GMO's 101

What are they, the impacts & the fuss

17 June 2024 / Summer Agriculture Institute

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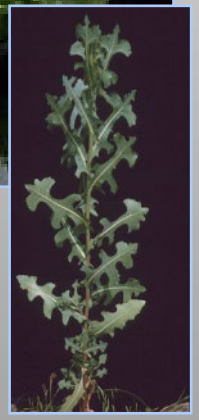
Agenda

- Making a GMO or gene edit basics
- Some impacts
- The public controversy / skepticism

These are highly genetically modified but not GMO



Many plant varieties derived from induced mutations – not GMO

Calrose 76 semi-dwarf rice

Over 3,000 crop varieties derived from mutagenesis have been commercialized

High oleic sunflower

Rio Red grapefruit

Domesticated animals are radically modified – not GMO





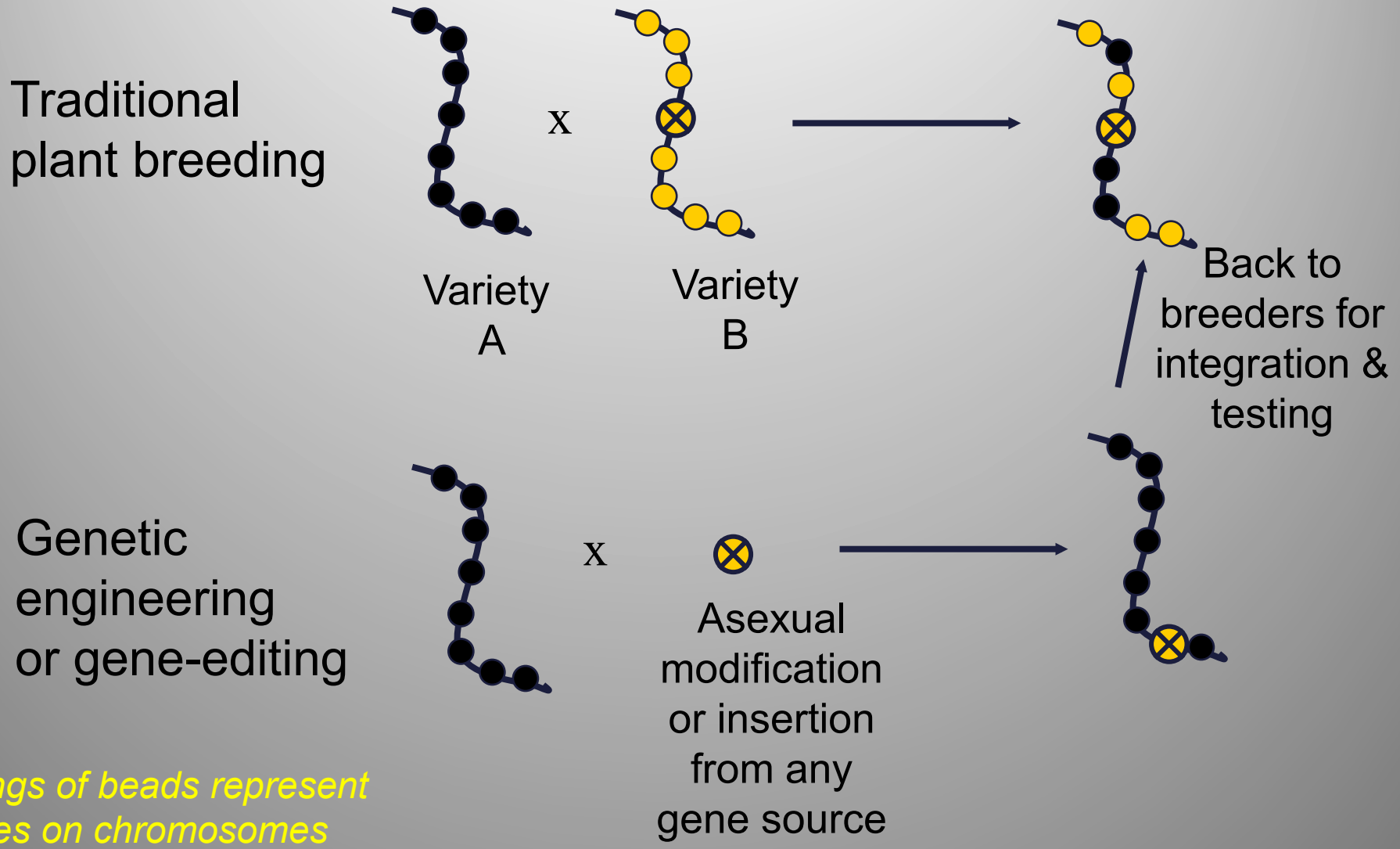








GE/GMO refers to a method of breeding, not particular kinds of products

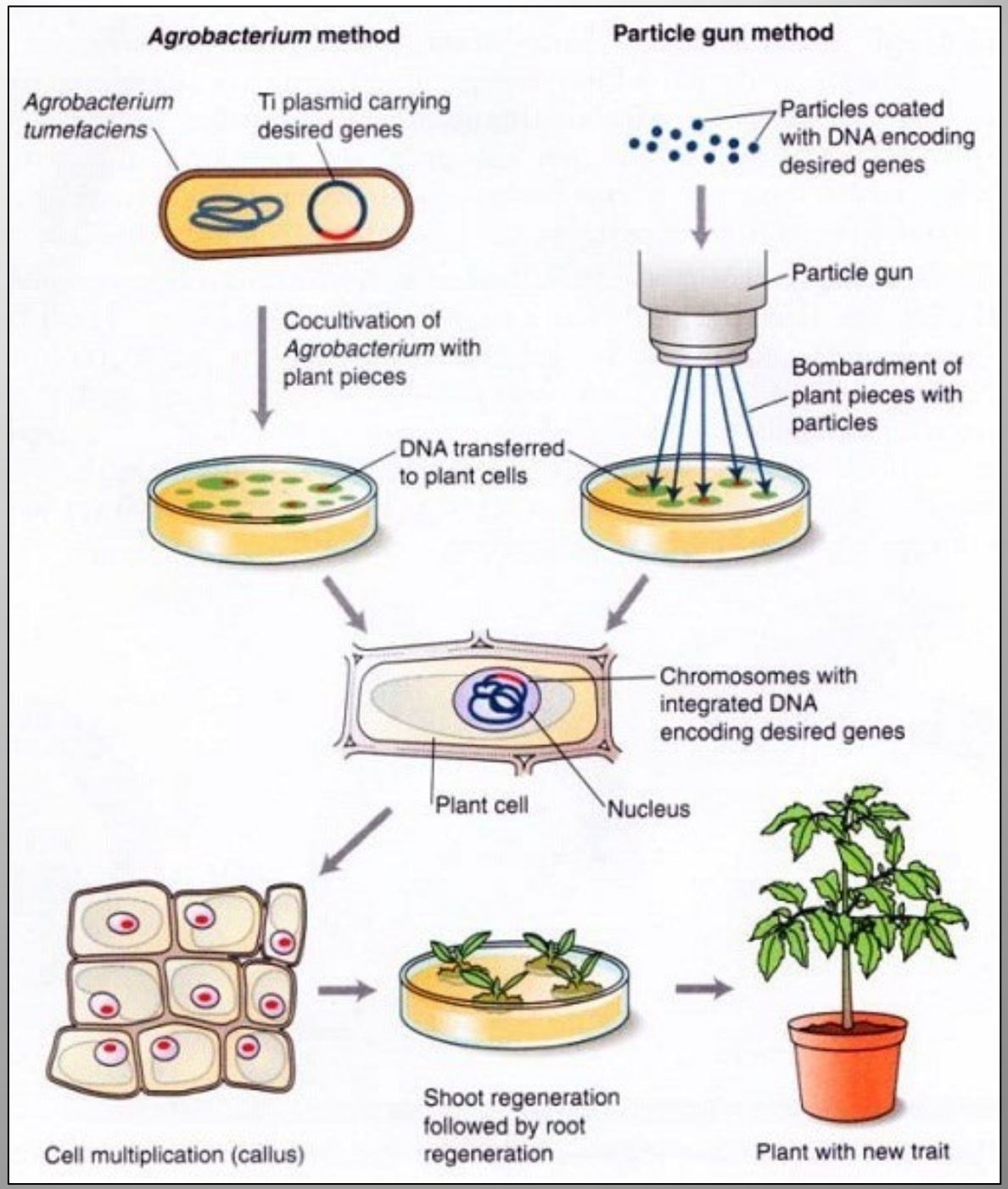


What is GE

- Direct modification of DNA
  - Vs. indirect modification in breeding
- Asexually modified, usually in somatic cells
  - Then regenerated into whole organisms, usually starting in Petri dishes

Young GE cottonwoods starting out their new life and “trying on new genes”

Overview of steps to create a GE plant



Gene editing

- A gene you insert to change other genes in the genome
- Gives highly specific, efficient modification of native genes
- CRISPR the main method out there
- Works well everywhere!

A gene-edited crop on the market: *Soybean with increased oleic acid*

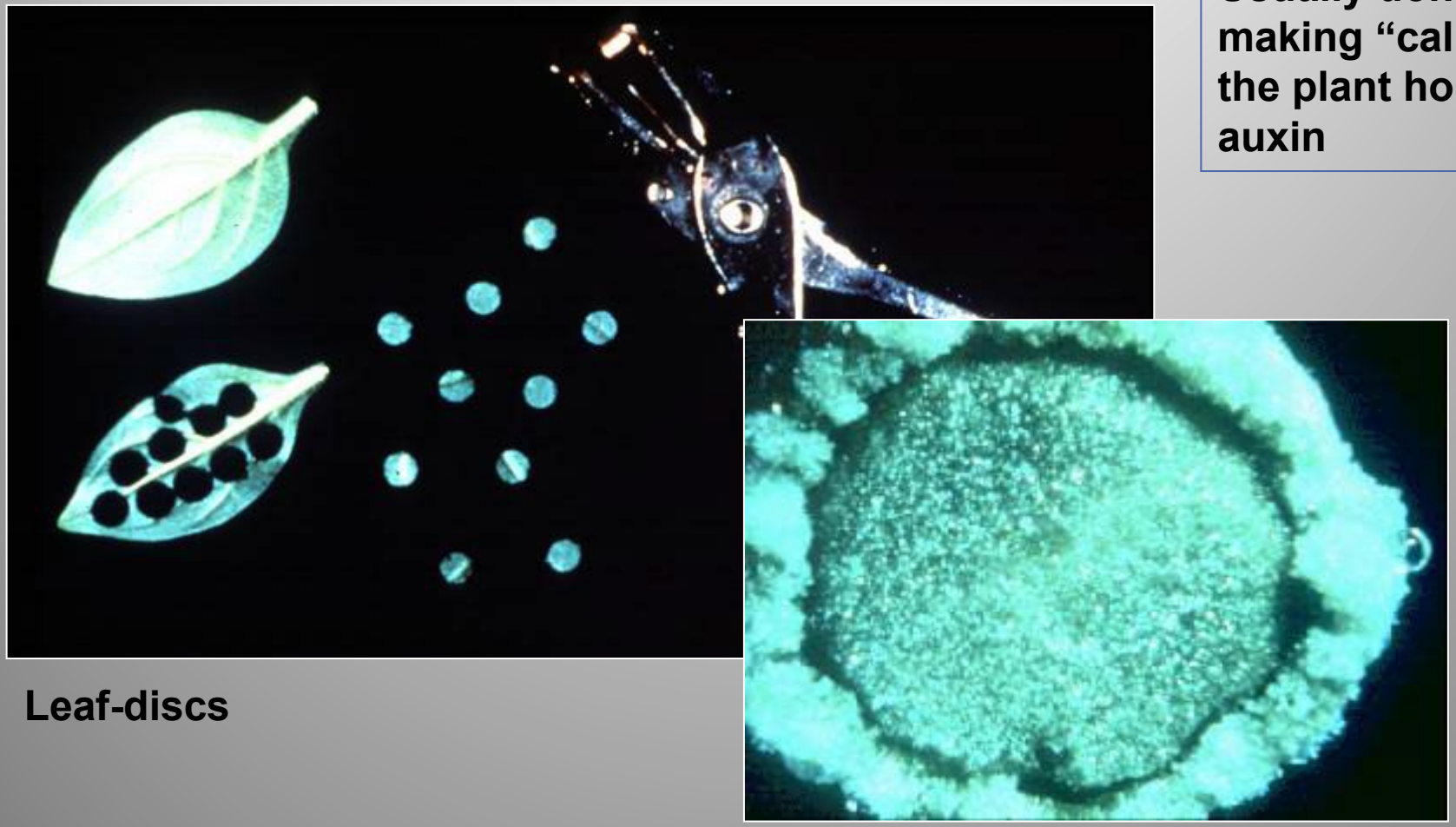
- Its soy oil with properties of olive oil!
- Two brands, two gene-edit methods
  - Calyxt used TALENS
  - DowDupont used CRISPR/Cas9
- Benefits to consumer and producer
  - Consumer-centric trait: Reduced saturated fats, no trans fats – same basic properties as olive oil!
  - Producer-centric trait: Improved shelf-life without need for hydrogenation

Step 1

Getting whole plants back from cultured cells = organismal cloning or plant regeneration

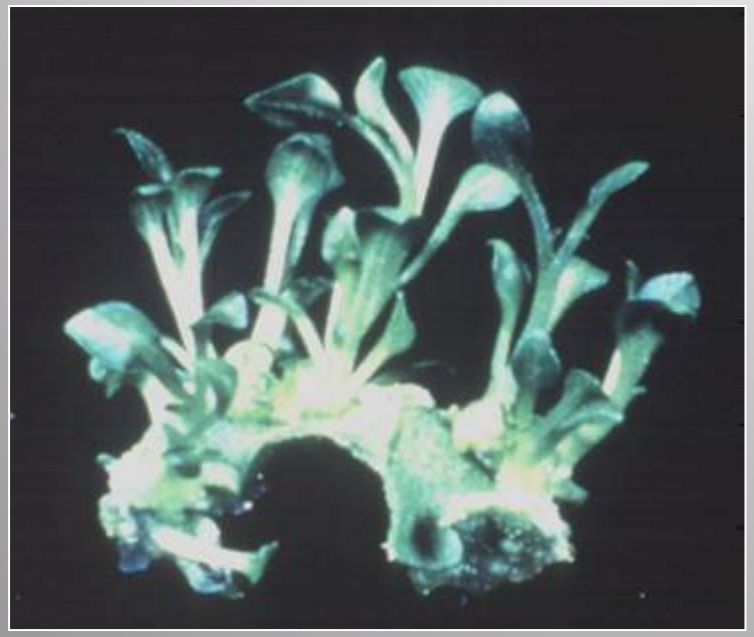
Differentiation of new plant organs (shoots, roots, embryos)

Usually done by making "callus" the plant hormone auxin



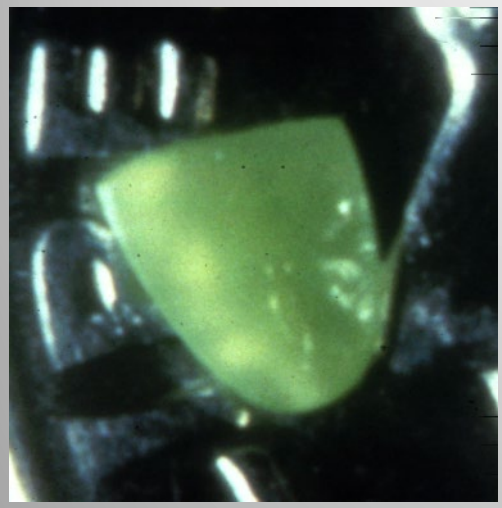
Leaf-discs

Organogenesis: Shoots produced first, then roots, using specific plant hormones for each step

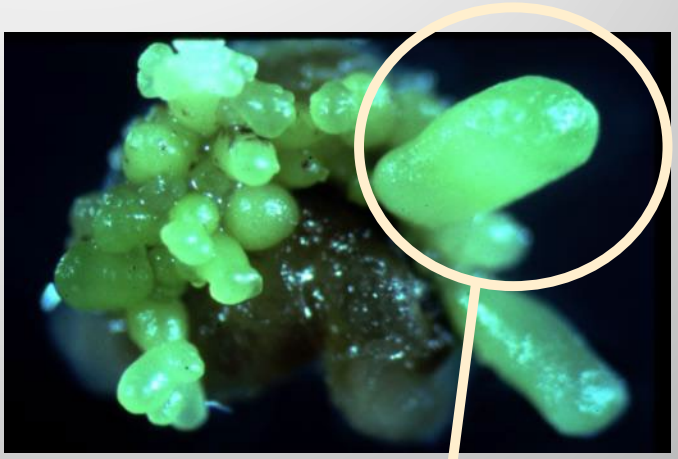


The plant hormone cytokinin key for shoot production

Somatic embryogenesis – shoot-root axis differentiated as a unit

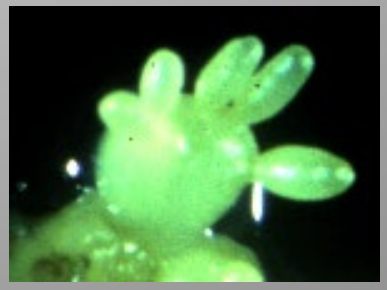


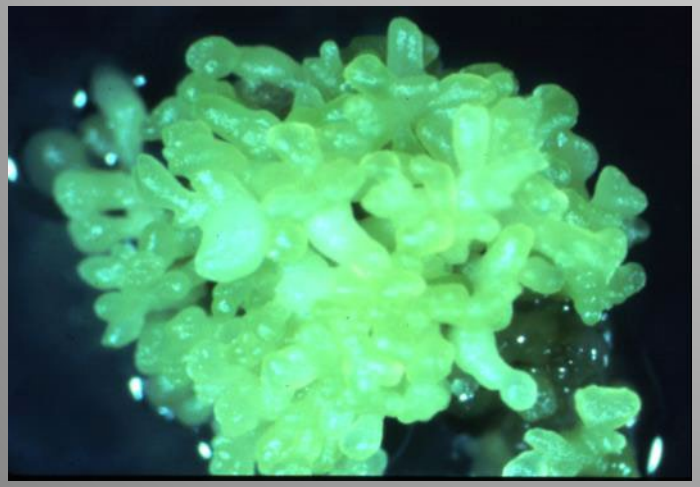
Immature cotyledon



Somatic embryos

Requires special juvenile or reproductive tissues, high auxin and cytokinin





Repetitive embryogenesis = cloning

Step 2

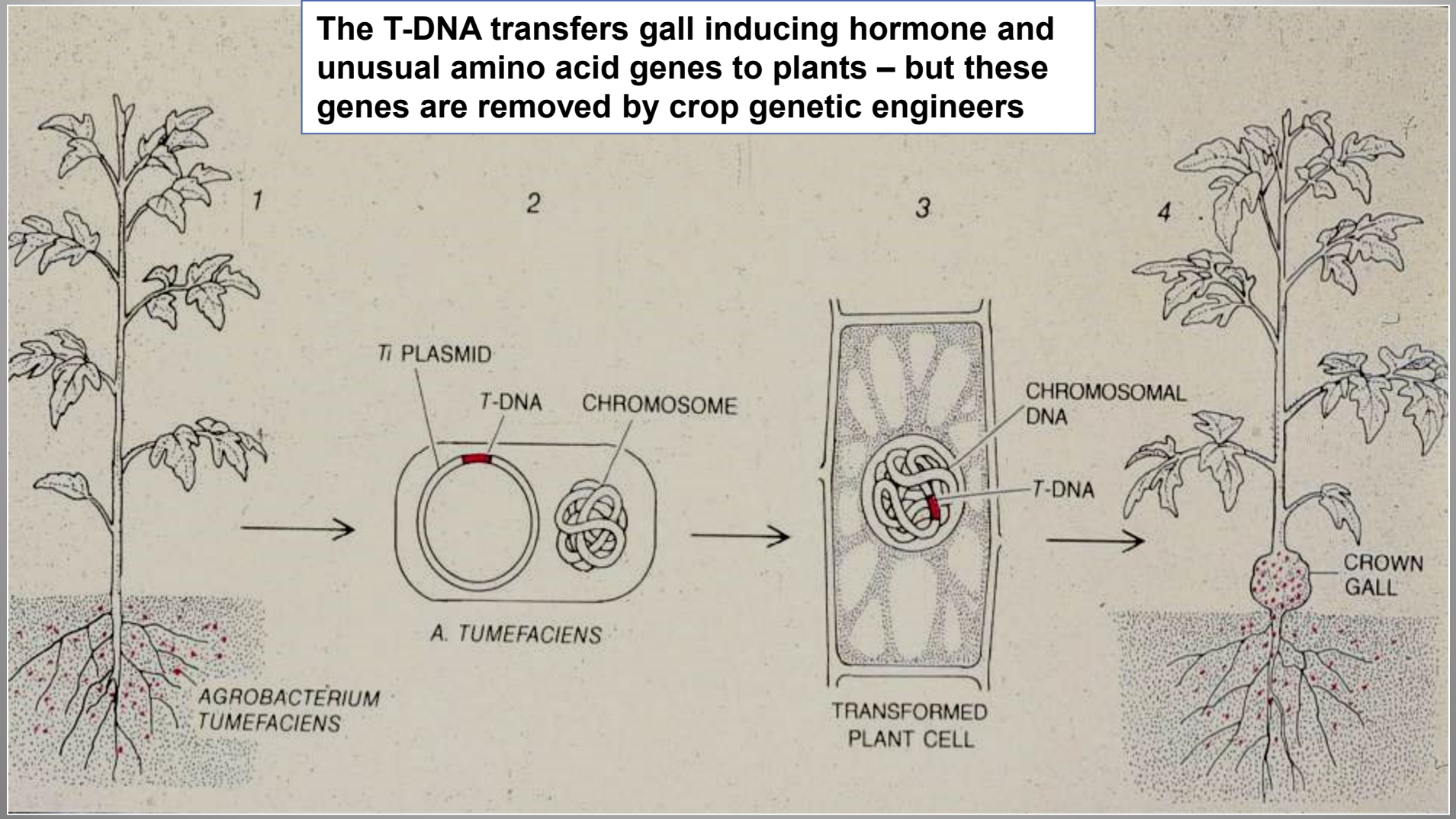
Getting DNA into plant cells

Main methods

- *Agrobacterium tumefaciens*
- Biolistics [gene gun]

Agrobacterium is a natural plant genetic engineer

The T-DNA transfers gall inducing hormone and unusual amino acid genes to plants – but these genes are removed by crop genetic engineers



“Horizontal gene transfer” is pretty common: *Plants often naturally contains Agrobacterium genes*

Plant Molecular Biology (2019) 101:415–437
https://doi.org/10.1007/s11103-019-00913-y

Check for updates

Widespread occurrence of natural genetic transformation of plants by *Agrobacterium*

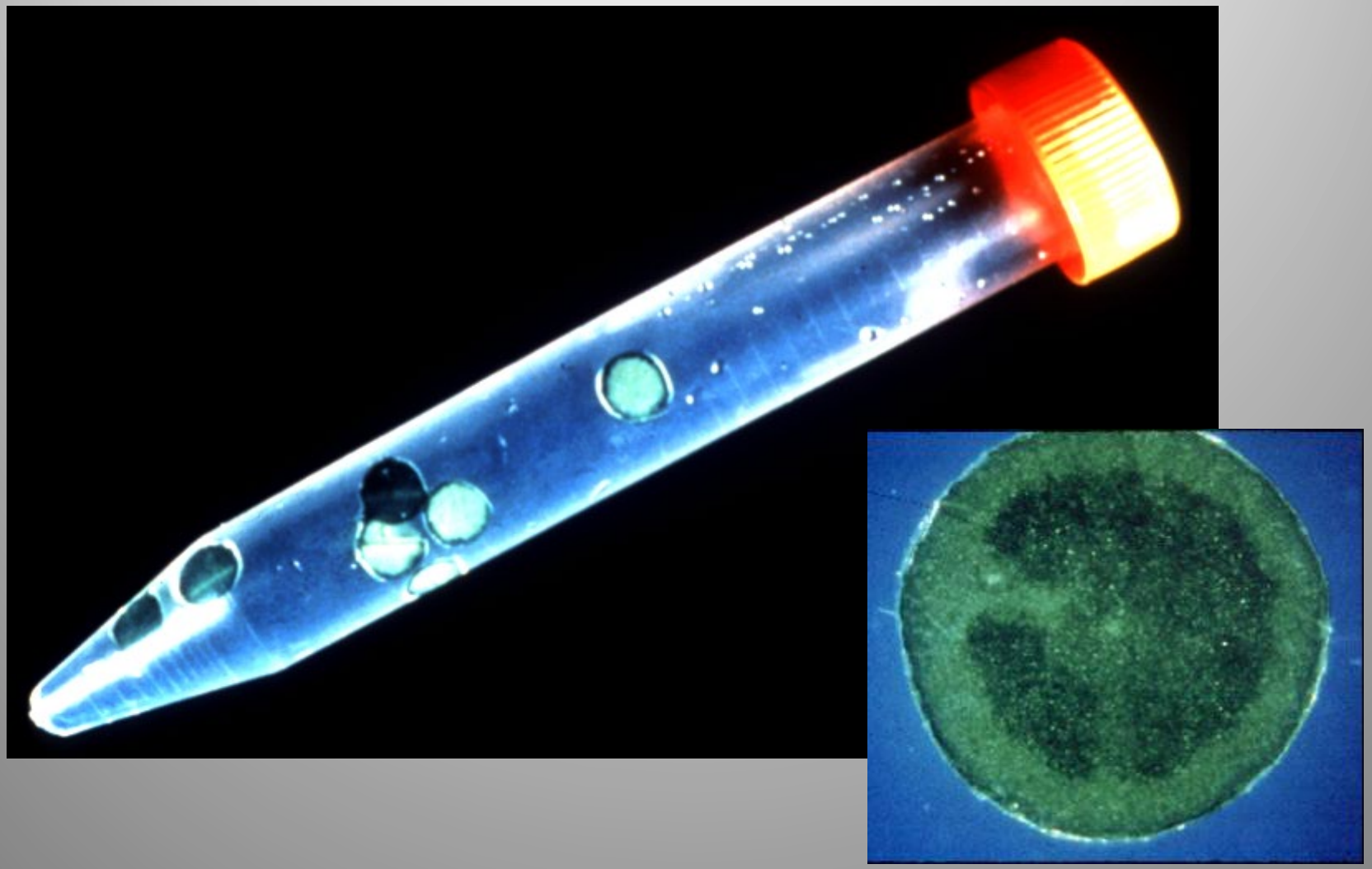
Tatiana V. Matveeva[1] · Léon Otten[2]

Received: 18 June 2019 / Accepted: 21 August 2019 / Published online: 21 September 2019

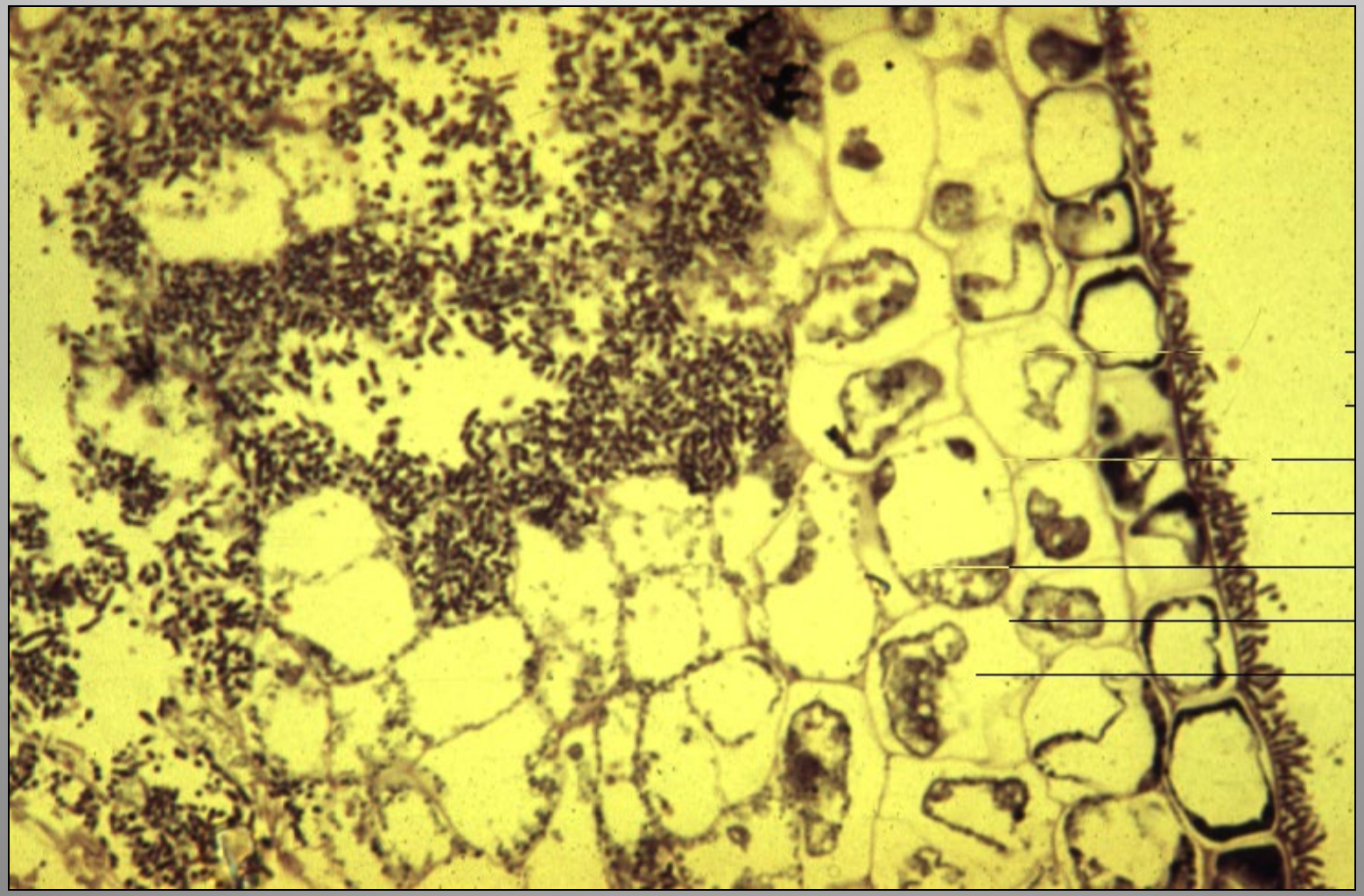
Abstract
Key message **Naturally transgenic plant species occur on an unexpectedly large scale.**

As we sequence plant genomes, we see many cases of Agrobacterium DNA that become permanent parts of plant genomes far back in evolutionary time (>23 out of 275 dicot species tested)

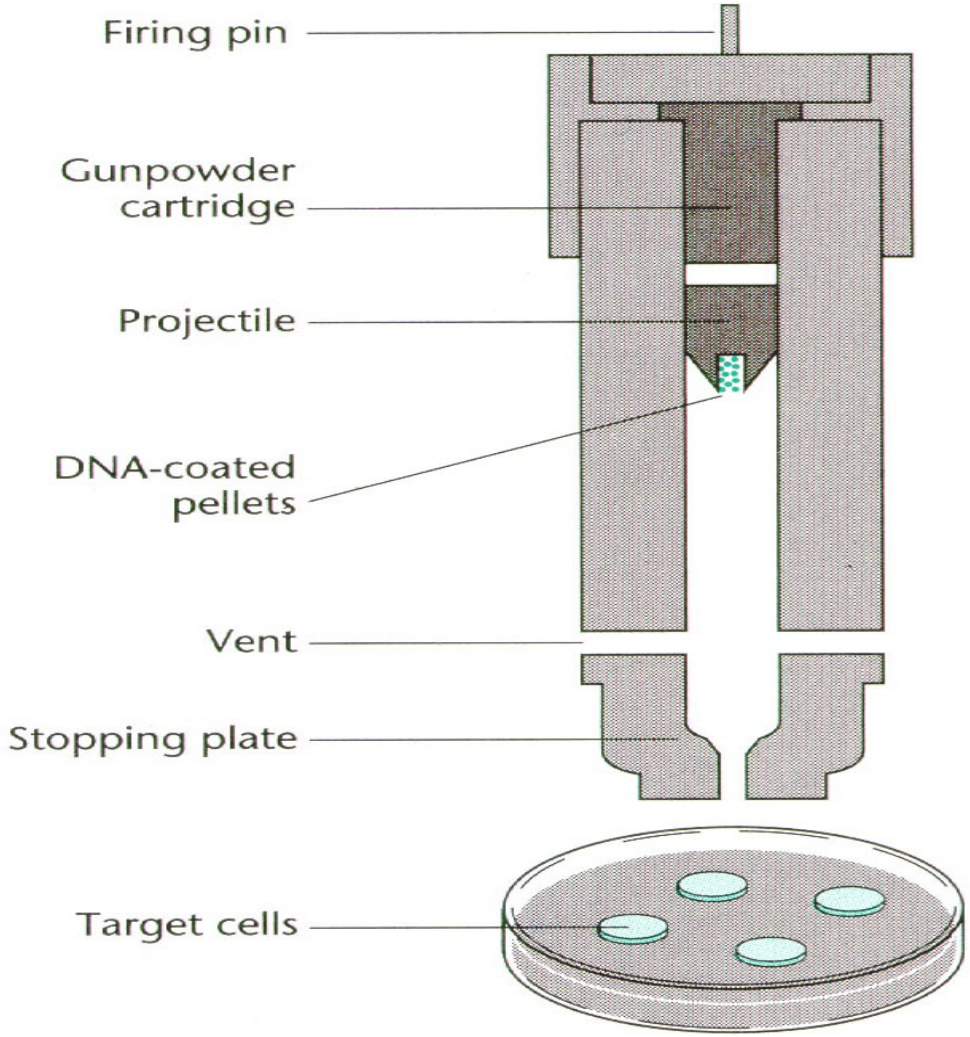
Cocultivation of Agrobacterium with plant tissues



Agrobacterium in contact with wounded plant tissues during cocultivation

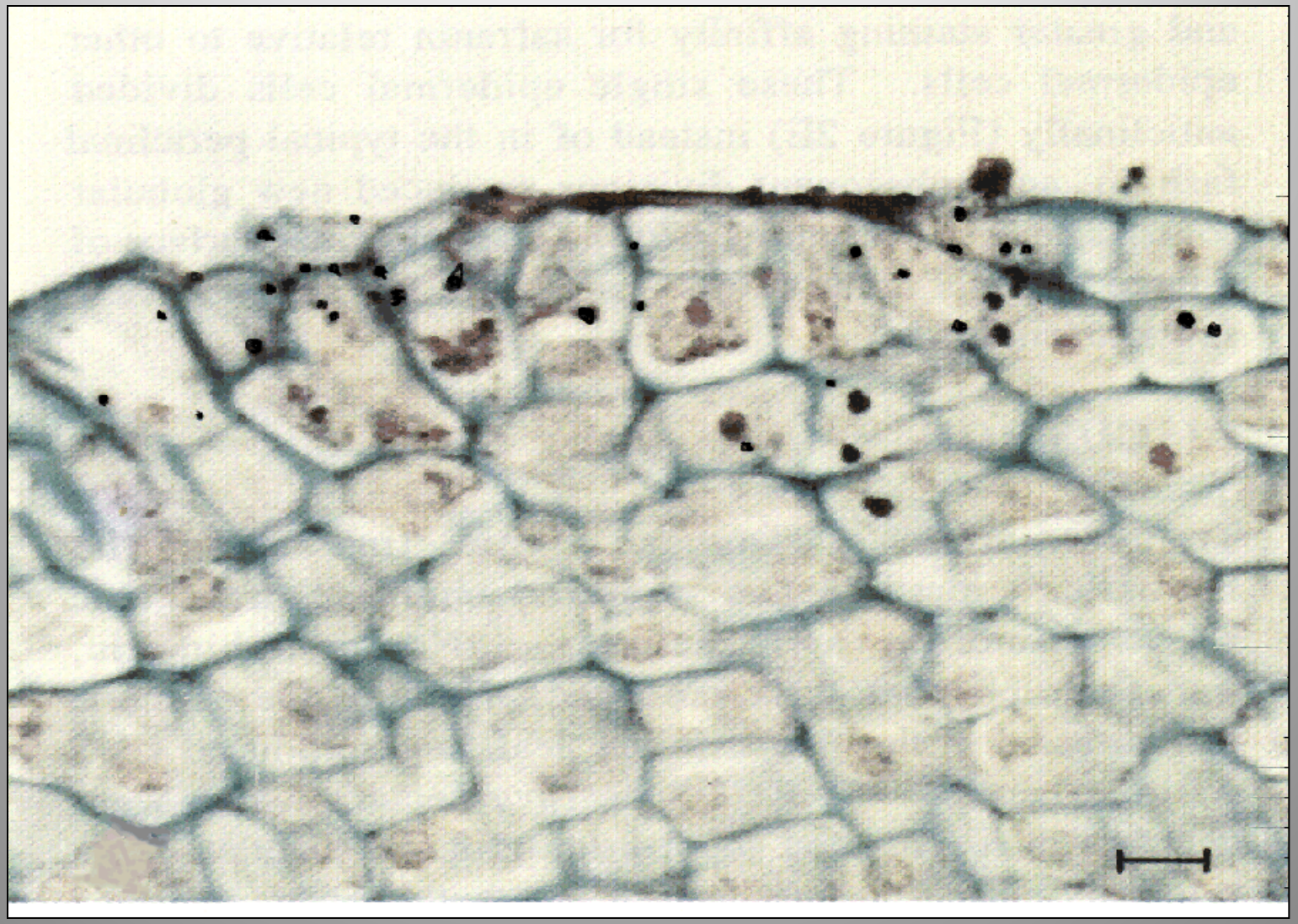


Gene-gun ("biolistic") bombardment of plant tissues

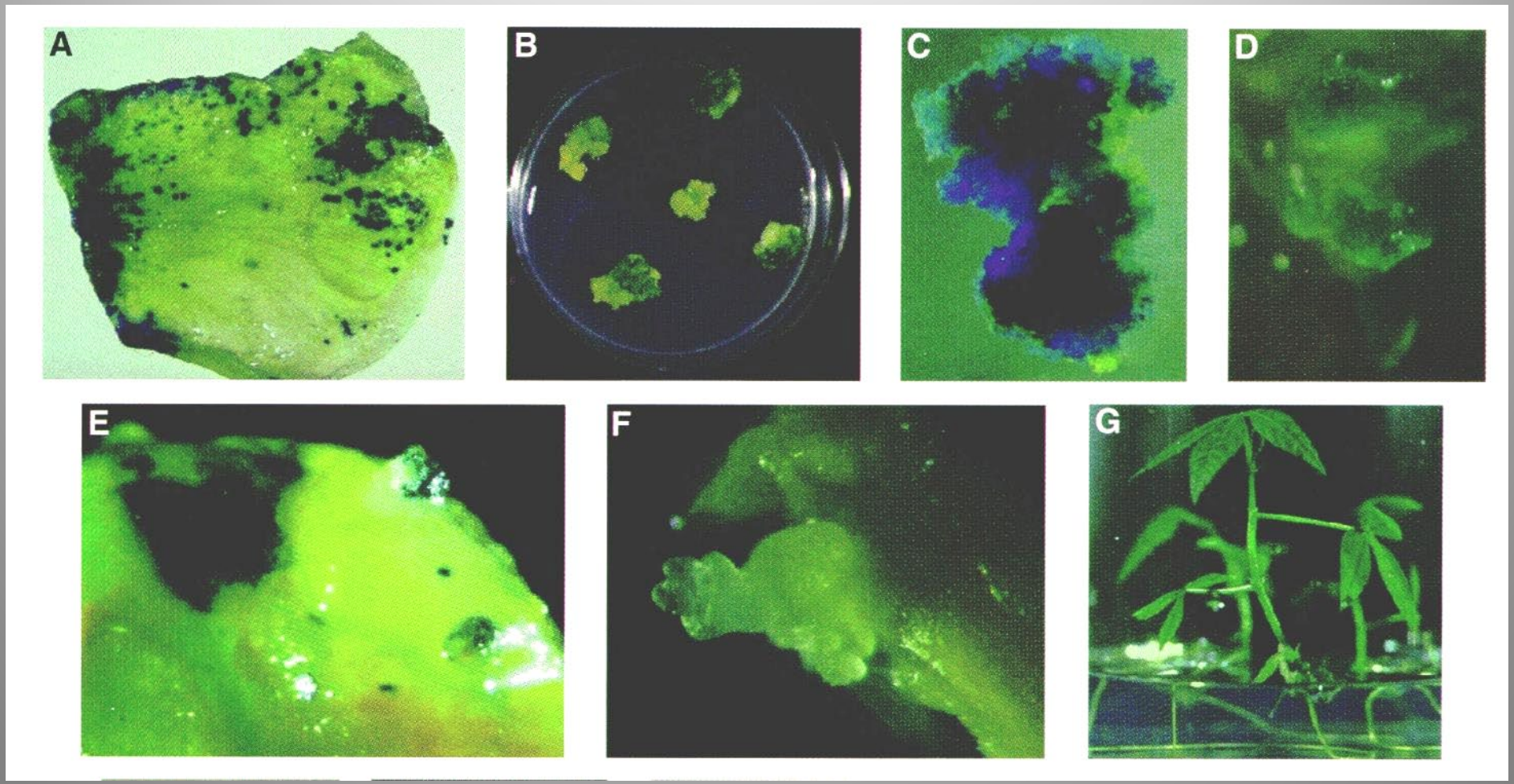


High pressure air pulse system

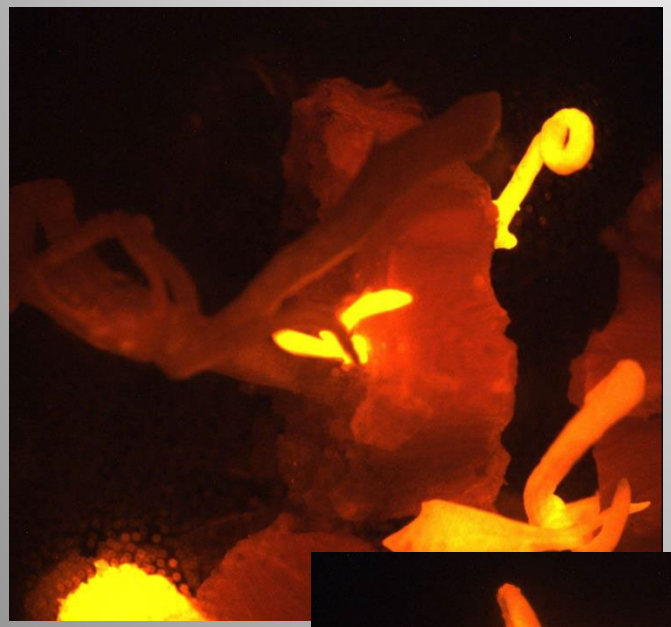
DNA coated metal particles after "gene gun" insertion into tissues



Transgenic cassava via gene gun - GUS "reporter gene" helps to visualize transgenic cells as they grow (blue color)



Fluorescent “reporter genes” now common, non-destructive (green fluorescent protein, dsRED, and many others



SCIENCE

LISTEN & FOLLOW

Watch your garden glow with new genetically modified bioluminescent petunias

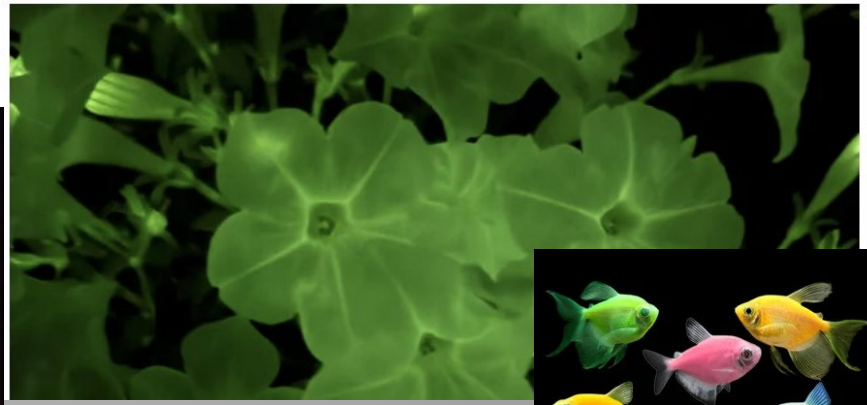
APRIL 8, 2024 · 3:01 PM ET

HEARD ON ALL THINGS CONSIDERED

By Sasa Woodruff

FROM BOISE STATE PUBLIC RADIO

3-Minute Listen + PLAYLIST

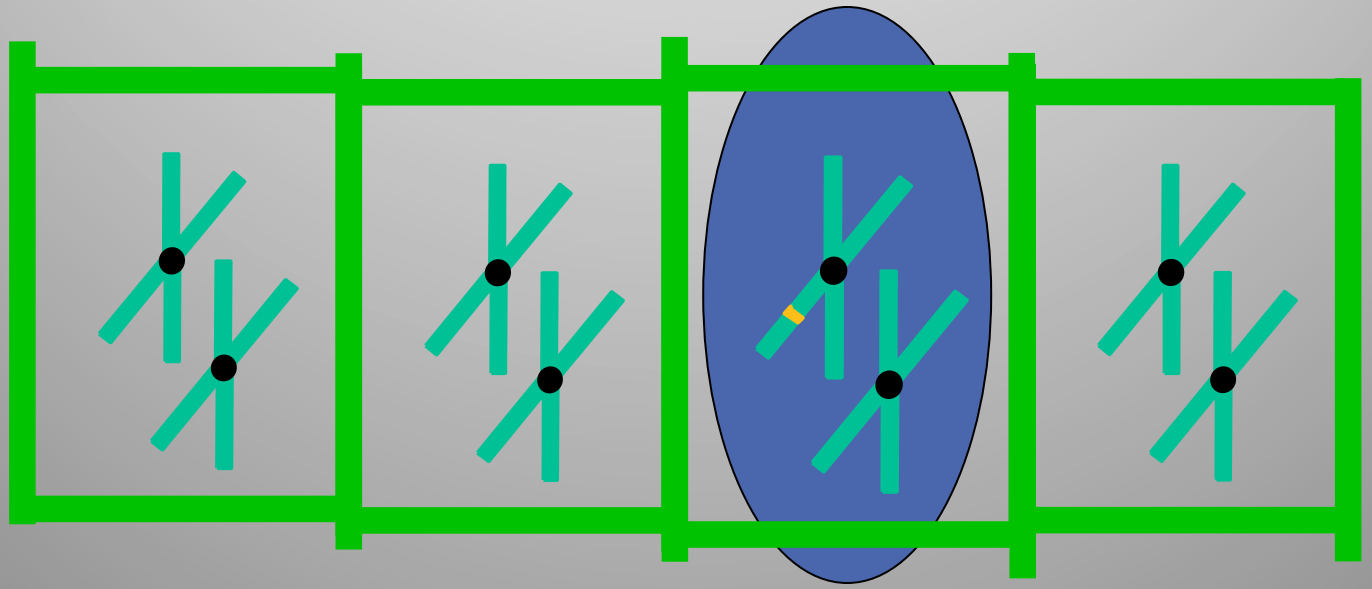


Step 3

Selection of transgenic cells

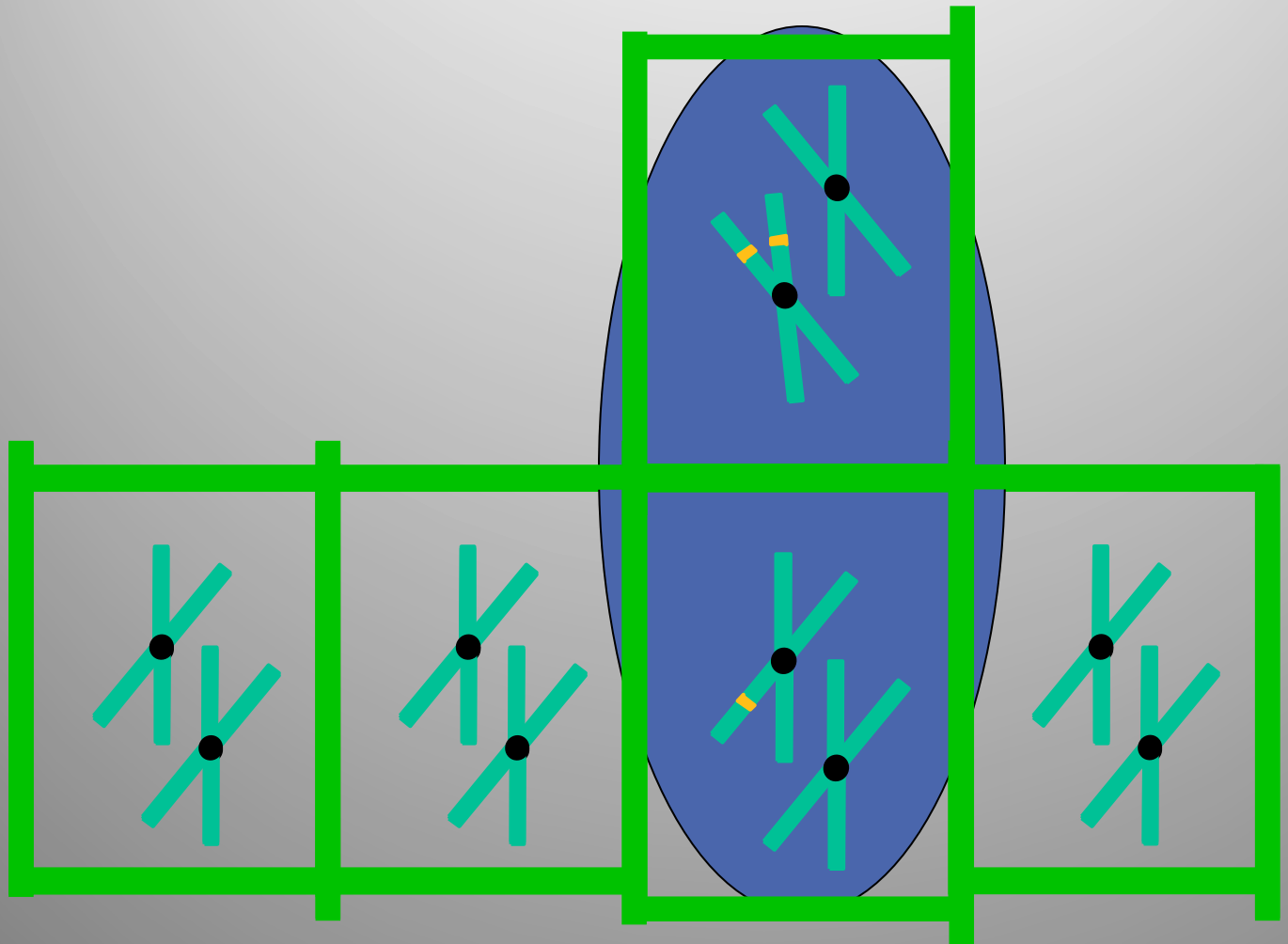
Only a few cells get engineered

Challenge: Recover plants from one cell so new plant is not chimeric (i.e., not genetically variable within the organism)



Antibiotics in plant tissue culture limit growth to engineered cells

Other kinds of genes can also be used to favor transgenic cells (e.g., sugar uptake, herbicide resistance, hormone sensitivity)



Antibiotic selection of transgenic tissues in poplar trees

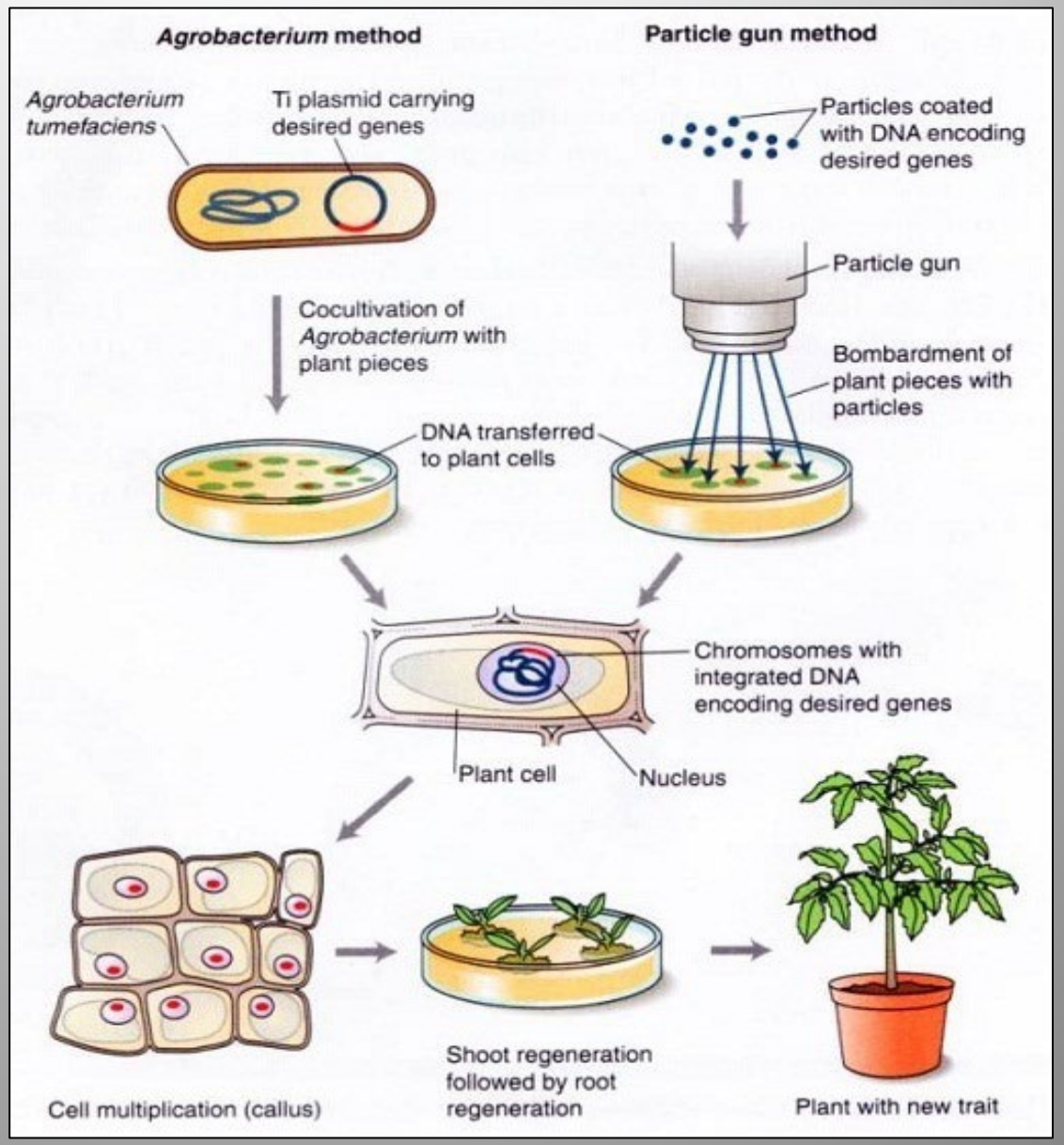
Then plants are propagated normally (seeds, cuttings) and tested for health and new qualities

Propagation of poplars in tissue culture

Growth in the field

Review of steps to create a GMO or gene-edited plant

- Genes added to cells by biological agent or "gene gun"
- Find modified cells using bio-tricks!
- Regenerate cells into uniform modified plant
- Segregate or excise gene-editing agents away



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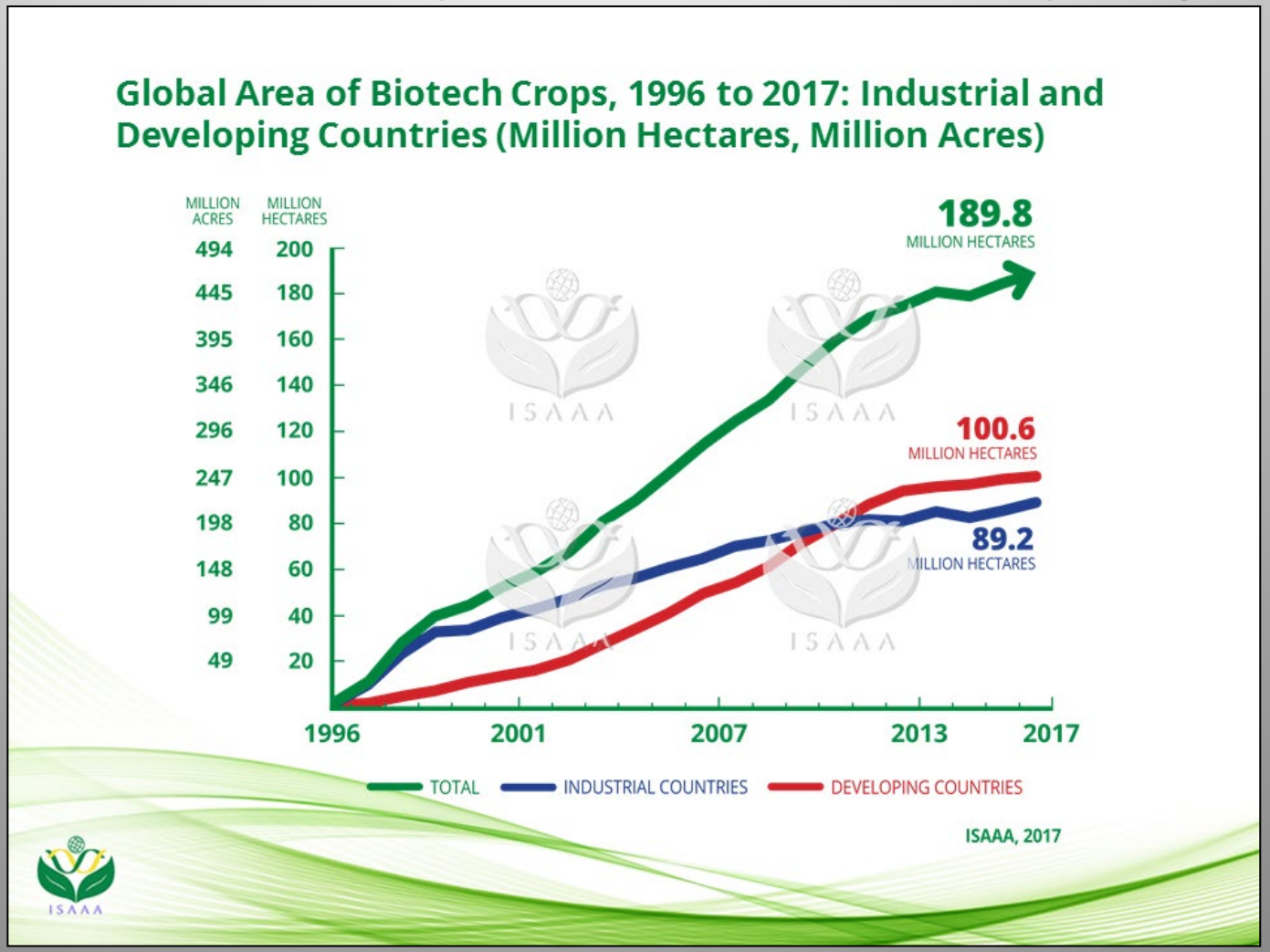
- Some impacts
- The public controversy / skepticism

Global Status of Commercialized Biotech/GM Crops in 2017:

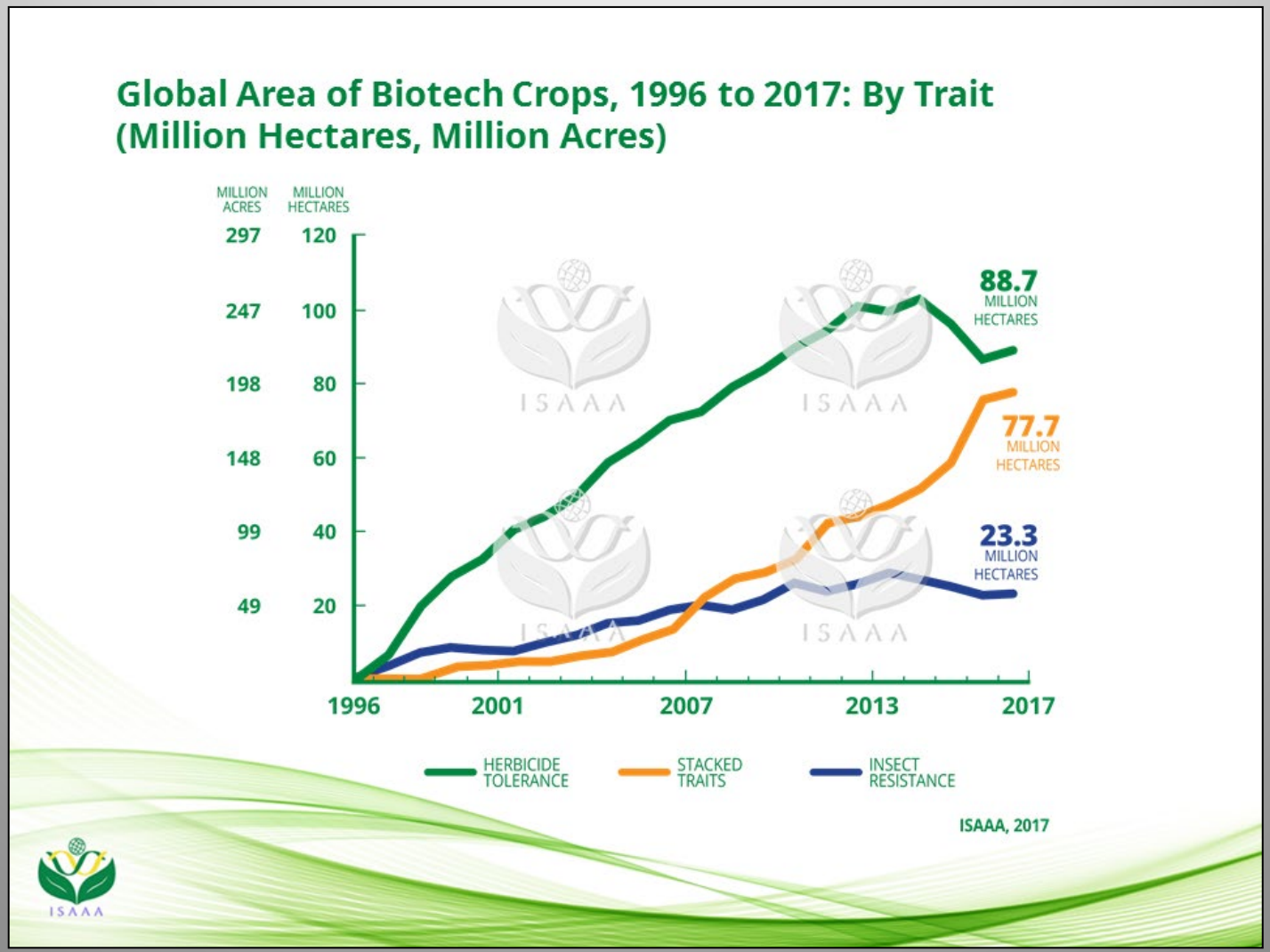
Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years

International Service for the Acquisition of Agri-biotech Applications (ISAAA)

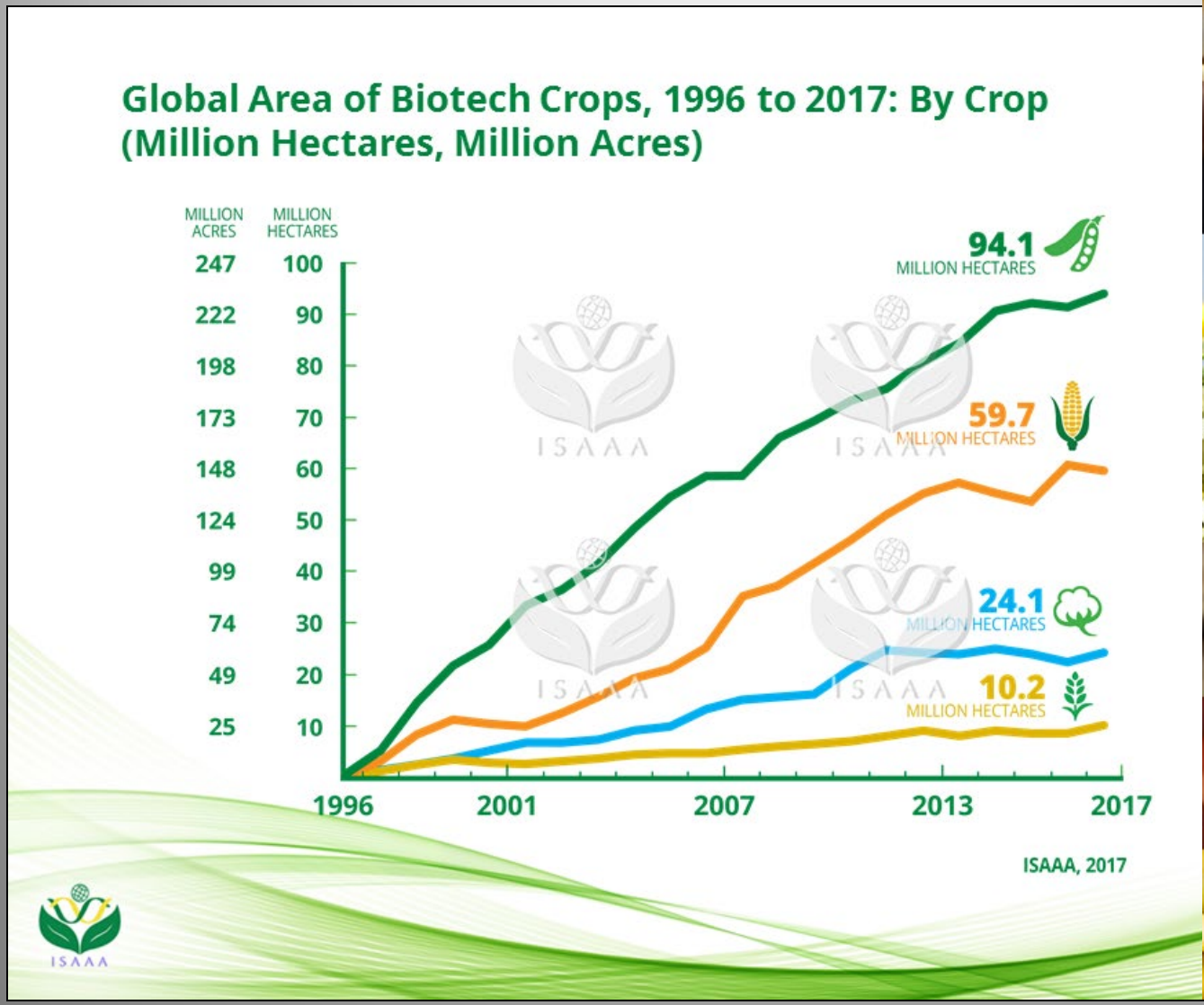
First generation herbicide and insect resistant crops rapidly adopted by farmers, in developed and developing world



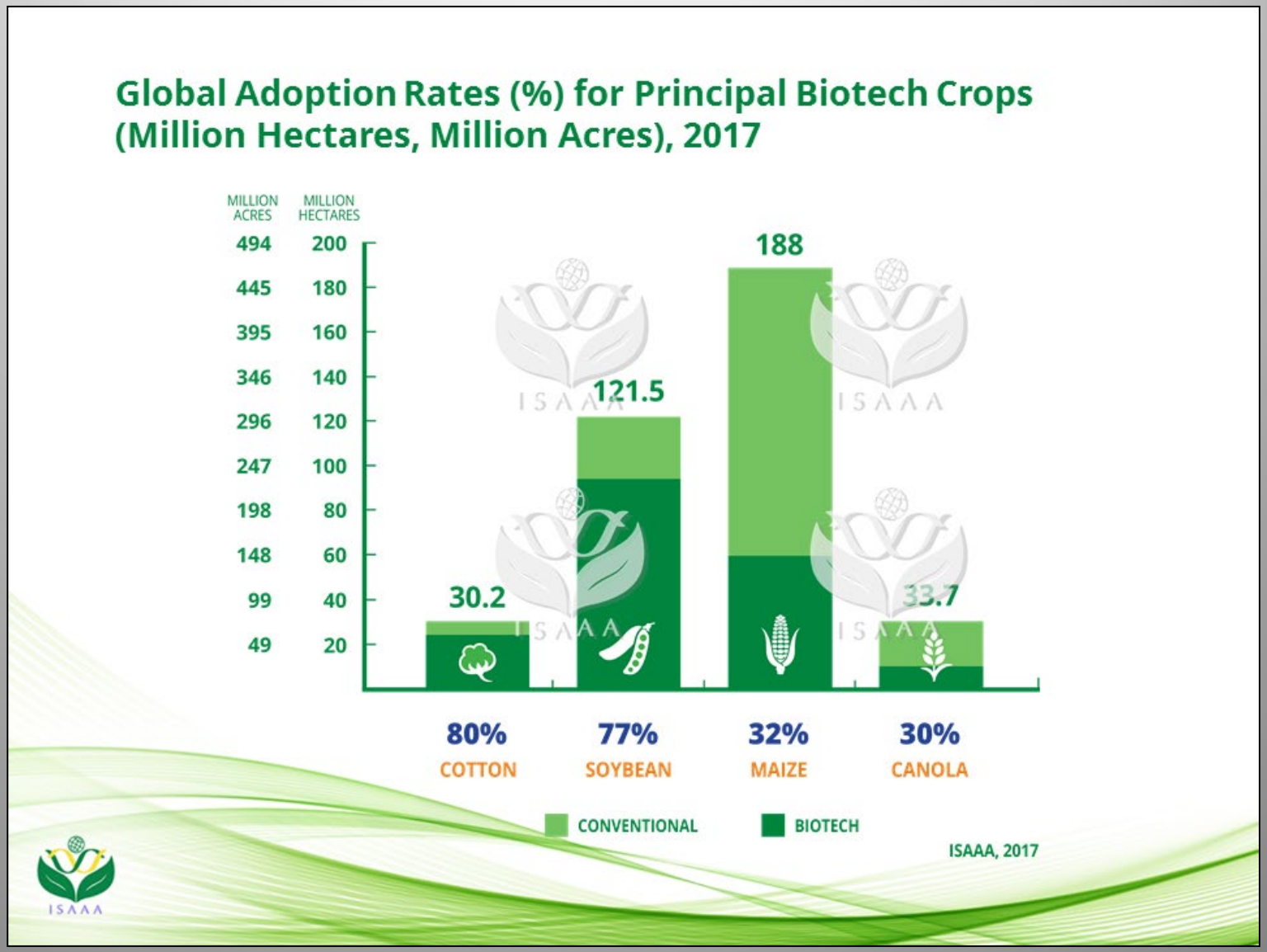
Herbicide and pest resistance traits dominate worldwide, increasingly “stacked” in trait-combinations



Four crops dominate, 8+ GMO crops in USA

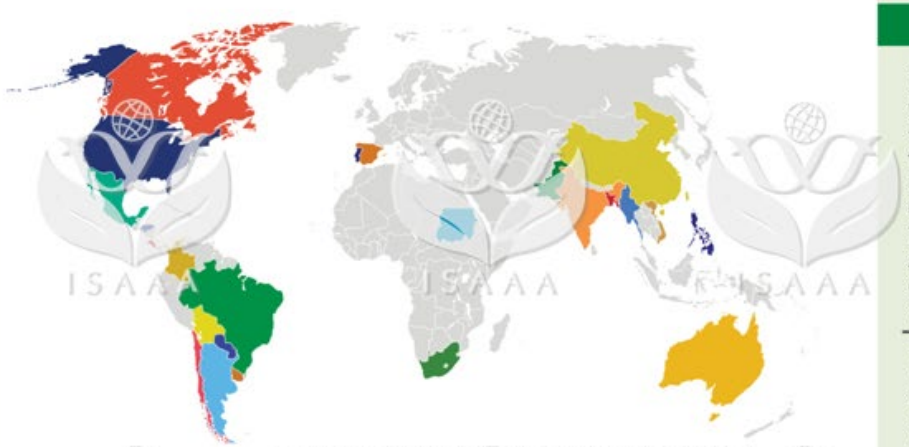


Large fractions of major crops are biotech varieties



But adoption rates highly variable

Global Area of Biotech Crops, 2017: By Country (Million Hectares)



24 countries which have adopted biotech crops

3% Increase from 2016

In 2017, global area of biotech crops was 189.8 million hectares, representing an increase of 3% from 2016, equivalent to 4.7 million hectares.

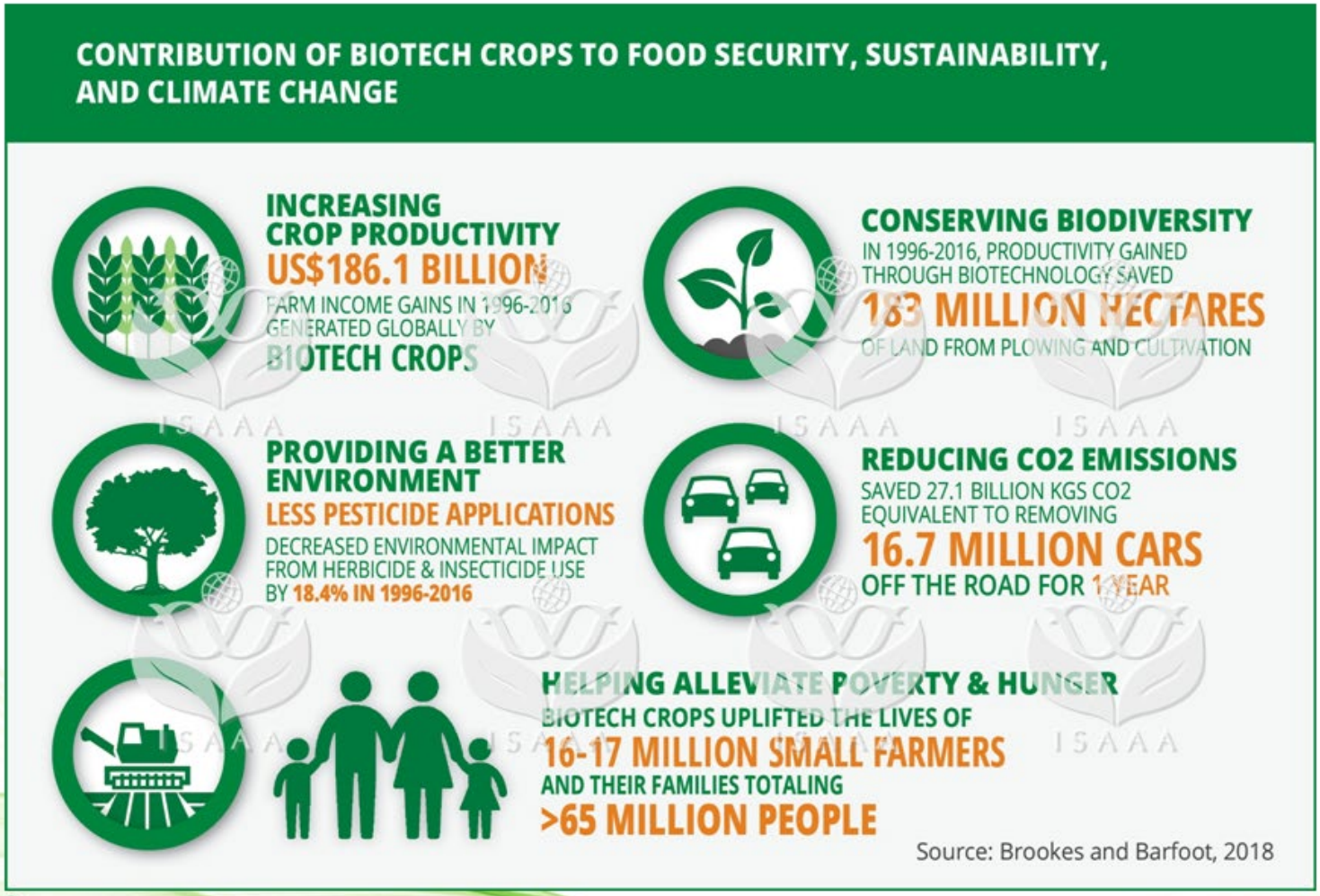
Source: ISAAA, 2017.

50,000 hectares, or more	
1. USA	75.0 million
2. *Brazil**	50.2 million
3. *Argentina**	23.6 million
4. Canada	13.1 million
5. *India**	11.4 million
6. *Paraguay**	3.0 million
7. *Pakistan**	3.0 million
8. *China**	2.8 million
9. *South Africa**	2.7 million
10. *Bolivia**	1.3 million
11. *Uruguay**	1.1 million
12. Australia	0.9 million
13. *Philippines**	0.6 million
14. *Myanmar**	0.3 million
15. *Sudan**	0.2 million
16. Spain	0.1 million
17. *Mexico**	0.1 million
18. *Colombia**	0.1 million

Less than 50,000 hectares	
*Vietnam**	Portugal
*Honduras**	*Bangladesh**
*Chile**	*Costa Rica**

* *Developing countries*

Claims of large environmental benefits



https://www.tandfonline.com/doi/full/10.1080/21645698.2017.1309490 for details/updates

Global “meta-analysis” of early impacts: 2014

“147 original studies were included.”
“On average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%.”

Insect-resistant crops with huge impact on economics and sustainability

Pray et al., 2002. Plant J. 31:423-430
Photo: entomologytoday.org Dominic Reisig

Non-GMO vs. insect resistant Bt cotton without pesticide use

Insect resistant eggplant a great success in Bangladesh, illegal plantings in India

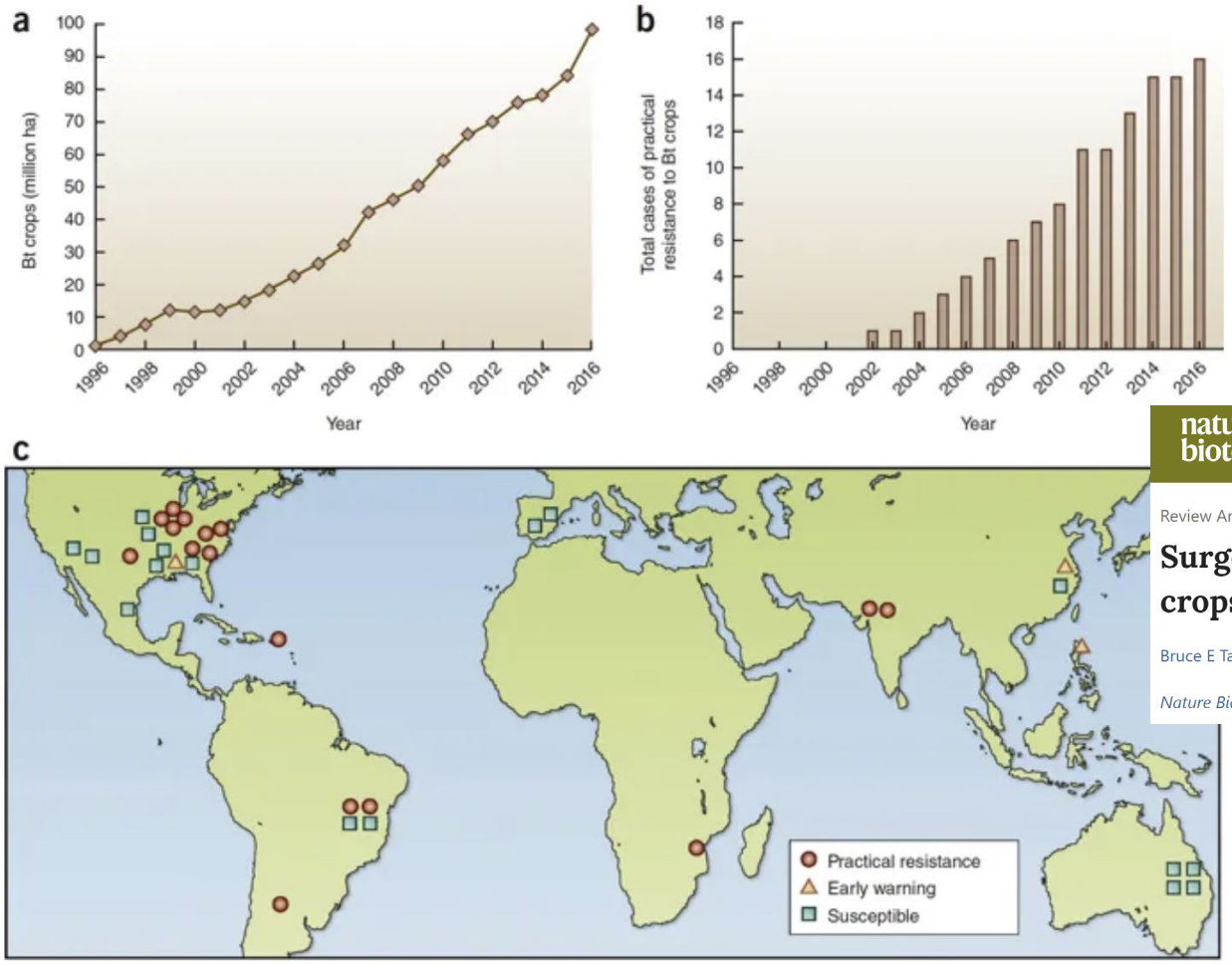
Non-Biotech

Biotech

http://www.isaaa.org/resources/publications/briefs/47/download/isaaa-brief-47-2014.pdf

But, insect resistance to BT also growing

Figure 1: Global status of pest resistance to Bt crops.



nature biotechnology

Review Article | Published: 11 October 2017

Surge in insect resistance to transgenic crops and prospects for sustainability

Bruce E Tabashnik & Yves Carrière

Nature Biotechnology **35**, 926–935(2017) | Cite this article

Herbicide tolerant plants promote conservation tillage – With many environmental benefits thereof

Conservation Technology Information Center

- Lowers greenhouse gas emissions
- Improves soil organic matter
- Reduces erosion and fertilizer runoff into water

GMO crops have accelerated development of herbicide-resistant weeds

And motivated development of new kinds of herbicide tolerant crops

nature biotechnology

nature.com ▸ journal home ▸ archive ▸ issue ▸ news ▸ full text

NATURE BIOTECHNOLOGY | NEWS

Glyphosate resistance threatens Roundup hegemony

Emily Waltz

Nature Biotechnology **28**, 537–538 (2010) | doi:10.1038/nbt0610-537
Corrected online **13 October 2010**
Corrigendum (October, 2010)

PDF | Citation | Reprints | Rights & permissions | Article metrics

Weeds are becoming increasingly resistant to glyphosate, a report from the US National Academy of Sciences (NAS) released in April has found. The driving force, according to the report, is farmers' dependence on the weed killer accompanied by the widespread adoption of genetically modified (GM) herbicide-tolerant crops. Seed makers are hoping to forestall the problem by developing GM crops with 'stacked' traits that tolerate multiple herbicides. But weed scientists warn that if farmers manage these new crops in the same way as they managed their glyphosate-tolerant predecessors, weeds will simply become resistant to the new technologies.

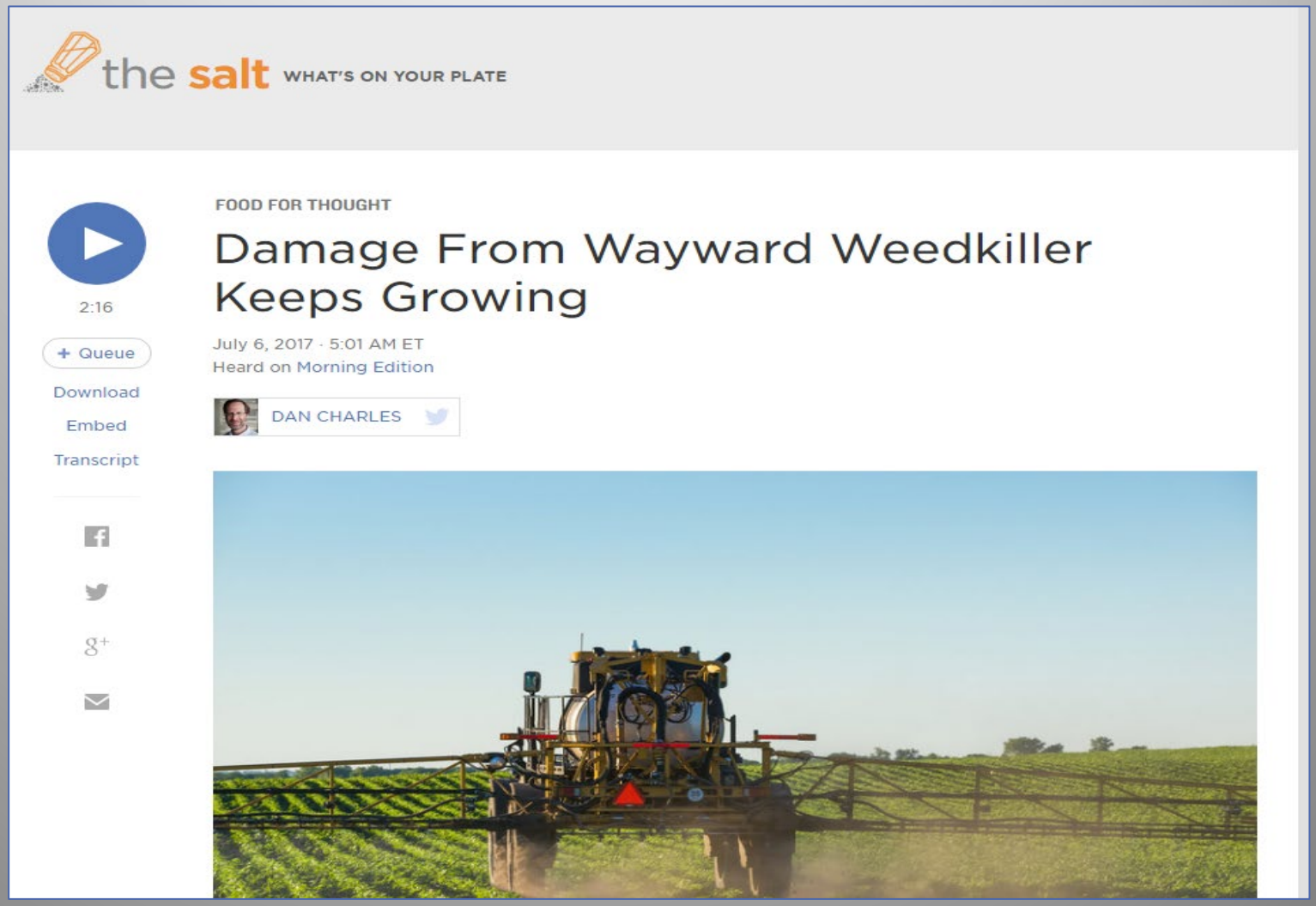
*The number of weed species evolving resistance to glyphosate

BILL BARKSDALE / AGSTOCKUSA /

The original clean fields – HR cotton

Not an uncommon sight now

Damage from growing use of dicamba resistant crops – due to chemical's volatility



Roundup-tolerant bentgrass escape in Oregon

http://www.oregonlive.com/business/index.ssf/2017/01/grass_seed_industry_fearful_ab.html

http://www.oregonlive.com/business/index.ssf/2017/01/post_248.html

Agenda

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Main sources of GMO/chemical controversy

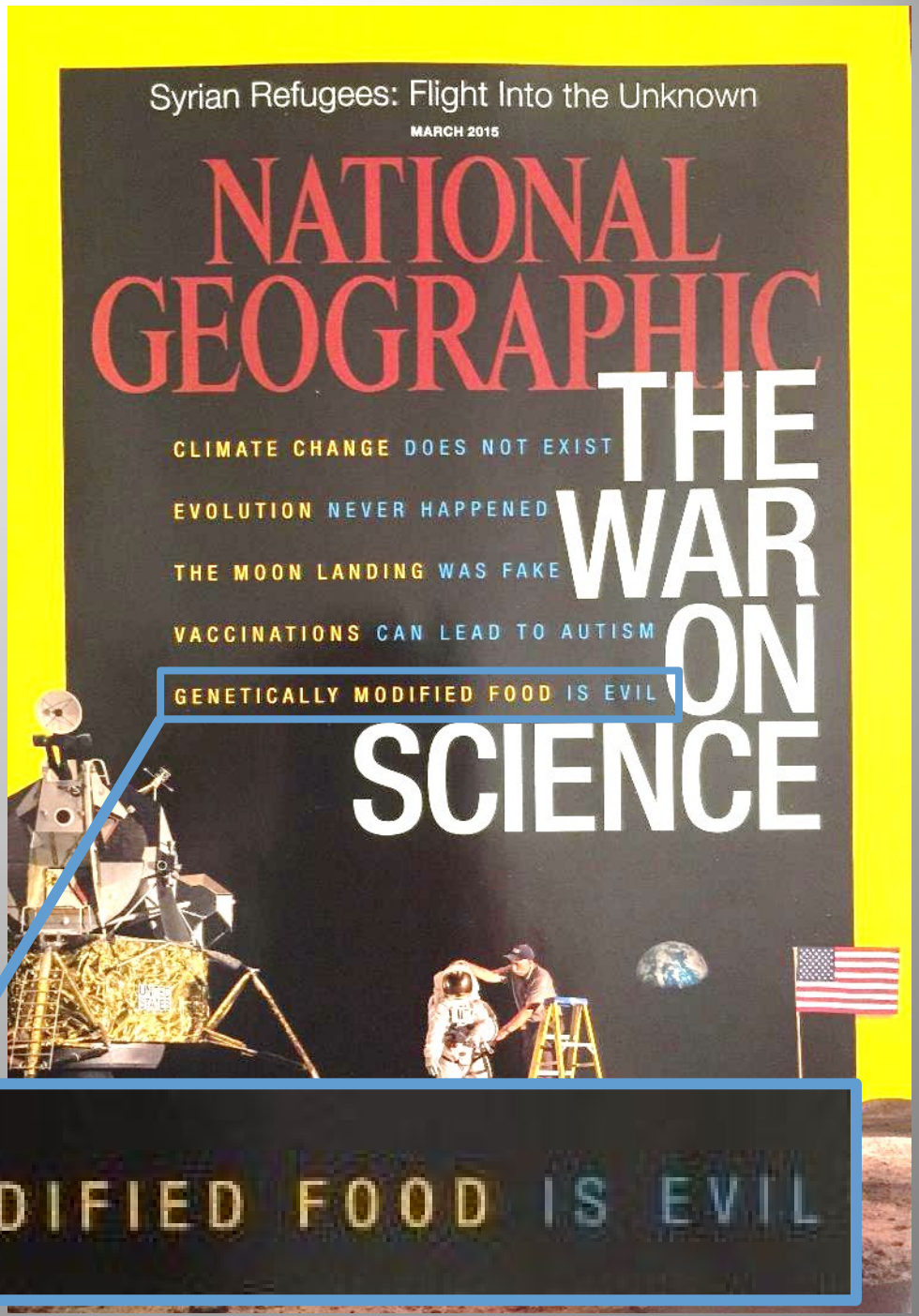
- Human need, new and rapid science
  - Population and consumption growth, food cost, widespread malnutrition, environmental damage
  - GE methods and chemicals give many solutions = technology push
- Ethics
  - Breaking of traditional boundaries in directly modifying and moving genes, putting chemicals in environment, press concepts of rightness
  - Is it OK to move a human modified gene into a wild gene pool?
- Risk perception
  - Complex and invisible science and technology, often without direct consumer benefits = high perception of risk
  - Chemophobia: All pesticides bad, GMOs make worse
- Appropriate role of government/laws
  - Extent of precaution? Regulation stringency?
  - Labeling/exemptions? Harmonizing rules to allow trade?

Why the controversy, continued

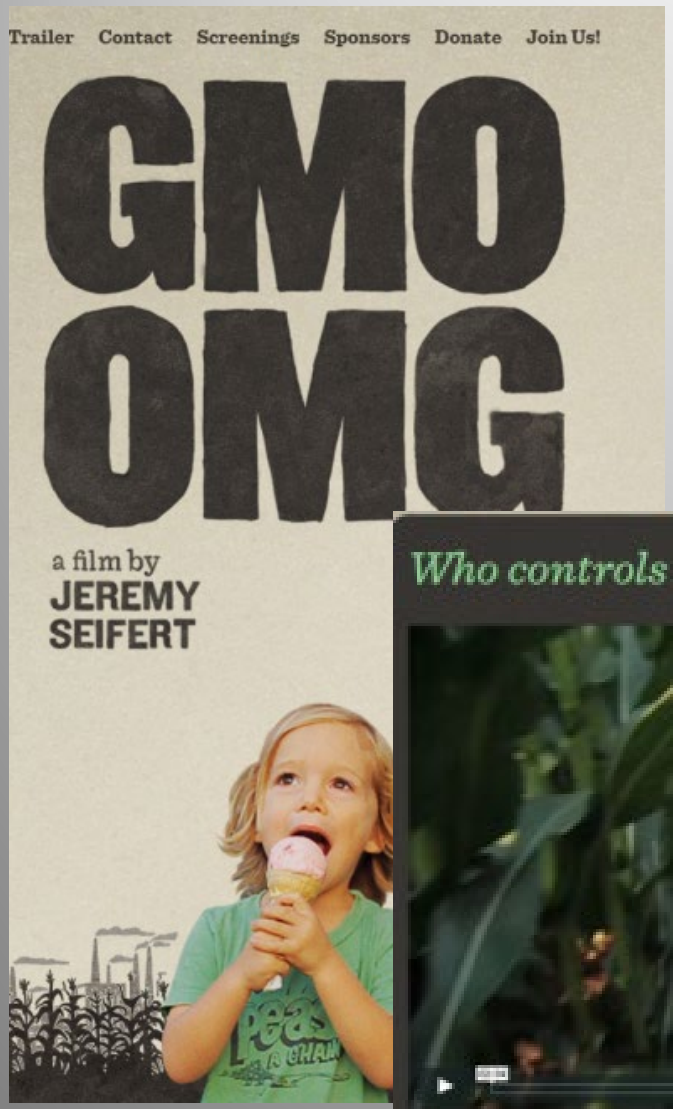
- Strong corporate role: Control of seeds, chemicals, patents, industrial ag, the "Monsanto effect"
  - Communitarian vs. hierarchic ideologies
  - Unfair? intellectual property control, influence on politics
- Private sector self-interest: Strong pro- and anti- GMO and chemical business and political forces
  - Pro: Strong financial interests, lobbying, resources
  - Anti: Strong private sector green/organic/alternative health/"natural" marketing
- Powerful political tool
  - Local politics: Strong pressure on politicians to oppose in EU, India
  - Global politics: Tool for state rivalries, non-tariff barriers (Russia, EU)
- Science uncertainties
  - Rapid new knowledge and technologies, blurring synthetic and natural
  - Technology progress, human safety, ecological impacts
- Gene flow and chemical dispersion
  - Ag is leaky, gene and chemical movement common, can be long distance
  - Seed purity: Coexistence challenges with low biotech tolerances, local and international issues

GMOs one of the "fake news - fake science" issues

It's hard to tell what science is saying amidst all the noise

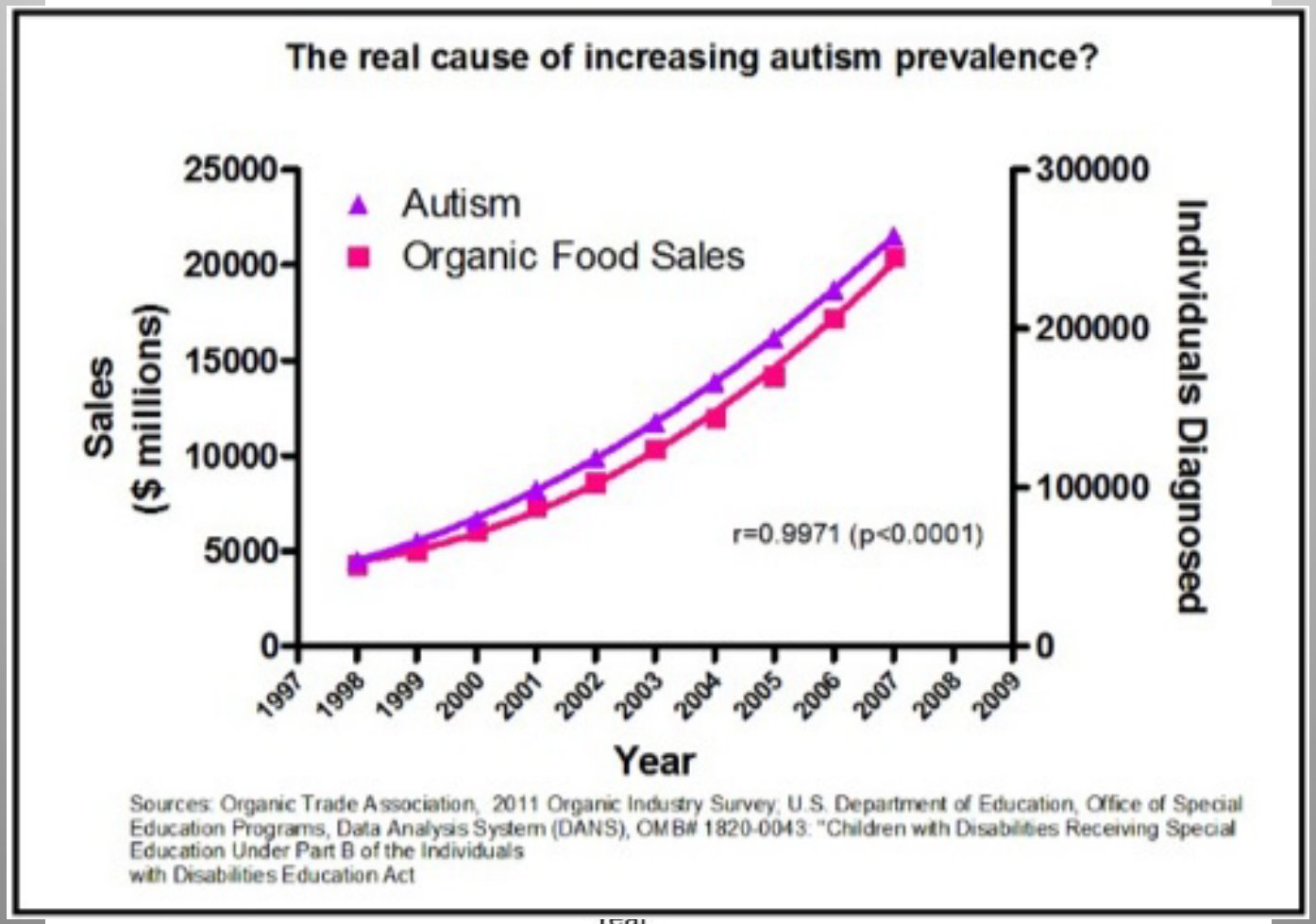


There are numerous myths that are rampant and recycled in media



"GMO" has taken on a social stigma that has nothing to do with science, environment, or food safety

Much pseudo-science: “Half of all children will be Autistic by 2025 due to Roundup warns MIT scientist”



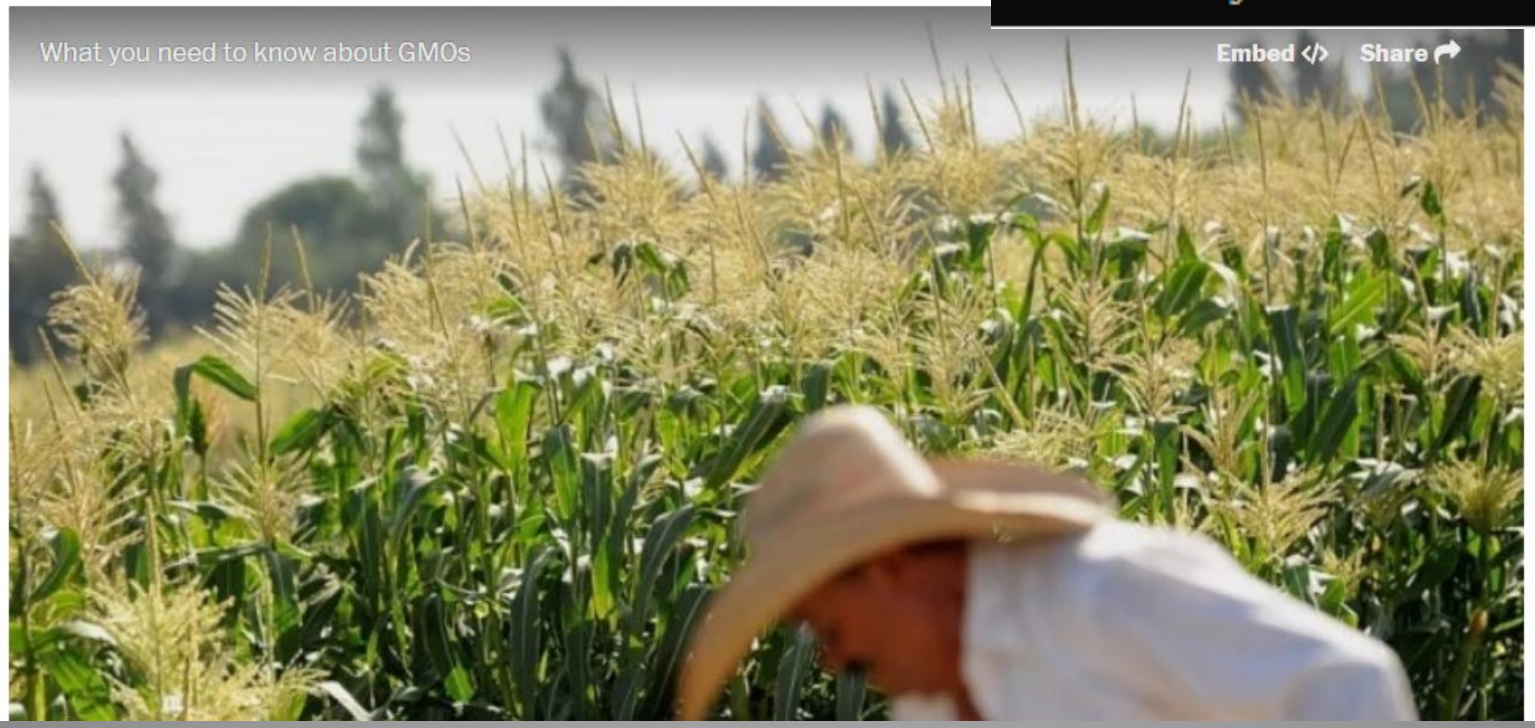
Some scientists try to change perception of GMOs

Speaking of Science

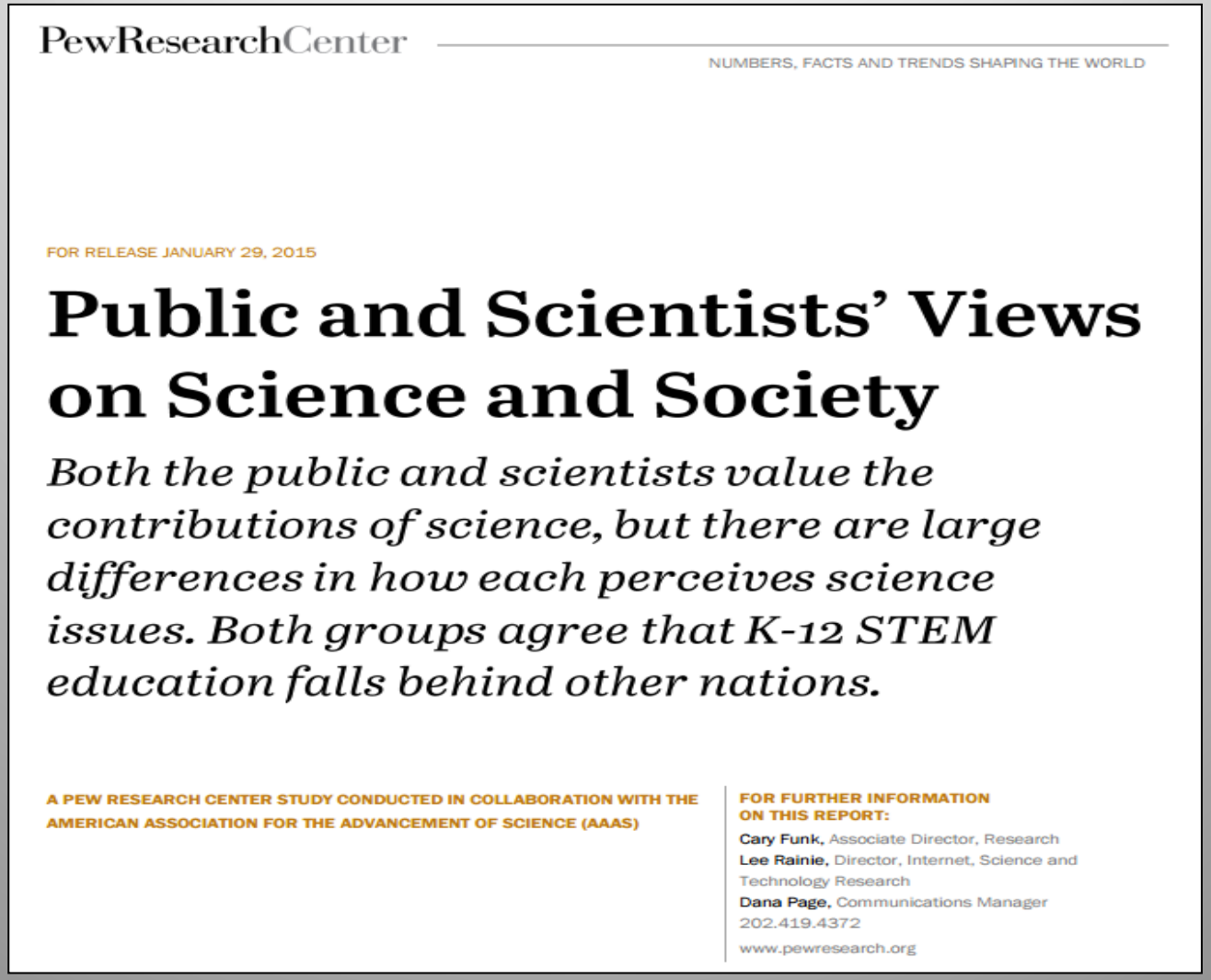
107 Nobel laureates sign letter blasting Greenpeace over GMOs

The Washington Post
Democracy Dies in Darkness

By Joel Achenbach June 30, 2016



Pew Survey on views of controversial science issues - 2015



PewResearchCenter

NUMBERS, FACTS AND TRENDS SHAPING THE WORLD

FOR RELEASE JANUARY 29, 2015

Public and Scientists' Views on Science and Society

Both the public and scientists value the contributions of science, but there are large differences in how each perceives science issues. Both groups agree that K-12 STEM education falls behind other nations.

A PEW RESEARCH CENTER STUDY CONDUCTED IN COLLABORATION WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS)

FOR FURTHER INFORMATION ON THIS REPORT:
Cary Funk, Associate Director, Research
Lee Rainie, Director, Internet, Science and Technology Research
Dana Page, Communications Manager
202.419.4372
www.pewresearch.org

http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

PewResearchCenter *Internet, Science & Tech*

U.S. POLITICS | MEDIA & NEWS | SOCIAL TRENDS | RELIGION | INTERNE

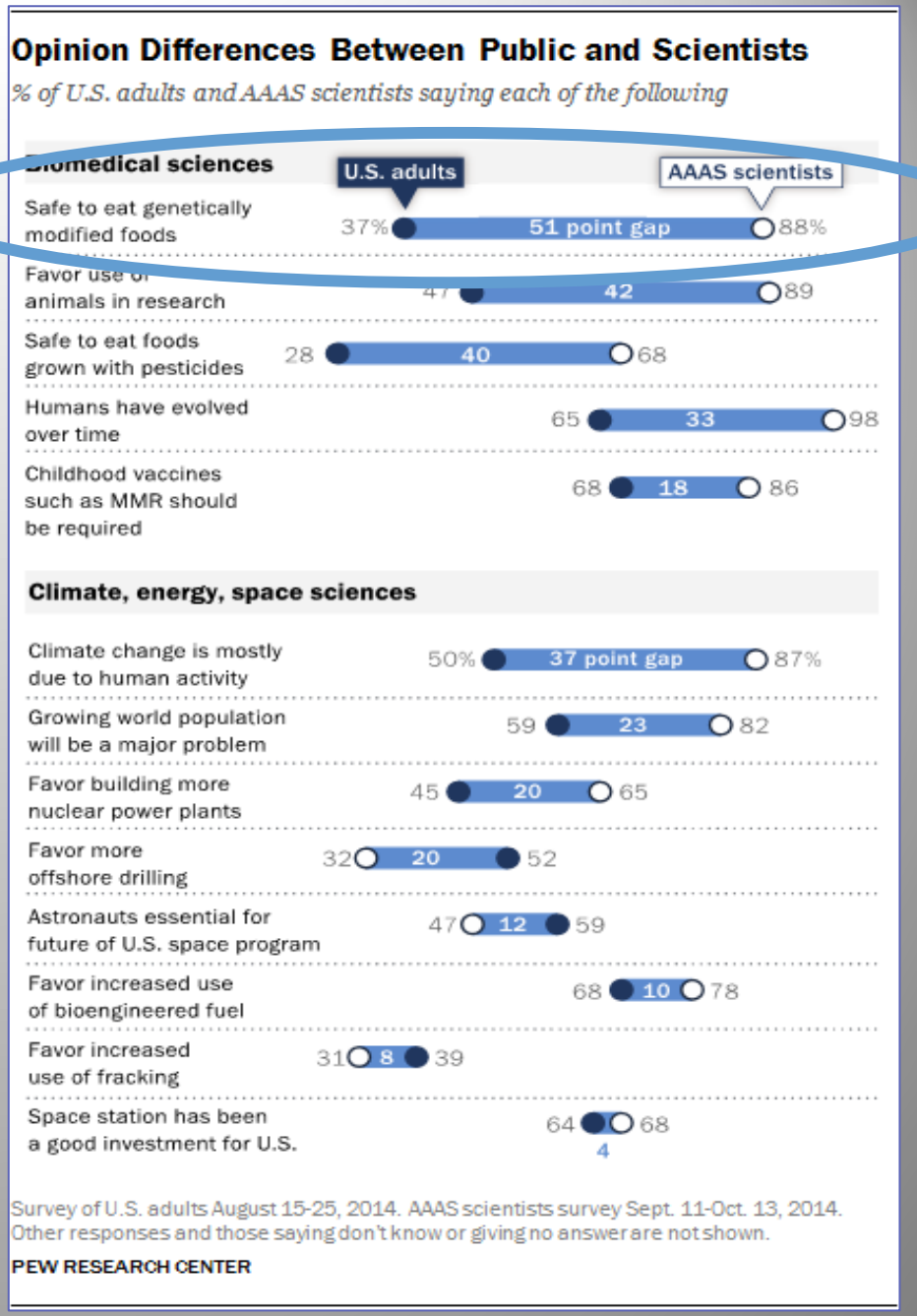
PUBLICATIONS | TOPICS | PRESENTATIONS | INTERACTIVES | KEY INDICATORS

JANUARY 28, 2015

PUBLIC AND SCIENTISTS' VIEWS ON SCIENCE AND SOCIETY

88% of AAAS scientists say genetically modified foods are safe to eat; only 37% of the public agrees

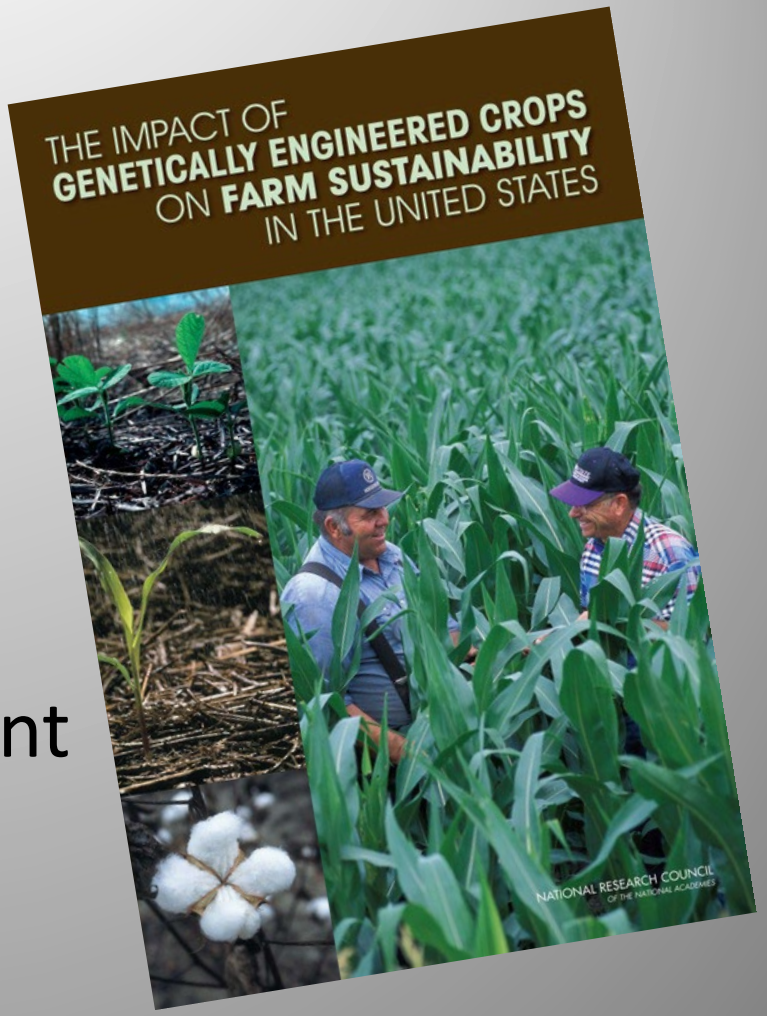
GMOs the largest scientist-public gap, 51%, of any issue surveyed



http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

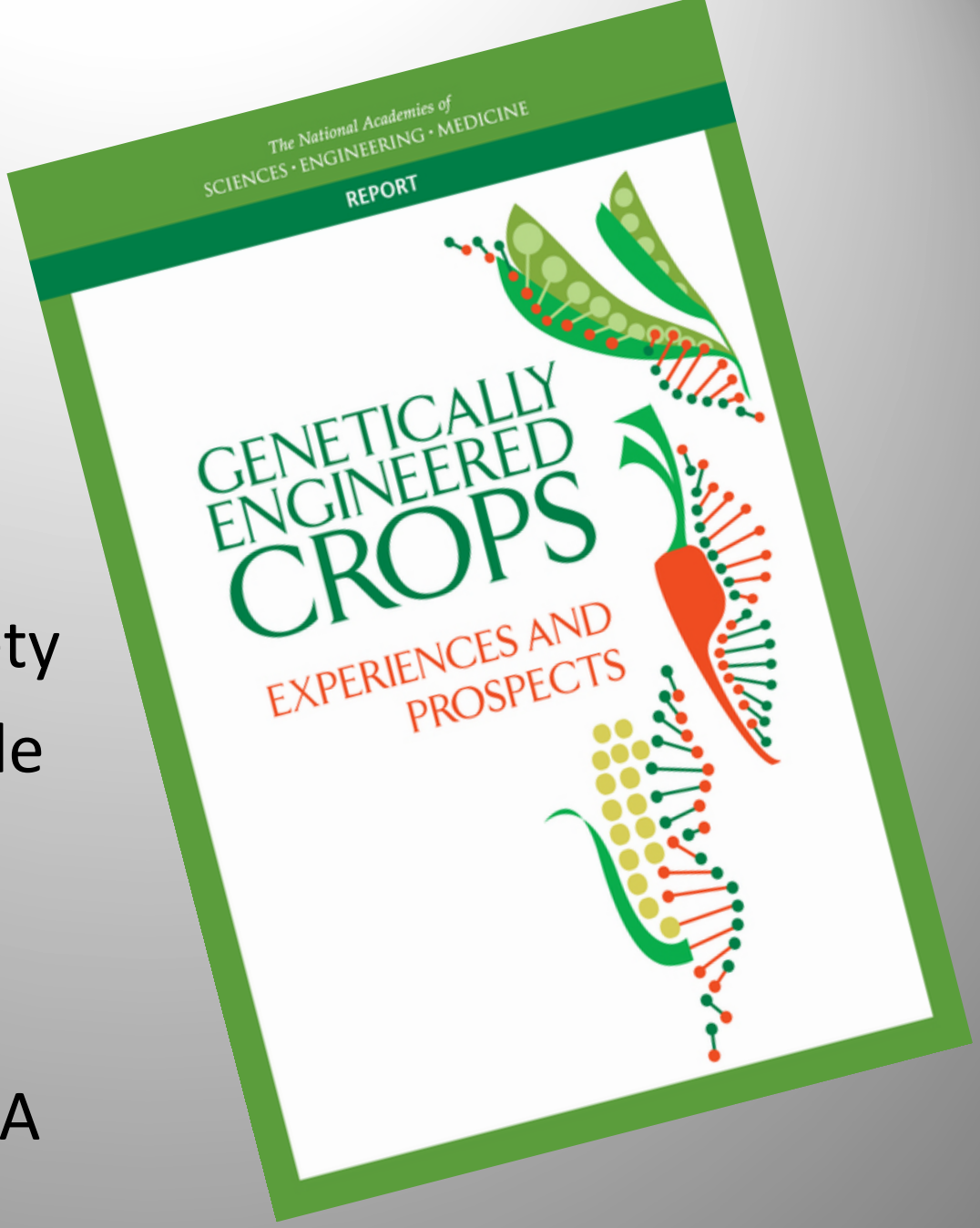
National Research Council report on GMO crops in USA - 2010

- Major pesticide reductions with Bt crops
- Helped to promote conservation tillage
- Growing need for more sustainable weed management



National Research Council Report - 2016

- Confirmed food safety
- Confirmed insecticide reduction with Bt crops
- Unclear yield improvements in USA



Some take-homes

- GMO and gene edit methods depend on ability to insert DNA and then regenerate cells with modified DNA into plants
  - A complement to conventional breeding
- Rapid uptake and large impacts of “old GMOs,” but also significant challenges to sustainable use
- Gene-editing such as CRISPR uses GMO methods to modify specific native genes to create useful traits such as healthier oil, and is not labeled as GMO under new US law
- GMOs a source of significant controversy among public, prompting wide commercial interest in no-GMO labels, stringent regulations, worldwide