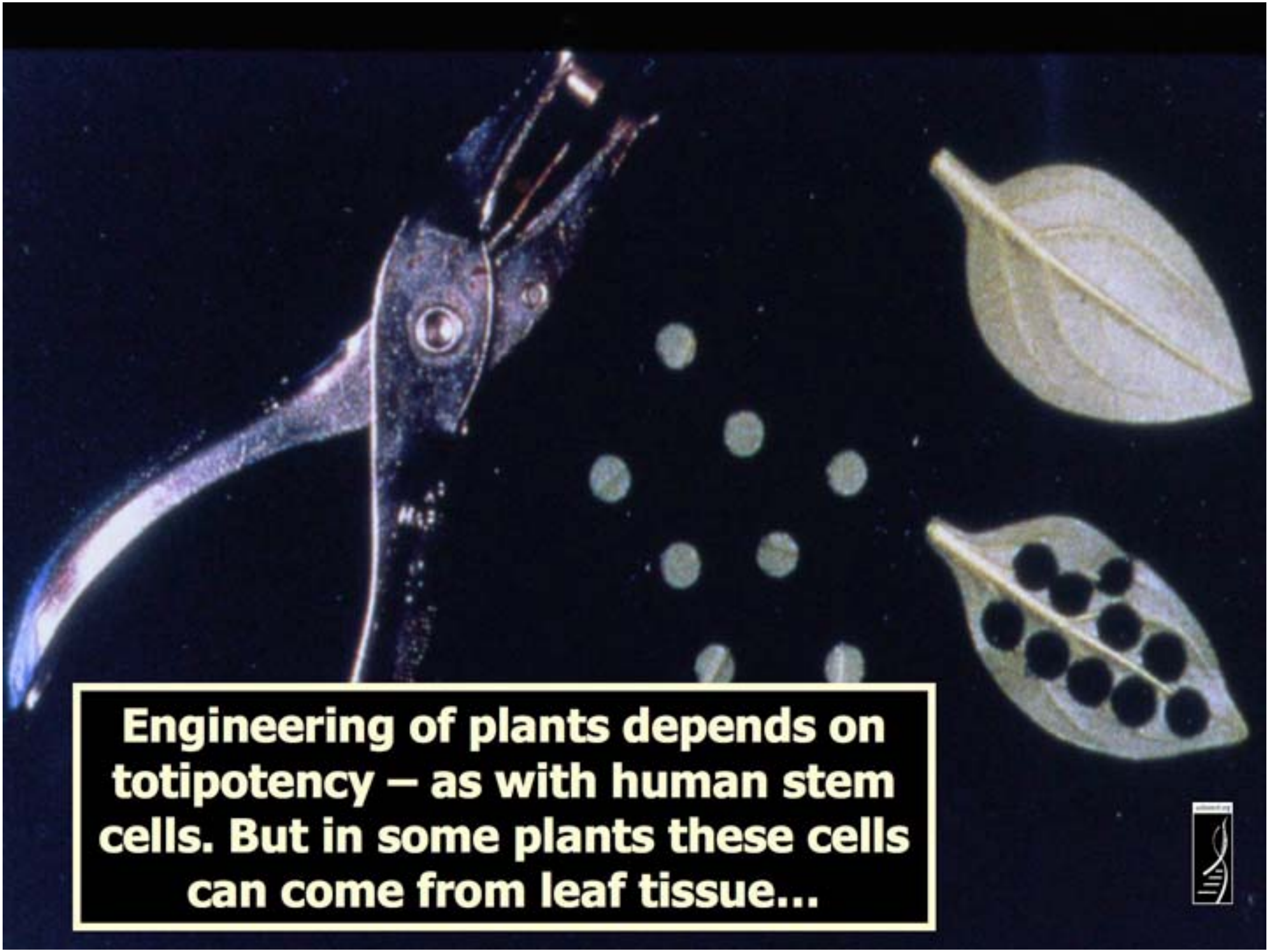


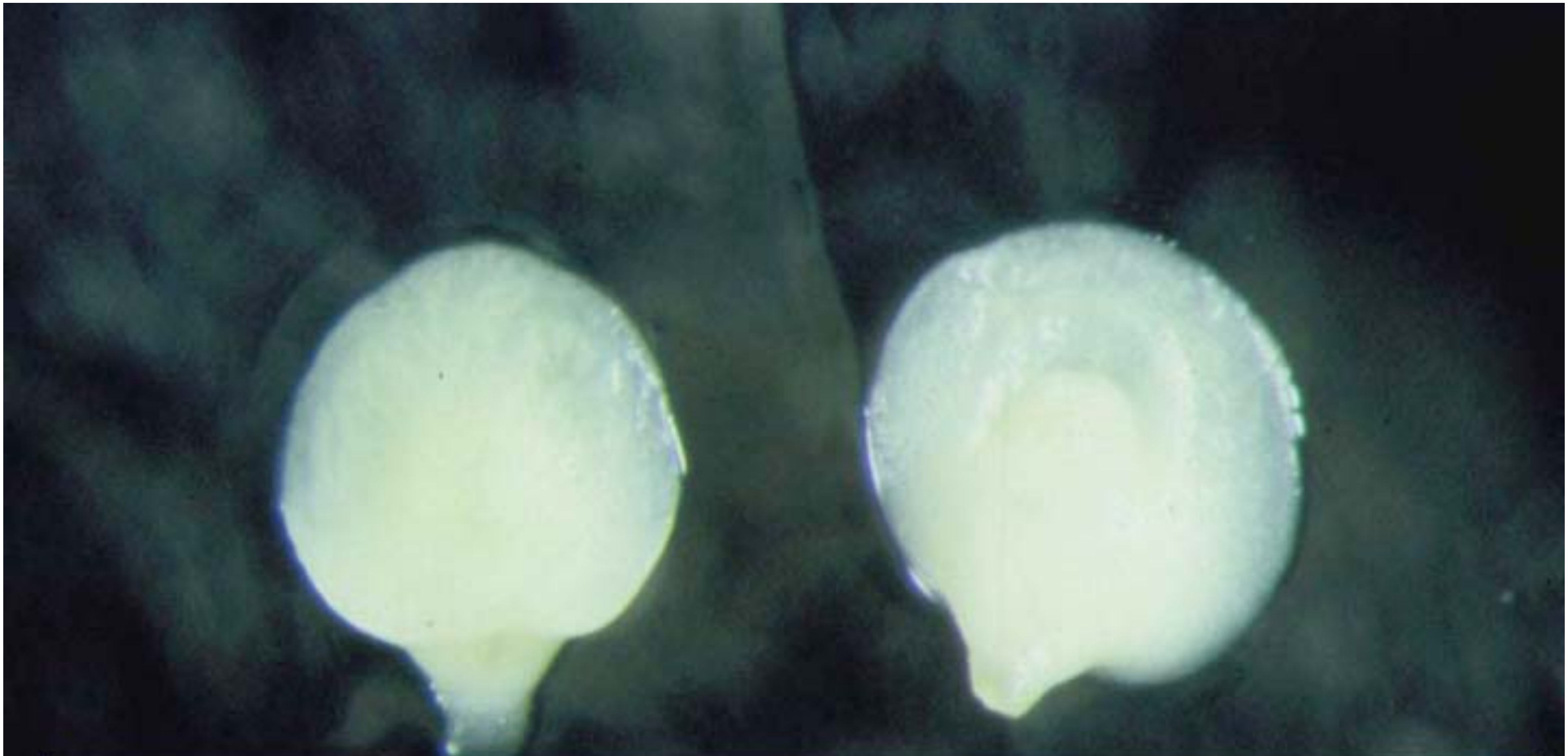

Creating less allergenic wheat varieties through genetic engineering
Li et al. 2009 Molecular Plant
ucbiotech.org

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 entire genome	Gene exchange is specific, single or a few genes
Only between closely related or within species	Source of gene from any organism

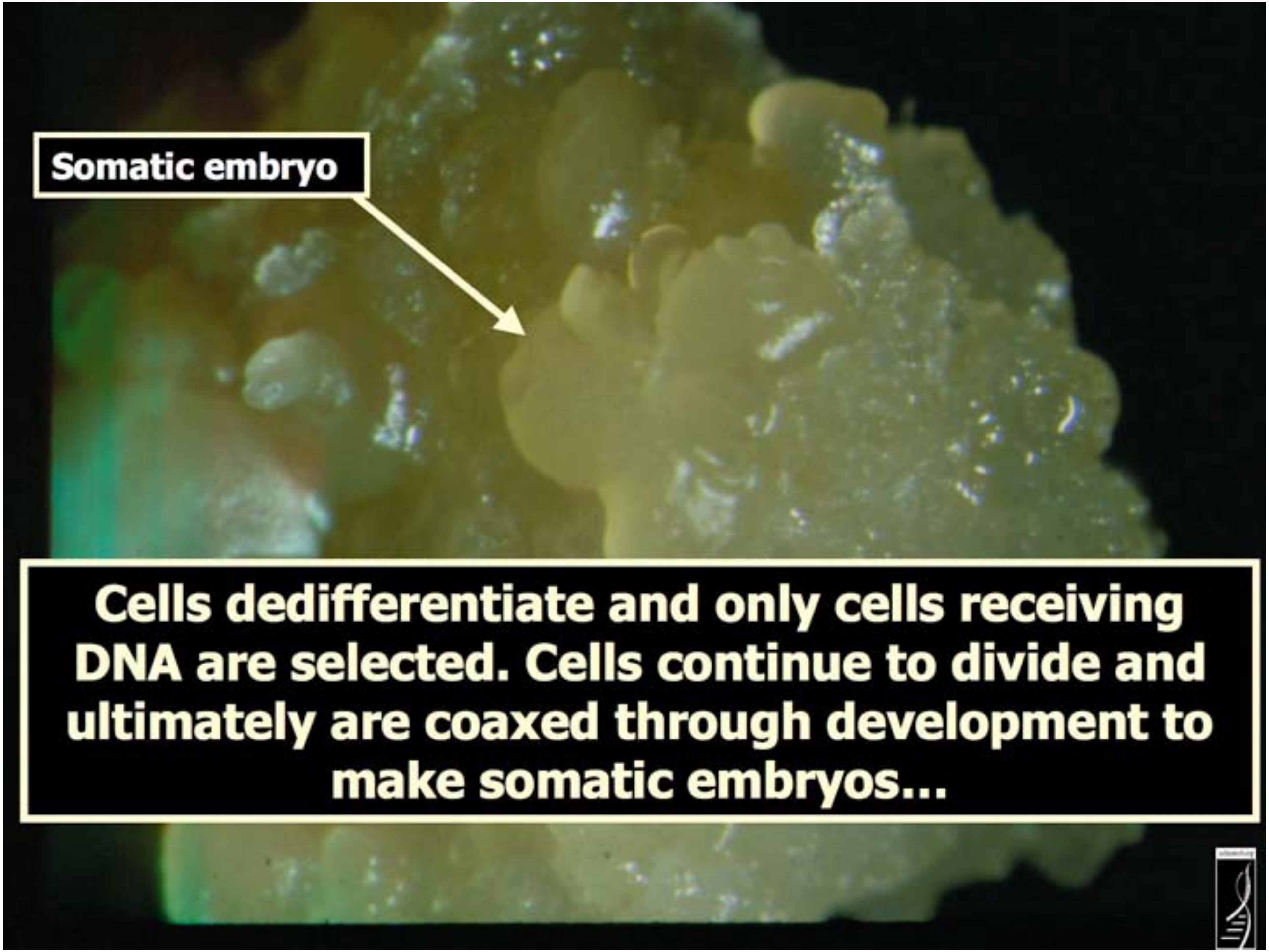

Exactly how do you perform genetic engineering of crops, like barley, wheat, corn, rice, sorghum…

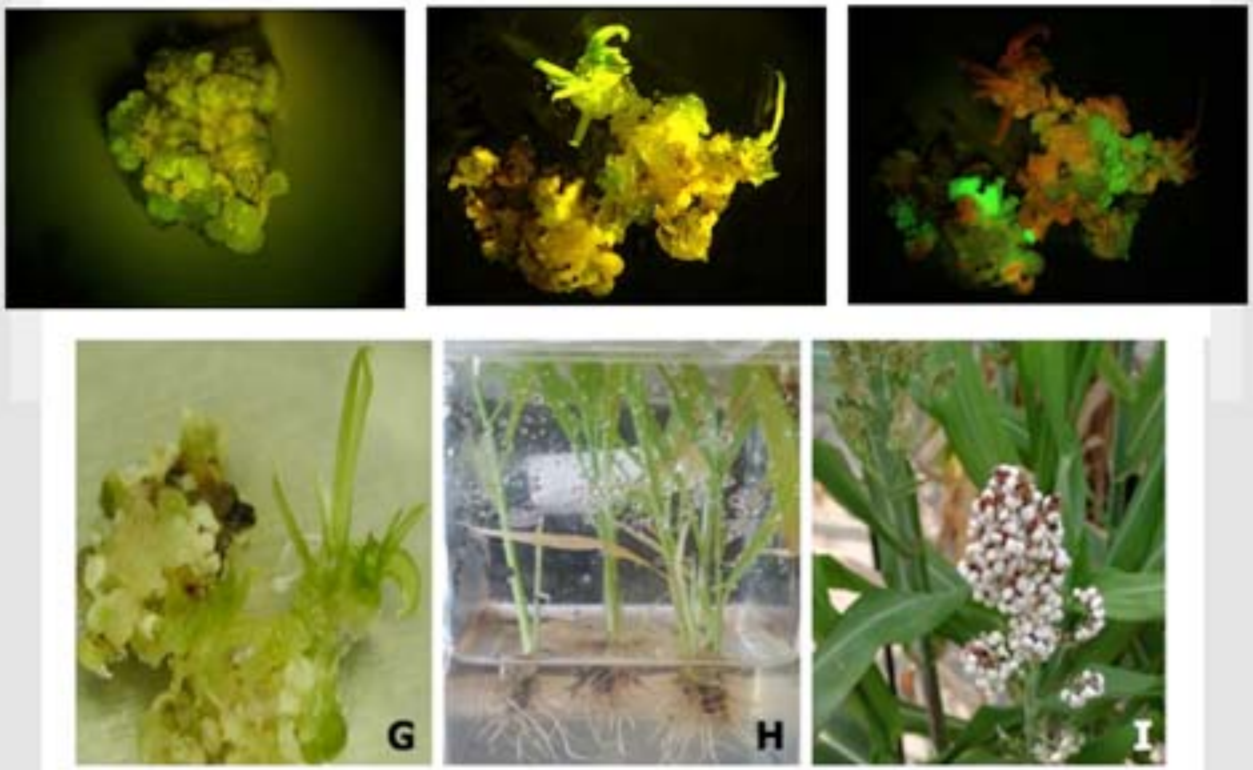

Engineering of plants depends on totipotency – as with human stem cells. But in some plants these cells can come from leaf tissue…



In cereal crops it is immature embryos that provide totipotent cells … embryos are placed on medium with plant hormones…


DNA with a gene responsible, in this case for green fluorescence, can be introduced using either a bombardment "gun" or a naturally occurring bacterium that injects DNA into the cell; seed germination stops and cells divide...


Somatic embryo
Cells dedifferentiate and only cells receiving DNA are selected. Cells continue to divide and ultimately are coaxed through development to make somatic embryos…



Cells containing your gene of interest and a selectable marker gene are then cued with other hormones to remind cells to form form leaves and then roots.

Now what kind of new traits would you like to introduce?

Finally you end up with an engineered plant, every cell of which has the introduced gene(s) and the plant has new characteristics.


GE Soybean
91% of 2007 acreage
(Herbicide resistant: 89%)
GE Cotton
87% of 2007 acreage
(Insect Resistant: 18% Herbicide resistant: 26% Stacked gene: 39%)
GE Canola
80% of 2006 acreage
GE Corn
73% of 2007 acreage
(Insect Resistant: 25% Herbicide resistant: 21% Stacked gene: 15%)
1% of corn with Bt (ECB) + Bt (rootworm) + herbicide
GE Sugar beet
~50% of 2009 acreage
(Source: SF Chronicle, 9/22/09)
GE Alfalfa
<0.5% of 2005
acreage
ucbiotech.org
DA ERS

Mainly two traits have been introduced into commercialized crops

Bollgard Cotton™

Engineered for insect resistance using gene from naturally occurring bacterium

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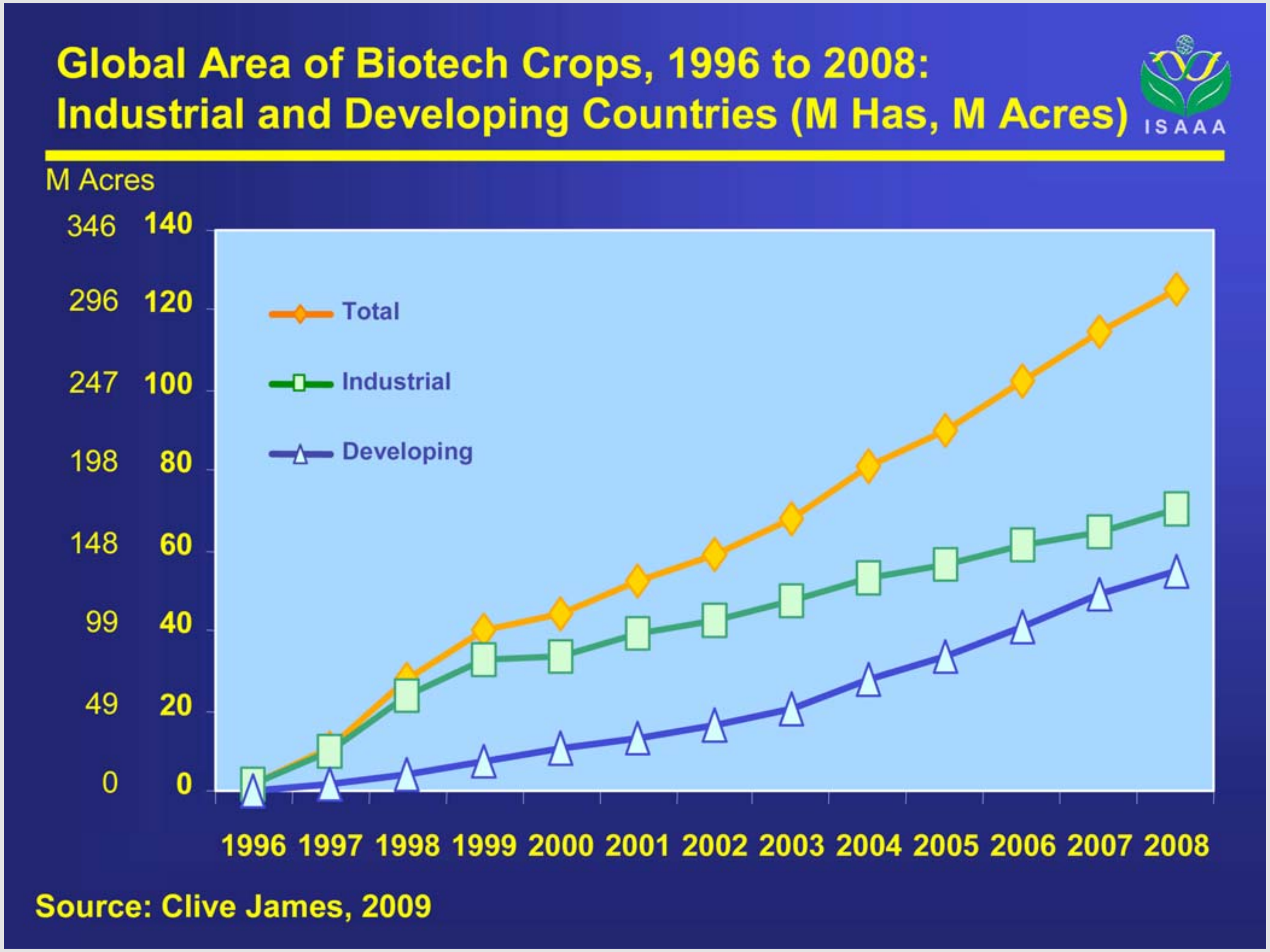
Roundup Ready Soybean™

Engineered with bacterial gene to tolerate herbicide application

Estimated over 75% of Processed Foods in U.S. Have GE Ingredients

Only a few whole foods on the market are genetically engineered

Are GE crops being grown?

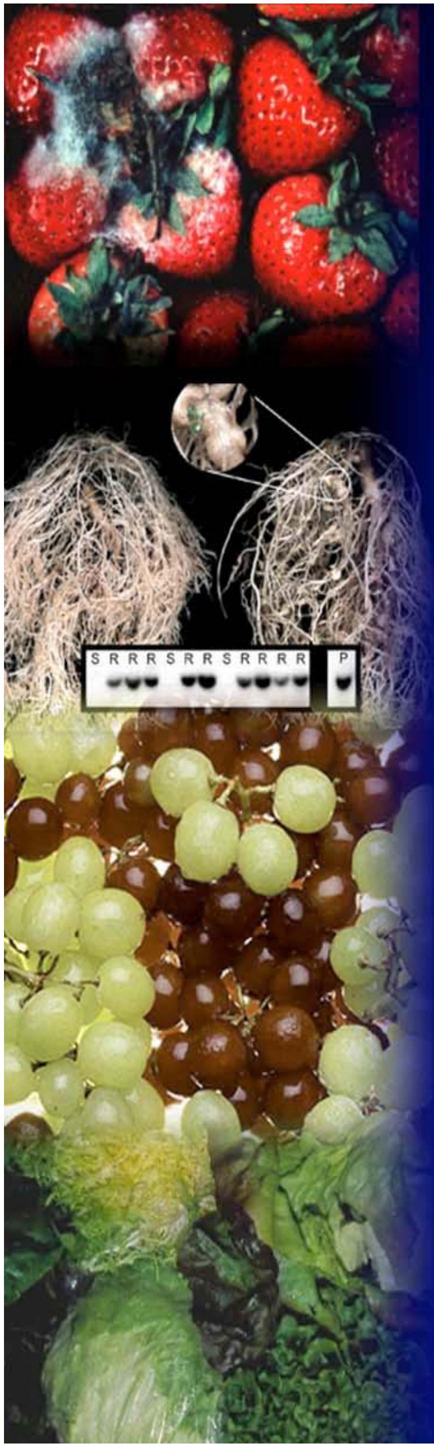


482,812 square miles worldwide in 2008 (equal to combined areas of CA, TX and NY) in 25 industrial and developing countries

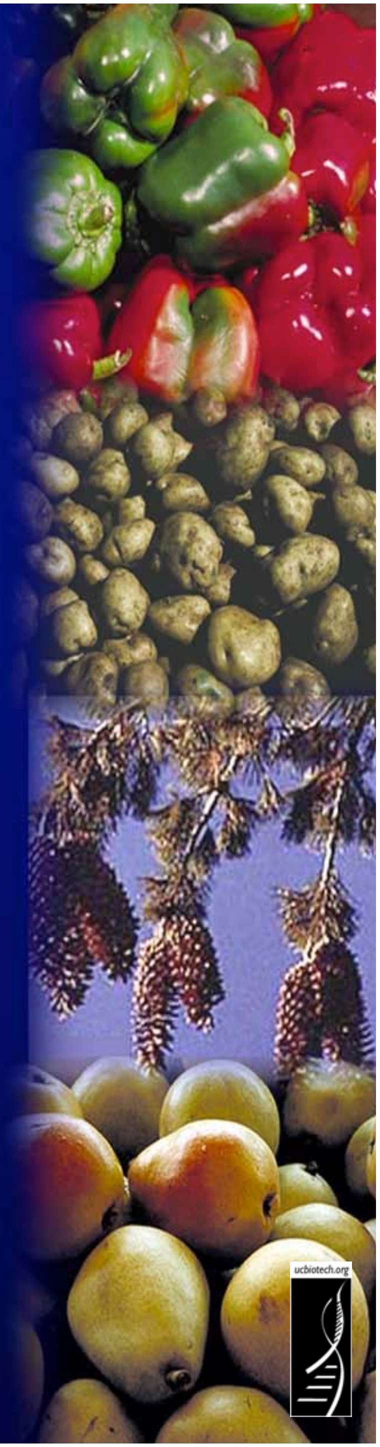
Most are in the U.S., Argentina and Brazil

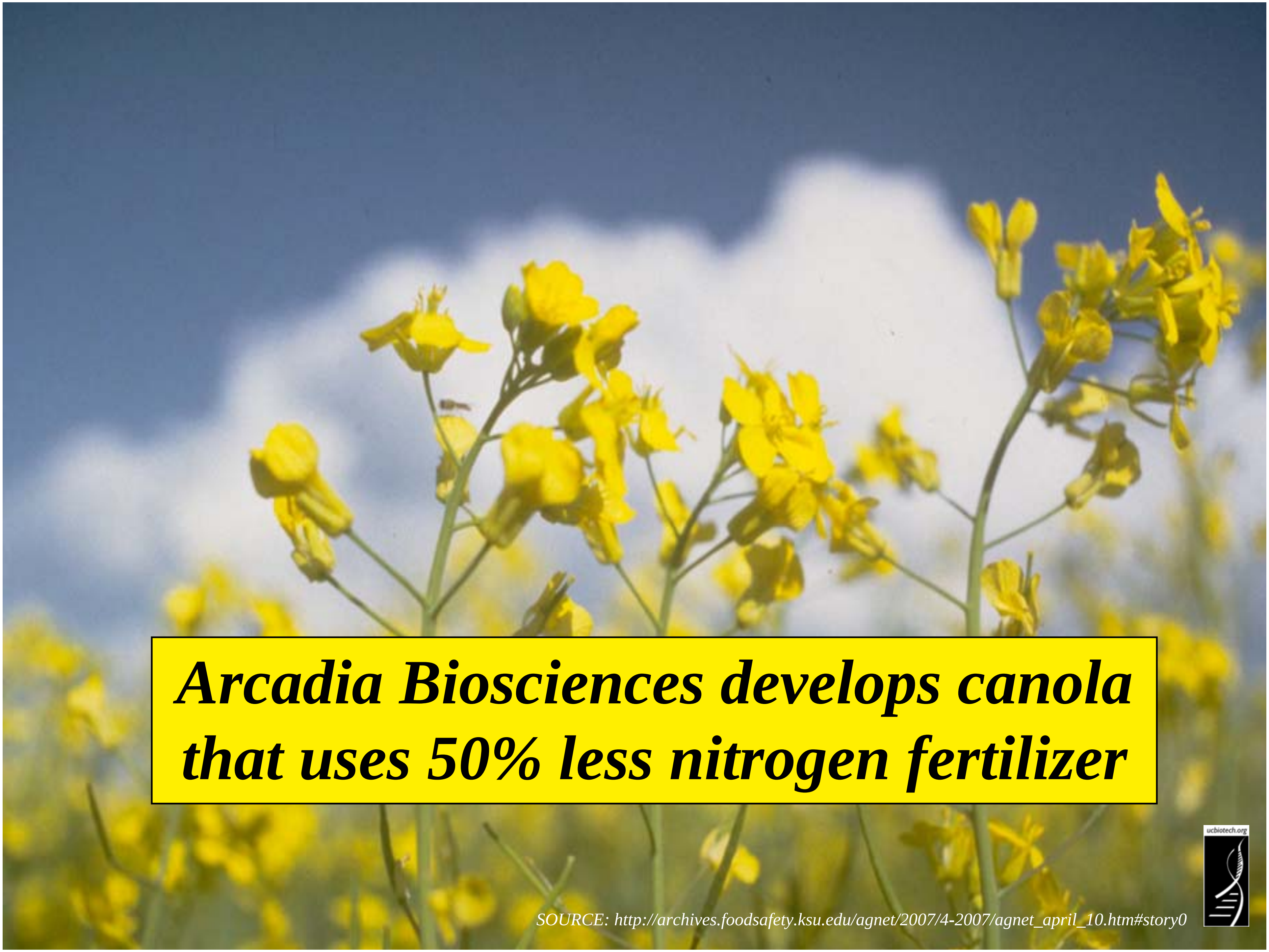
But overalls there are 25 industrial and developing countries in order of acreage:

United States, Argentina, Brazil, Canada, India, China, Paraguay, South Africa, Uruguay, Bolivia, Philippines, Australia, Mexico, Spain, Chile, Colombia, Honduras, Burkina Faso, Czech Republic, Romania, Portugal, Germany, Poland, Slovakia, Egypt.



WHAT'S IN THE PIPELINE?




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
ucbiotech.org

Drought tolerant plants grow vigorously after prolonged drought

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


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

Genetically engineered pollen reduces allergy symptoms

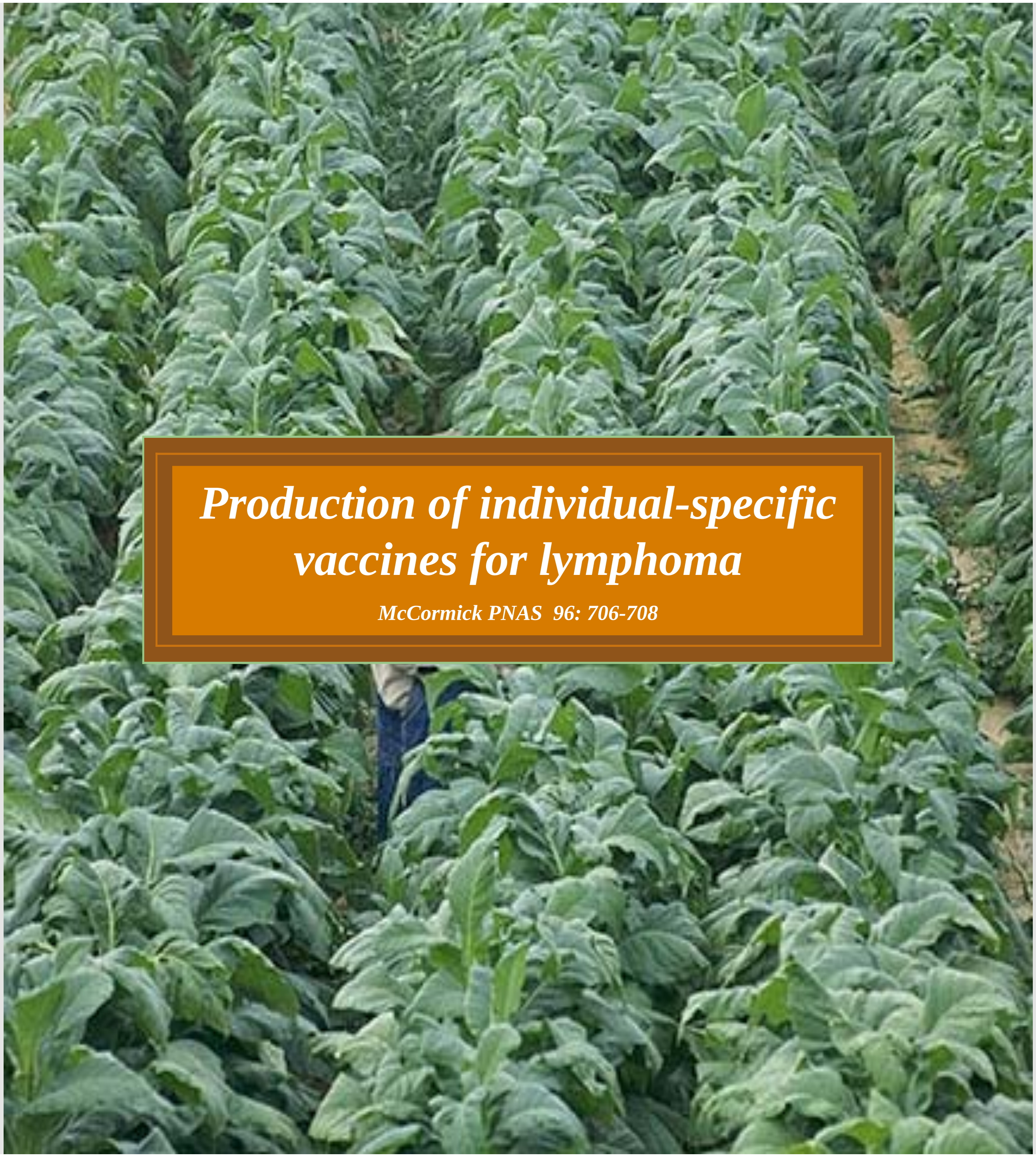
SOURCE: Niederberger et al., 2004. Vaccination with genetically engineered allergens prevents progression of allergic disease. PNAS early edition (August 13, 2004)

Slow-Mow grass addresses water, 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

Japanese scientists create blue rose with blue pigments from pansies

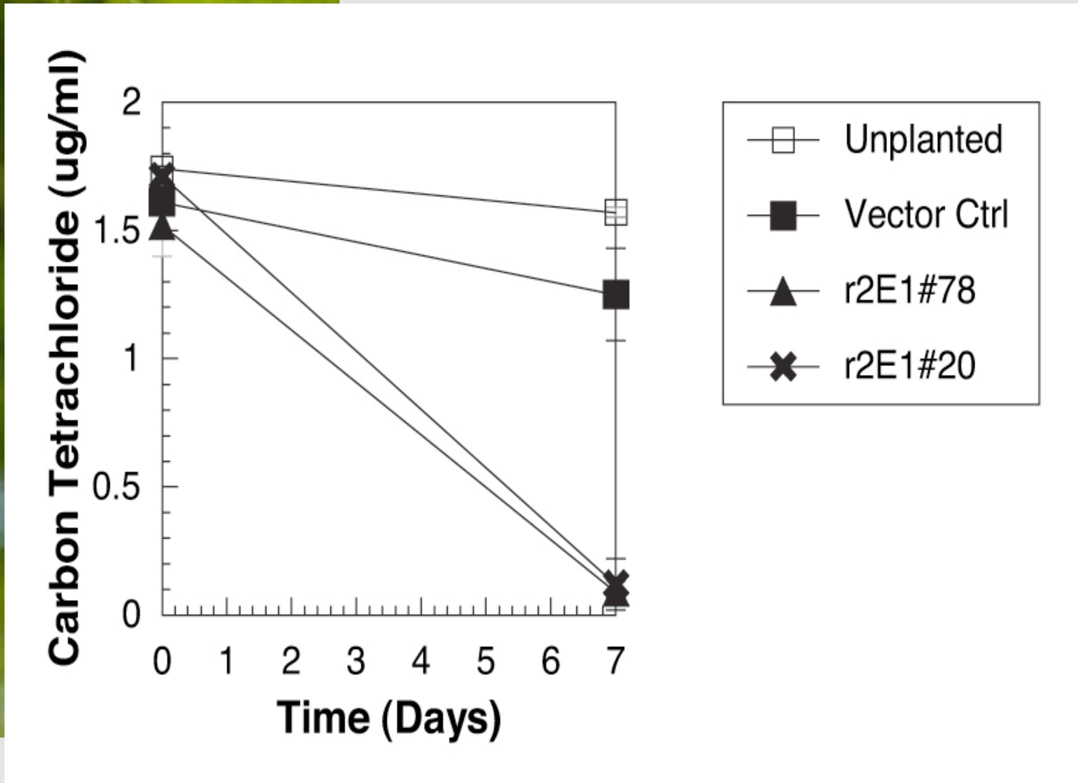
SOURCE: http://www.japantimes.co.jp/cgi-bin/getarticle.pl5?nn20040701a2.htm



Production of individual-specific vaccines for lymphoma

McCormick PNAS 96: 706-708

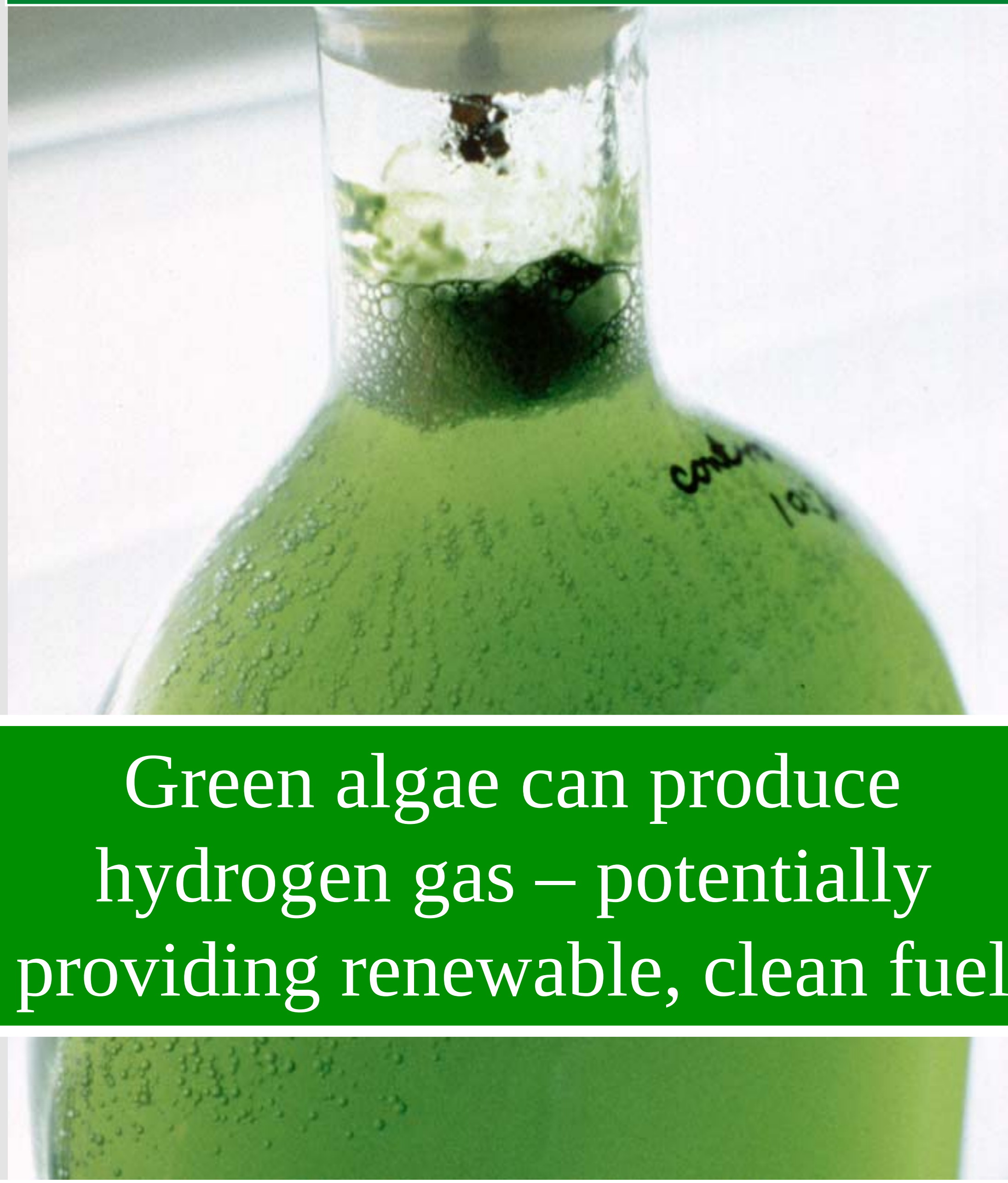
Engineered poplar removes environmental pollutants through roots and air



Removal of carbon tetrachloride

SOURCE: Doty, S.L., James, C.A., Moore, A.L., Vajzovic, A., Singleton, G.L., Ma, C., Khan, Z., Xi, G., Kang, J.W., Park, J.Y., Meilan, R., Strauss, S.H., Wilkerson, J., Farin, F. and Strand. S.E. 2007. Enhanced phytoremediation of volatile environmental pollutants with transgenic trees. Proceedings of the National Academy of Sciences USA 104:16816-16821.

ENERGY FARMS



Green algae can produce hydrogen gas – potentially providing renewable, clean fuel

WHAT EDUCATIONAL RESOURCES ARE AVAILABLE ON THESE TOPICS AND WHERE CAN THEY BE FOUND?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know GMOS
This website, developed for the University of California Division of Agricultural and Natural Resources Statewide Biotechnology Workgroup, 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.
DISPLAY CARDS NOW IN SPANISH!
We now have Spanish cards available to distribute with both educational displays. Click here for more details!
BIOTECHNOLOGY INFORMATION
ANNUAL REVIEWS
Review articles: Focused on food, environmental and socioeconomic issues of GE crops and foods.
Issues and Responses: Searchable list of issues related to agriculture, foods, technologies linked to responses.
RESOURCES FOR OUTREACH & EXTENSION, RESEARCHERS & TEACHERS
Slide Archive: Extensive collection of PP slides on agriculture & biotechnology.
Available on loan:
Educational displays: "Genetics and Foods" and Genetic Diversity and Genomics" available with companion educational cards and teacher worksheet in English and Spanish.
Gene-IE Juice Bar: Interactive activity to isolate DNA from common fruits and vegetables.
Tic Tac Grow: Educational game to teach what foods come from what crops.
HELPFUL SITES
Seed Biotechnology Center Mobilizes research, education & outreach efforts in partnership with seed & biotechnology industries.
Animal Genomics & Biotechnology Cooperative Extension Program, UC Davis
Provides education on use of animal genomics & biotechnology in livestock production.
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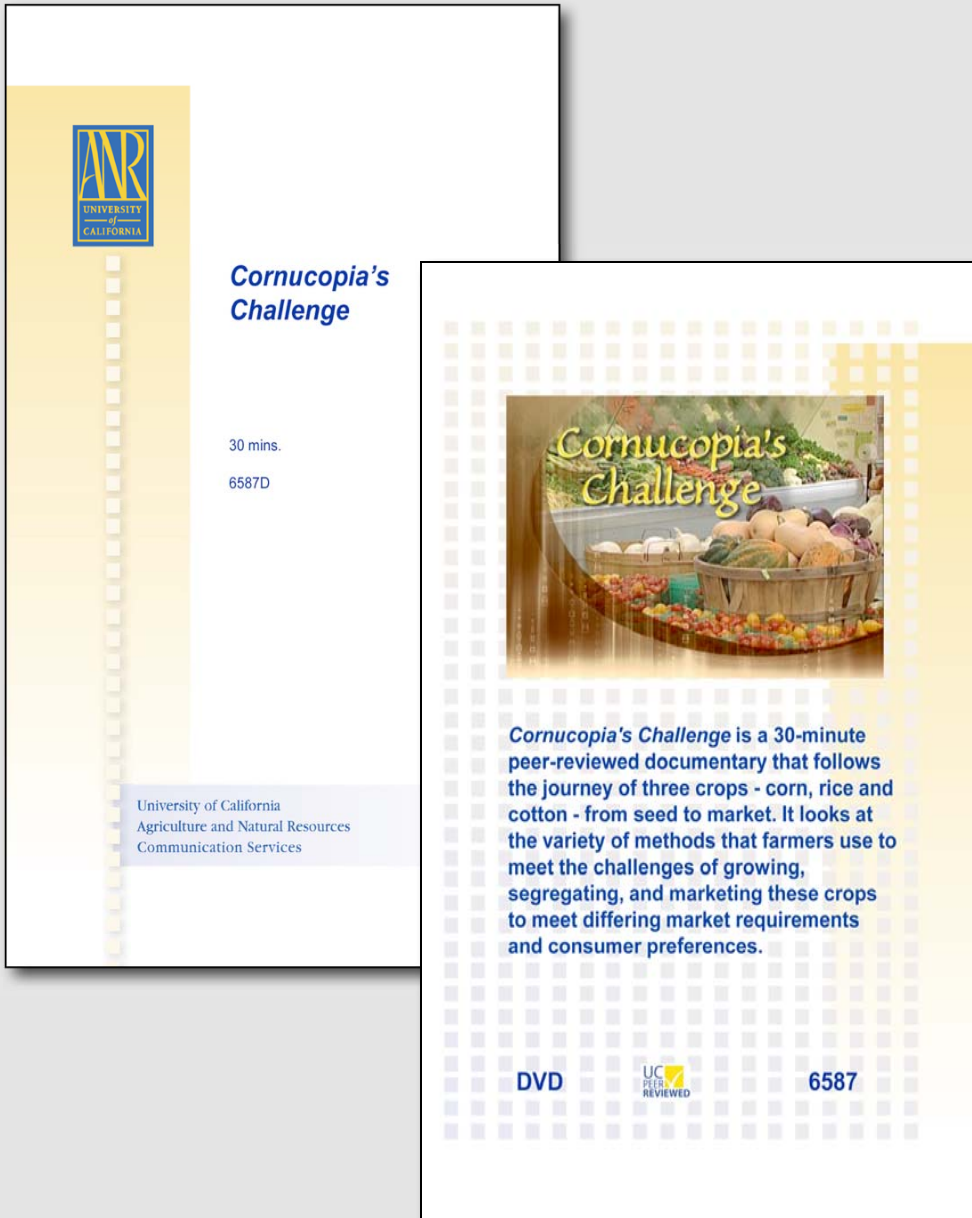
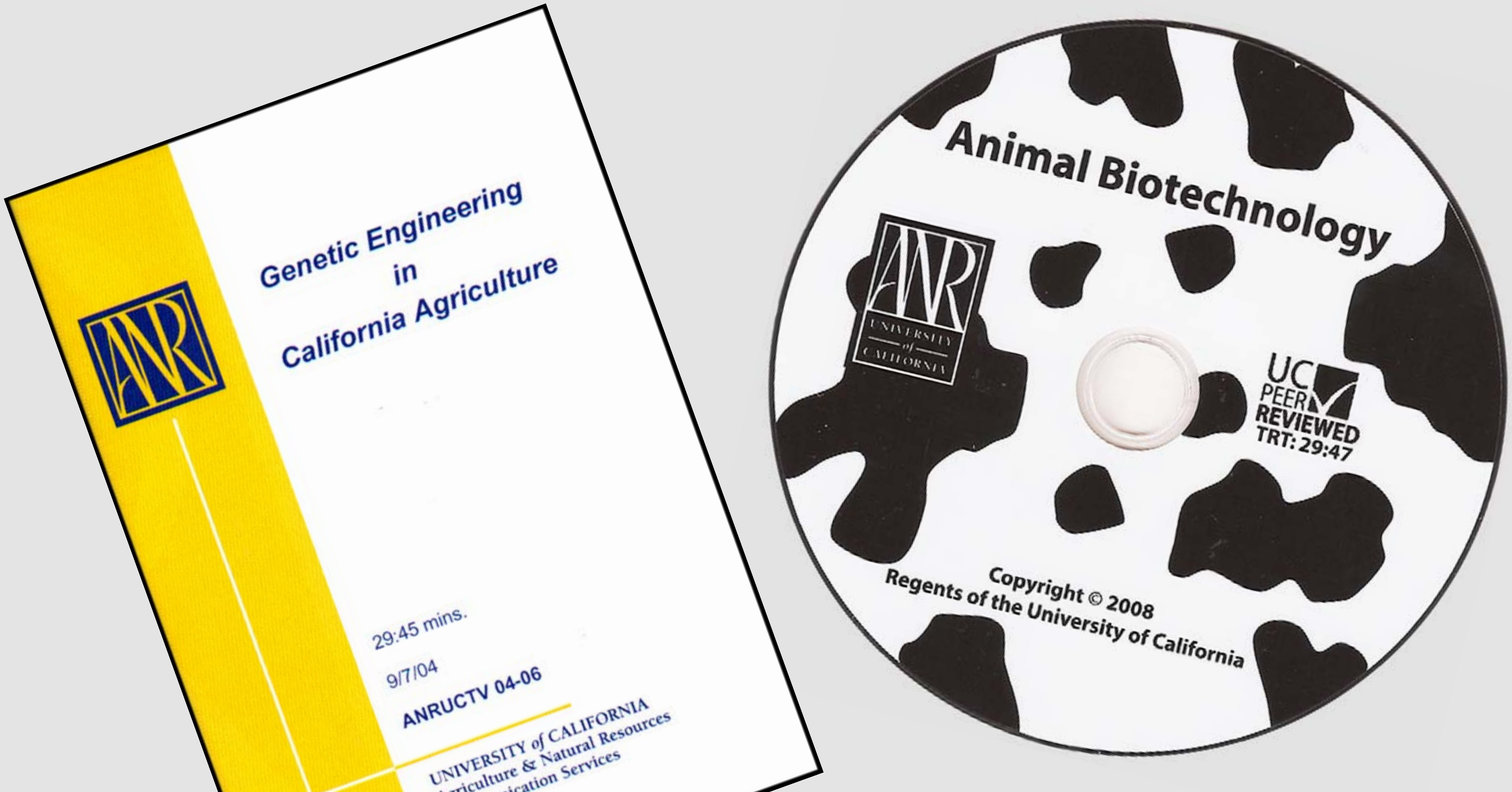
SCIENCE-BASED INFORMATION & RESOURCES ON AGRICULTURAL BIOTECHNOLOGY

SLIDE ARCHIVE

Available below is an archive of PowerPoint slides on agriculture, food and related topics. They are constantly updated by Peggy G. Lemaux and Barbara Alonso and used in presentations (can be viewed by clicking here). They are provided as potential resources to be used in others' efforts.

They are organized by topic are are available for download as Powerpoint files. You can preview the slides in each section by clicking on the first slide and watching the slideshow, or click on any slide you wish. You can pause the slideshow at any time.


University of California
Cornucopia's Challenge
30 mins.
6587D
University of California
Agriculture and Natural Resources
Communication Services
Cornucopia's Challenge
Cornucopia's Challenge is a 30-minute peer-reviewed documentary that follows the journey of three crops - corn, rice and cotton - from seed to market. It looks at the variety of methods that farmers use to meet the challenges of growing, segregating, and marketing these crops to meet differing market requirements and consumer preferences.
DVD
UC PEER REVIEWED
6587



30-minute, Peer-reviewed Videos

"Genetic Engineering in California Agriculture": where and why GE crops and animals are being used in California.

"Animal Biotechnology": addresses biomedical and agricultural applications of animal biotech, history, controversy

Partnership for Plant Genomics and Biotechnology Education

UNIVERSITY OF CALIFORNIA DAVIS NATIONAL SCIENCE FOUNDATION

Virtual DNA Fingerprinting Laboratory

Program Outline

Virtual DNA Fingerprinting Laboratory 2.0© involves students in solving a forensic mystery. Over the course of seven episodes, students collect evidence, extract DNA, perform a southern blot, use PCR, and finally solve the crime.

Information about the subject of DNA fingerprinting builds as students progress through the episodes. Please see the ***help & info.pdf*** file located on the CD-ROM for details about installation, game play, scoring, and teacher options. Teachers may also find the ***DNA lab quiz.pdf*** file a useful tool to help track student comprehension of material as they complete each episode.

Designed for the secondary level and above, this software addresses the following facets of the National Science Education Standards:

Science as Inquiry

- Identify questions and concepts that guide scientific investigations
- Use technology and mathematics to improve investigations and communications
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models
- Understandings about scientific inquiry

Life Science

- The cell
- Molecular basis of heredity
- Matter, energy, and organization in living systems

Click on display to see detailed versions

Describes the way foods have changed in the past and now in the present using the new genetic tools, using tacticle, visually striking and informative modules.

Display and accompanying cards are available on loan. Please click here to arrange a reservation. Some shipping costs can be provided.

Partial funding provided by the American Society of Plant Biologists. Design by B. Alonso.

Click on display to see detailed versions

Describes importance of plant variation to the future of foods and how and why plants have changed over time. Composed of tactile, visually attractive interchangeable modules.

Display and accompanying cards are available on loan. Please click here to arrange a reservation.

Partial funding provided by the American Society of Plant Biologists. Design by B. Alonso.

TOP

Informational Cards

Based on educational display on genetics and foods, these "baseball" cards and the displays are available for teachers. Each cards is based on a display module and can be used in the classroom and beyond. Available in both English and Spanish.

In English

In Spanish

Click on images to see detailed versions | *Instructions (PDF file)*

This interactive activity, mimicking contemporary juice bars, stands alone or can accompany the Foods display. It teaches that DNA and genes are a natural part of our every day lives. Bar includes materials needed for DNA isolation: blender, reagents, colorful beakers and tubes, and an educational handout.

Juice bar is available on loan. Please click here to arrange a reservation. The "How Much DNA Do You Eat" module is also available separately.

An extraction method for strawberry DNA is also available (Download PDF).

Instructional Video - click to watch!

Additional DNA extraction information:

Steven Ruzin, Biological Imaging Facility, UCB: Isolating DNA from Veggies (9MB)
(downloadable movie file: Mac (hqx: 13.3MB); PC (zip: 9.6MB). Strawberry DNA extraction (PDF).

Presence of transgenes can be detected with commercial test kits.

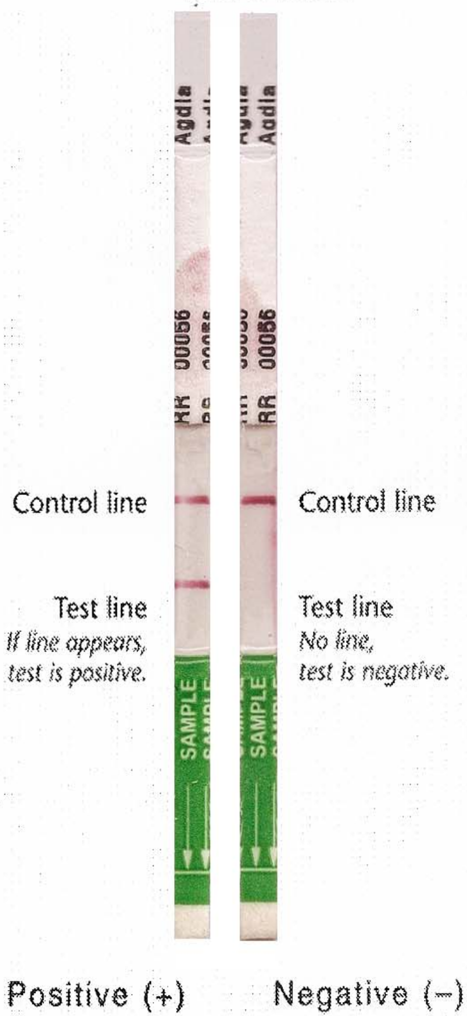
ucbiotech.org

Roundup Ready® (CP4 EPSPS) ImmunoStrip Test

Strip tests for the detection of CP4 EPSPS protein

Catalog no. STX 74000

Results



The control line will appear in 3 to 5 minutes. Maximum reaction occurs in 20 minutes at which time the ImmunoStrip should be removed from the buffer. The control line assures that the test is working properly. If the control line does not appear, the test is invalid.

If the sample is positive, the test line will also appear. If the sample is negative, the test line will not appear.

Do not remove the strip from the sample if control line is not visible. Leave the strip in the sample until the control line is visible and the sample flows into the wicking pad. Depending on the flow characteristics of the sample, the time to develop the signal may vary.

If you wish to keep the strips as permanent records cut off the sample pads and blot the ImmunoStrips between paper towel. This prevents any liquid still in the sample pads from interfering with results.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General
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Norman C. Ellstrand, ANR publication 8182 - PDF
*Genetic Engineering and Organic Production Systems
Pamela Ronald and Benny Fouche, ANR publication 8188 - PDF
*Methods to Maintain Genetic Purity of Seed Stocks
Kent Bradford, ANR publication 8189 - PDF
*Methods to Enable Coexistence of Diverse Production Systems Involving Genetically
Cotton
Robert B. Hutmacher, Ron N. Vargas and Steven D. Wright, ANR publication 8191 - PDF
*Methods to Enable to Coexistence of Diverse Corn Production Systems
Kent Brittan, ANR publication 8192 - PDF
*Methods to Enable Coexistence of Diverse Production Systems Involving Genetic
Alfalfa
Dan Putnam, ANR publication 8193 - PDF | Handout (condensed from alfalfa fact sheet)
Publication, "Gene Flow in Alfalfa: Biology, Mitigation, and Potential Impact on Producti
TOP OF PAGE
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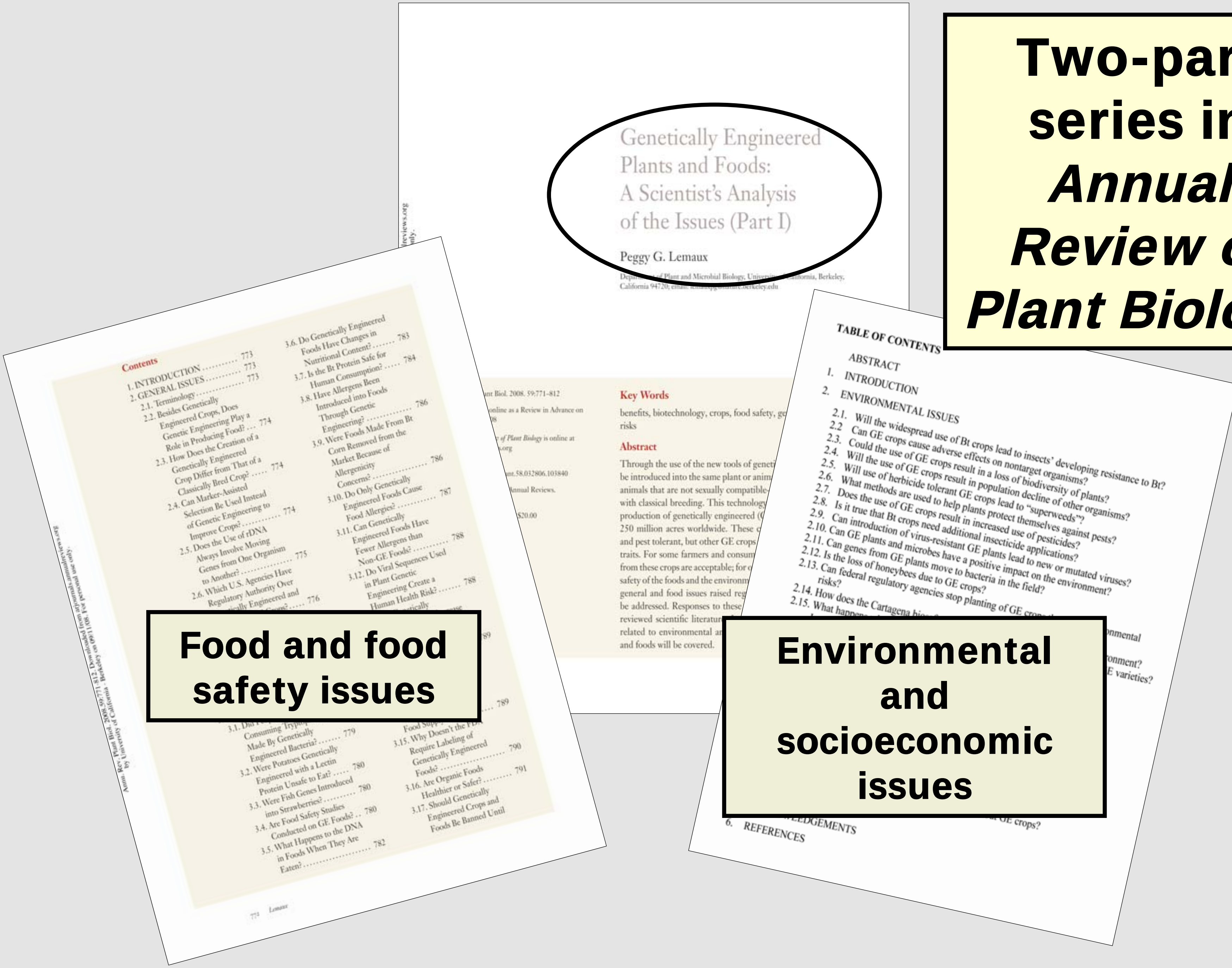
PUBLICATION 8192
Methods to Enable the Coexistence of Diverse Corn Production Systems
UNIVERSITY OF CALIFORNIA
Division of Agriculture and Natural Resources
Does cross-pollination occur in corn?
How far does corn pollen travel?
UC PEER REVIEWED
AGRICULTURAL BIOTECHNOLOGY IN CALIFORNIA SERIES
PUBLICATION 8191
Methods to Enable the Coexistence of Diverse Cotton Production Systems
Does cross-pollination occur in cotton?
UC PEER REVIEWED

Two-part series in *Annual Review of Plant Biology*



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CONTACT BARBARA balonso@berkeley.edu OR

PEGGY lemauxpg@berkeley.edu