

# GMO crops

The science, impacts, and  
controversy

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# Why do GMOs matter to you?

- Conflicting information about them is widespread in marketplace and online – I want truth, both the facts and context – **knowledge**
- Not being duped by costly but unfounded greenwash and natural food claims – **confusion**
- Wish to see wise use of a critical technology for food, medicine, and energy production in a highly insecure world, especially for the poor – **a moral issue**
- Smart (safe, ethical, economic) food choices for you and your family – **a personal issue**

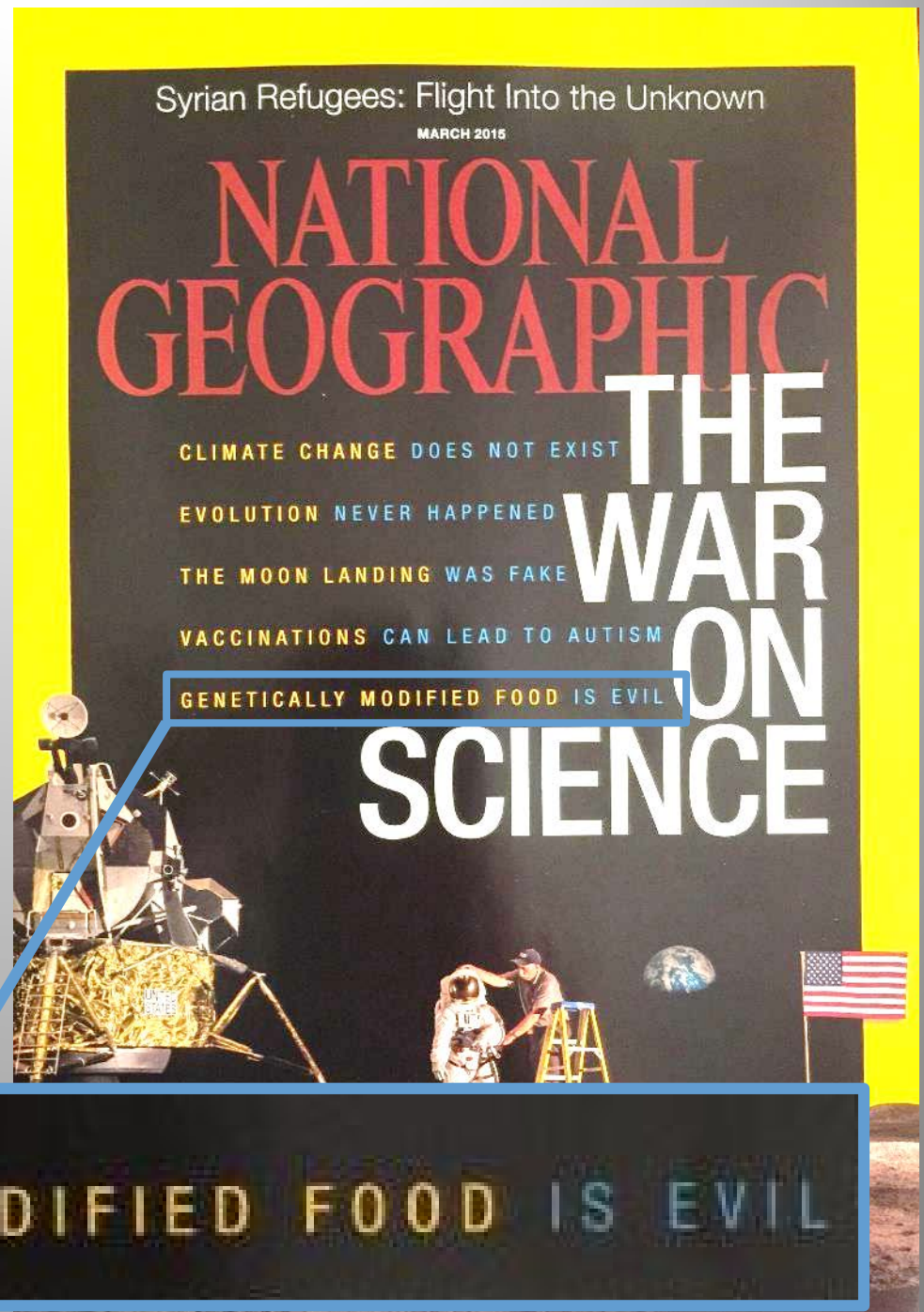
# **My goal**

Speaking as scientist, and seeking  
to reflect what mainstream  
science is thinking and saying

## **Big picture**

Impossible to know every use, regulation, concern, impact...in all the crops, societies, environments where used around the USA or the world

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



GENETICALLY MODIFIED FOOD IS EVIL

# 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)

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JANUARY 28, 2015

PUBLIC AND SCIENTISTS' VIEWS ON SCIENCE AND SOCIETY

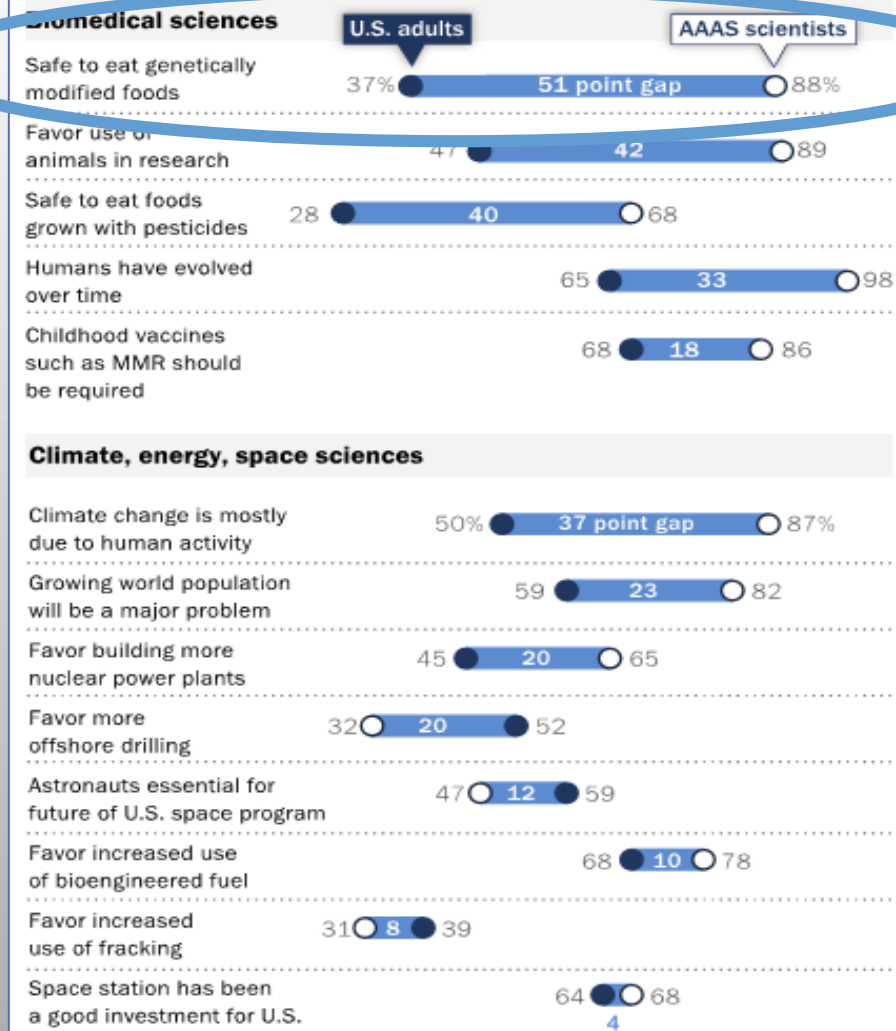
## 88% of AAAS scientists say genetically modified foods are safe to eat; only 37% of the public agrees



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

## Opinion Differences Between Public and Scientists

% of U.S. adults and AAAS scientists saying each of the following



Survey of U.S. adults August 15-25, 2014. AAAS scientists survey Sept. 11-Oct. 13, 2014. Other responses and those saying don't know or giving no answer are not shown.

PEW RESEARCH CENTER

# Mainstream science is supportive of responsible uses of GMOs



American Society  
of Plant Biologists

*Cultivating a better future through plant biology research.*

## REVISED POSITION STATEMENT ON PLANT GENETIC ENGINEERING

Advances in agriculture are cumulative and build on the integration of new approaches with established breeding techniques and farming practices. The Food and Agricultural Organization anticipates the need for a 70% increase in agricultural productivity to meet the food, feed, fiber and fuel needs of an ever-growing world population, without further degrading the environment

The American Society of Plant Biologists (ASPB) supports the continued responsible use of genetic engineering (hereafter referred to as GE) as an effective tool for advancing food security and reducing the negative environmental impacts of agriculture. ASPB also supports the

and reducing the negative environmental impacts of agriculture. ASPB also supports the continued use and further development of appropriate, science-based procedures and regulations

The use of GE to modify plants represents an important advance in plant science and agriculture that builds on centuries of human involvement in the genetic modification of crop species. GE

The use of GE to modify plants represents an important advance in plant science and agriculture that builds on centuries of human involvement in the genetic modification of crop species. GE allows for the transfer into a plant of well-characterized genes. The precision of this technology, coupled with the knowledge of the specific nature of the manipulated genetic information, makes the risks of unintended consequences of this type of gene transfer comparable to or less than the random mixing of genes that occurs during classical breeding (National Research Council, 2004).

Revised  
2014



# AAAS: Position on GMO labeling

**“Legally mandating such a label can only serve to mislead and falsely alarm consumers”**

## Statement by the AAAS Board of Directors On Labeling of Genetically Modified Foods

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE  
20 October 2012

There are several current efforts to require labeling of foods containing products derived from genetically modified crop plants, commonly known as GM crops or GMOs. These efforts are not driven by evidence that GM foods are actually dangerous. Indeed, the science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe. Rather, these initiatives are driven by a variety

conclusion: consuming foods containing ingredients derived from GM crops is no riskier than consuming the same foods containing ingredients from crop plants modified by conventional plant improvement techniques.

Civilization rests on people's ability to modify plants to make them more suitable as food, feed and fiber plants and all of these modifica-

added, the protein must be shown to be neither toxic nor allergenic. As a result and contrary to popular misconceptions, GM crops are the most extensively tested crops ever added to our food supply. The occasional claim that GM foods are harmful to animals, ranging from digestive problems to sterility, tumor growth, and death. Although such claims are often sensationalized and receive a

Approved by the AAAS Board of Directors on 20 October 2012



# GE/GMO a technology with diverse outcomes, including many.....

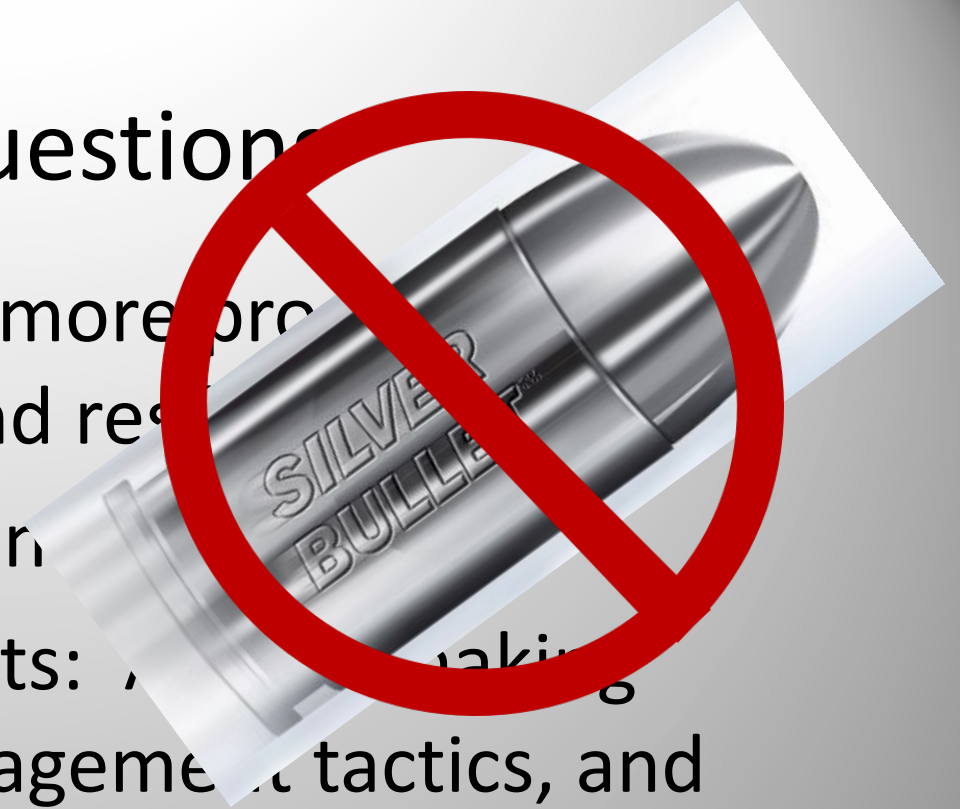
- Genes/traits - Types of crops - Places
- Societies - Crop/Eco-systems
  
- **A general technology:** More like a wheel or computer than a medicine or saxophone
  
- **“Product not process,” “case by case,”** is global consensus for science assessments

Are GE/GMO foods safe? Are they good for the environment?



# The more relevant questions

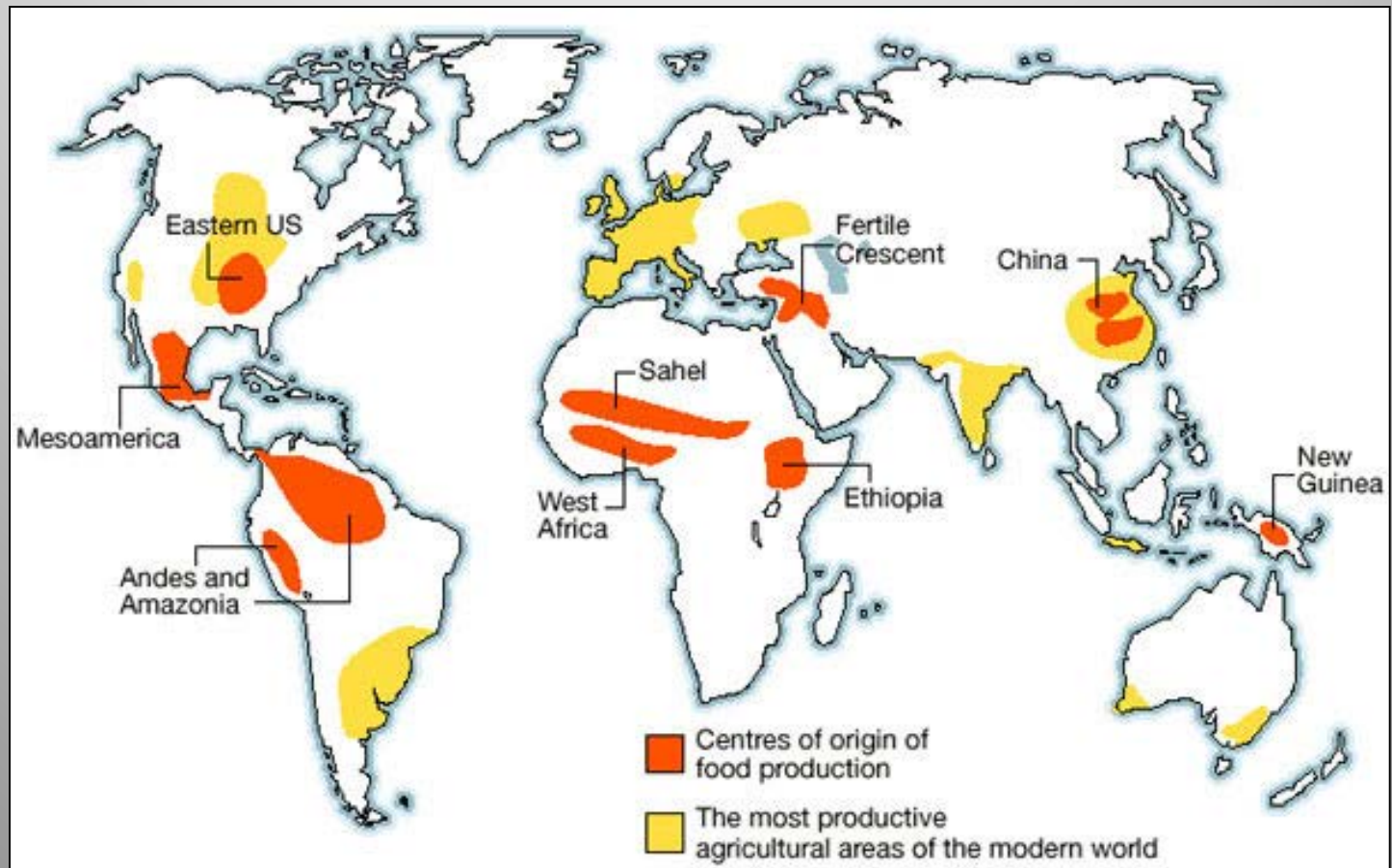
- Is agriculture becoming more productive, more sustainable, efficient, and resilient?
- Is food becoming safer and more nutritious?
- There are no silver bullets: making progress requires making intelligent choices, management tactics, and tradeoffs to move in the right direction ?



# Agenda

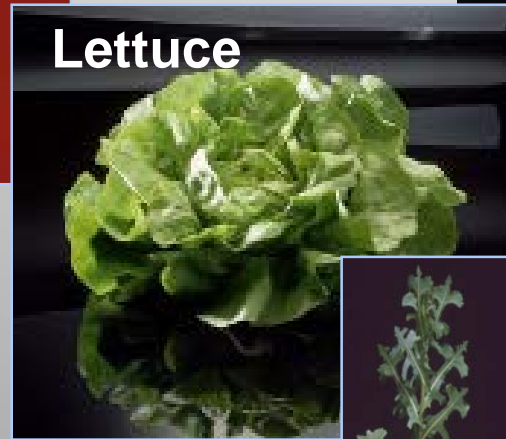
- What they are and are not – a brief reminder
- Extent in the world
- Some impacts
- New forms in pipeline
- Why so controversial, stigmatized?

Crops were domesticated in parallel in several regions of the globe – then moved and further bred all over the world



Reprinted by permission from Macmillan Publishers Ltd.: [Nature] Diamond, J. (2002). Evolution, consequences and future of plant and animal domestication. Nature 418: [700-707](#), copyright 2002.

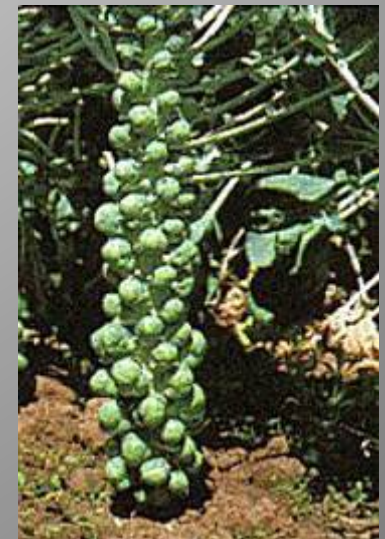
# Most crops intensively bred, prior to GMOs



# Mutants are some of our best friends: Domestication of wild cabbage



Ornamental kale  
Late 1900's





# Many plant varieties derived from randomly induced mutations



Calrose 76 semi-dwarf rice

**Over 2,000 crop varieties derived from mutagenesis have been commercialized**



High oleic sunflower



Rio Red grapefruit

# Radical changes in domesticated animals

All dogs derived from the wolf by breeding

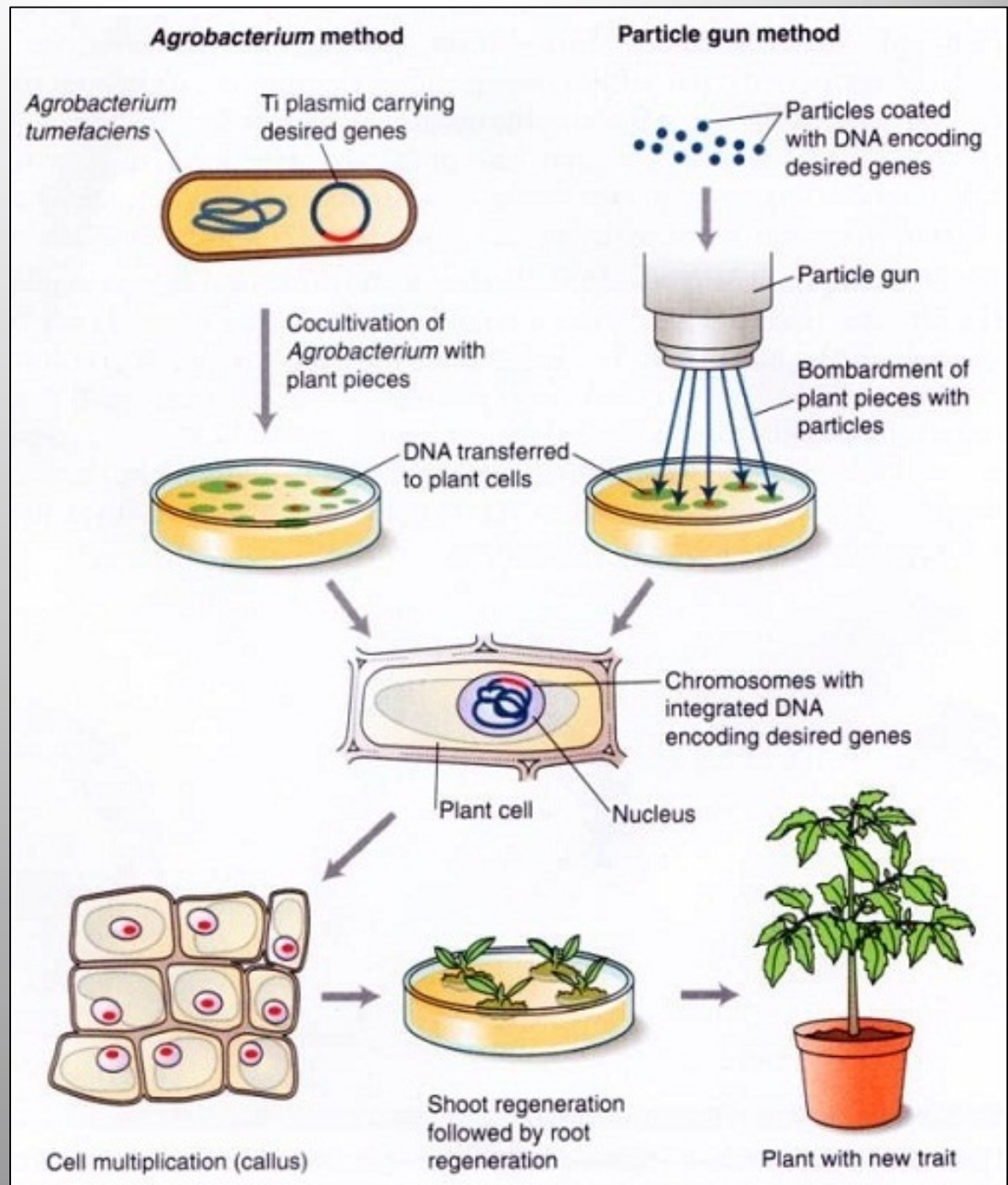


# What is genetic engineering (GE)

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



# Steps to create a GE plant



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



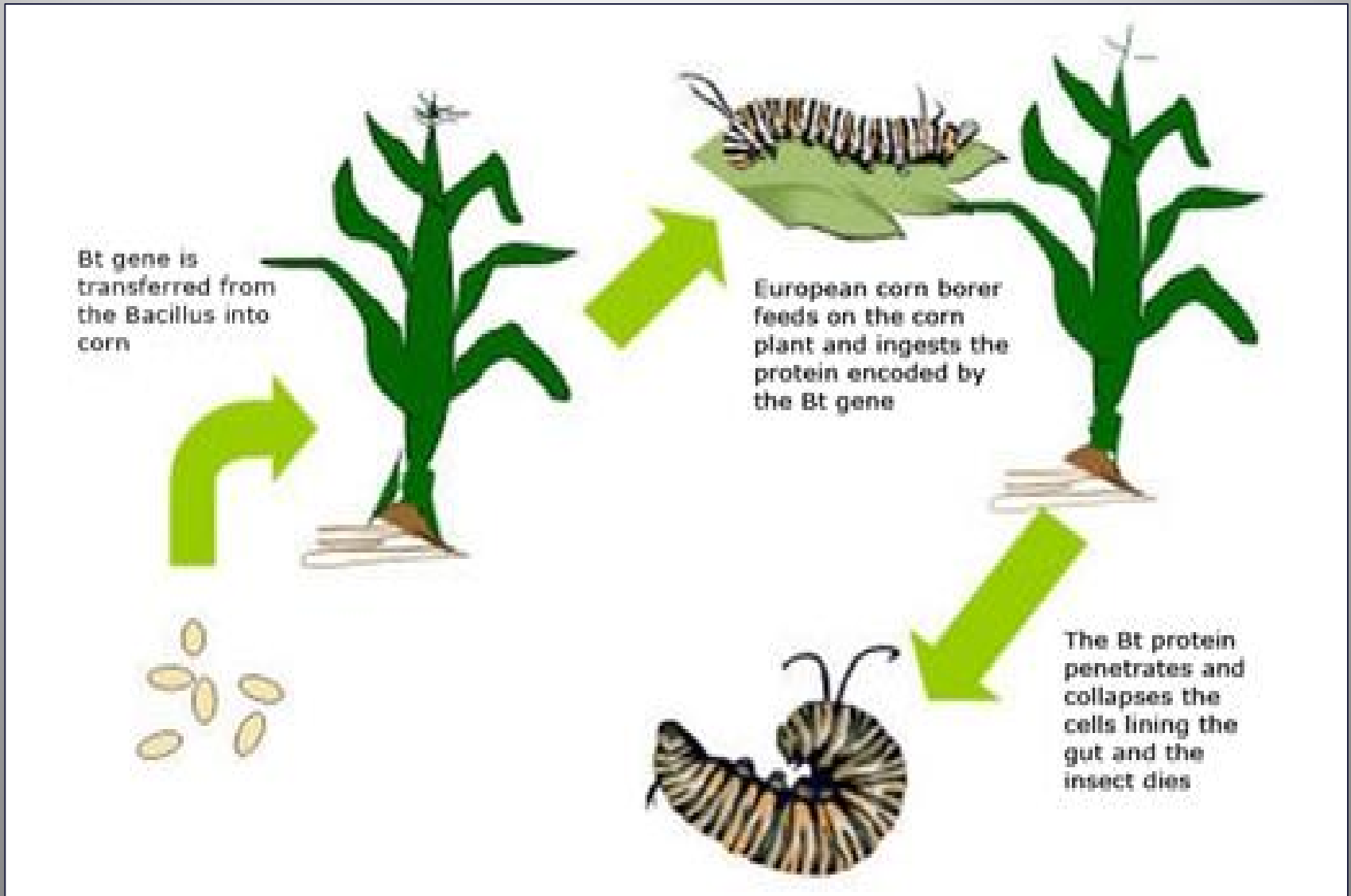
**Propagation of poplars  
in tissue culture**



**Growth in the field**

# Insect-resistant “Bt crops”

More efficient and less harmful to non-targets than sprays --  
Bt sprays widely used in organic agriculture



Breakthrough of the Year, 2015

Science

AAAS

2015

BRE  
of t

JULY 4, 2015

TIME

The Gene Machine

What the CRISPR experiments mean for humanity *By Alice Park*

time.com

# Gene editing described



- Technique that allows specific changes to the genome – modification of **native DNA**
- Employs methods of genetic engineering but does not leave the editing agent in the genome



# A big deal?

- Ability to modify genes efficiently
- The theoretical becomes practical



ELSEVIER

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

ScienceDirect

Current Opinion in  
Biotechnology

## Editing plant genomes with CRISPR/Cas9

Khaoula Belhaj<sup>1</sup>, Angela Chaparro-Garcia<sup>1</sup>, Sophien Kamoun,  
Nicola J Patron and Vladimir Nekrasov



CRISPR/Cas9 is a rapidly developing genome editing technology that has been successfully applied in many organisms, including model and crop plants. Cas9, an RNA-guided DNA endonuclease, can be targeted to specific genomic sequences by engineering a separately encoded guide RNA with which it forms a complex. As only a short RNA sequence must be synthesized to confer recognition of a new

nucleases, the repair may be imperfect. HDR, however, uses a template for repair and therefore repairs are likely to be perfect. In a natural situation the sister chromatid would be the template for repair, however templates to recode a target locus or to introduce a new element between flanking regions of homology can be delivered with an SSN [2]. In mammalian cells, DSBs were shown

**“CRISPR/Cas9 is a game-changing technology that is poised to revolutionize basic research and plant breeding.”**

# Sandman CRISPR !



# Will gene edited crops be shunned, stigmatized as a GMO?

PUBLISHED: 8 JANUARY 2015 | ARTICLE NUMBER: 14011 | DOI: 10.1038/NPLANTS.2014.11

comment

## Regulatory uncertainty over genome editing

Huw D. Jones

Genome editing opens up opportunities for the precise and rapid alteration of crops to boost yields, protect against pests and diseases and enhance nutrient content. The extent to which applied plant research and crop breeding benefit will depend on how the EU decides to regulate this fledgling technology.

We are at the dawn of a new paradigm in plant breeding. Classical approaches to crop improvement based on hybridization and selection can now be complemented by targeted genome editing that exploits knowledge of specific gene sequences in a systematic way. Unlike conventional genetic modification that results from the insertion of large pieces of exogenous DNA,

or maize renders the plants highly resistant to lepidopteron pests; these lepidopteron-resistant crops are grown around the world. However, this technique cannot be used to make small edits to existing genes, and can lead to the random disruption of native genes because the destination of the inserted DNA cannot be dictated.

In contrast to traditional genetic modification, genome editing makes use of

one or a few bases at the cut site, resulting in a mutation. Mutations generated in this way are indistinguishable from those that occur naturally and drive evolution, as well as from those induced through the application of chemical mutagens or radiation, as employed in mutation breeding programmes since the 1940s.

Here, I focus on the potential applications and regulation of this simple 'cut and repair'

# Markets are another thing....

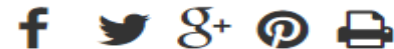
The National Organic Standard Boards has **banned** gene editing technologies

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## Organic board bans gene editing technology

[CATTLE AND BEEF INDUSTRY NEWS](#)

NOV 25, 2016 By [KERRY HALLADAY](#), WLJ MANAGING EDITOR



When a government agency describes something as causing the “demise” of species and displacing Americans, they must surely be describing a foreign enemy, right? Or maybe some pandemic plaguing the countryside?

Apparently not. To the surprise of many, the National Organic Standards Board would, among other things, prevent the use of genetic engineering—an “excluded method” additionally attributed to the “demise” of species.

“Every organic stakeholder has a right to expect the integrity of the organic system. Every effort must be made to protect that integrity.”

Among other things, the board has banned the use of Cas 9, Zinc Finger Nucleases, and other genetic engineering for the purpose of “excluded methods” of production.

“Every organic stakeholder is clear that genetic engineering is an imminent threat to organic integrity. Every effort must be made to protect that integrity,”

# Agenda

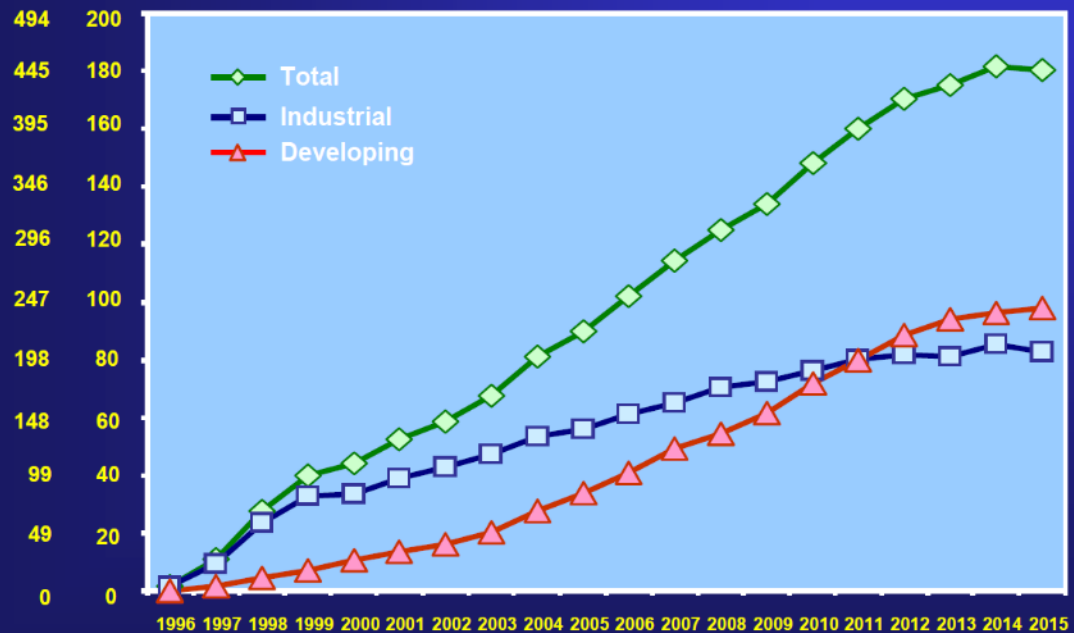
- What they are and are not – a brief reminder
- Extent in the world
- Some impacts
- New forms in pipeline
- Why so controversial, stigmatized?

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

**Global Area of Biotech Crops, 1996 to 2015:  
Industrial and Developing Countries (M Has, M Acres)**



M Acres



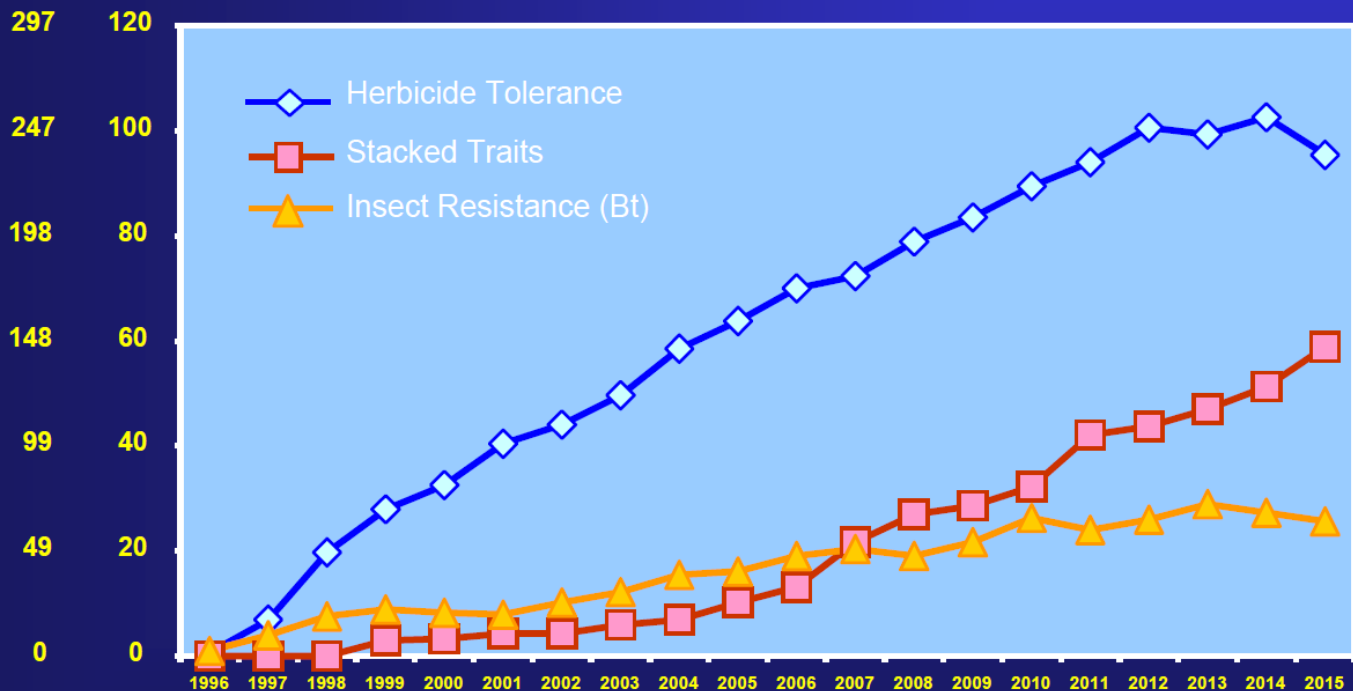
Source: Clive James, 2015

# Two traits dominate worldwide, increasingly “stacked” in combinations

## Global Area of Biotech Crops, 1996 to 2015: By Trait (Million Hectares, Million Acres)



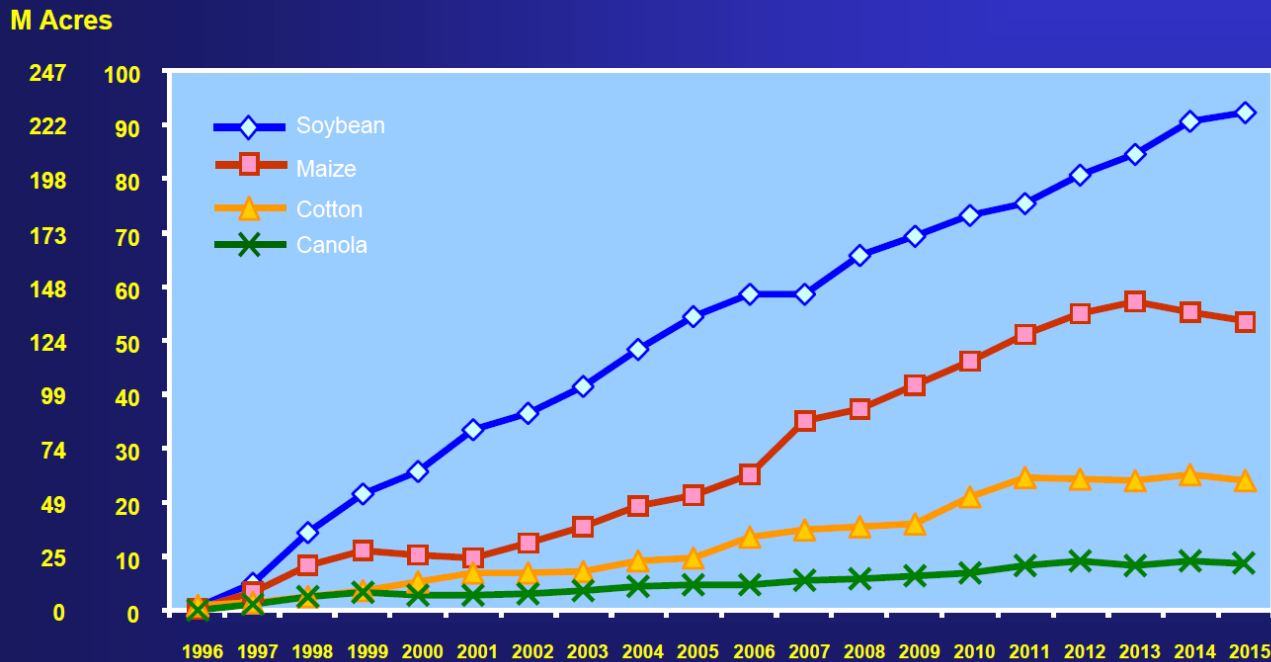
M Acres



Source: Clive James, 2015

# Four crops dominate, 8+ crops in USA

## Global Area of Biotech Crops, 1996 to 2015: By Crop (Million Hectares, Million Acres)



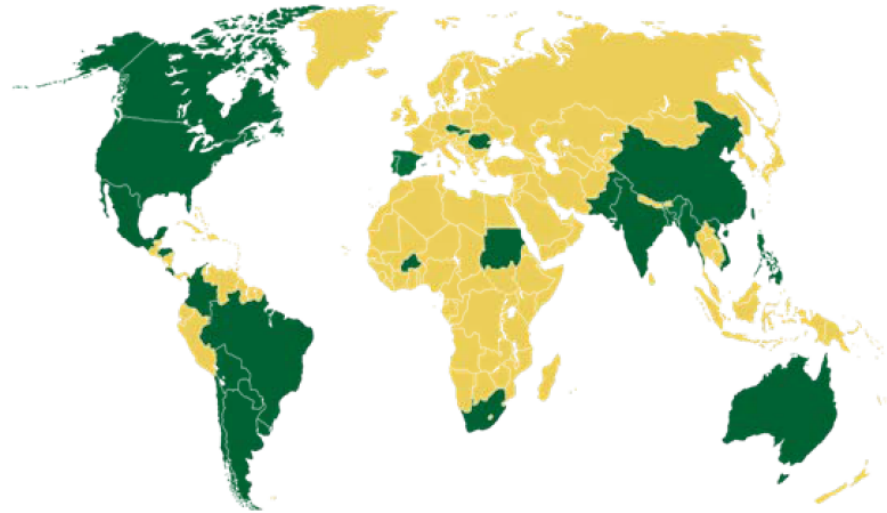
Source: Clive James, 2015



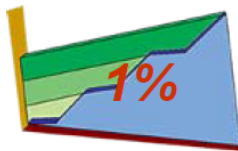


# Adoption by 28 countries, but rates highly variable

## Global Area (Million Hectares) of Biotech Crops, 2015: by Country



Marginal Decrease from 2014



28 countries which have adopted biotech crops

In 2015, global area of biotech crops was 179.7 million hectares, representing a marginal decrease of 1% from 2014, equivalent to 1.8 million hectares.

Source: Clive James, 2015.

### Biotech Mega Countries

50,000 hectares (125,000 acres), or more

Million Hectares

1.	USA	70.9
2.	Brazil*	44.2
3.	Argentina*	24.5
4.	India*	11.6
5.	Canada	11.0
6.	China*	3.7
7.	Paraguay*	3.6
8.	Pakistan*	2.9
9.	South Africa*	2.3
10.	Uruguay*	1.4
11.	Bolivia*	1.1
12.	Philippines*	0.7
13.	Australia	0.7
14.	Burkina Faso*	0.4
15.	Myanmar*	0.3
16.	Mexico*	0.1
17.	Spain	0.1
18.	Colombia*	0.1
19.	Sudan*	0.1

Less than 50,000 hectares

Honduras*	Slovakia
Chile*	Costa Rica*
Portugal	Bangladesh*
Vietnam*	Romania
Czech Republic	

\* Developing countries

# Global admixture of GM and non-GM crops/food create immense coexistence, trade problems under current regulations

Many costly cases of trade disruption and lawsuits with corn, soy, and rice

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## Steady increase in incidents of genetically modified crops found in traded food, UN agency reports

Source: UN Photo/Tobin Jones



Source: UN Photo/Tobin Jones

14 March 2014 – As a result of the increased production of genetically modified crops worldwide, the United Nations food agency warns in a ground-breaking survey that an increasing number of incidents of low levels of genetically modified organisms (GMOs) are being reported in traded food and feed.

18 Likes

21 Comments

Oregon with  
major  
coexistence  
struggles due  
to seed  
industry, much  
non-GMO  
production &  
many exports  
2014 Task Force  
Report

## Governor's Task Force on Genetically Engineered Seeds and Agricultural Products

Task Force Report



GMO ban voted on in Benton County, Oregon last year – defeated, but with much public support for the ban

Statesman Journal  
A GANNETT COMPANY

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## Voters reject proposal to ban GMO food in County

Associated Press 9:54 a.m. PDT May 20, 2015



In this May 1, 2015 photo, Oregon State University forestry professor Steven Strauss stands in a grove of genetically engineered poplar trees near Corvallis, Ore. Oregon State University says a Benton County ballot measure that seeks to ban the cultivation of genetically modified crops in

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# Agenda

- What are they and are not – a brief reminder
- Extent in the world
- Some impacts
- New forms in pipeline
- Why so controversial, stigmatized?

# Virus-resistant GM papaya

Saved the Hawaiian industry in the mid-1990s, ~80% of crop today

Like a vaccine  
—  
“RNAi immunization”  
via implanting  
a viral gene in  
the papaya  
genome



Courtesy of Denis Gonsalves, formerly  
of Cornell University

GMO, virus-  
resistant trees

# Global “meta-analysis” of early impacts: 2014

The screenshot shows the PLOS ONE website interface. At the top left is the PLOS ONE logo. Navigation links for 'Subject Areas', 'For Authors', and 'About Us' are visible. A search bar is located at the top right. Below the navigation is a white banner with 'OPEN ACCESS' and 'PEER-REVIEWED' icons. The article title 'A Meta-Analysis of the Impacts of Genetically Modified Crops' is prominently displayed, along with the authors 'Wilhelm Klümper, Matin Qaim' and the publication date 'November 3, 2014'. A statistics box on the right shows 2 Saves, 0 Citations, 79,064 Views, and 948 Shares.

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RESEARCH ARTICLE

## A Meta-Analysis of the Impacts of Genetically Modified Crops

Wilhelm Klümper, Matin Qaim

Published: November 3, 2014 • DOI: 10.1371/journal.pone.0111629

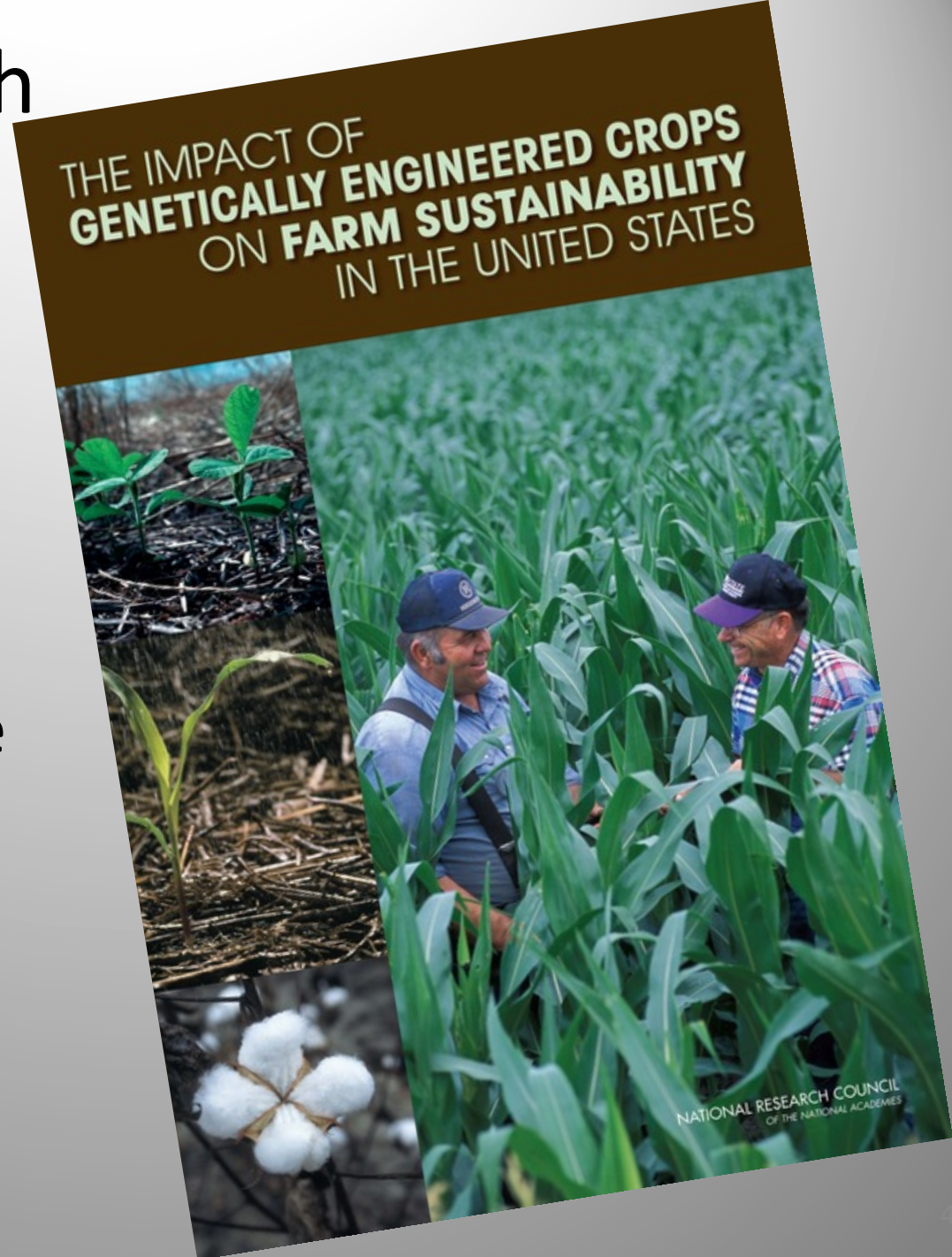
2 Saves	0 Citations
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“147 original studies were included.”

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

# National Research Council Report 2010

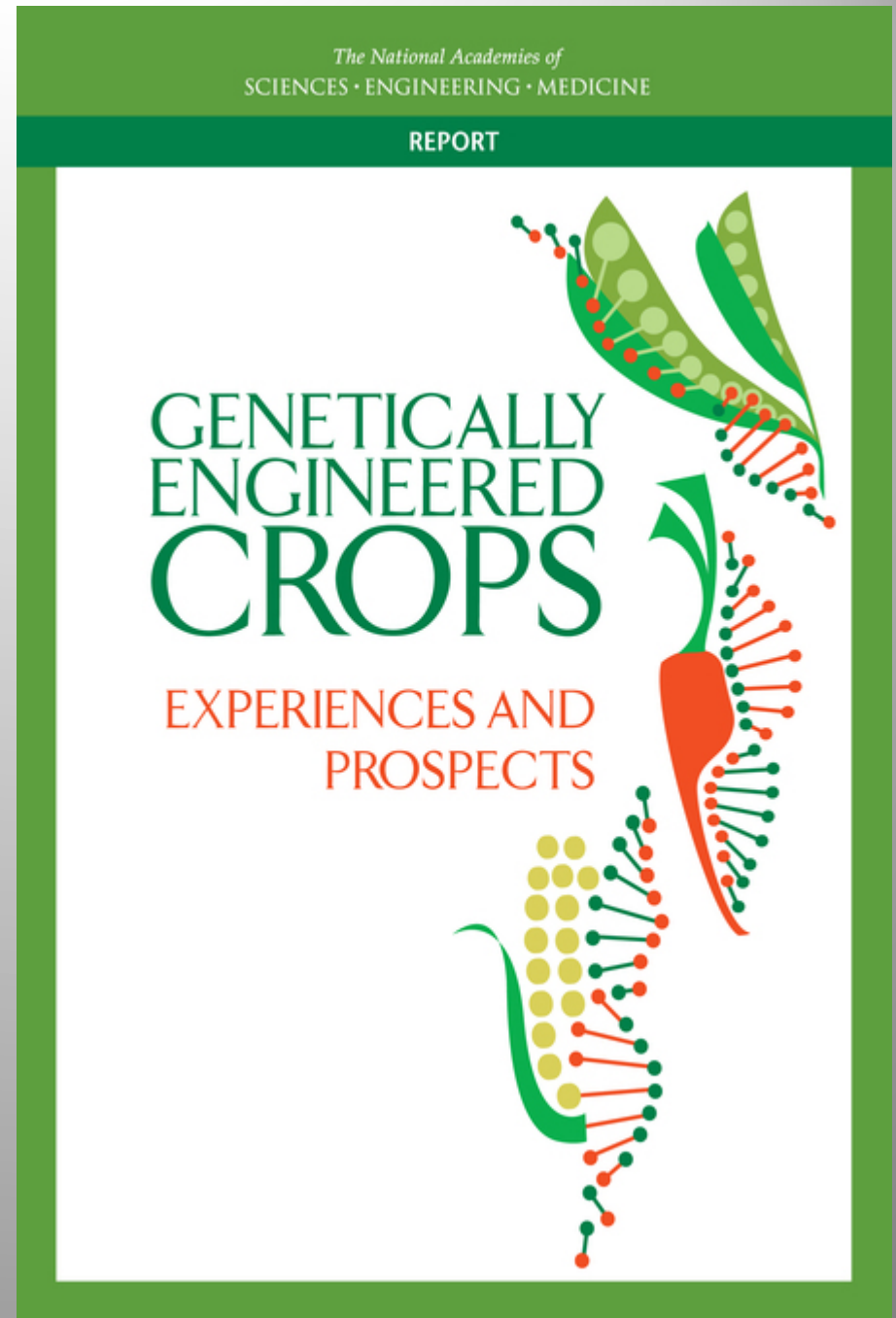
- Major pesticide reductions - Bt
- Expanded conservation tillage
- Herbicide tolerant weeds
  - Need more sustainable management





# National Research Council Report 2016

- Confirmed food safety
- Confirmed insecticide reduction with Bt crops



# Is GM food safe?

if an overwhelming majority of experts say something is true, then any sensible non-expert should assume that they are probably right



The American Association for the Advancement of Science (AAAS) is the premier scientific body in the United States. It is the largest non-profit organization in the world with over 100,000 members.



The American Medical Association (AMA) is the premier body of physicians in the United States. It is the largest non-profit organization in the world with over 200,000 members.



The World Health Organization (WHO) is the directing and coordinating authority for health within the United Nations system. It is the largest non-profit organization in the world with over 100 million members.



The National Academy of Sciences is an independent organization in the United States that is the premier scientific body in the United States.



The European Commission (EC) is the executive body of the European Union. It is the largest non-profit organization in the world with over 100 million members.



The American Association for the Advancement of Science is an international non-profit organization AAAS serves some 261 affiliated societies and academies of science.

"The science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe."

The premier body of physicians in the United States

"There is no scientific justification for special labeling of genetically modified foods."

Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

The European Commission (EC) is the executive body of the European Union

The World Health Organization (WHO) is the directing and coordinating authority for health within the United Nations system.

"No effects on human health have been shown as a result of the consumption of GM foods by the general population in the countries where they have been approved."

"To date more than 98 million acres of genetically modified crops have been grown worldwide. No evidence of human health problems associated with the ingestion of these crops or resulting food products have been identified"

The Royal Society of Medicine is an independent educational organisation for doctors, dentists, scientists and others involved in medicine and health care

"Foods derived from GM crops have been consumed by hundreds of millions of people across the world for more than 15 years, with no reported adverse effects on human health."

The European Commission (EC) is the executive body of the European Union

"The main conclusion to be drawn from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are no more risky than e.g. conventional plant breeding technologies."



The American Council on Science and Health (YACSH) is a non-profit organization in the United States that is the premier scientific body in the United States.



The American Society for Cell Biology (ASCB) is the premier body of cell biologists in the United States. It is the largest non-profit organization in the world with over 100,000 members.



The American Society for Cell Biology is a professional scientific organization dedicated to advancing scientific research in cell biology.



The American Society for Microbiology (ASM) represents over 42,000 microbiologists worldwide.



The Crop Science Society of America (CSSA) is the premier scientific body in the United States.



The International Seed Federation (ISF) is the premier scientific body in the United States.



The Center for Science and Environment (CAST) is a non-profit organization in the United States that is the premier scientific body in the United States.



The International Society of African Biologists (ISAB) is the premier scientific body in the United States.



The International Society of African Biologists (ISAB) is the premier scientific body in the United States.



The Federation of Animal Science Societies (FAS) is the premier scientific body in the United States.



The Society of Toxicology (SOT) is the premier scientific body in the United States.



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The Society of Toxicology (SOT) is the premier scientific body in the United States.



The Union of Concerned Scientists (UCS) is the premier scientific body in the United States.



The International Council for Science (ICSU) is the premier scientific body in the United States.

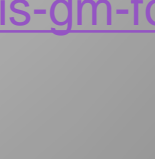
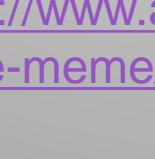
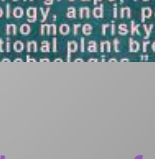
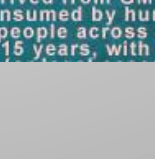
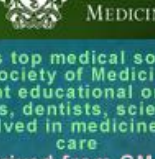
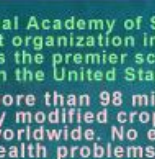
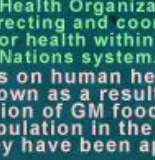
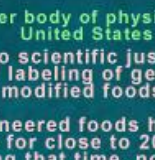
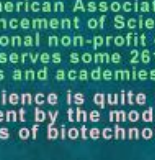


The International Council for Science (ICSU) is the premier scientific body in the United States.

The scientific consensus around the safety of genetically modified foods is as strong as the scientific consensus around climate change. These foods are subjected to more testing than any other, and everything tells us that they're safe.

# Is GM food safe?

if an overwhelming majority of experts say something is true, then any sensible non-expert should assume that they are probably right



<http://www.axismundionline.com/blog/the-new-is-gm-food-safe-meme/>

Useful academic web sites and outreach programs are few – Purdue a rare and recent exception

# The Science of GMOs

Genetically Modified Organisms, or GMOs, are a major issue about which many of us know relatively little. We want to know what we're eating, and we want to know how this issue is impacting the environment. Knowing more equips us to make the best decisions for ourselves and generations to come. GMOs are complex, so we've broken the issue down into different categories. Click on the question that most concerns you. Read the answer or listen to an interview with one of Purdue's College of Agriculture scientists. You can always count on this site to address this complicated and evolving issue with neutral, scientifically sound information.



**What are  
GMOs?**



**Why do we  
use GMOs?**



**Do GMOs  
harm health?**



**How do  
GMOs affect  
insects?**



**How does the  
regulation process  
work?**



**What about GMOs  
and weeds?**



**What's the story  
on GMOs and  
labeling?**

# 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



# Poor weed management has led to rapid 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 BARNESDALE / AGSTOCKUSA /



# Roundup tolerant bentgrass escape in Oregon

## Feds deregulate controversial GMO grass seed



Linn County bills itself as the grass seed capital of the world. But the thriving grass business has been divided by a controversial genetically modified grass developed by Scotts Miracle-Gro. *(Jeff Manning/The Oregonian)*



By **Jeff Manning** | [The Oregonian/OregonLive](#)

[Email the author](#) | [Follow on Twitter](#)

on January 18, 2017 at 10:00 AM, updated January 18, 2017 at 10:18 AM

The U.S. Department of Agriculture on Tuesday deregulated a genetically modified grass that some Oregon farmers and dealers say threatens the state's grass seed business.

483

## GMO grass divides gra



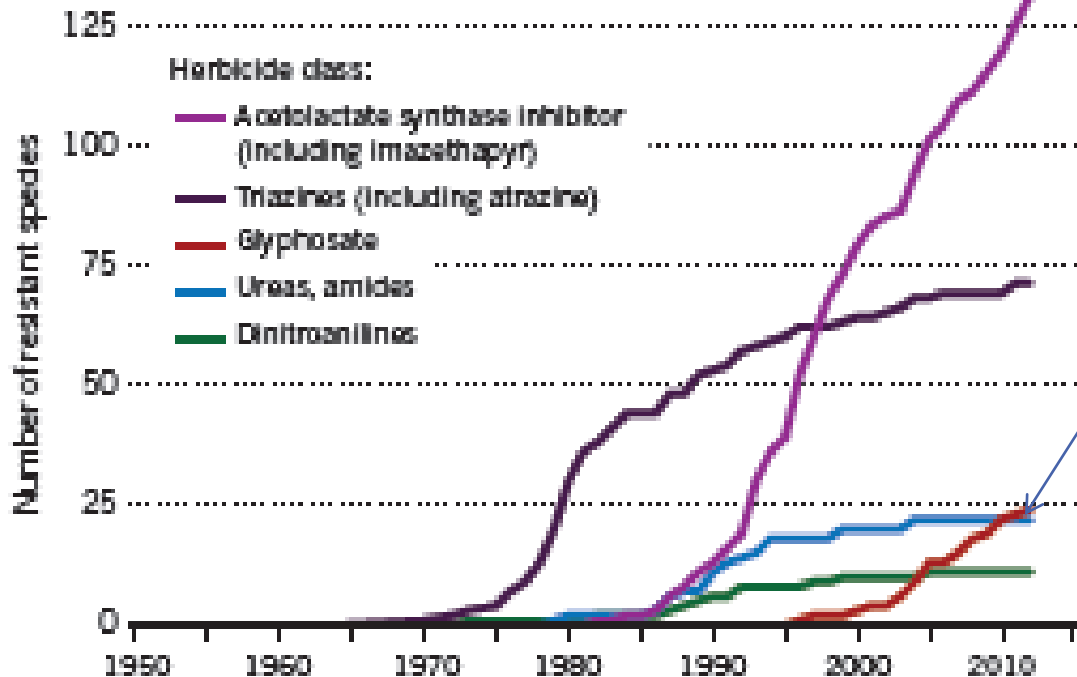
8.1k shares

# Herbicide-resistant weeds are an old problem in agriculture, but exacerbated by GE herbicide tolerant crops

## THE RISE OF SUPERWEEDS

Weed species often become resistant to herbicides. Glyphosate resistance, once deemed unlikely, rose after genetically engineered crops were introduced in the mid-1990s.

SOURCE: UNIVERSITY OF CALIFORNIA, SURVEY OF HERBICIDE RESISTANT WEEDS WWW.WEEDS.EDUCATION.ORG/RESISTANT WEEDS (2010)



Accelerated by  
GE Roundup-  
tolerant crops ?



# Genetically engineered crops and pesticide use in U.S. maize and soybeans

Edward D. Perry,<sup>1</sup> Federico Ciliberto,<sup>2</sup> David A. Hennessy,<sup>3</sup> GianCarlo Moschini<sup>4\*</sup>

2016 © The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. Distributed under a Creative Commons Attribution NonCommercial License 4.0 (CC BY-NC). 10.1126/sciadv.1600850

The widespread adoption of genetically engineered (GE) crops has clearly led to changes in pesticide use, but the nature and extent of these impacts remain open questions. We study this issue with a unique, large, and representative sample of plot-level choices made by U.S. maize and soybean farmers from 1998 to 2011. On average, adopters of GE glyphosate-tolerant (GT) soybeans used 28% (0.30 kg/ha) more herbicide than nonadopters, adopters of GT maize used 1.2% (0.03 kg/ha) less herbicide than nonadopters, and adopters of GE insect-resistant (IR) maize used 11.2% (0.013 kg/ha) less insecticide than nonadopters. When pesticides are weighted by the environmental impact quotient, however, we find that (relative to nonadopters) GE adopters used about the same amount of soybean herbicides, 9.8% less of maize herbicides, and 10.4% less of maize insecticides. In addition, the results indicate that the difference in pesticide use between GE and non-GE adopters has changed significantly over time. For both soybean and maize, GT adopters used increasingly more herbicides relative to nonadopters, whereas adopters of IR maize used increasingly less insecticides. The estimated pattern of change in herbicide use over time is consistent with the emergence of glyphosate weed resistance.

## INTRODUCTION

One of the most salient developments in global agriculture in the past 20 years is the widespread adoption of genetically engineered (GE) crops over time. In particular, there have been little data to assess whether the

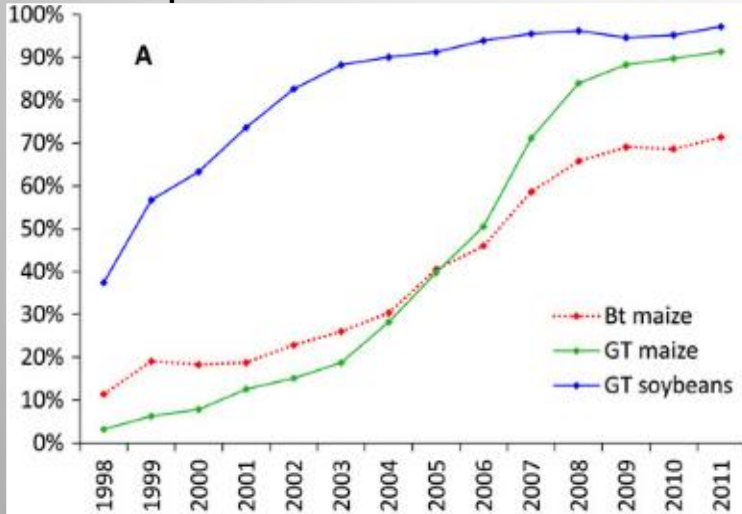
20 years of GE crop varieties (1). 94% of plot-level choices of this new varieties by GfK specializes 80% of plot-level GE varieties year, the 80% of plot-level GE varieties exceeded 80% of plot-level GE varieties for maize or soybeans data, for from other herbicides (7). Conversely, IR varieties can substitute for each farmer, we match the amount of pesticide used with the size of the

“....[national surveys over 13 years] representative at the crop reporting district (CRD) level and include an annual average of 5,424 farmers for maize and 5,029 farmers for soybeans ...”

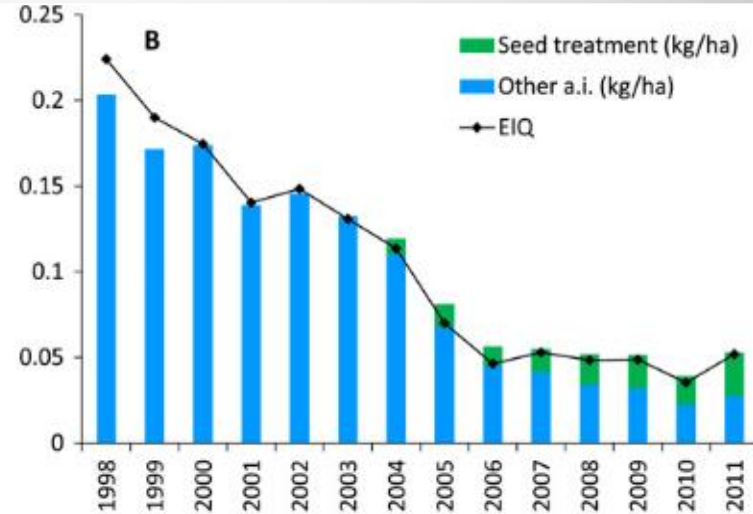


# GE ADOPTION AND PESTICIDE USE, MAIZE AND SOYBEANS, USA 1998–2011

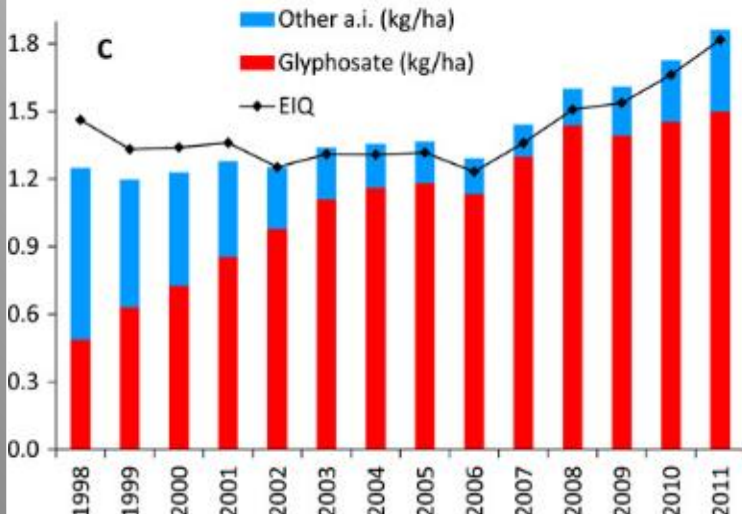
## Adoption rates



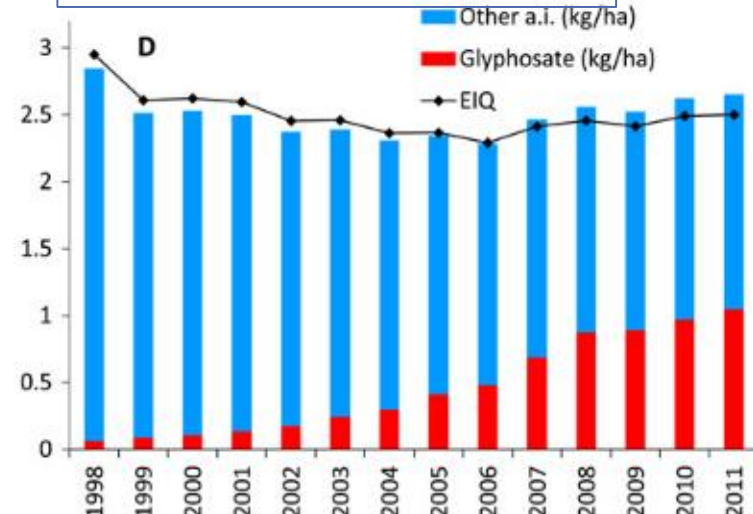
## Insecticide use in maize



## Herbicide use in soybeans



## Herbicide use in maize



# Key results (Perry et al. 2016)

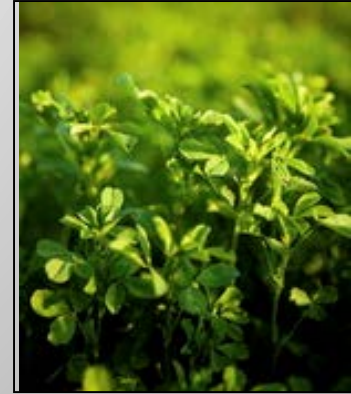
- “...weighted by the environmental impact quotient, ...we find that (relative to non-adopters) GE adopters used about....
- the same amount of soybean herbicides
- 9.8% less of maize herbicides
- 10.4% less of maize insecticides
- ...the difference in pesticide use has changed significantly over time....
  - GT adopters used increasingly more herbicides relative to non-adopters, (... consistent with the emergence of glyphosate weed resistance)
  - Adopters of IR maize used increasingly less insecticides...”

# Agenda

- What they are and are not – a brief reminder
- Extent in the world
- Some impacts
- **New forms in pipeline**
- Why so controversial, stigmatized?

# Newly approved GE crop varieties in USA

- Soybean – insect resistant (Apr. 2014)
- Alfalfa – reduced lignin (Nov. 2014)
- Potato – reduced black spot bruise and low acrylamide production (Nov. 2014), reduced browning and disease resistant as well (August 2015)
- Soybean and cotton – new herbicide tolerances (Jul. 2014 – Jan. 2015)
- Apple – non-browning (Feb. 2015)
- Plum – virus resistant (2014)

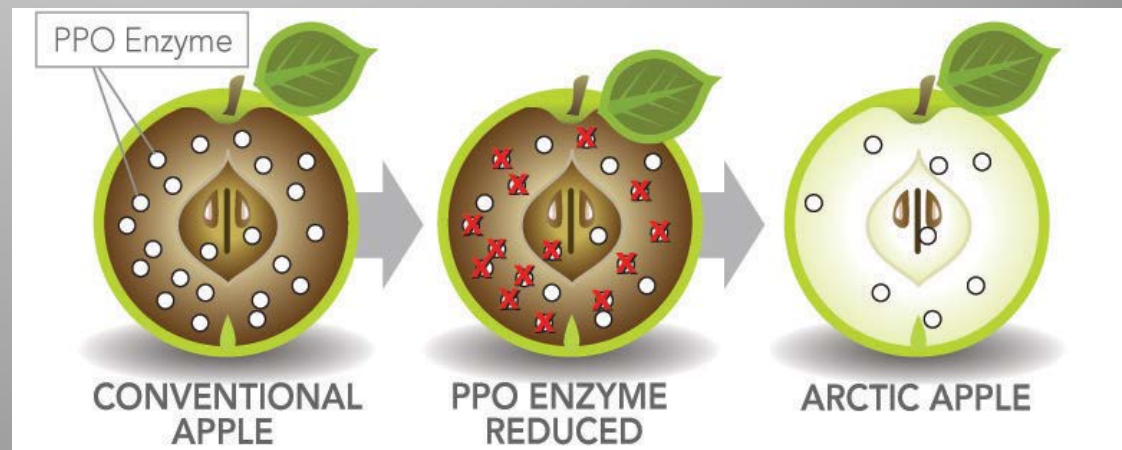


# Non-browning “Arctic Apple”

Reduced spoilage/waste, improved quality – USDA approved



Courtesy of Jennifer Armen,  
Okanagan Specialty Fruits,  
Canada



# Non-browning “Arctic Apple”

Time lapse video





### Arctic Apples

Genetically engineered to be non-browning when sliced.  
Developed by a small Canadian company, Okanagan Specialty Fruits  
Approved for consumption and cultivation in the US in Feb 2015

They tasted good for  
several hours



# “Innate” potato – native DNA, non-browning and other traits

One hour after cutting – Control vs. Innate

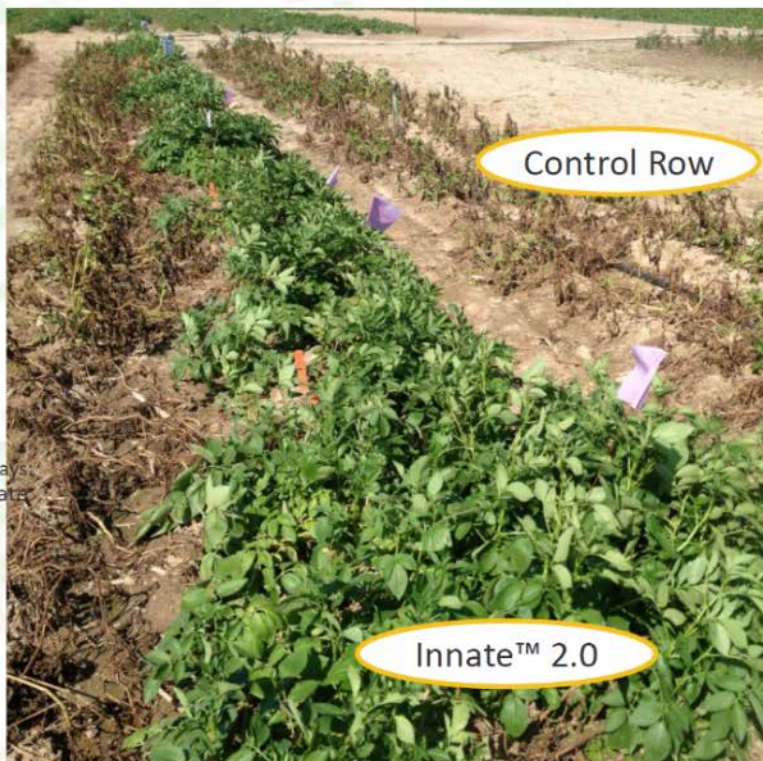


Two days after cutting –  
Control vs. Innate



# “Innate” potato 2.0 – late blight resistant, reduced acrylamide, reduced sprouting and browning (↓ waste, ↑ safety, ↓ pesticide, ↑ yield)

Midwest - Sept 4<sup>th</sup> 2013



Days  
Rate

Zebra Chip

Control

Innate™ 2.0



Burbank



Innate™  
Burbank



# Potential Innate Potato benefits

- If all USA potatoes had it's improved traits, each year....
- Waste reduced by 5 billion pounds
- CO<sub>2</sub> emissions reduced by 734 million pounds
- Water use reduced by 84 billion gallons
- 2.5 million fewer pesticide acre-applications
- Marketable yields increase ~ 20%
- Growers save \$240 million in production costs



Drought-tolerant maize – Planted on  
>150,000 acres – Also tested in Africa  
*Important tool given climate change, water shortages?*

**How Hydroefficiency Works**

**Advanced Biotechnology**  
Because of the advanced drought-tolerant biotech trait, Genuity® DroughtGard™ Hybrids adapt to drought conditions. Slowing down water consumption and using available water more efficiently to help endure the stress.

**The Result**  
Superior genetics along with innovative drought-tolerant trait technology helps DroughtGard Hybrids withstand drought conditions for a better chance of maximizing kernels per ear and overall yield potential.

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THE INNOVATOR OF HYDROEFFICIENCY  
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**Doing more with less water.**

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# Diverse pipeline of biofortification products = enhancement of critical vitamins or nutrients



Food for Thought A lecture series on the science of food and food technology

# GOLDEN RICE

Humanitarian Vision and Political Roadblocks

## Ingo Potrykus

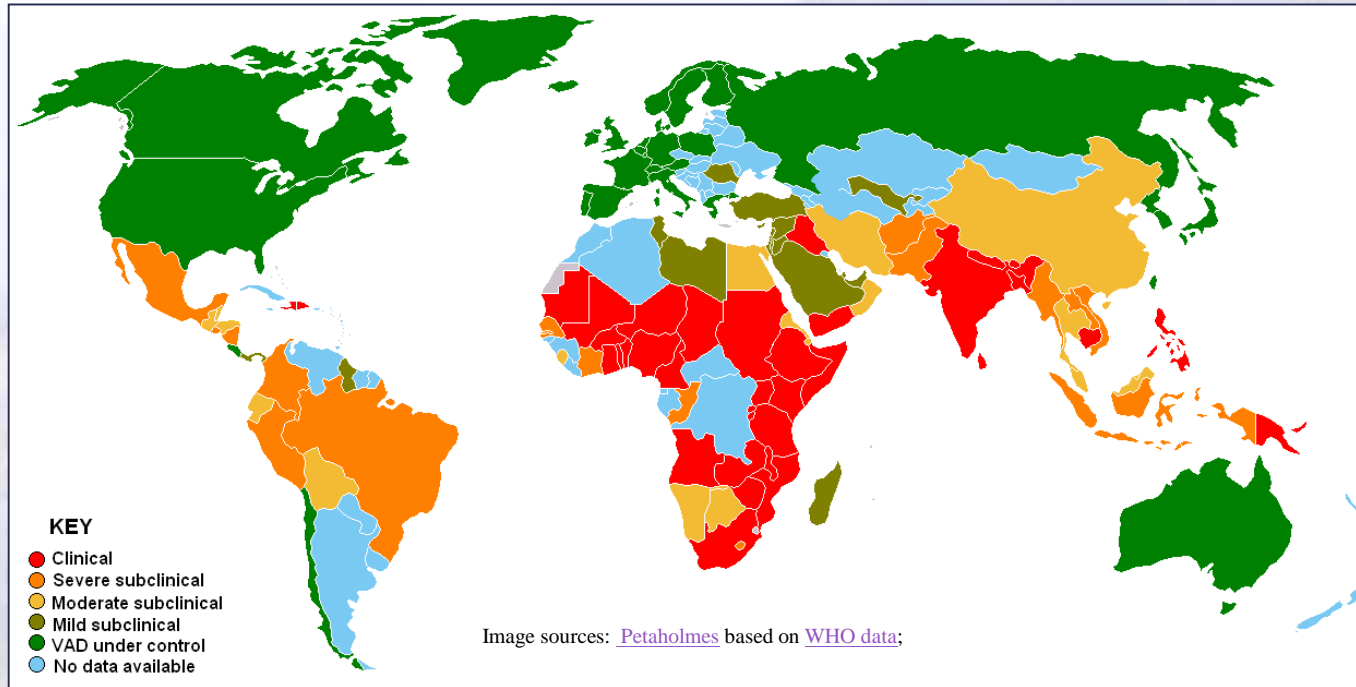
Science Community Lecture  
Genetic Engineering of Pro-vitamin A Production in Rice  
THURSDAY OCT. 13 4-5PM  
Agriculture and Life Sciences Building (AC-1) Rm. 4001

\*Genetically engineered with pro-vitamin A, may be capable of helping millions of impoverished children in the developing world. Dr. Ingo Potrykus shares the basic science of how it was created, how it has been received in Europe and the developing world, and the personal and political battles he has faced during its development.

The poster is titled 'Food for Thought' and features a bowl of golden rice. The main title is 'GOLDEN RICE' in large yellow letters, with the subtitle 'Humanitarian Vision and Political Roadblocks' and the speaker's name 'Ingo Potrykus' below it. The central image shows a blue bowl filled with golden rice, with a map of Africa visible on the bowl's side. At the bottom, there is a section for a 'Science Community Lecture' on 'Genetic Engineering of Pro-vitamin A Production in Rice' scheduled for Thursday, Oct. 13, 4-5 PM in Agriculture and Life Sciences Building (AC-1) Rm. 4001. A quote on the right side of the poster describes the potential of Golden Rice to help millions of children in the developing world.

# Why use breeding and biotechnology for $\beta$ -carotene (pro-vitamin A) enrichment?

Deficiency is widespread, impacts severe, and decades of supplements are unable to overcome



Young women suffering blindness due to Vit A deficiency

Vitamin A deficiency is estimated to affect approximately **one third of children under the age of five around the world**. It is estimated to **claim the lives of 670,000 children under five annually**. Approximately **250,000-500,000 children in developing countries become blind each year** owing to vitamin A deficiency....

# Biofortified plants are improving nutrition for many today, and can do more with aid of GE methods



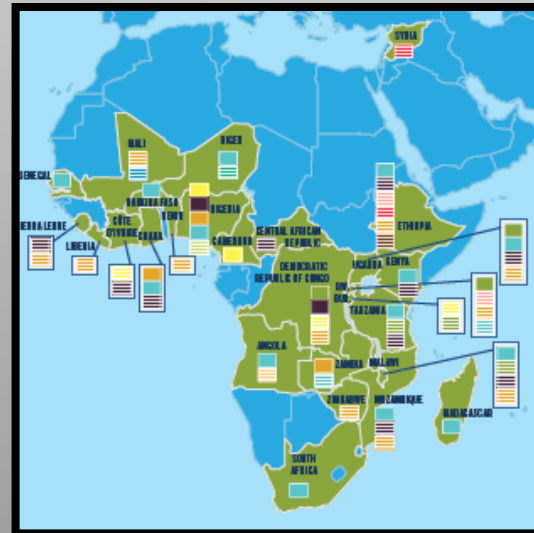
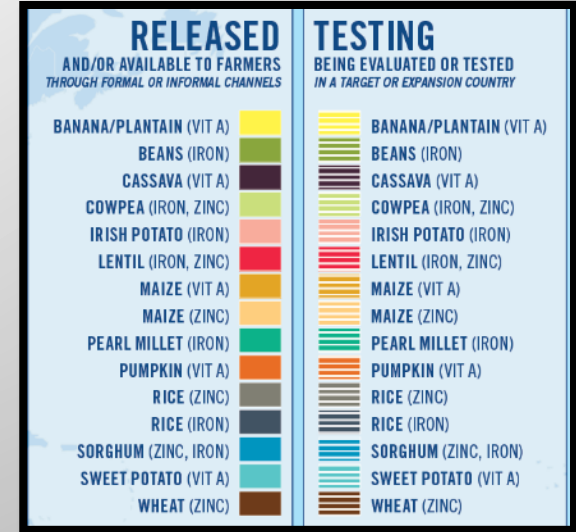
**Biofortification breeding well underway**, including a provitamin A enriched sweet potato that is **currently** being grown by > half a million families.

Other projects are underway to increase levels of protein, iron, zinc, antioxidants, and other beneficial components in food.

Gates Foundation a major supporter

# The HarvestPlus program – worldwide impact by traditional breeding

- Nutrient targets start at:
  - 30% of the EAR of iron
  - 40% of the EAR of zinc
  - 50% of the EAR of provitamin A
- Reaches more than 40 countries



# Biotech methods useful where breeding is ineffective or slow

- Rice
- Cassava
- Sorghum
- Banana

Rice



Cassava





# Agenda

- What they are and are not – a brief reminder
- Extent in the world
- Some impacts
- New forms in pipeline
- Why so controversial, stigmatized?

# The GMO controversy is complex: There are many pieces

- *“It is accurate to say that many of the real ethical issues [of GMOs in agriculture] have little to do with the use of transgenic technologies”*  
(Burkardt et al. 2005, Agricultural Ethics, CAST)

**CAST**  
COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY

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**ISSUE PAPER**  
NUMBER 29                      FEBRUARY 2005

**AGRICULTURAL ETHICS**

**I**NTRODUCTION

It is widely known that agriculture has a long history. Starting approximately 12,000 years ago, the domestication of plants and animals began independently in several different places, including centers in West Asia, East Asia, Central America, and South America. Domestication also may have occurred in other locations, although convincing archeological evidence has not been found. In the

**TASK FORCE MEMBERS:** Jeffrey Burkhardt, Chair, Department of Food and Resource Economics, University of Florida, Gainesville; Gary Comstock, Department of Philosophy and Religion, North Carolina State University, Raleigh; Peter G. Hartel, Department of Crop and Soil Sciences, University of Georgia, Athens; Paul B. Thompson, Department of Philosophy, Michigan State University, East Lansing; **REVIEWERS:** Maarten J. Chrispeels, Center for Molecular Agriculture, University of California–San Diego; Charles C. Muscoplat, College of Agricultural, Food and Environmental Sciences, University of Minnesota, St. Paul; Robert Streiffer, Department

commented on the importance of agricultural knowledge in the quest for the “good life” by the individual and the polity. The fundamental value of agriculture was highlighted by Enlightenment thinkers from John Locke to Thomas Jefferson, who underscored the political, economic, and philosophical importance of “tillers of the soil” (Spiegel 1991). In the United States, problems faced by farmers became the focus of the nine-

# My list of key factors

1. Complexity in an internet powered world looking for slogans and simple answers
  - Clean label movement
2. Vested interest in stigma for economic and ideological reasons
  - Internet, media celebrity experts
  - Fake and “half-truthed” news and science
3. Phobia for pesticides, chemicals in any dose
  - The “Food Babe” effect
4. Scientific novelty and complexity vs. inertia of regulations and marketing systems

# My list of key factors

5. Roles and perceptions of large seed/chemical and food corporations – the “Monsanto effect”
6. Tool in global battles / trade wars
7. Scientific complexity of environmental impacts – biodiversity vs. climate vs. pesticide impacts
8. Poor management, fear of herbicide tolerant GE crops
9. Legal complications and perceptions around gene flow and patents
10. Decreasing confidence in experts, scientists – who to trust?

# There are numerous myths that are rampant and recycled in media

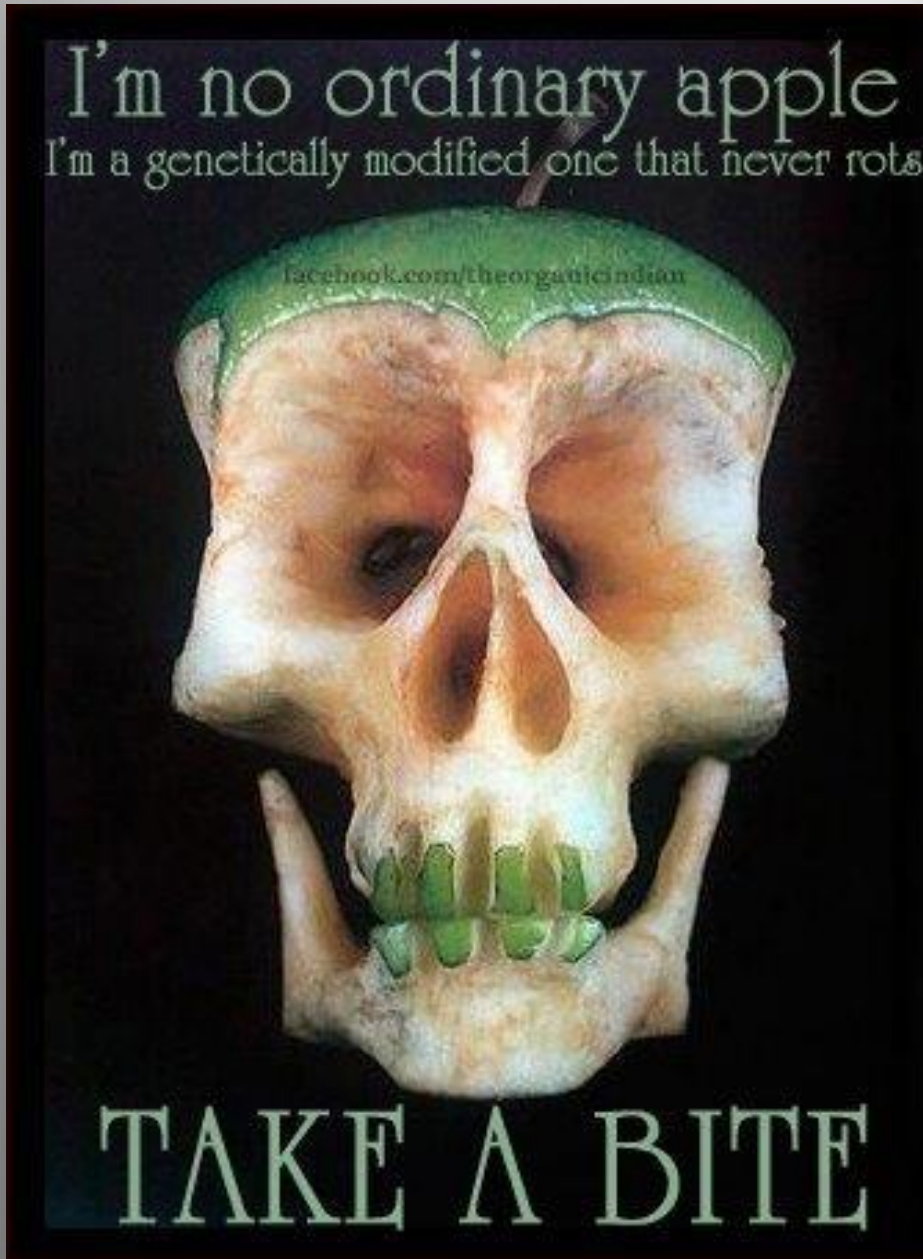


*Vandana Shiva accuses multinational corporations such as Monsanto of attempting to impose "food totalitarianism" on the world.*

# Vicious anti-GMO messages widespread



# And many more

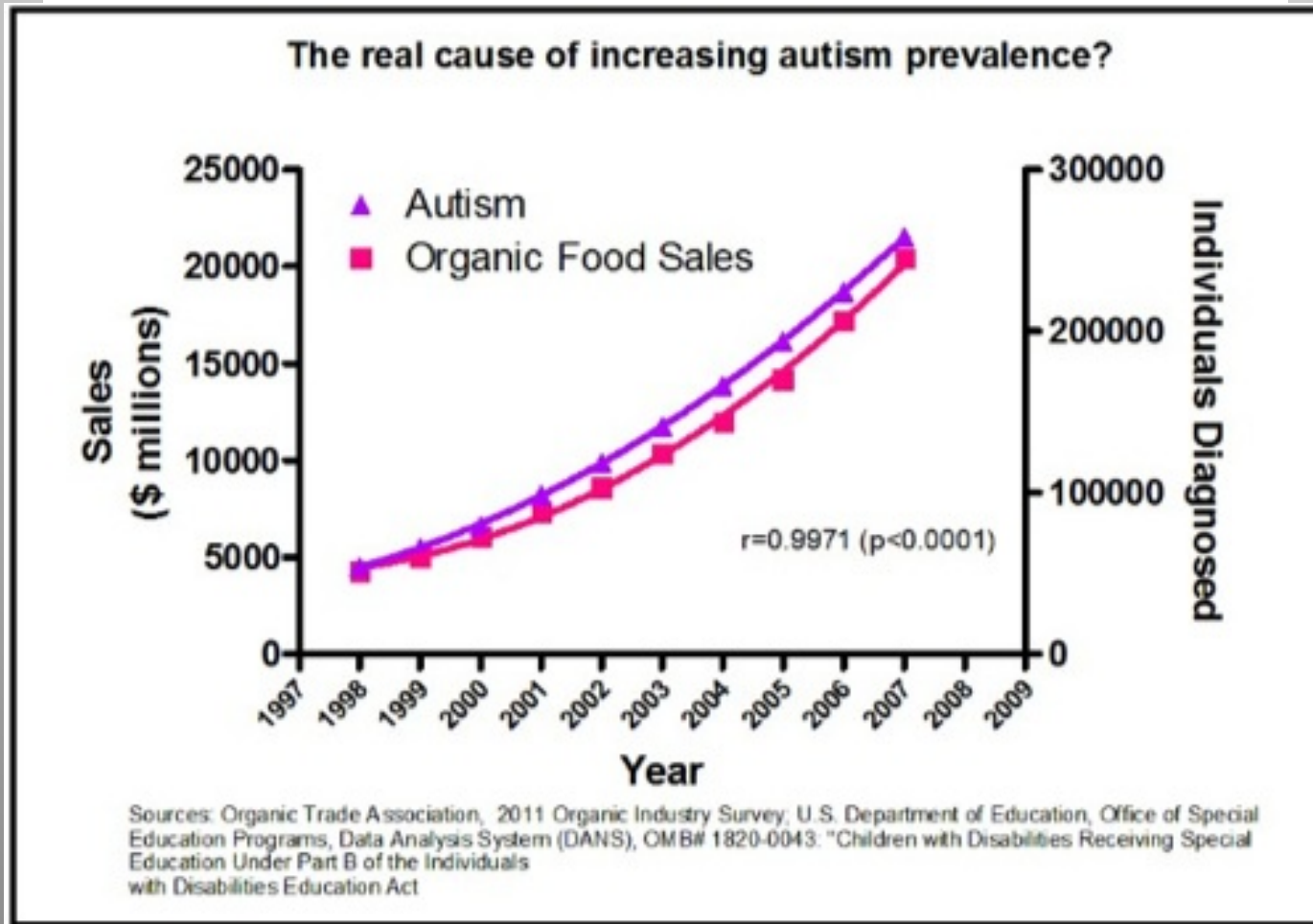


My colleague  
Steve Savage's  
favorite!

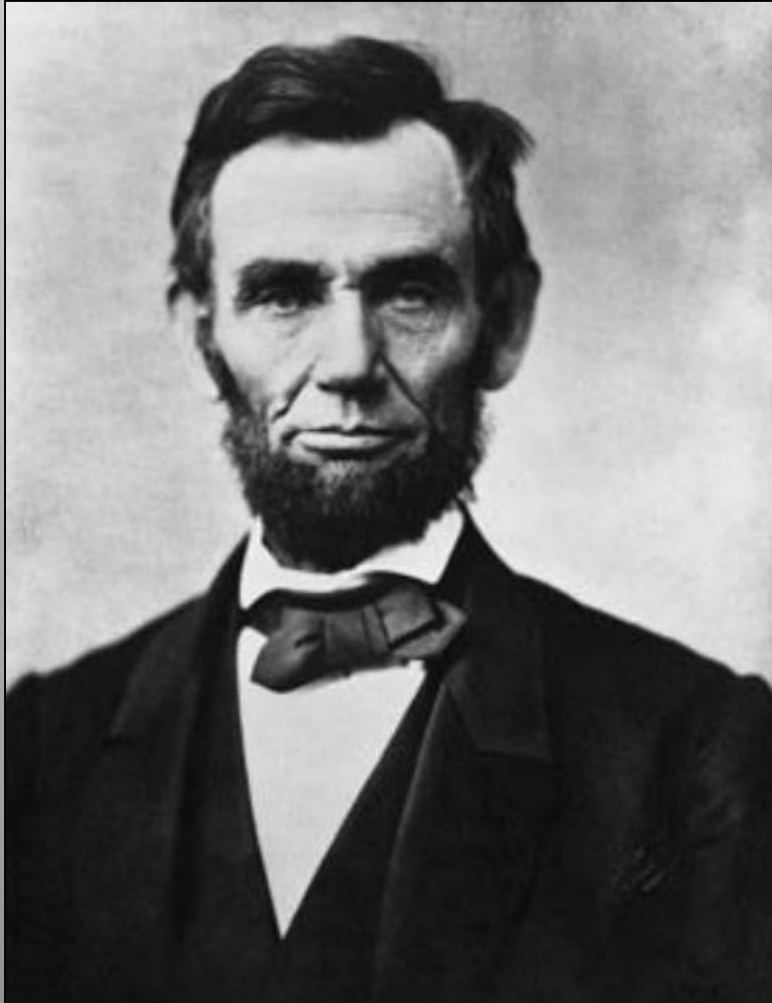




Much pseudo-science: “Half of all children will be Autistic by 2025 due to Roundup warns MIT scientist”



# Abe Lincoln warned us, but....



**“Don’t believe everything you read on the Internet just because there’s a picture with a quote next to it.”**

**—Abraham Lincoln**

<http://weknowmemes.com/2012/07/dont-believe-everything-you-read-on-the-internet>



# Trend of the Year: Clean Label

Industry answers the call for simple ingredients



Kraft has announced that the orange glow of its iconic Macaroni & Cheese will no longer come from synthetic coloring agents. (Kevin Diasezian / Getty Images)

ment for

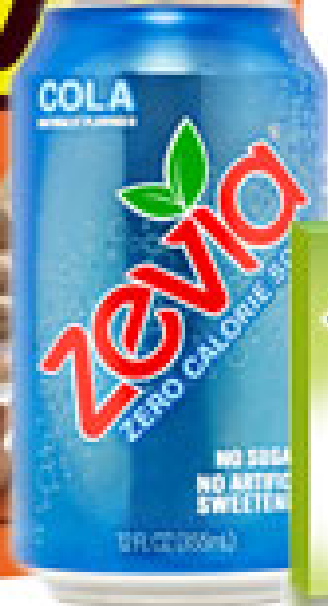


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<http://features.foodbusinessnews.net/corporateprofiles/2015/trend-index.html>

<http://www.chicagotribune.com/business/sc-clean-labels-food-0210-20160218-story.html>



# The clean label movement

Harvard Business Review 2015

- ...focuses on having fewer ingredients that are very clear about their origins, and recognizable
- ...“clean” is a catchall for a much broader and growing list of demands about the human and planetary impacts of all products and services (and the companies behind them)
- Two major forces are driving this clean label world:
  - **Technology-driven**, transparency about products and their supply chains, and
  - Millennials, who are regularly demanding good behavior from the companies they buy from and work for

# What clean-label millennials want to know

- What is every ingredient in your product, why is it there, and what does it do, exactly?
- How much of your energy comes from clean, renewable sources?
- Who are your suppliers and what are their workers' lives like? And how about your suppliers' suppliers?
- How much do you know about the dangers of your product and when did you know it?
- What goals do you have and how do they tie to global challenges (like reducing carbon emissions or dealing with inequity in your communities and value chain)?
- Which organizations, political causes, or candidates are you donating to, how much is it, and why?

# FDA laxity one reason for demand, but not clear “clean” products are “cleaner”

WEBMD SPECIAL REPORT: FOOD ADDITIVES

## The Dirty Secrets of 'Clean' Labels

By Brenda Goodman, MA, Reviewed by Michael W. Smith, MD on July 20, 2015

WebMD News Archive 

July 23, 2015 -- Consumers have become deeply distrustful of their food.

There's Samantha Adams, who had her “aha moment” when she happened to read the label of the barbecue sauce she was feeding her 1-year-old.

# GMO-free labels a significant feature of clean label movement





# Meteoric rise of no-GMO labels

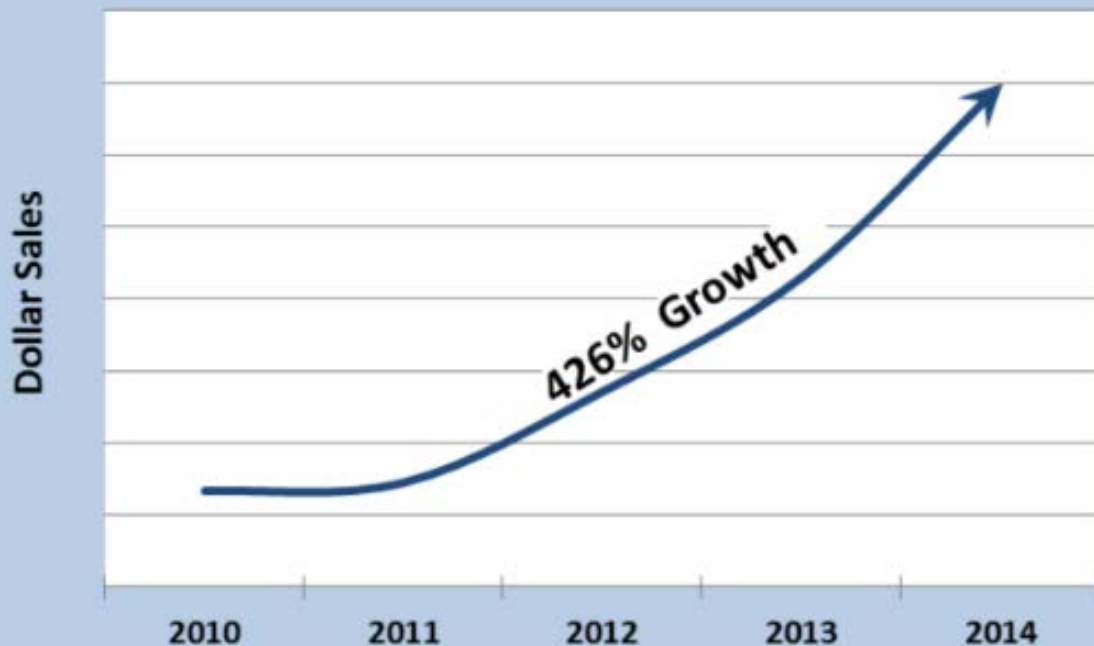
- GMO-free claims jumped 237% in new products 2012 to 2013



Organic and Non GMO Market  
Growth 2015

Errol Schweizer  
Executive Global Grocery Coordinator  
Whole Foods Market

## Non-GMO SALES



## ORGANIC SALES

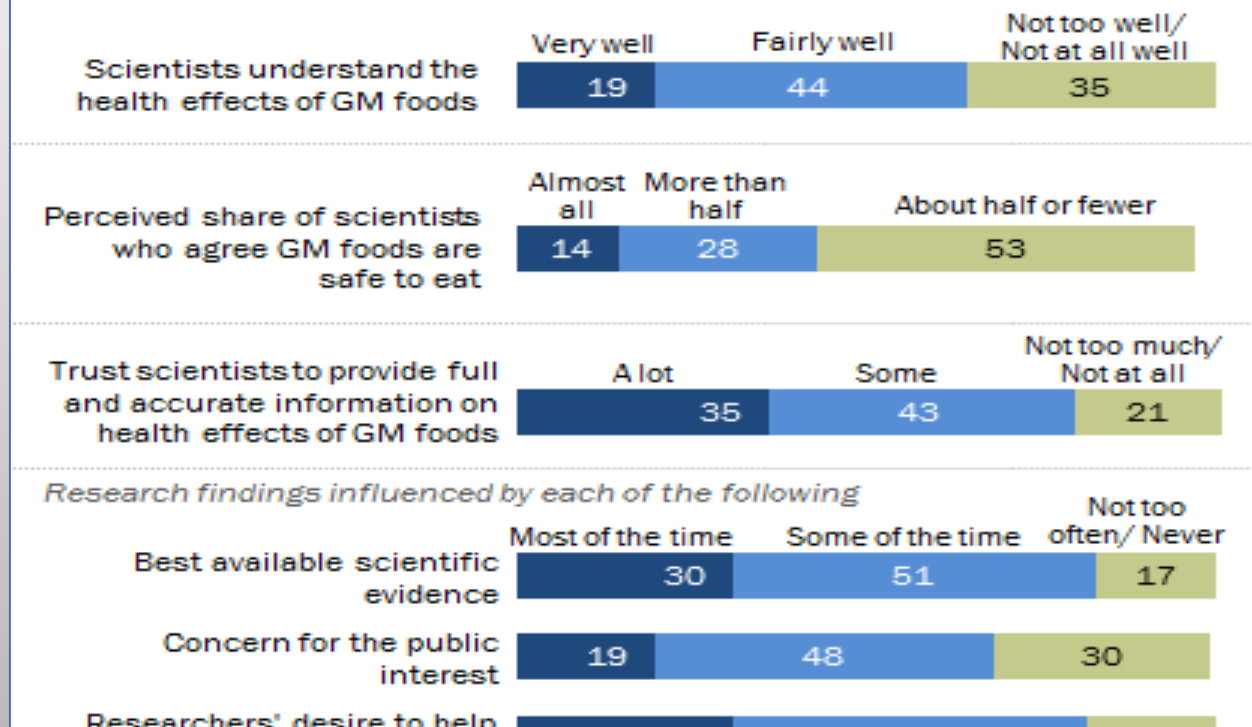


# Limited public trust in science and scientists

Pew Survey 2016

## Americans have limited trust in scientists connected with genetically modified foods

% of U.S. adults



Note: Respondents who did not give an answer are not shown.

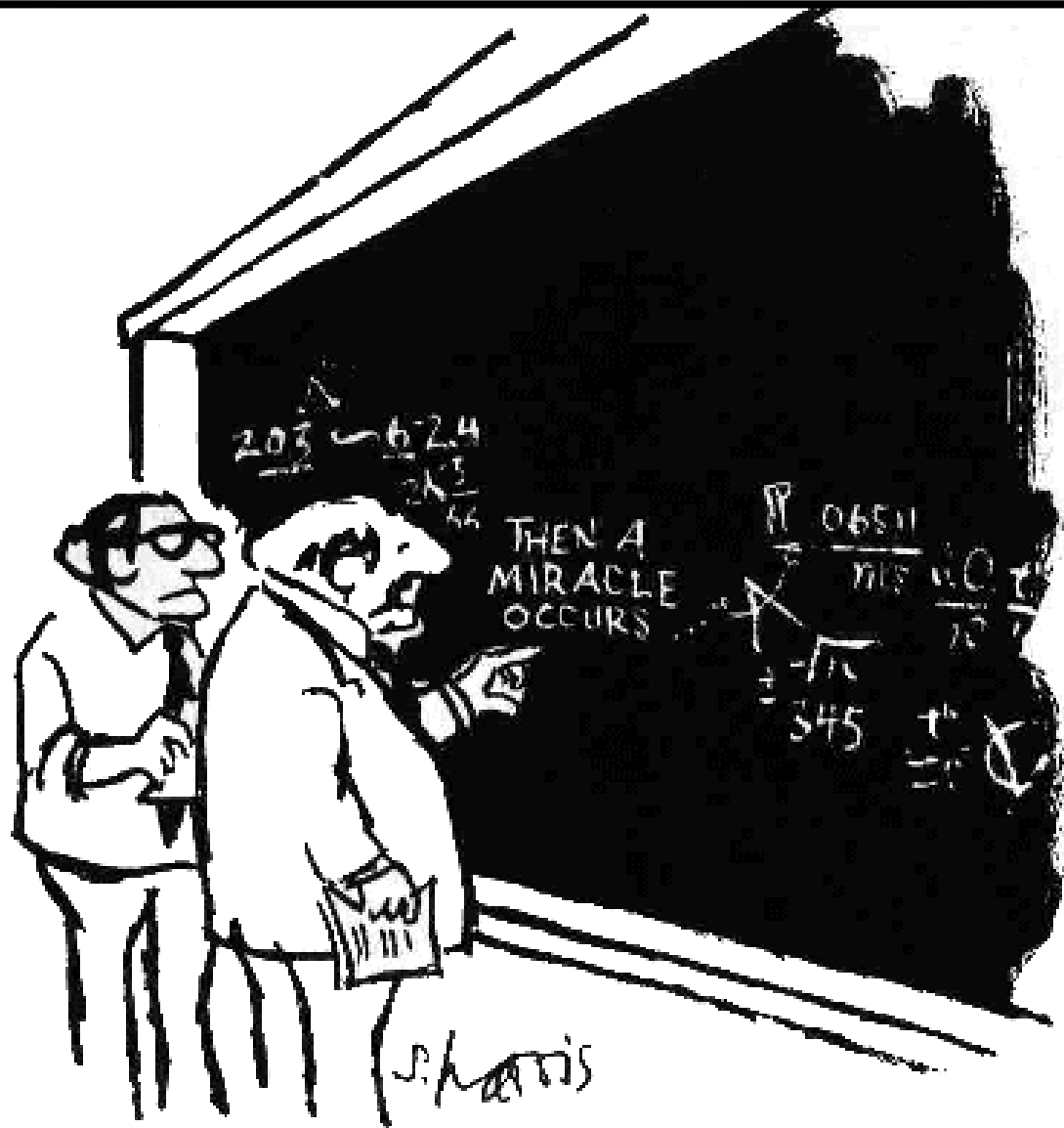
Source: Survey conducted May 10-June 6, 2016.

"The New Food Fights: U.S. Public Divides Over Food Science"

PEW RESEARCH CENTER

# Summary

- GMO is a breeding method not a particular kind of product
- Large benefits for economics, soil tillage, humanitarian applications
- Also very significant management, global acceptance, trade problems
- Diverse pipeline of new products
  - Gene editing a major new tool, but acceptance unclear
- “Clean label” movement limiting GMOs, teaching public they are unsafe as a group?
- Decreasing trust in scientists, government, media, many institutions inflames and confuses



"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."