Navigating the perfect storm?

Biotech, society, and forest health

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Plan

- The perfect storm over genetic engineering (GE) in society
- Relevance of GE as a tool for enhancement of tree productivity and health
  - RNAi and gene editing examples

Global "meta-analysis" of early GE crop 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%."

GMOs add a lot of value to the economy, environment

If removed, lower yields (~5-19%), higher prices (~$19 billion/year), more land farmed, higher greenhouse gases

AgBioForum
THE JOURNAL OF AGROBIOTECHNOLOGY MANAGEMENT & ECONOMICS
Volume 19 // Number 2 // Article 6

Evaluation of Economic, Land Use, and Land-use Emission Impacts of Substituting Non-GMO Crops for GMO in the United States

Farzad Taheripour, Harry Mahaffey, and Wallace E. Tyner
Purdue University

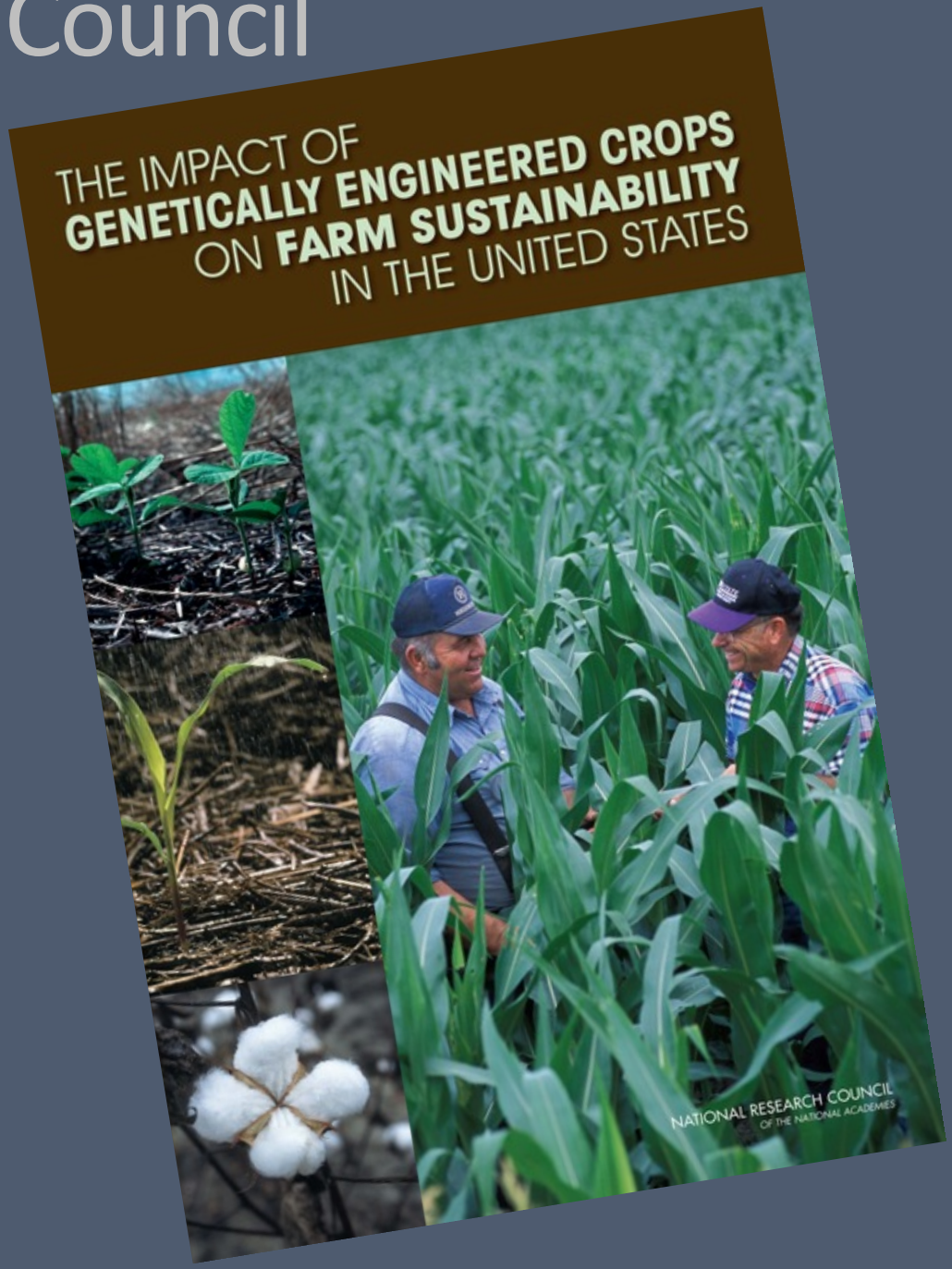
The main objective of this study was to evaluate potential economic and environmental consequences of losing GMO traits in the United States for the major crops of corn, soybeans, and cotton. The first step was to obtain from the literature a range of estimates of the yield losses if we move away from GMO traits in the United States. The second step was to calculate the weighted average GMO and non-GMO area to get the overall shock value. The third step was to introduce the yield losses obtained into a well-known CGE model, GTAP-BIO, to quantify the land use and economic impacts of banning GMO traits in the United States. Absent the GMO technology, more land would be needed to produce corn, soybeans, and cotton. That land comes from switching from other crops and conversion of cropland pasture, pasture, and forest in many global areas. The land expansion likely is similar to the entire US ethanol program. Furthermore, induced land-use emissions were significantly larger than the corresponding figure for US corn ethanol. We evaluated three cases representing different levels of yield shocks. The price changes for corn were as high as 28% and for soybeans as high as 22%. In general, the price increases for two of the three cases were higher than those observed previously for the US ethanol mandate shocks. Food cost changes in the United States amount to $14-$24 billion per year. As expected, welfare falls both in the United States and globally.

Key words: GMO crops, productivity, computable general equilibrium, economic impacts, land use, land-use emissions.

Introduction

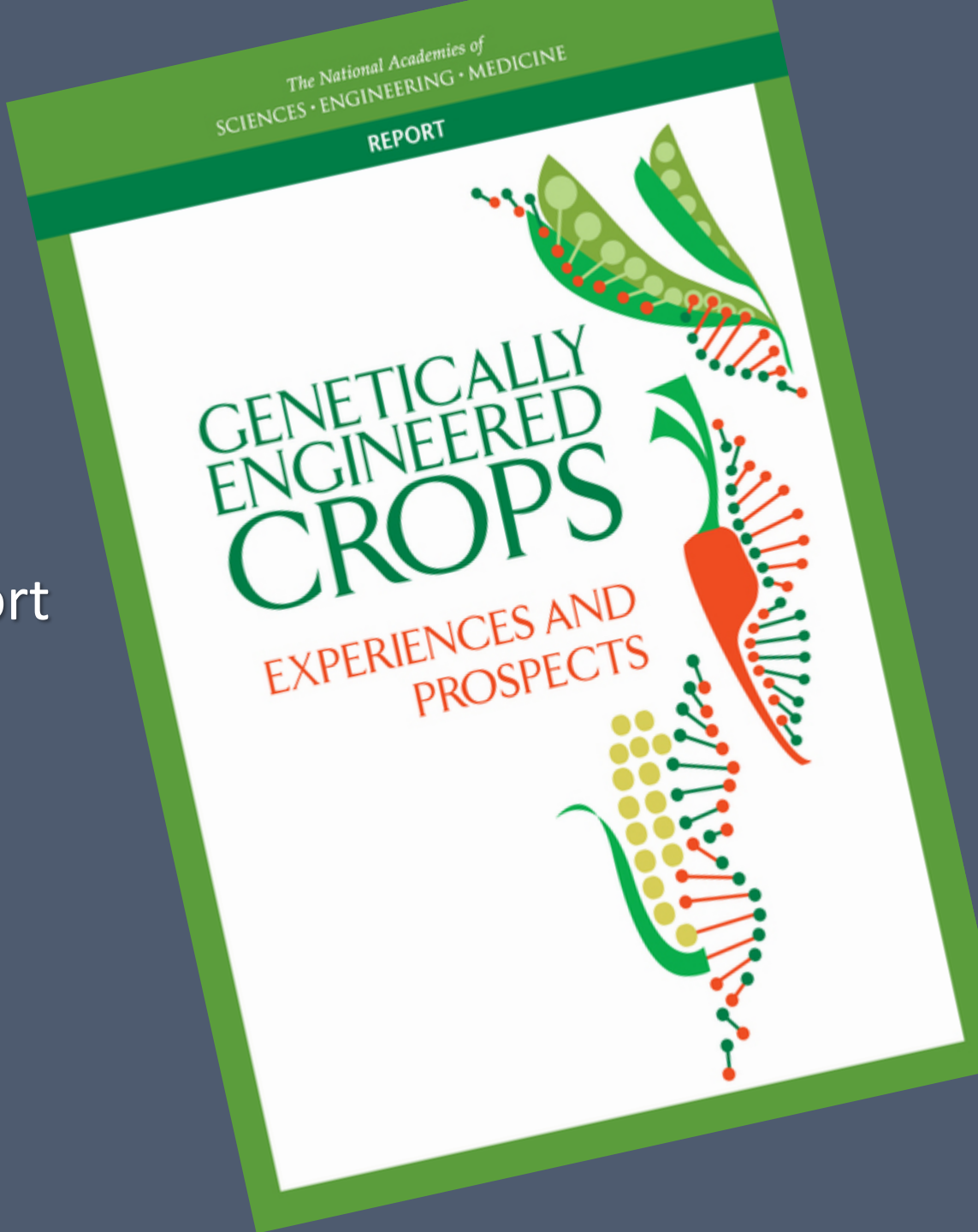
National Research Council Report 2010

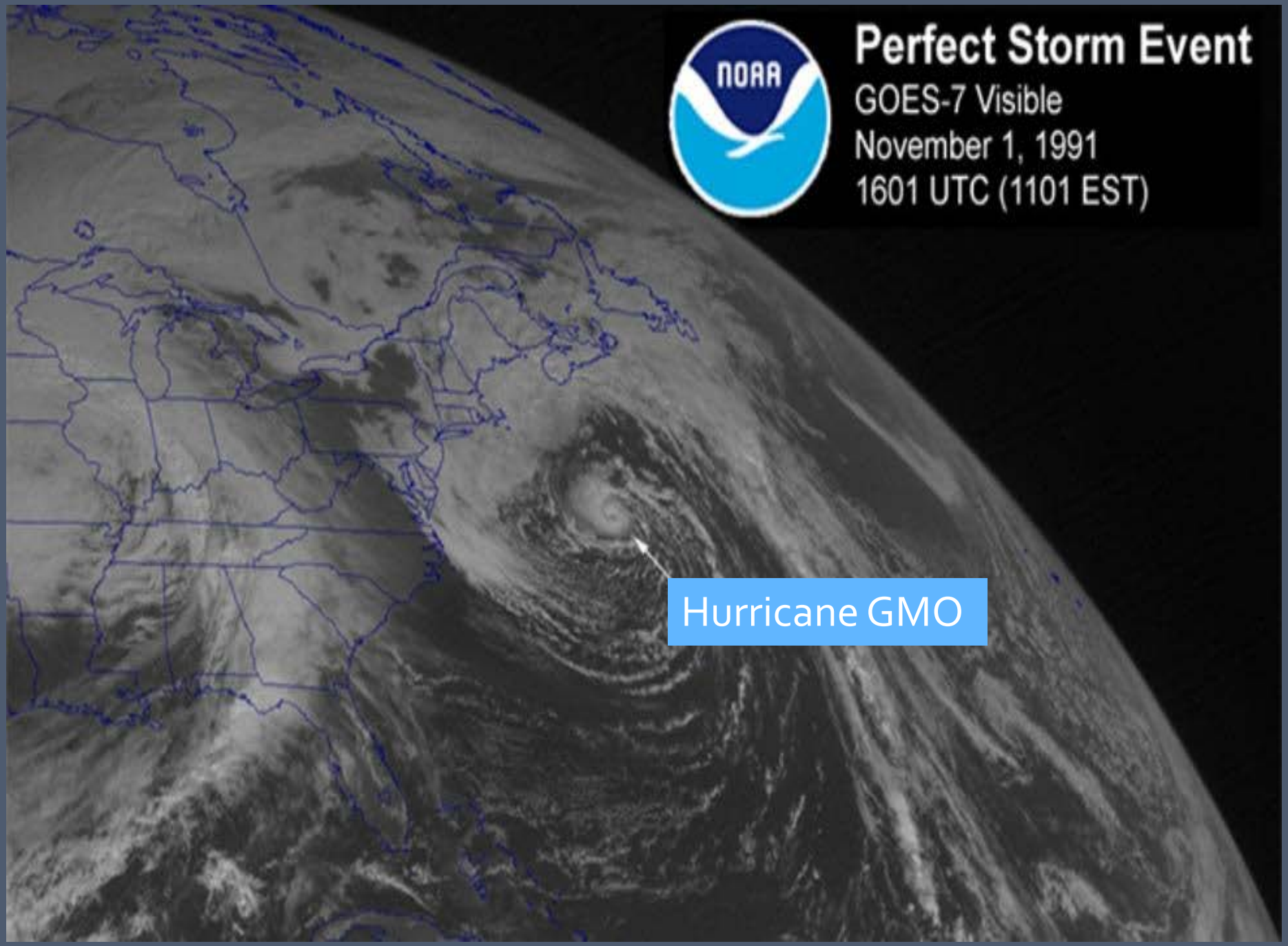
- Major pesticide reductions - Bt
- Expanded conservation tillage
- Herbicide tolerant weeds
  - Need more sustainable management



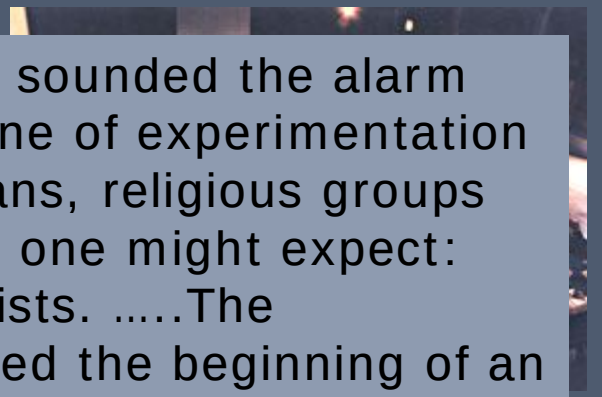
National Research Council Report 2016

- No evidence to support food/feed safety concerns
- Confirmed large insecticide reduction with Bt crops




Perfect Storm Event
GOES-7 Visible
November 1, 1991
1601 UTC (1101 EST)
Hurricane GMO

Asilomar, CA meeting on rDNA research 1975



"The people who sounded the alarm about this new line of experimentation were not politicians, religious groups or journalists, as one might expect: they were scientists. …..The conference marked the beginning of an exceptional era for science and for the public discussion of science policy."

"Scientists around the world hotly debated the wisdom of our call for caution, and the press had a field day conjuring up fantastical 'what if' scenarios."

" …the fear among scientists that artificially moving DNA among species would have profound effects on natural processes has substantially disappeared with the discovery that such exchanges occur in nature."

OPINION MEETINGS THAT CHANGED THE WORLD

ESSAY

Asilomar 1975: DNA mo

The California meeting set standards allowing geneticists to … public health. Organizer Paul Berg asks if another such meeting could resolve today's controversies.

Today, the benefits of genetic engineering, and the risks and ethical dilemmas that it presents, are part of everyday public discourse, thrashed out in newspaper columns and by politicians and commentators everywhere. In the early 1970s, it was a very different picture. Scientists were only just learning how to manipulate DNA from various sources into combinations that were not known to exist naturally. Although they were confident that the new technology offered considerable opportunities, the potential health and environmental risks were unclear.

The people who sounded the alarm about this new line of experimentation were not

and could ultimately lead to exceptional … moratorium would be a blunder. Others opportunities in medicine, ag… industry. But we conceded th… pursuit of these goals might ha… and damaging consequences fo… and Earth's ecosystems.

Earlier, in mid-1974, I had … tee that communicated those c… president of the US National A… ences and published them in S… and in *Proceedings of the Nati… of Sciences*. We recommende… moratorium on certain recon… experiments that were consi… tially hazardous. The committee was par-

What turned the debate around was the

The first field tests: Litigation and regulation and vandalism

modern farmer

PREVIOUS POST
O-Inked: Is Tattooing A Pig Art

The First GMO Field Tests

From their very first field test in 1987, GMOs have been the subject of intense debate. What we fight about when we fight about GMOs.

By Brooke Borel on May 20, 2014

"Dressed in billowy white safety jumpers and peaked caps, the EPA agents looked like apocalyptic bakers…

Nearby, journalists eagerly took notes and snapped photos of this eerie scene, which would become national news — this was the world's first field experiment of a controversial new technology: genetically modified organisms."

Tree Biotechnology was no exception

Conference at Oxford in 1999 / Vandalism against lignin modified trees to “welcome” conferees, Euro-press attacks

FRANKENSTEIN'S FOREST

The tree-top protesters, who confounded the Government's road-building programme by camping in the path of bulldozers, are now poised to target the very trees they might once have called home.

Whilst public attention has been focused on the threat of 'Franken... same corporations who are ... genetically modified (GM) ... quietly perpetrating yet ... against the environment.

The biotech industry has ... ably tight-lipped about its ... genetic revolution. But it is ... ing to take over the world's ... left of them – and grow ... genetically engineered (mod...

Big deals are currently ... tween forest and biotech co... Monsanto. By replacing pla... over with GM trees, they ar... in on faster growth rates a... of saleable wood pulp.

But what's good for M... cronics is not necessarily good for the environ-

ment. Campaigners fear that GM trees will sap up water, nutrients and light, leaving indigenous trees to die out along with the host of insects, plants and fungi which rely upon them. In turn, birds and animals would lose

1997. The trees, engineered by the University of Derby, to be disease- and insect-resistant were destroyed by removing the bark. A growing spate of raids on food crops caused AstraZeneca to make a statement to the press

vention, which governs global emissions of greenhouse gases, came into force after the 1997 Kyoto conference, industrialised countries have been forced to clean up. However, the corporations argue that by planting more ... 'carbon credits', ... dioxide.

...ative forests have ... to be replaced by ... species such as ...ng eye, one forest ...nother, allowing ...ow well they are ... Look behind the ...uch as Shell are ...raits.

...iola Sampson of ...

Whilst public attention has been focused on the threat of 'Frankenstein Foods', the same corporations who are forcing us to ingest genetically modified (GM) meals have been quietly perpetrating yet another crime against the environment.

”Eco” vandalism in Pacific Northwest USA in 2001

Oregon State

U Wash

2015 vandalism in Brazil

March 5, 2015: 1,000 women of the Brazil Landless Workers' Movement (MST) vandalized Suzano/FuturaGene's GE eucalyptus greenhouse at Itapetininga, in São Paulo

Many companies have long avoided GMOs due to brand risk from activists/consumers

The clean label explosion

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


PEACE
ALL NATURAL
BONUS 35% MORE!
NO
NO
NO
SWEET & CRUNCHY CORN PUFFS
Reese's Puffs
NEW!
SELECTS
NEW YORK STYLE
RESPECT
Breakfast Sandwich
NO ARTIFICIAL PRESERVATIVES OR FLAVORS
Kraft
Singles
AMERICAN
16g Protein
NET WT. 4.80 OZ. (136 g)
COLA
zevia
ZERO CALORIE
OVEN ROASTED
DELI TURKEY
NO PRESERVATIVES
Hormel
NATURAL
CHOICE
DOUBLEMINT
perfectly
sweet
NO ARTIFICIAL SWEETENERS

Kevin Folta
Land-grant scientist exploring ways to make better food with less input, also learning and teaching how to effectively communicate science to the public.
Feb 15 · 4 min read

The Deeply Offensive Marketing Ploy of "Clean Food"

When the commercial says that I should select ***clean food*** it makes my blood boil

GMO-free labels a major feature of clean label movement

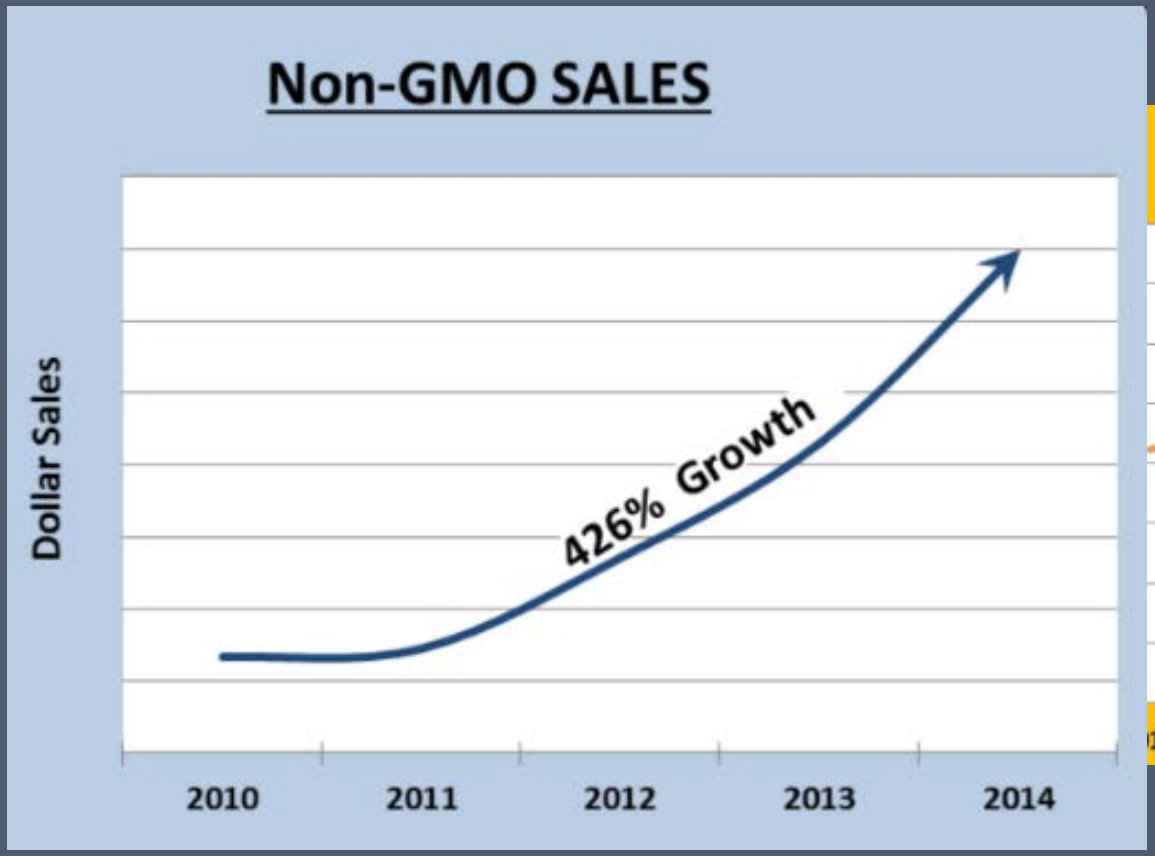
NON GMO Project
VERIFIED
nongmoproject.org

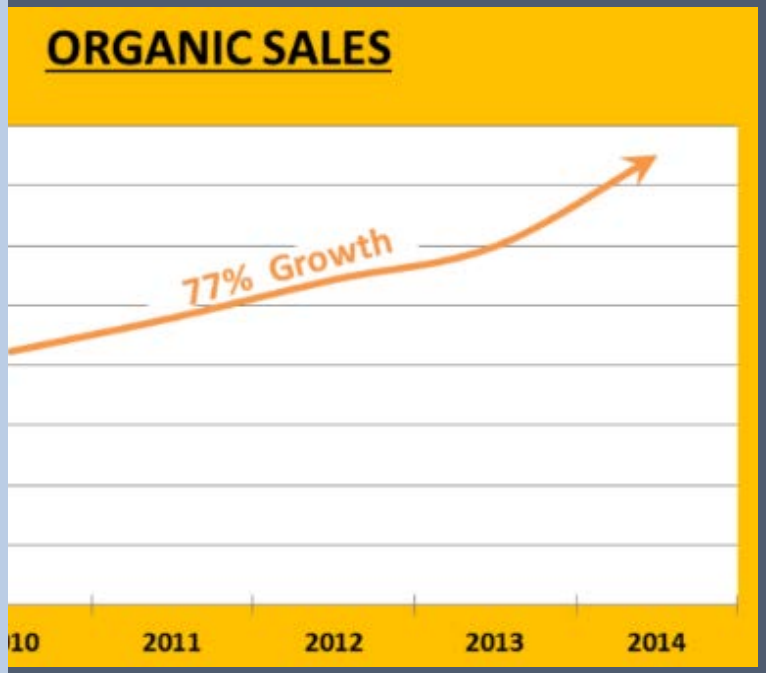
Meteoric rise of no-GMO labels

- 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



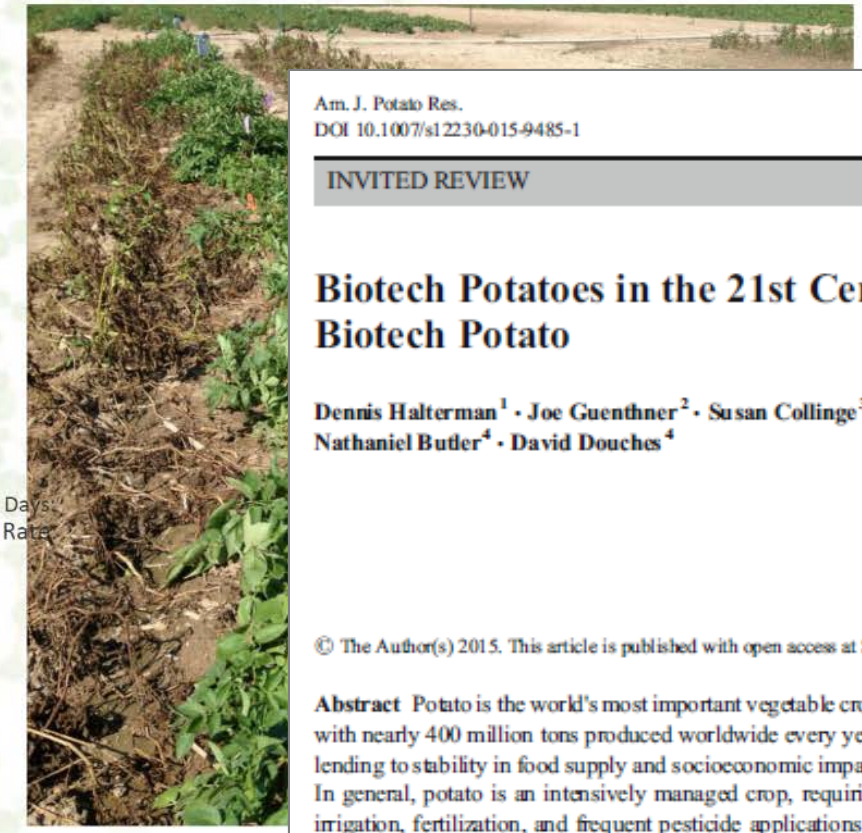


https://www.aphis.usda.gov/stakeholders/downloads/2015/coexistence/Errol-Schweizer.pdf

No-GMO labels on potatoes, in contrast to expected benefits of new GMO products

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

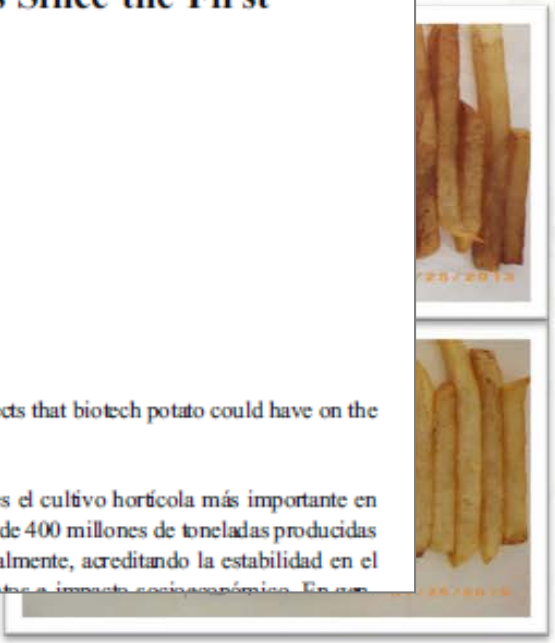
Midwest - Sept 4th 2013



Days
Rate

Control

Innate™ 2.0



Am. J. Potato Res.
DOI 10.1007/s12230-015-9485-1

INVITED REVIEW

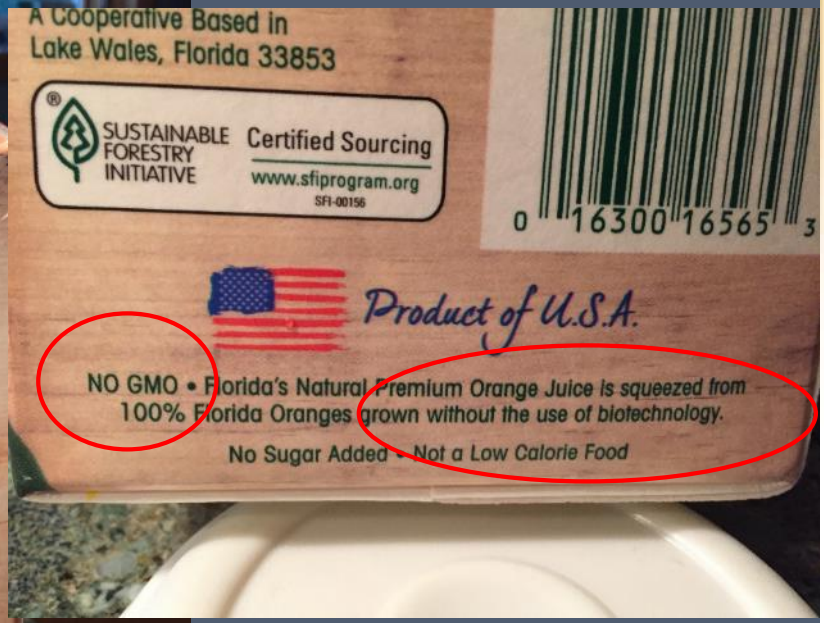
Biotech Potatoes in the 21st Century: 20 Years Since the First Biotech Potato

Dennis Halterman[1] · Joe Guenthner[2] · Susan Collinge[3] · Nathaniel Butler[4] · David Douches[4]

Abstract Potato is the world's most important vegetable crop, with nearly 400 million tons produced worldwide every year, lending to stability in food supply and socioeconomic impact. In general, potato is an intensively managed crop, requiring irrigation, fertilization, and frequent pesticide applications in order to obtain the highest yields possible. Important traits are easy to find in wild relatives of potato, but their introduction and the potential effects that biotech potato could have on the industry.

Resumen La papa es el cultivo hortícola más importante en el mundo, con cerca de 400 millones de toneladas producidas a nivel mundial anualmente, acreditando la estabilidad en el

No-GMO claims on orange juice



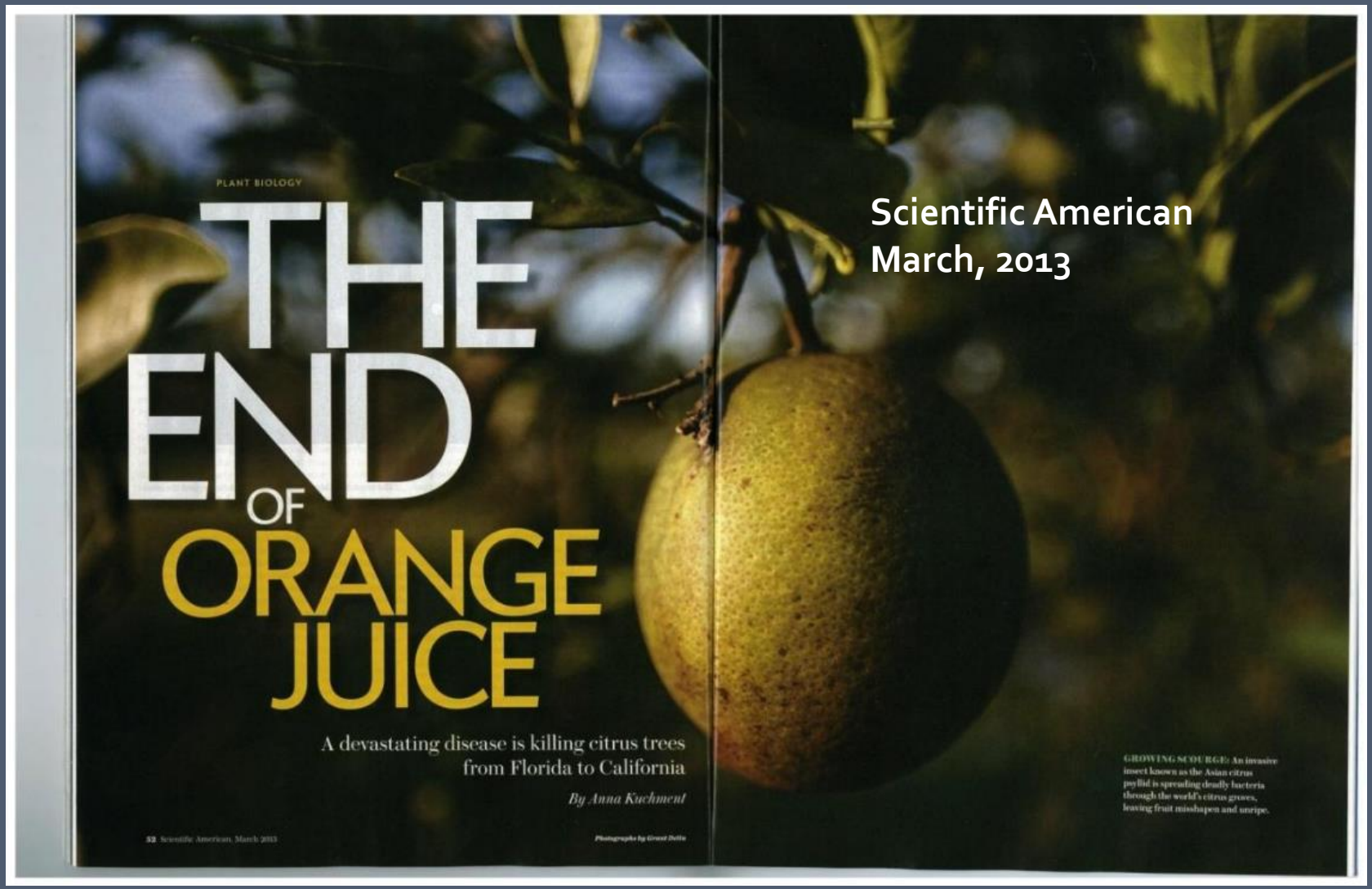
BUSINESS DAY

Some Tropicana and Other PepsiCo Products to Carry Non-GMO Project Seal

The New York Times

By STEPHANIE STROM DEC. 10, 2015

In spite of GE solutions to devastating ‘citrus greening’ threatening the industry



Very well funded activism against GMOs and related issues

Agbiotech Info Net
Agribusiness Examiner
ACGA
American Pasturage
APHA
Animal Protection Institute

Farm Animal Reform Movement
Farm Aid
Farm Sanctuary
Friends of the Earth
GRACE
Government

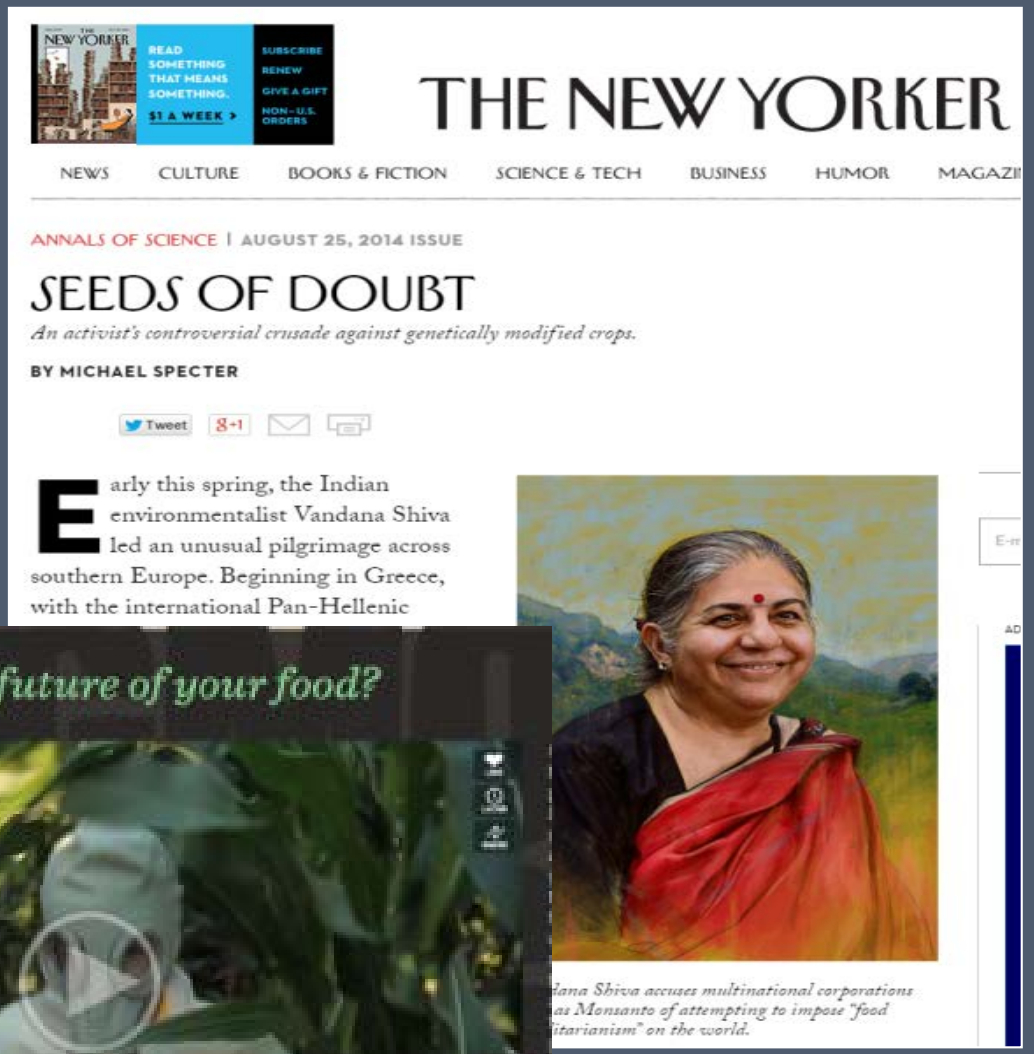
More than 500 activist organizations in North America are spending in excess of $2 billion annually engaging in food-related campaigns targeting biotech and many other elements

Chef's Collaborative
Children's Health Env Coalition
Common Dreams
Consumer Federation of America
Consumers Union
Crop Choice
David Suzuki Foundation

Humane Society US
IATP
Institute for Public Accuracy
Land Institute
Local Harvest
NFFC

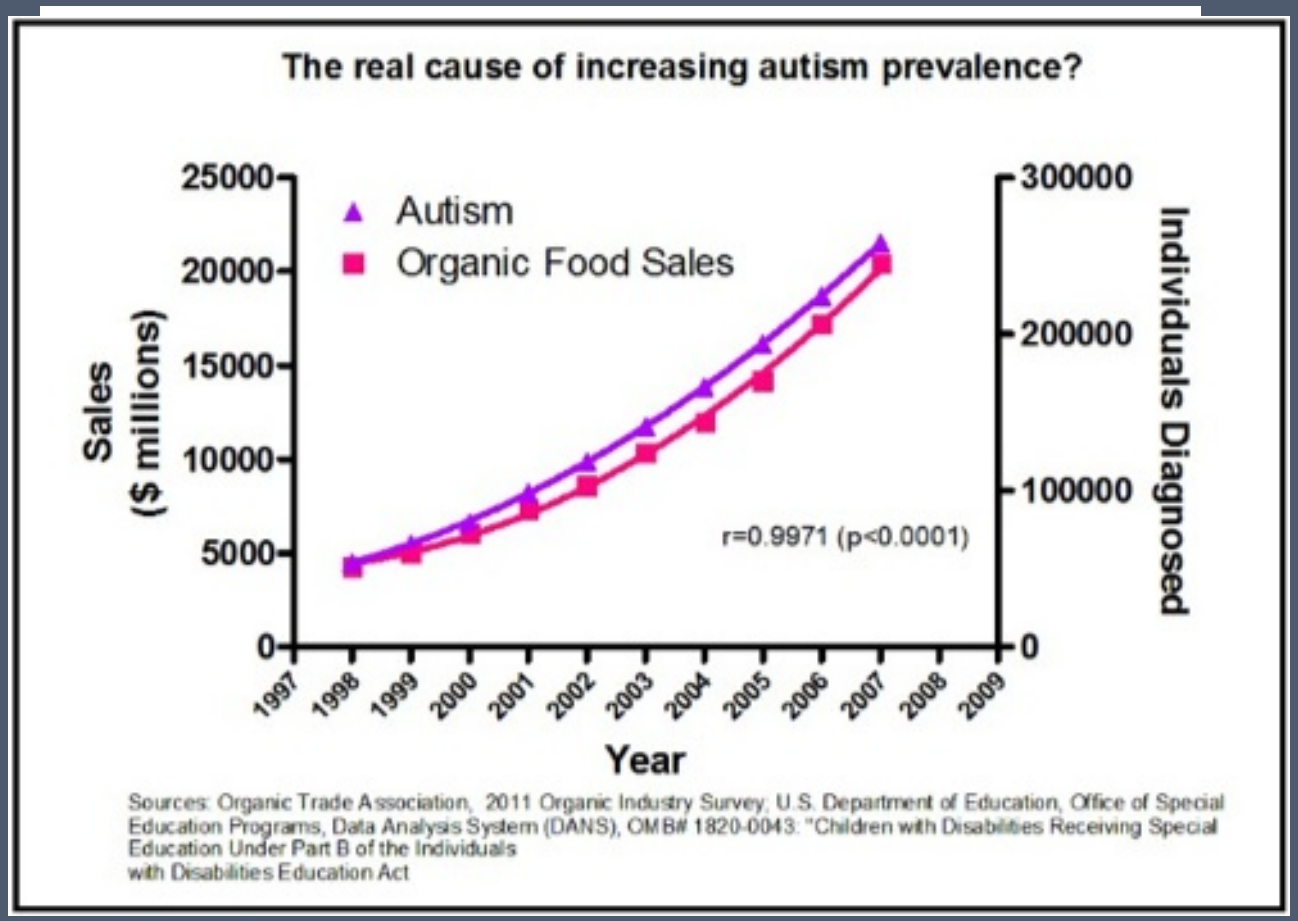
Jay Byrne, 2012, V-fluence

There are numerous myths that are rampant and recycled in media



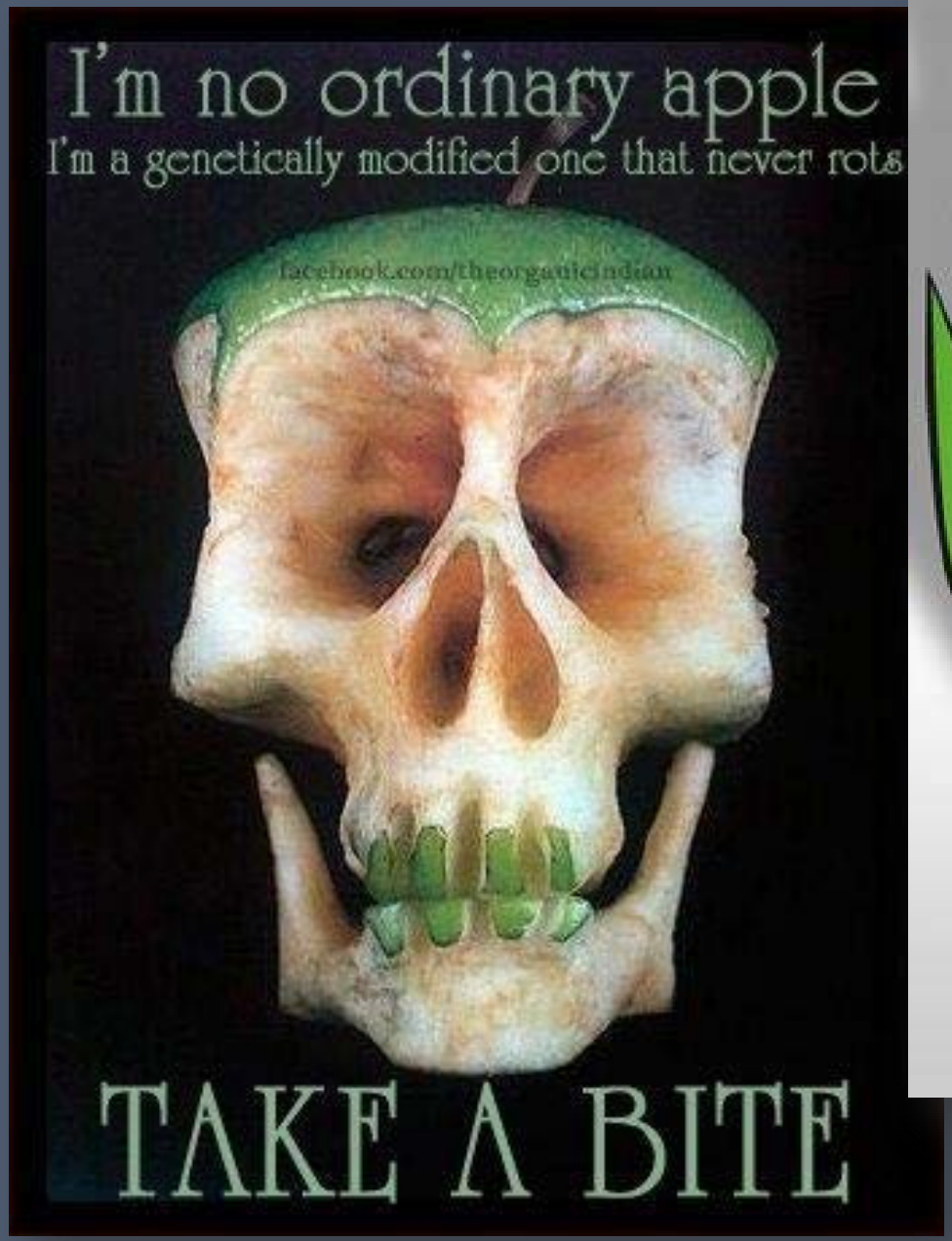
With GMOs, we have had fake-science for years, and its "heroes" abound

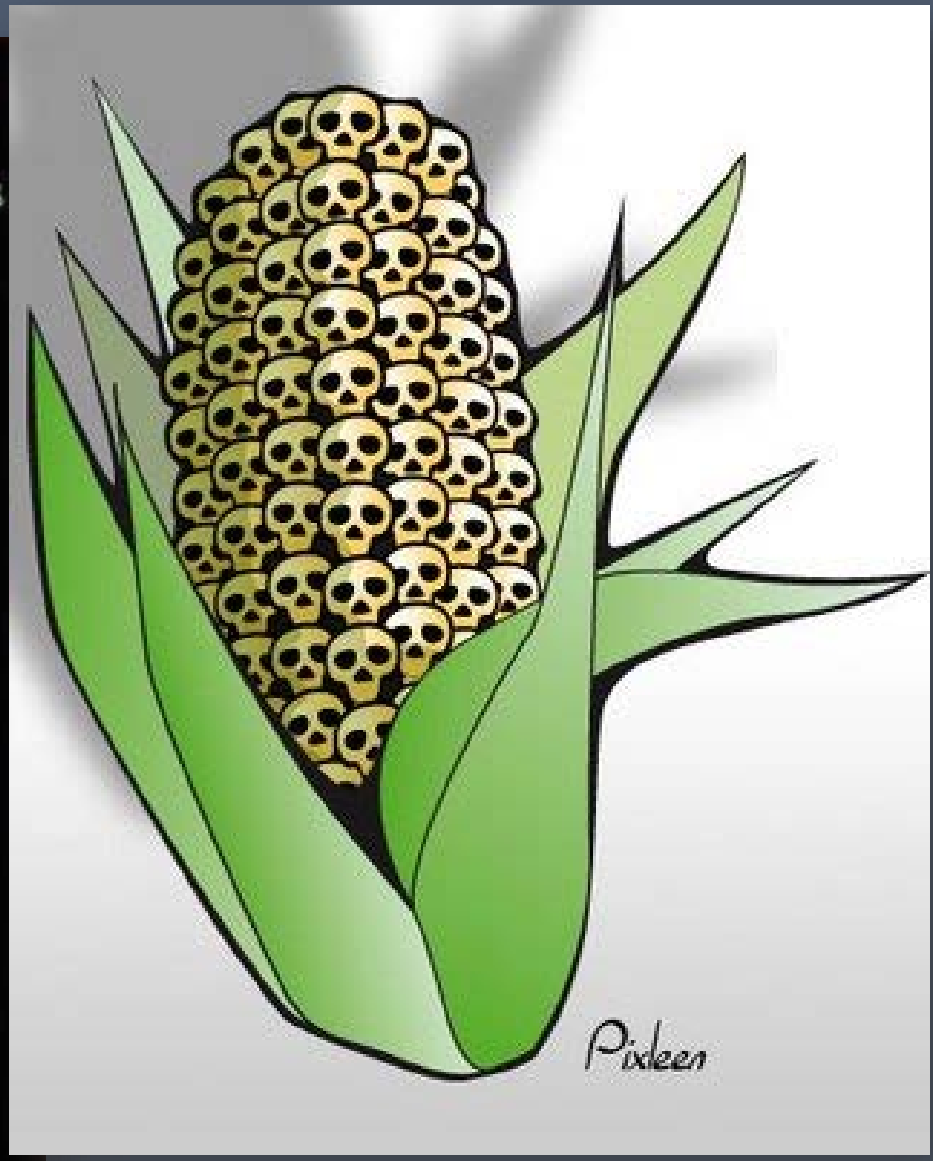
"Half of all children will be Autistic by 2025 due to Roundup warns MIT scientist"



Vicious anti-GMO messages widespread

And many more…





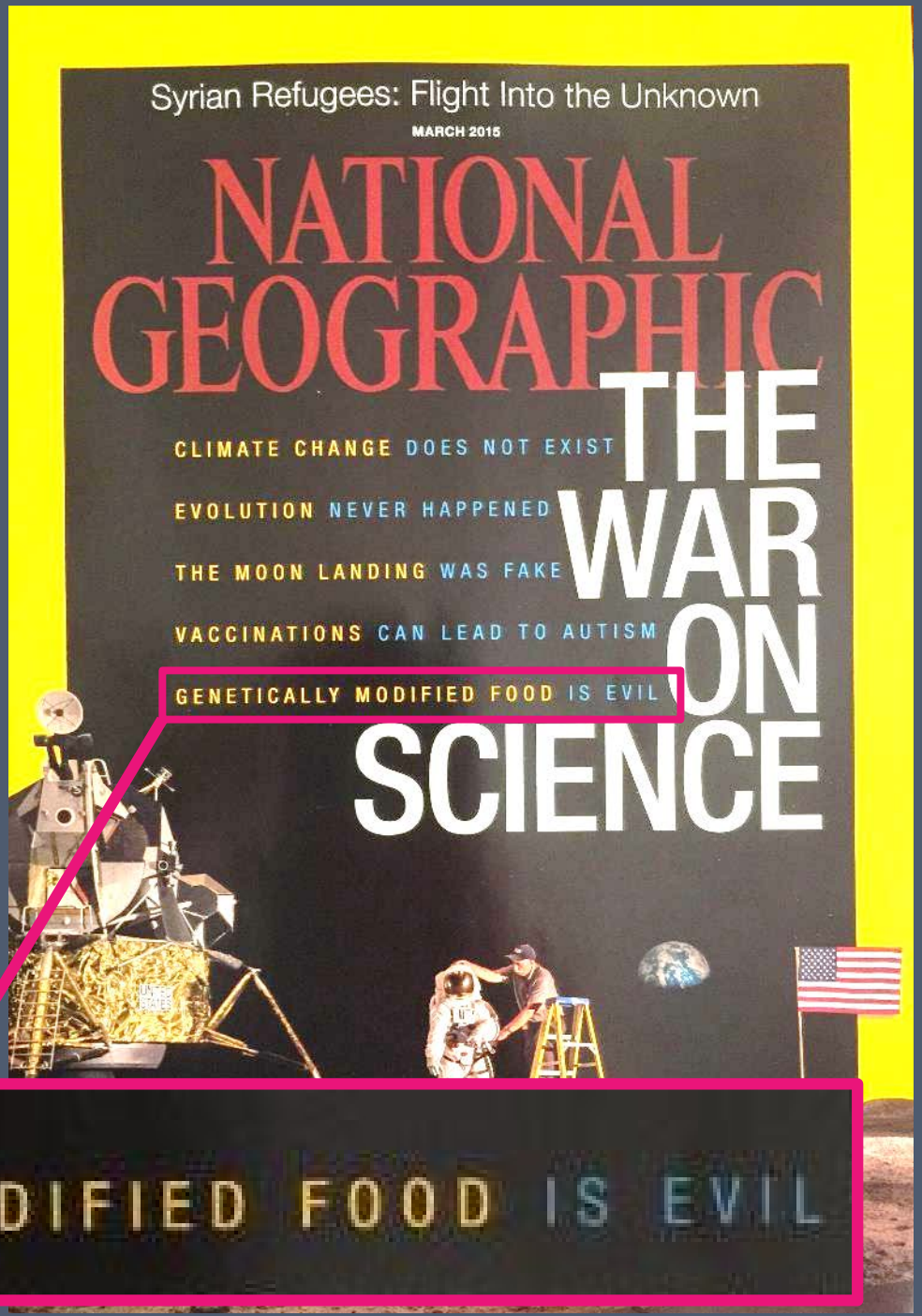
My colleague Steve Savage's favorite!

Remember good ol' fake news?

Social media and other online filters of information entrench, polarize

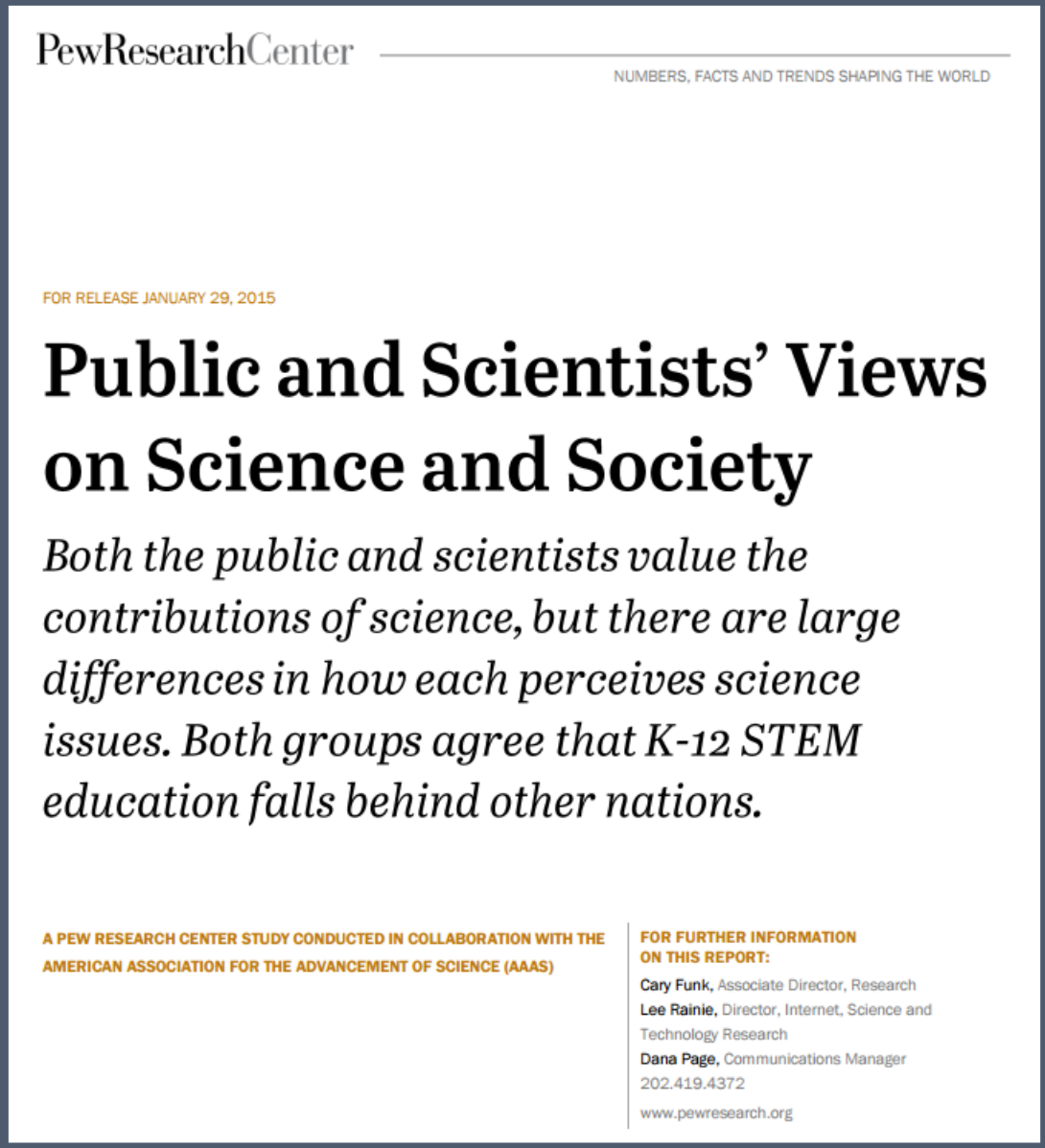
https://www.ted.com/talks/eli_pariser_beware_online_filter_bubbles

It’s hard to tell what science is saying amidst all the noise and pushback



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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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

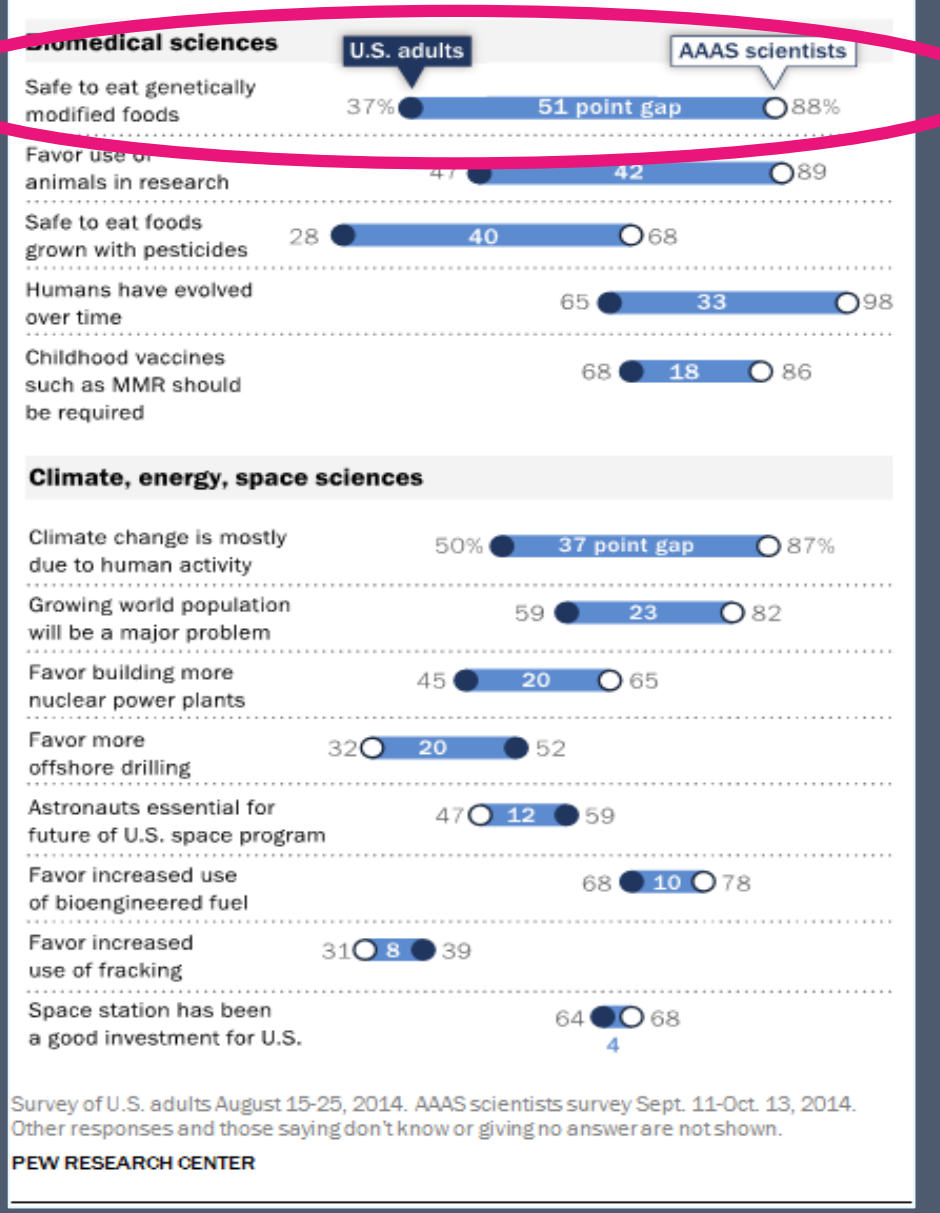
JANUARY 28, 2015

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

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.

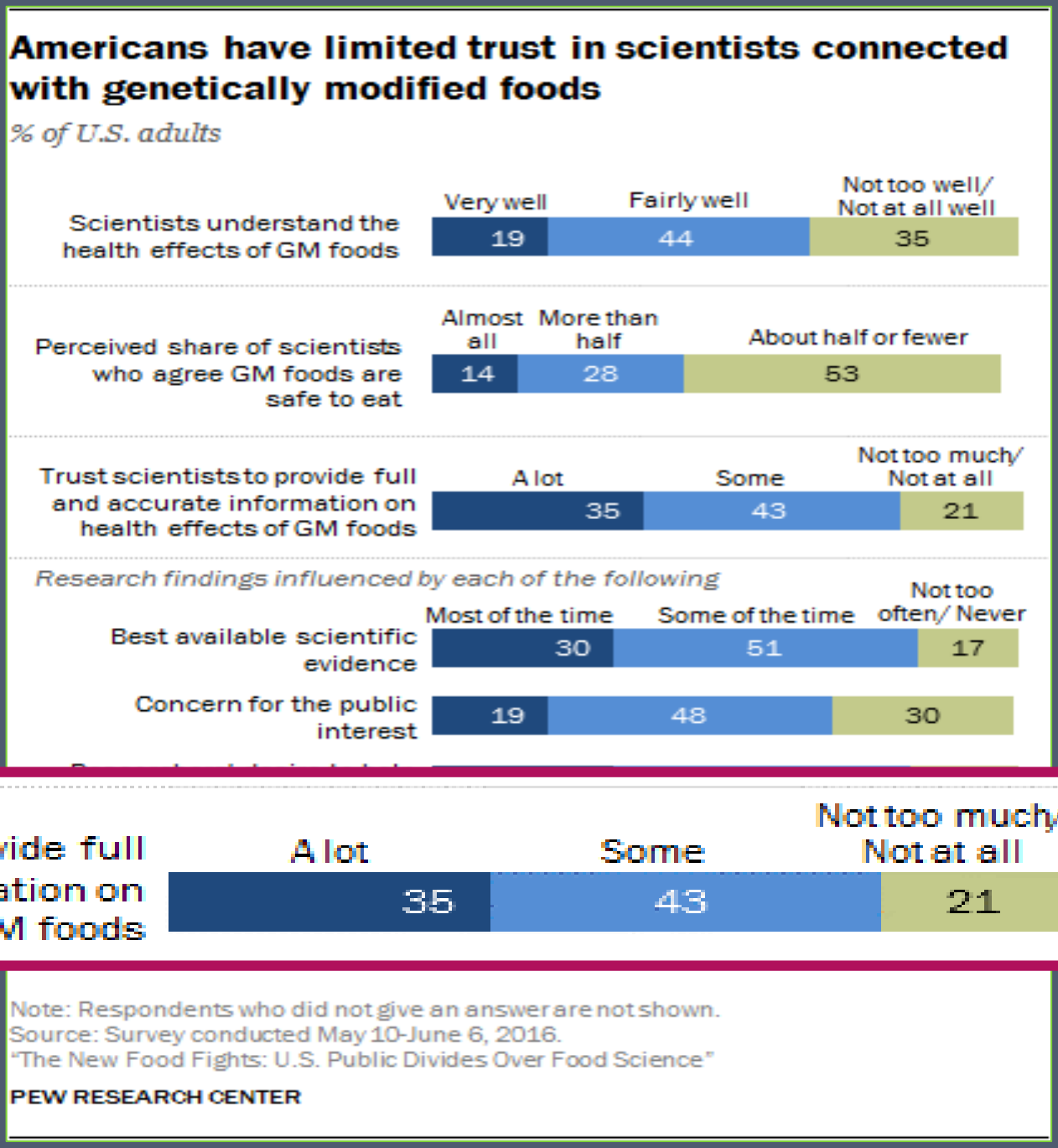
PEW RESEARCH CENTER

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

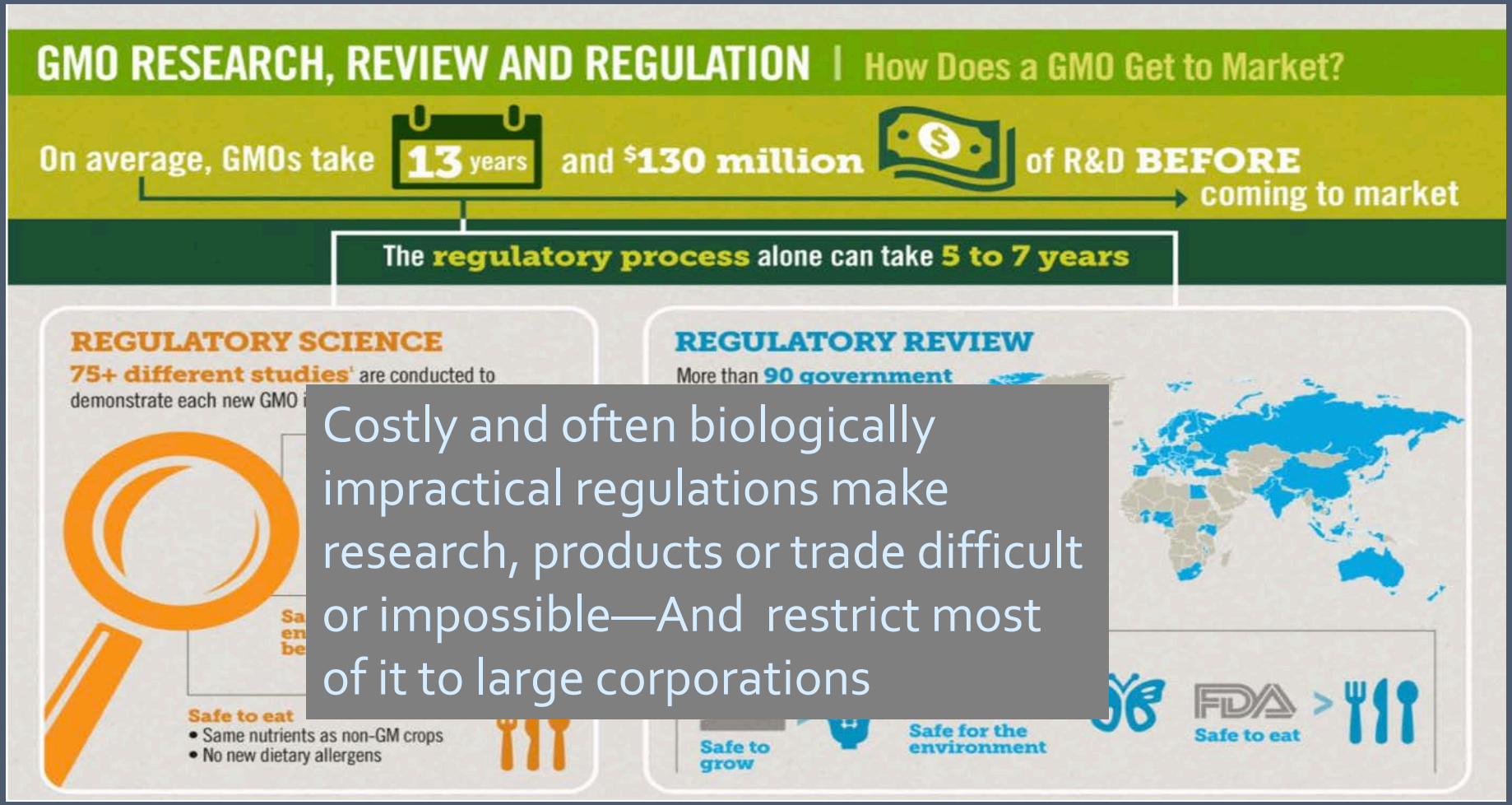
http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

Limited public trust in GMO-science and scientists

Pew Survey 2016



Regulations, both government and market based, reflect where society is at, with science a minor player by comparison



Costly and often biologically impractical regulations make research, products or trade difficult or impossible—And restrict most of it to large corporations

One of the big problems is the cost of regulating every gene insertion event vs. classes of novel gene products

Ending event-based regulation of GMO crops

To the Editor:

Getting regulation of agricultural biotechnologies right is no simple task. Stringent regulations for genetically modified organisms (GMOs) in the European Union (EU: Brussels) have nearly stifled the use of biotech crops on farms or in derived foods there, and in the United States the diversified 'Coordinated Framework' has produced a strange patchwork of rules, exceptions and lengthy delays. As the Editorial in the December issue highlights[1], the US Executive Branch has launched a process to reform its regulatory structure, calling for an integrated system that recognizes and balances safety, environment, innovation and economic growth[2]. On the heels of the release of a White House memo, the US House of Representatives passed the Safe and Accurate Food Labeling Act of 2015, which is on its way to the Senate for consideration. Contrary to current regulations, this legislation would explicitly preempt state-by-state labeling and require the US Food and Drug Administration (FDA) to conduct a safety review for all GMOs entering commerce[3]. This recent activity by both the executive and legislative branches provides a welcome opportunity to take a fresh look at

Field research for trees is difficult and often impossible to do beyond “boutique” levels

Far-reaching Deleterious Impacts of Regulations on Research and Environmental Studies of Recombinant DNA-modified Perennial Biofuel Crops in the United States

STEVEN H. STRAUSS, DREW L. KERSHEN, JOE H. BOUTON, THOMAS P. REDICK, HUIMIN TAN, AND ROGER A. SEDJO

October 2010 / Vol. 60 No. 9 • BioScience 729

International as well as national regulatory pressure given Cartagena Protocol

Strangled at birth? Forest biotech and the Convention on Biological Diversity

Steven H Strauss, Huimin Tan, Wout Boerjan & Roger Sedjo

Against the Cartagena Protocol and widespread scientific support for a case-by-case approach to regulation, the Convention on Biological Diversity has become a platform for imposing broad restrictions on research and development of all types of transgenic trees.

The Convention on Biological Diversity (CBD) has become a major focus of activist groups that wish to ban field research and commercial development of all types of genetically modified (GM) trees. Recent efforts to influence CBD recommendations by such groups has led to the adoption of recommendations for increased regulatory stringency that are inconsistent with the views of most scientists and most of the major environmental organizations. We suggest that the increasingly stringent recommendations adopted by the CBD in recent years are impeding, and in many places may foreclose, much of the field research needed to develop useful and safe applications of

A convention co-opted

Negotiated under the United Nations (UN) Environment Program, CBD was adopted in June 1992 and subsequently entered into force in December 1993. The CBD has been signed by 191 of the 192 members of the UN, making it one of the largest international treaties. The aim of the CBD is to promote the conservation and sustainable use of biodiversity, and the fair and equitable sharing of benefits from the use of genetic resources. Because transgenic organisms have the potential to affect biodiversity, special provisions of the CBD cover the use and trade in living modified organisms (LMOs, also known as genetically modified organisms; GMOs).

In 2000, the Cartagena Protocol on Biosafety

he CBD

NATURE BIOTECHNOLOGY VOLUME 27 NUMBER 6 JUNE 2009

Market certification systems for forestry also a serious constraint

Traces of the emerald ash borer on the trunk of a dead ash tree in Michigan, USA. This non-native invasive insect from Asia threatens to kill most North American ash trees.

BIOTECHNOLOGY

Genetically engineered trees: Paralysis from good intentions

Forest crises demand regulation and certification reform

By **Steven H. Strauss[1]*, Adam Costanza[2], Armand Séguin[3]**

Intensive genetic modification is a long-standing practice in agriculture, and, for some species, in woody plant horticulture and forestry (*1*). Current regulatory systems for genetically engineered

recently initiated an update of the Coordinated Framework for the Regulation of Biotechnology (*2*), now is an opportune time to consider foundational changes.

Difficulties of conventional tree breeding make genetic engineering (GE) methods relatively more advantageous for forest trees than for annual crops (*3*). Obstacles

Although only a few forest tree species might be subject to GE in the foreseeable future, regulatory and market obstacles prevent most of these from even being subjects of translational laboratory research. There is also little commercial activity: Only two types of pest-resistant poplars are authorized for commercial use in small areas in China and two types of eucalypts, one approved in Brazil and another under lengthy review in the USA (*5*).

METHOD-FOCUSED AND MISGUIDED. Many high-level science reports state that the GE method is no more risky than conventional breeding, but regulations around the world essentially presume that GE is hazardous and requires strict containment

“Green” certification of forests create severe barriers to field research, markets

Plantation Certification & Genetic Engineering

FSC’s Ban on Research Is Counterproductive

Steven H. Strauss, Malcolm M. Campbell, Simon N. Pryor, Peter Coventry, and Jeff Burley

ABSTRACT

Genetic engineering, also called genetic modification (GM), is the isolation, recombinant modification, and asexual transfer of genes. It has been banned in forest plantations certified by the Forest Stewardship Council (FSC) regardless of the source of genes, traits imparted, or whether for research or commercial use. We review the methods and goals of tree genetic engineering research and argue that FSC’s ban on research is counterproductive because it makes it difficult for certified companies to participate in the field research needed to assess the value and biosafety of GM trees. Genetic modification could be important for translating new discoveries about tree genomes into improved growth, quality, sustainability, and pest resistance.

Keywords: biotechnology; entomology and pathology; ethics; genetics; silviculture

Genetic engineering, commonly called genetic modification (GM) in much of the world, is the use of recombinant DNA and asexual gene transfer methods to breed more productive or pest-resistant crops. It has been the subject of considerable controversy, with concerns raised from biological, socioeconomic, political, and ethical perspectives. Some of the issues are similar to those raised by the use of molecular biology and genetic engineering in medicine, which we see in the news headlines daily. However, genetic modification in agriculture and forestry raises environmental issues as well.

GM crops, mainly herbicide- and pest-resistant varieties of soybeans, maize, or cotton, have been vigorously adopted by farmers in North America because they are easy to manage and they improve yields, reduce costs, or reduce pesticide ecotoxicity (Carpenter and Gianessi 2001). However, the controversy, primarily embodied in regulatory barriers to trade of GM crops with Europe and Japan, has slowed their adoption considerably in recent years.

If GM trees are used in forestry in the near future, they are likely to occur primarily in intensively managed environments, such as urban forests or plantations. In urban forestry, genetic modification is expected to help trees adapt to the stresses and special demands of human-dominated systems. Examples would be trees that are more tolerant of heavy metals or other pollutants, resist urban pests or diseases, grow slower, or do not produce fruits when these create hazards in street environments (Brunner et al. 1998).

Plantations, although very different from natural forests in structure and function, are considered part of the spectrum of methods in sustainable forest management (Romm 1994). Plantations can relieve pressure on natural forests for exploitation and can be of great social value by supplying community and industrial wood needs and fueling economic development. The environmental role of plantations is recognized by the Forest Stewardship Council (FSC), an international body for certification of sustainably managed forests. FSC Principle 10 states that plantations should “complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests” (FSC 2001).

FSC has certified some of the most intensively managed plantations in the world, including poplar plantations and the intensive pine and eucalypt plantations of the Southern Hemisphere. Although many environmental mitigations are built into these certified plantation systems, within the areas dedicated to wood production they function as tree farms. Such intensive plantation systems often use highly bred genotypes, possibly including exotic species, hybrids, and clones, as well as many other forms of intensive silvicultural management. It is in the context of these biointensive systems that the additional expense of GM trees is likely to be worthwhile.

However, FSC currently prohibits all uses of GM trees, and is the only certification system to have done so

Forest Stewardship Council

“…genetically modified trees are prohibited…”

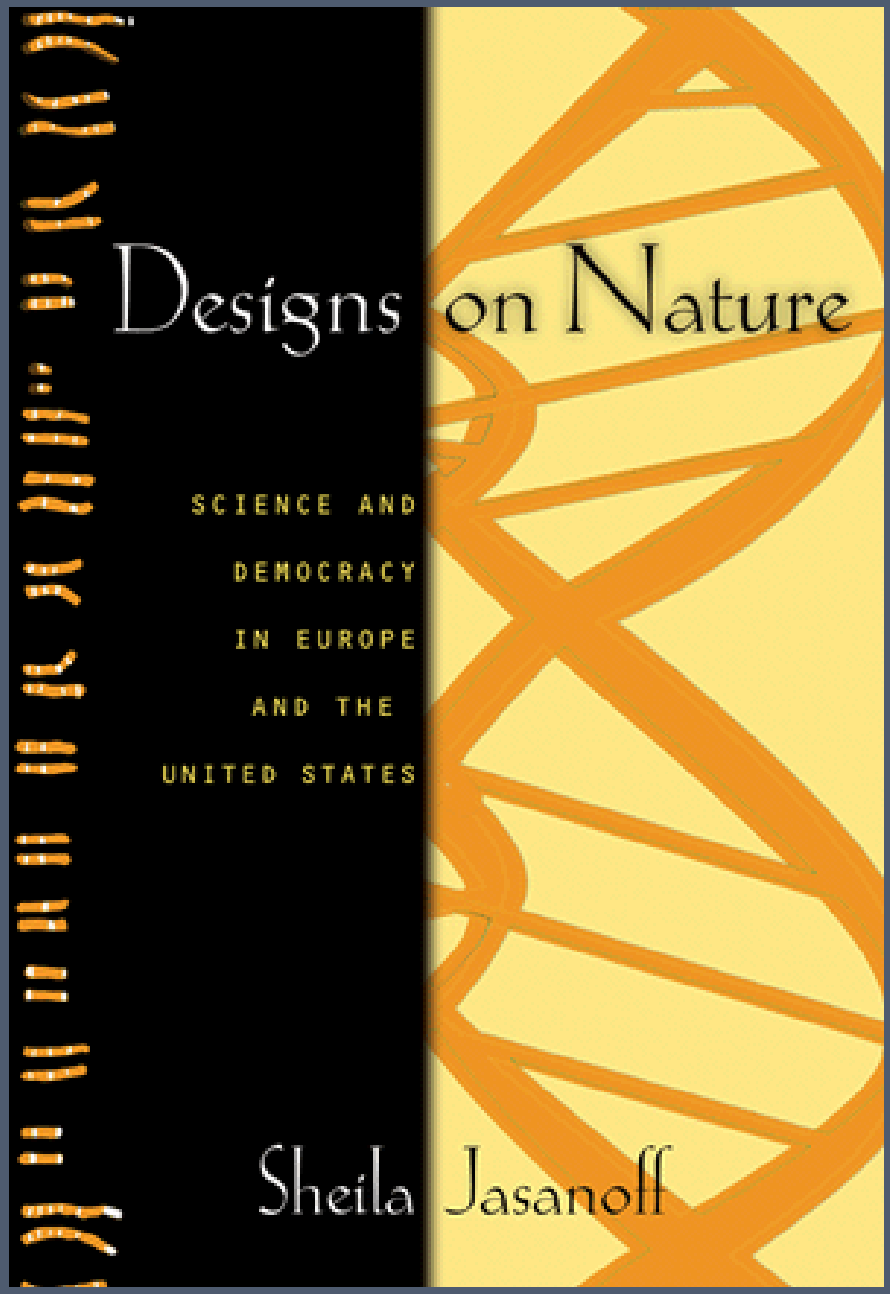
All forest certification systems now ban all GE trees – no exemptions

System	Region	GM Tree Approach / Reason
PEFC : Programme for Endorsement of Forest Certification	International	**Banned** / Precautionary approach based on lack of data
FSC : Forest Stewardship Council	International	**Banned** / Precautionary approach based on lack of data
CerFlor : Certificação Florestal	Brazil	**Banned** via PEFC registration / No additional rationale
CertFor : Certficación Forestal	Chile	**Banned** via PEFC registration / No additional rationale
SFI : Sustainable Forestry Initiative	North America	**Banned** via PEFC registration / Awaiting risk-benefit data
ATFS : American Tree Farm System	USA	**Banned** via PEFC re No additional ra
CSA : Canadian Standards Association	Canada	**Banned** via PEFC re Allows public to deterr
CFCC : China Forest Certification Council	China	**Banned** via PEFC re No additional ra

Adam Costanza, Institute for Forest Biotechnology

A hard lesson in "Civic Epistemology" a la Jasanoff

"..the institutionalized ways in which members of a society test and deploy knowledge claims as a basis for making collective choices."



Plan

- The perfect storm over genetic engineering (GE) in society
- Relevance of GE as a tool for enhancement of tree productivity and health
  - RNAi and gene editing focus

What is genetic engineering (GE)

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

GE methods of special value for trees due to breeding constraints

- Difficulty to inbreed
- Long breeding cycle
- Important ag crop breeding tools unavailable
  - Hard to introgress desired genes from other species or genotypes
  - Hard to fix rare, desired (e.g., loss of function) mutations
  - Hard to identify and use dominant, major genes
- Asexually propagated varieties of high value
  - Capacity to “tweak” intact genotypes without sexual recombination a powerful tool

Trees and forests: A highly diverse milieu for GE

- Food: Orchards
  - High genetic control – often one or very few varieties (=clones) – Intensive agronomy
- Wood, pulp, energy: Short rotation, fast growing
  - Often limited number of varieties (dozens), agronomic management, 1-10 year harvest cycle
- Wood, pulp, energy: Planted but long rotation times
  - Very high genetic diversity, many decadal cycle, little management, some ecological services, 10-60 year cycle
- Wild trees
  - Many genotypes, many species, many ecological services and social values, poor access & economics

RNA interference (RNAi) for gene suppression

The Nobel Prize in Physiology or Medicine 2006
Andrew Z. Fire, Craig C. Mello

Share this: 28

The Nobel Prize in Physiology or Medicine 2006

Photo: L. Cicero
Andrew Z. Fire
Prize share: 1/2

Photo: J. Mottern
Craig C. Mello
Prize share: 1/2

The Nobel Prize in Physiology or Medicine 2006 was awarded jointly to Andrew Z. Fire and Craig C. Mello *"for their discovery of RNA interference - gene silencing by double-stranded RNA"*

Dominant gene action / RNAi

Lignin-modification of elite poplar variety in France by RNAi

Field trials of flowering-modified RNAi poplars in Oregon

Sterility, normal growth of *LEAFY*-RNAi poplars

limited, in large part owing to concerns over transgene flow into wild or feral tree populations[1–4]. Unlike other crops, trees are long-lived, weakly domesticated and their propagules can spread over several kilometers[5]. Although male sterility has been engineered in pine, poplar, and eucalyptus trees grown under field conditions by expression of the barnase RNase gene in anther tapetal cells[6,7], barnase can reduce rates of genetic transformation and vegetative growth[6]. Furthermore, barnase expression may not be fully stable[8]. Bisexual sterility would allay concerns over seed dispersal, could be used to control invasive exotic trees, and might increase wood production[9]. We

poplar.

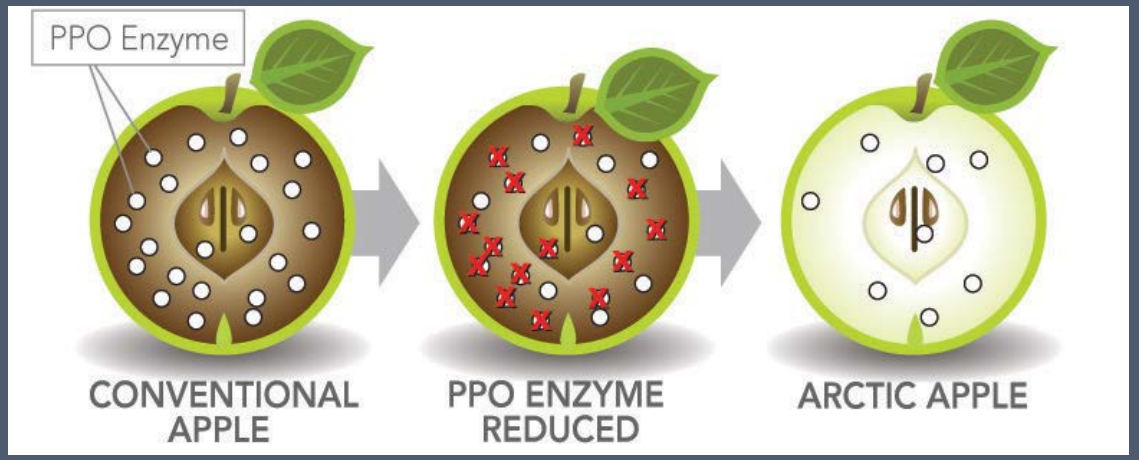
RNAi has been used to reduce gene expression in many plant species[10,11], and the reduction in gene expression that RNAi confers is highly stable in trees under field conditions[12]. *LFY* is required for the early stages of male and female floral organ formation in plants, and encodes a transcription factor that promotes floral meristem identity[13,14]. In *Arabidopsis thaliana*, loss of *LFY* function results in the formation of vegetative structures instead of floral meristems, whereas reduction of *LFY* expression decreases floral abundance and results in partial conversion of floral organs to leaf-like structures[13,14]. We selected *LFY*

Klocko et al. 2016, *Nature Biotechnology*

Non-browning "Arctic Apple"

RNAi suppression of native polyphenol oxidase gene expression

Courtesy of Jennifer Armen, Okanagan Specialty Fruits, Canada



Virus-resistant GM papaya by HIGS – Host Induced Gene Silencing

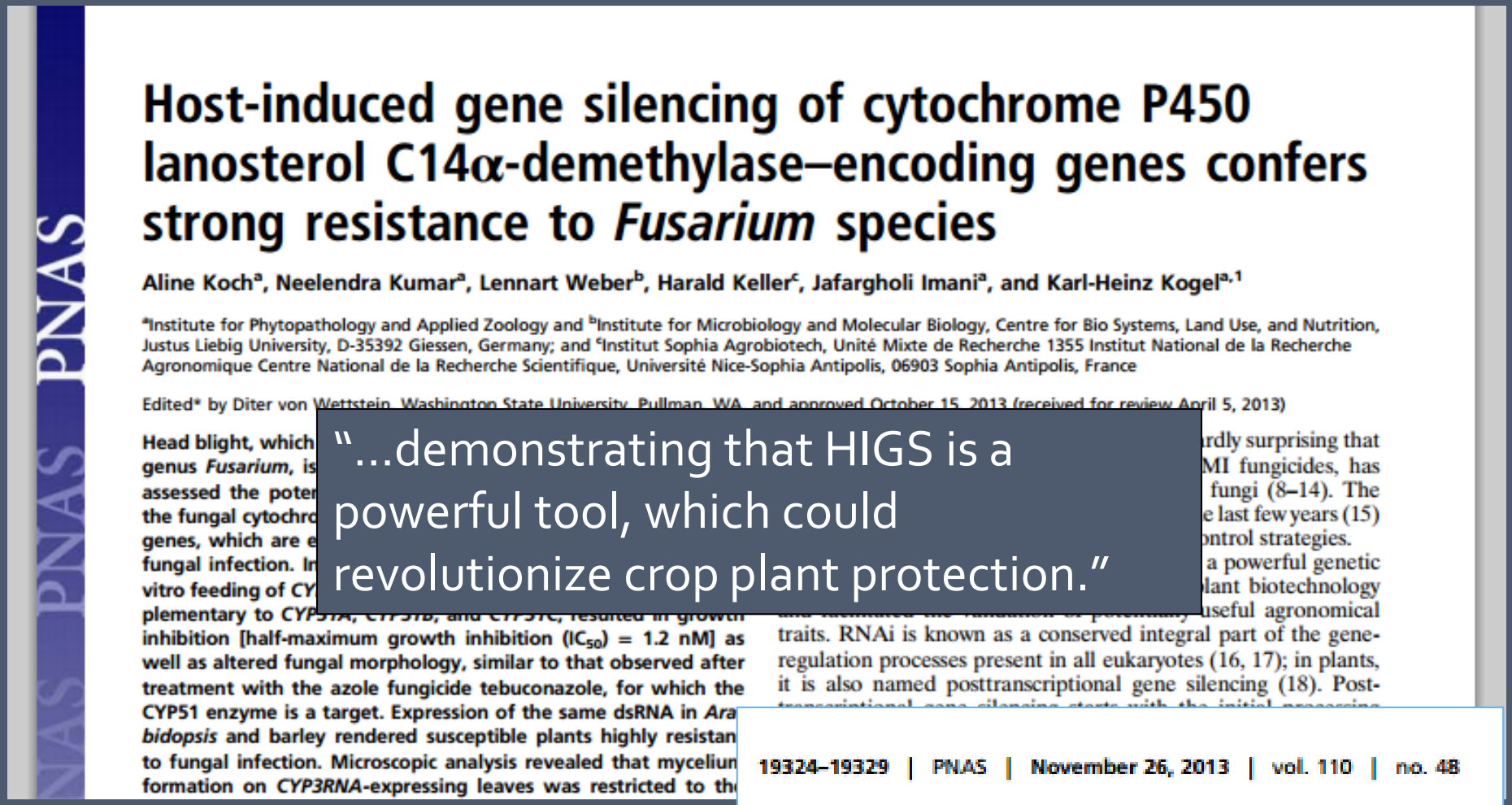
Saved the Hawaiian industry in the mid-1990s, ~80% of crop today

Like a vaccine – "RNAi immunization" via implanting a viral gene in the papaya genome

GMO, virus-resistant trees

Courtesy of Denis Gonsalves

HIGS can also be effective for fungal resistance



PNAS

Host-induced gene silencing of cytochrome P450 lanosterol C14α-demethylase–encoding genes confers strong resistance to *Fusarium* species

Aline Koch[a], Neelendra Kumar[a], Lennart Weber[b], Harald Keller[c], Jafargholi Imani[a], and Karl-Heinz Kogel[a,1]

[a]Institute for Phytopathology and Applied Zoology and [b]Institute for Microbiology and Molecular Biology, Centre for Bio Systems, Land Use, and Nutrition, Justus Liebig University, D-35392 Giessen, Germany; and [c]Institut Sophia Agrobiotech, Unité Mixte de Recherche 1355 Institut National de la Recherche Agronomique Centre National de la Recherche Scientifique, Université Nice-Sophia Antipolis, 06903 Sophia Antipolis, France

Edited* by Diter von Wettstein, Washington State University, Pullman, WA, and approved October 15, 2013 (received for review April 5, 2013)

Head blight, which
genus *Fusarium*, is
assessed the poter
the fungal cytochro
genes, which are e
fungal infection. In
vitro feeding of *CY*
plementary to *CYP51A*, *CYP51B*, and *CYP51C*, resulted in growth
inhibition [half-maximum growth inhibition (IC_{50}) = 1.2 nM] as
well as altered fungal morphology, similar to that observed after
treatment with the azole fungicide tebuconazole, for which the
CYP51 enzyme is a target. Expression of the same dsRNA in *Ara*
bidopsis and barley rendered susceptible plants highly resistan
to fungal infection. Microscopic analysis revealed that myceliun
formation on *CYP3RNA*-expressing leaves was restricted to th

"…demonstrating that HIGS is a powerful tool, which could revolutionize crop plant protection."

rdly surprising that
MI fungicides, has
fungi (8–14). The
e last few years (15)
ntrol strategies.
a powerful genetic
lant biotechnology
useful agronomical
traits. RNAi is known as a conserved integral part of the gene-regulation processes present in all eukaryotes (16, 17); in plants, it is also named posttranscriptional gene silencing (18). Post-

Domain for HIGS in pest resistance seems to keep expanding

Plant Biotechnology Journal

Plant Biotechnology Journal (2014) **12**, pp. 821–831 doi: 10.1111/pbi.12226

Review article

New wind in the sails: improving the agronomic value of crop plants through RNAi-mediated gene silencing

Aline Koch* and Karl-Heinz Kogel

Centre for BioSystems, Land Use and Nutrition, Institute of Phytopathology and Applied Zoology, Justus Liebig University, Giessen, Germany

Received 13 January 2014;
revised 6 May 2014;
accepted 27 May 2014.
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Keywords: genetically engineered plants, host-induced gene silencing, RNA interference, plant protection, resistance.

Summary

RNA interference (RNAi) has emerged as a powerful genetic tool for scientific research over the past several years. It has been utilized not only in fundamental research for the assessment of gene function, but also in various fields of applied research, such as human and veterinary medicine and agriculture. In plants, RNAi strategies have the potential to allow manipulation of various aspects of food quality and nutritional content. In addition, the demonstration that agricultural pests, such as insects and nematodes, can be killed by exogenously supplied RNAi targeting their essential genes has raised the possibility that plant predation can be controlled by lethal RNAi signals generated *in planta*. Indeed, recent evidence argues that this strategy, called host-induced gene silencing (HIGS), is effective against sucking insects and nematodes; it also has been shown to compromise the growth and development of pathogenic fungi, as well as bacteria and viruses, on their plant hosts. Here, we review recent studies that reveal the enormous potential RNAi strategies hold not only for improving the nutritive value and safety of the food supply, but also for providing an environmentally friendly mechanism for plant protection.

RNA interference: discovery of a novel mechanism for gene regulation

RNA interference (RNAi) is a conserved and integral aspect of

(Hammond *et al.*, 2001a). This latter phenomenon was termed co-suppression in plants and quelling in fungi. PTGS also could be induced in plants by cytoplasmically replicating viruses (Hammond *et al.*, 2001a). Given the similar phenotypes associated with PTGS

Insect control via RNAi in corn on commercial track

LETTERS

nature biotechnology

Control of coleopteran insect pests through RNA interference

James A Baum[1], Thierry Bogaert[2], William Clinton[1], Gregory R Heck[1], Pascale Feldmann[2], Oliver Ilagan[1], Scott Johnson[1], Geert Plaetinck[2], Tichafa Munyikwa[1], Michael Pleau[1], Ty Vaughn[1] & James Roberts[1,3]

Commercial biotechnology solutions for controlling lepidopteran and coleopteran insect pests on crops depend on the expression of *Bacillus thuringiensis* insecticidal proteins[1,2], most of which permeabilize the membranes of gut epithelial cells of susceptible insects[3]. However, insect control strategies involving a different mode of action would be valuable for managing the emergence of insect resistance. Toward this end, we demonstrate that ingestion of double-stranded (ds)RNAs supplied in an artificial diet triggers RNA interference in several coleopteran species, most notably the western corn rootworm (WCR) *Diabrotica virgifera virgifera* LeConte. This may result in larval stunting and mortality. Transgenic corn plants engineered to express WCR dsRNAs show a significant reduction in WCR feeding damage in a growth chamber assay, suggesting that the RNAi pathway can be exploited to control insect pests via *in planta* expression of a dsRNA.

initial bioassays, dsRNAs were applied to the surface of the WCR agar diet at concentrations from 520 ng/cm^2 to 780 ng/cm^2. As we anticipated a slower response to dsRNAs than to *B. thuringiensis* insecticidal proteins, the WCR bioassay incubation period was extended from 5 d to 12 d. Indeed, 7 d after infestation, little if any effect was observed. However, numerous dsRNAs exhibited significant activity 12 d after infestation, resulting in both larval stunting and mortality (**Supplementary Table 1** online).

Subsequent feeding assays demonstrated that certain dsRNA samples, including dsRNAs targeting putative genes encoding vacuolar ATPase (V-ATPase) subunit A, D and E, as well as α-tubulin, were active at applied concentrations well below 52 ng/cm^2. We identified additional WCR genes that caused mortality when targeted for suppression using dsRNAs in the WCR feeding assay. A two-tiered screen was implemented in which dsRNAs targeting different genes were tested at 52 and 5.2 ng/cm^2. Of the 290 dsRNAs tested, 125 showed significant ($P < 0.05$) larval mortality and/or stunting at 52 ng/cm^2. Of these, 67 showed significant mortality and/or stunting

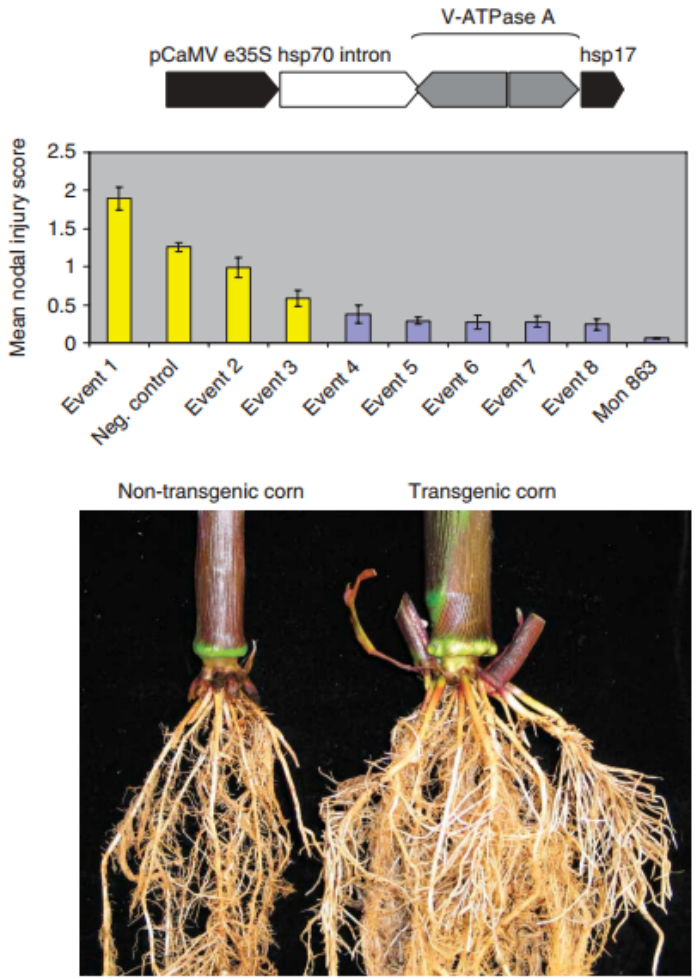

Figure 2 F1 plants expressing a V-ATPase A dsRNA are protected from WCR feeding damage. (**a**) Map of the expression cassette. (**b**) Mean root damage ratings for eight F_1 populations, the parental inbred line (negative control) and the corn rootworm–protected Cry3Bb event MON863; NIS, nodal injury score (Iowa State ranking system). (**c**) The plant on left is a non-transgenic control with average root damage, whereas the plant on the right shows the average root protection seen when the transgene is expressed.

Forest health a major and growing concern

REVIEW

Planted forest health: The need for a global strategy

M. J. Wingfield,[1]* E. G. Brockerhoff,[2] B. D. Wingfield,[1] B. Slippers[1]

Several key tree genera are used in planted forests worldwide, and these represent valuable global resources. Planted forests are increasingly threatened by insects and microbial pathogens, which are introduced accidentally and/or have adapted to new host trees. Globalization has hastened tree pest emergence, despite a growing awareness of the ng of the costs, and an increased focus on the importance of and potential of planted forests, innovative solutions and a ach are needed. Mitigation strategies that are effective only in invasions elsewhere in the world, ultimately leading to global st problems in the future should mainly focus on integrating lly, rather than single-country strategies. A global strategy to portant and urgently needed.

ems are a huge- ce, easily over- d (*1–3*). Globally, ted to rely on y more depend have been separated from their natural enemies. However, when plantation trees are reunited with their coevolved pests, which may be introduced accidentally, or when they encounter novel pests to which they have no resistance, substantial

n September 8, 2015

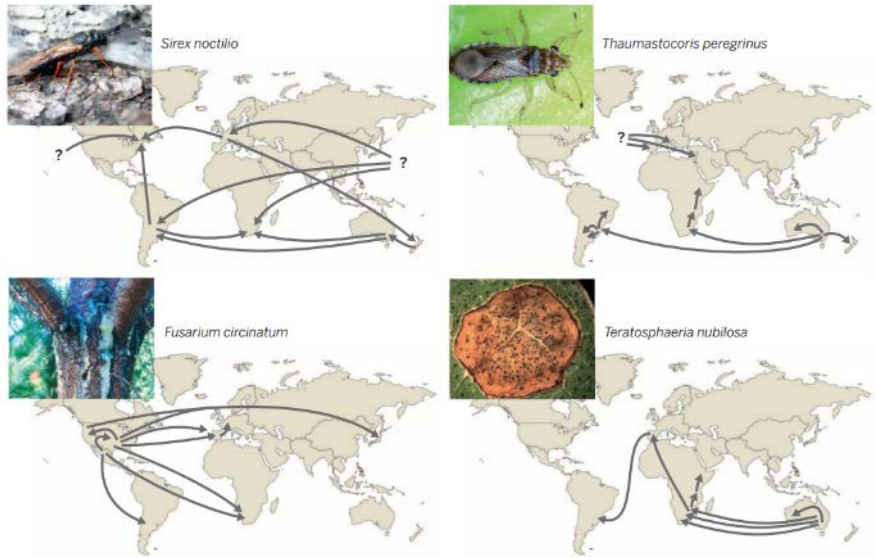

Fig. 2. Examples of invasion routes of pests of planted forests that illustrate an apparently common pattern of complex pathways of spread to new environments, including repeated introductions and with either native or invasive populations serving as source populations (*18*). Invasion routes of the pine pitch canker pathogen *Fusarium circinatum* (origin in Central America) (*39*), eucalypt leaf pathogen *Teratosphaeria nubilosa* (origin in southeast Australia) (*40*), the pine woodwasp *Sirex noctilio* (origin in Eurasia) (*23*), and the eucalypt bug *Thaumastocoris peregrinus* (origin in southeast Australia) (*41*) were determined through historical and genetic data. [Photo credits: (top left) Brett Hurley; (top right) Samantha Bush; (bottom left) Jolanda Roux; (bottom right) Guillermo Perez]

Extensive pest introductions

"Non-native insects have accumulated in United States forests at a rate of ~2.5 per yr over the last 150 yr. "

"Non-native forest pests are the only disturbance agent that has effectively eliminated entire tree species … within decades."

Ecological Applications, 26(5), 2016, pp. 1437–1455

Nonnative forest insects and pathogens in the United States: Impacts and policy options

Gary M. Lovett,[1,12] Marissa Weiss,[2,3] Andrew M. Liebhold,[4] Thomas P. Holmes,[5] Brian Leung,[6] Kathy Fallon Lambert,[2,3] David A. Orwig,[3] Faith T. Campbell,[7] Jonathan Rosenthal,[8] Deborah G. McCullough,[9] Radka Wildova,[8] Matthew P. Ayres,[10] Charles D. Canham,[1] David R. Foster,[3] Shannon L. LaDeau,[1] and Troy Weldy[11]

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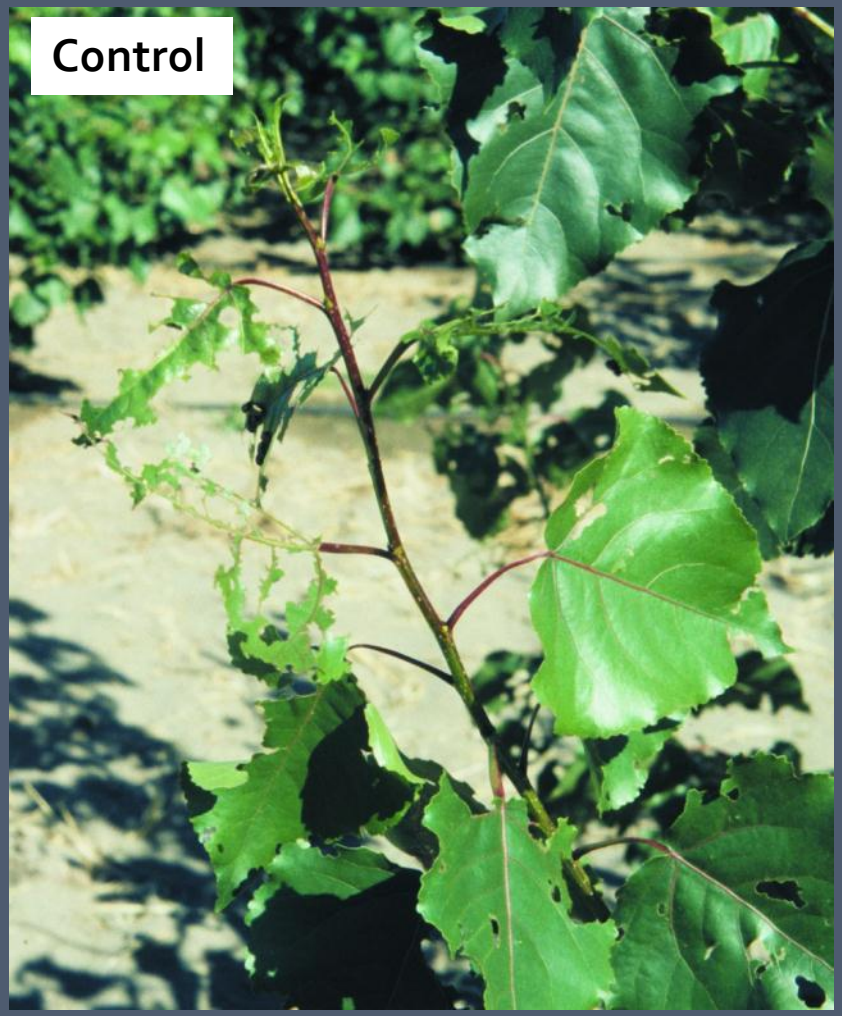
[11]*The Nature Conservancy, New York State Chapter, Albany, New York 12205 USA*

Abstract. We review and synthesize information on invasions of nonnative forest insects and diseases in the United States, including their ecological and economic impacts, pathways of arrival, distribution within the United States, and policy options for reducing future invasions. Nonnative insects have accumulated in United States forests at a rate of ~2.5 per yr over the last 150 yr. Currently the two major pathways of introduction are importation of live plants and wood packing material such as pallets and crates. Introduced insects and diseases occur in forests and cities throughout the United States, and the problem is particularly severe in the Northeast and Upper Midwest. Nonnative forest pests are the only disturbance agent that has effectively eliminated entire tree species or genera from United States forests within decades. The resulting shift in forest structure and species composition alters ecosystem functions such as productivity, nutrient cycling, and wildlife habitat. In urban and suburban areas, loss of trees from streets, yards, and parks affects aesthetics, property values, shading, stormwater runoff, and human health. The economic damage from nonnative pests is not yet fully known, but is likely in the billions of dollars per year, with the majority of this economic burden borne by municipalities and residential property owners. Current policies for preventing introductions are having positive effects but are insufficient to reduce the influx of pests in the face of burgeoning global trade. Options are available to strengthen the defenses against pest arrival and establishment, including measures taken in the exporting country prior to shipment, measures to ensure clean shipments of plants and wood products, inspections at ports of entry, and post-entry measures such as quarantines, surveillance, and eradication programs. Improved data collection procedures for inspections, greater data accessibility, and better reporting would support better evaluation of policy effectiveness. Lack of additional action places the nation, local municipalities, and property owners at high risk of further damaging and costly invasions. Adopting stronger policies to reduce establishments of new forest insects and diseases would shift the major costs of control to the source and alleviate the economic burden now borne by homeowners and municipalities.

Key words: disease; forest; insect; invasive; pathogen; policy.

Coleopteran resistant Bt-cottonwoods in eastern Oregon field trial



Growth benefits (10-20%) despite low insect pressure during large field trial of resistant genotypes

NRC Research Press

ARTICLE

Bt-Cry3Aa transgene expression reduces insect damage and improves growth in field-grown hybrid poplar

Amy L. Klocko, Richard Meilan, Rosalind R. James, Venkatesh Viswanath, Cathleen Ma, Peggy Payne, Lawrence Miller, Jeffrey S. Skinner, Brenda Oppert, Guy A. Cardineau, and Steven H. Strauss

Abstract: The stability and value of transgenic pest resistance for promoting tree growth are poorly understood. These data are essential for determining if such trees could be beneficial to commercial growers in the face of substantial regulatory and marketing costs. We investigated growth and insect resistance in hybrid poplar expressing the *cry3Aa* transgene in two field trials. An initial screening of 502 trees comprising 51 transgenic gene insertion events in four clonal backgrounds (*Populus trichocarpa* × *Populus deltoides*, clones 24-305, 50-197, and 198-434; and *P. deltoides* × *Populus nigra*, clone OP-367) resulted in transgenic trees with greatly reduced insect damage. A large-scale study of 402 trees from nine insertion events in clone OP-367, conducted over two growing seasons, demonstrated reduced tree damage and significantly increased volume growth (mean 14%). Quantification of Cry3Aa protein indicated high levels of expression, which continued after 14 years of annual or biannual coppice in a clone bank. With integrated management, the *cry3Aa* gene appears to be a highly effective tool for protecting against leaf beetle damage and improving yields from poplar plantations.

Résumé : La stabilité et la valeur de la résistance transgénique aux ravageurs pour favoriser la croissance des arbres ne sont pas bien connu
être profita
marché de

Can. J. For. Res. 44: 28–35 (2014) dx.doi.org/10.1139/cjfr-2013-0270

Published at www.nrcresearchpress.com/cjfr on 28 October 2013.

American Chestnut restoration – genomics and genetic engineering

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The American Chestnut's Genetic Rebirth

A foreign fungus nearly wiped out North America's once vast chestnut forests. Genetic engineering can revive them

By William Powell

In 1876 Samuel B. Parsons received a shipment of chestnut seeds from Japan and decided to grow and sell the trees to orchards. Unbeknownst to him, his shipment likely harbored a stowaway that caused one of the greatest ecological disasters ever to befall eastern North America. The trees probably concealed spores of a pathogenic fungus, *Cryphonectria parasitica*, to which Asian chestnut trees—but not their American cousins—had evolved resistance. *C. parasitica* effectively strangles

More In This Article

A New Generation of American Chestnut Trees May Redefine America's Forests

March 2014 issue - Scientific American

Hemlock in USA under siege today

Corrected 2 September 2015; see full text. *FOREST HEALTH* **SPECIAL SECTION**

BATTLING A GIANT KILLER

The iconic eastern hemlock is under siege from a tiny invasive insect

By **Gabriel Popkin** *in Highlands, North Carolina; photography by* **Katherine Taylor**

On a frigid morning this past March, arborist Will Blozan snuck behind a small church here and headed down into a gorge thick with rhododendron. He crashed through the shrubs until he spotted the gorge's treasure: the world's largest

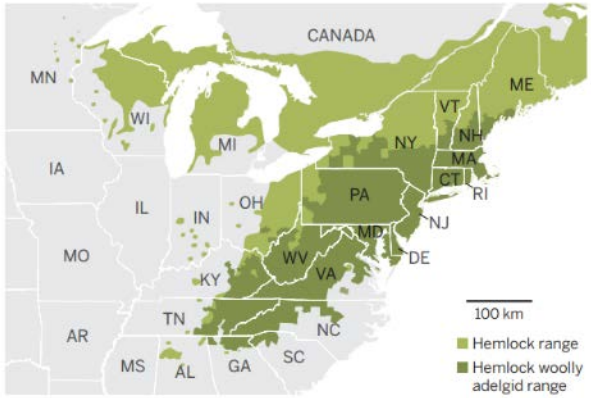
park, "are in intensive care." Like the family of a gravely ill patient, ecologists are also preparing for the possibility that these efforts will fail, and the eastern forest will lose one of its defining species.

TSUGA CANADENSIS is one of eastern

branches, creating a thick canopy that blocks up to 99% of sunlight. Few plants grow in the gloom, but a hemlock seedling can bide its time for decades or more, waiting for a sunlit opening. Hundreds of species of insects, mites, and spiders appear to live primarily or exclusively in hemlock forests, and some

A creeping conflict

The hemlock woolly adelgid now infests about half of the eastern hemlock's range, and has been spreading by about 15 kilometers per year.



Emerald Ash Borer killing ~all ashes in USA – costing billions

Thriving Ash Trees in 2006

Emerald ash borer larva (26–32 mm long)

Dead Ash Trees in 2009

The emerald ash borer was first detected in North America in 2002. Native to Asia, the beetle has proven to be highly destructive in its new range. Since its arrival, it has killed tens of millions of ash trees and continues to spread into new areas.

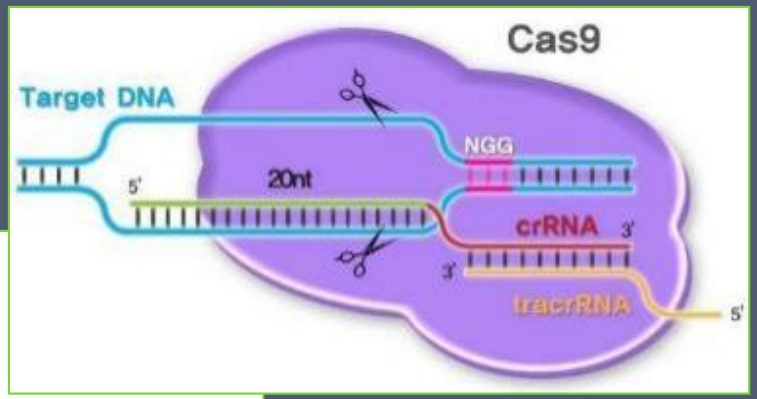
Photo credits - Trees: Daniel A. Herms, The Ohio State University - Borer larva: Dr. Robert Lavallée, Natural Resources Canada

Swiss Needle Cast in Oregon Douglas-fir – breeding ineffective

What is the cost of exclusion of a major technology platform?

- Cognitively difficult to imagine
- Economically difficult to estimate
- Billions for GE crop removal
- Millions of cars in greenhouse gas impacts
- Lower fertility soils, higher erosion rates
- How many schools could be built, teachers hired, medicines provided, and pesticide impacts avoided?

Gene editing technology for diverse traits



Science magazine names CRISPR 'Breakthrough of the Year'

By Robert Sanders | DECEMBER 18, 2015

In its year-end issue, the journal *Science* chose the CRISPR genome-editing technology invented at UC Berkeley 2015's Breakthrough of the Year.

A runner-up in 2012 and 2013, the technology now revolutionizing genetic research and gene therapy "broke away from the pack, revealing its true power in a series of spectacular achievements," wrote *Science* correspondent John Travis in the Dec. 18 issue. These included "the creation of a long-sought 'gene drive' that

Will plant gene editing be a big deal?

Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Biotechnology

Editing plant genomes with CRISPR/Cas9

Khaoula Belhaj[1], Angela Chaparro-Garcia[1], 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."

Gene editing described

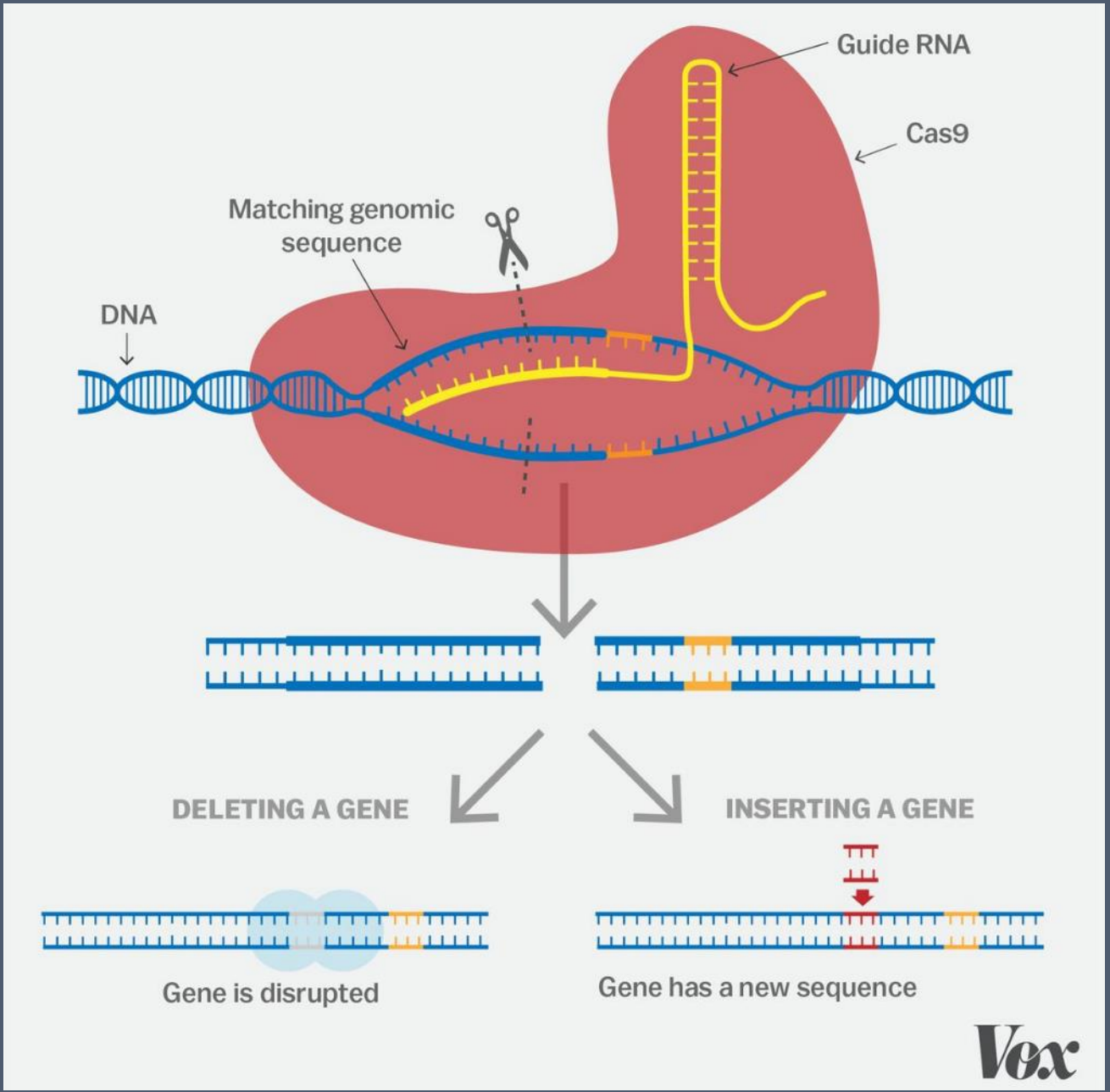
- Technique that allows specific changes to the genome
- Employs methods of genetic engineering but generally does not leave the editing agent in the genome
  - Editing agent enters cell but does not become part of genome
  - Editing agent sexually segregated away (progeny chosen with the edit, but not the editing agent)
  - Or agent somatically excised after editing

CRISPR gene editing system can be used for multiple purposes

- Mutations to destroy gene function
- Directed changes to sequence to change function
  - Proteins, RNAs, regulatory regions
- Gene or chromosome scale rearrangements (inversions, translocations)
- Ability to readily multiplex and mutate numerous genes at once
- Gene insertions directed at specific places
- Very low off-target rate in plants
- Conversion of alleles in successive generations (gene drive) – a useful means for control of serious diseases, pests, invasive exotic species?

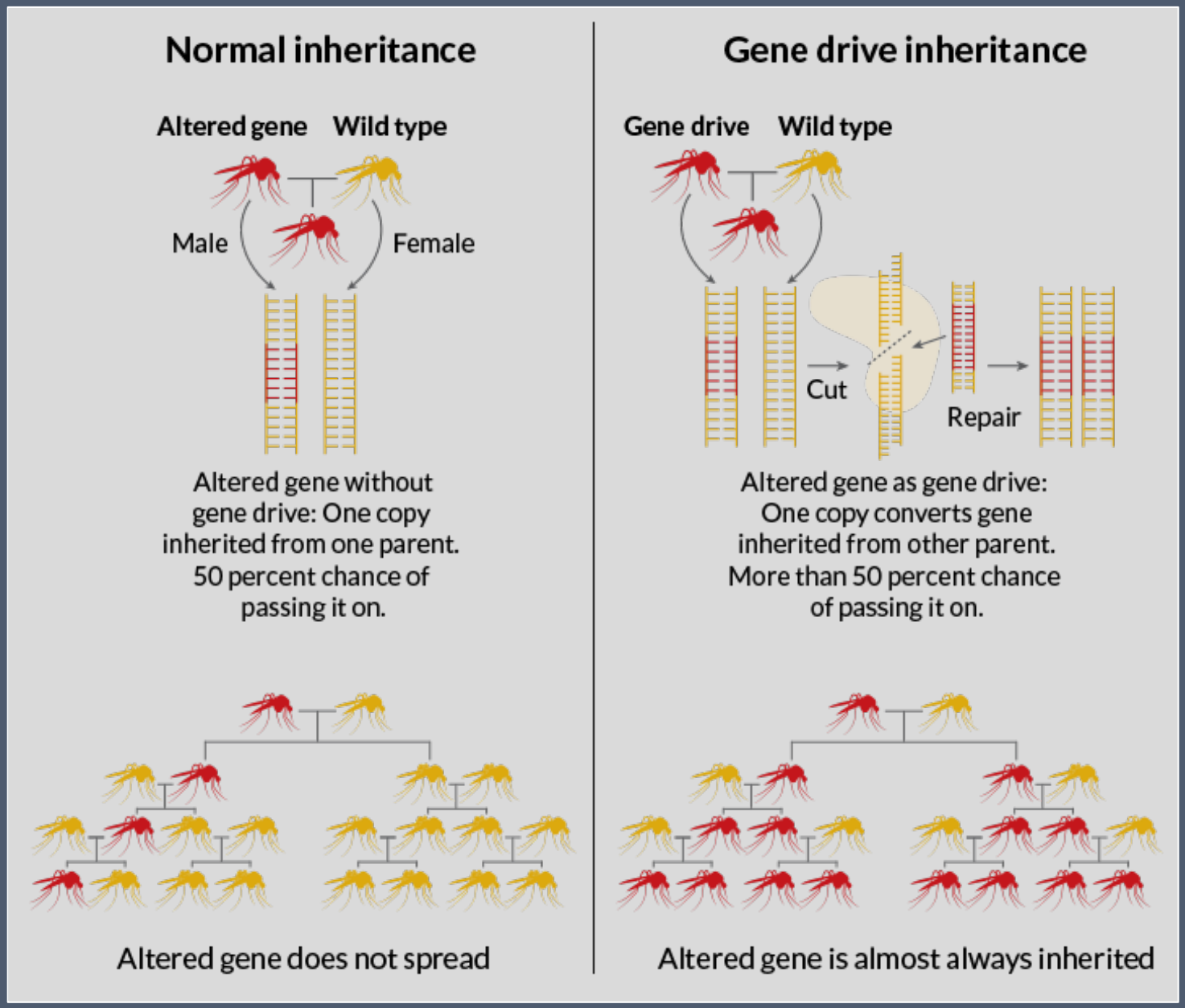
Summary of CRISPR Cas-mechanism

Two major types of edits



Sandman CRISPR !

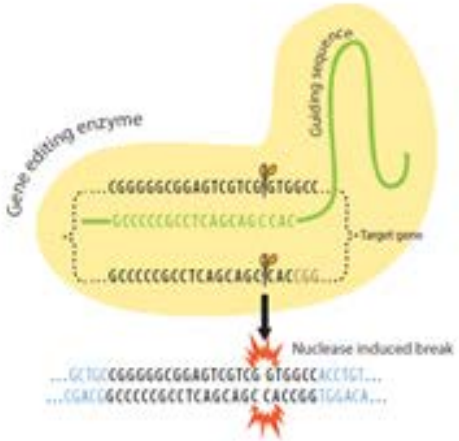
Gene drives for suppression of crop pests?

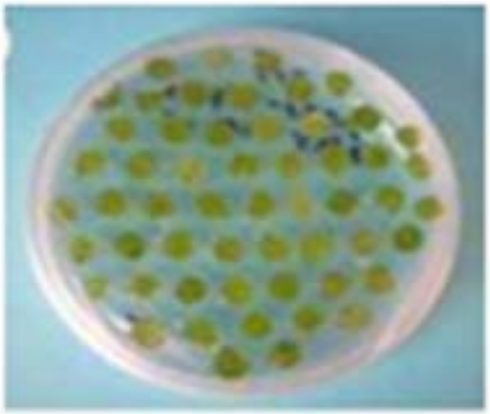


CRISPR-Cas9 targeting of floral genes for genetic containment

- **Goal:** To develop robust male and female containment technologies for vegetatively propagated forest trees
- **Why:** Regulatory, market, and public acceptance with exotic and native trees can be costly or impossible – even for field research
- **Advantage of gene editing:** Expected to be more predictable and stable than alternative genetic containment methods that depend on modified gene expression
- **High efficiency**: Biallelic knock-outs needed in one or more genes

Overview of CRISPR methods in poplar



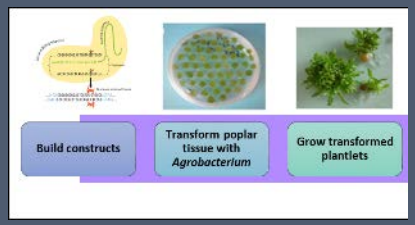


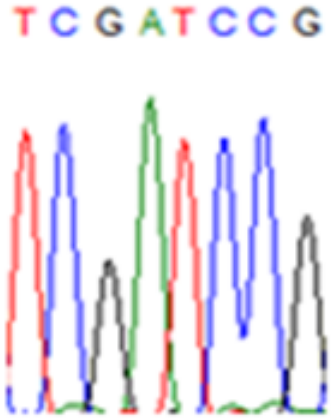
Build constructs

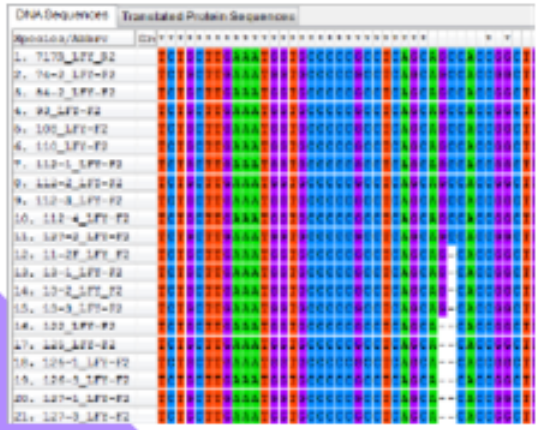
Transform poplar tissue with *Agrobacterium*

Grow transformed plantlets

Overview of CRISPR methods in poplar







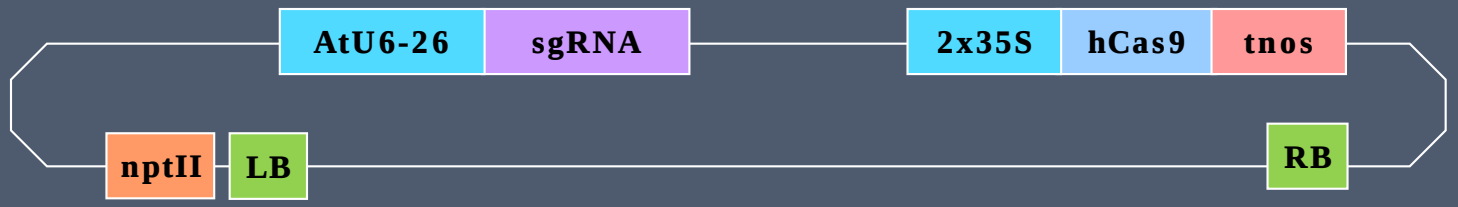
Extract DNA and gel-purify gene amplicons

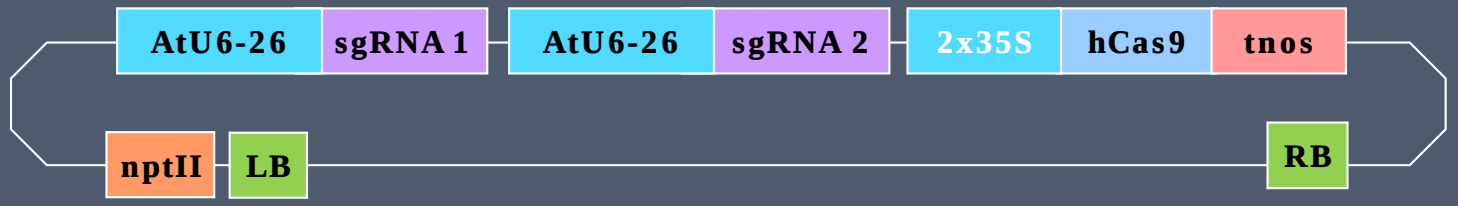
Sequence amplicons across target sites

Identify mutation types and determine frequency

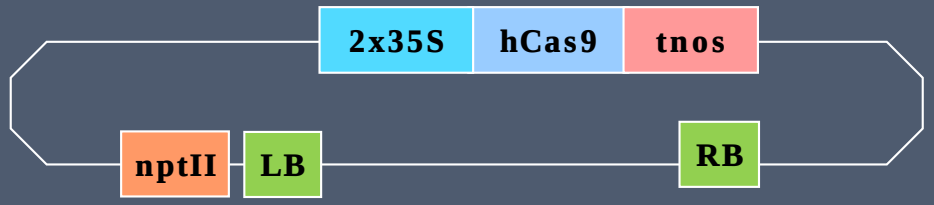
Experimental constructs – single and double targets per gene

Nuclease constructs





Control construct



High mutation rates observed

After analysis of hundreds of insertion events….

- Cas9-only control events
  - No mutations
- CRISPR-Cas events
  - 80% with mutations
  - 50% knock-outs!

Large and small mutations – many routes to non-functioning genes

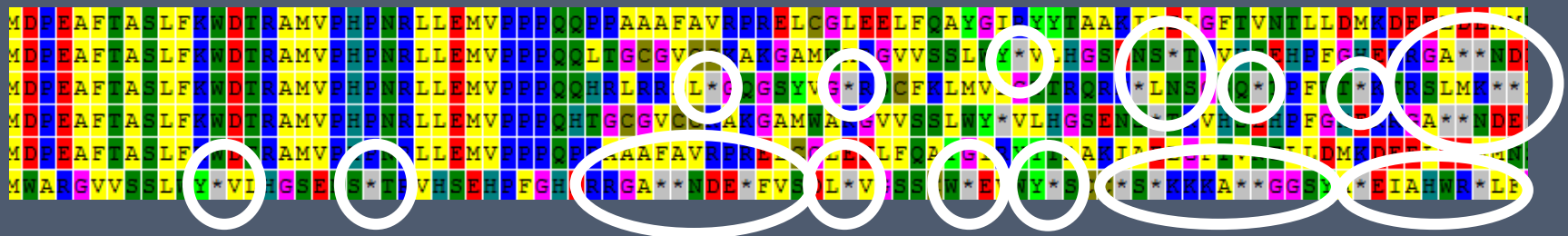
Mutations

Target site for LFYsg2

...100bps...

Target site for LFYsg1

Partial peptide sequence



Early stop codons

Global regulatory quandry

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.

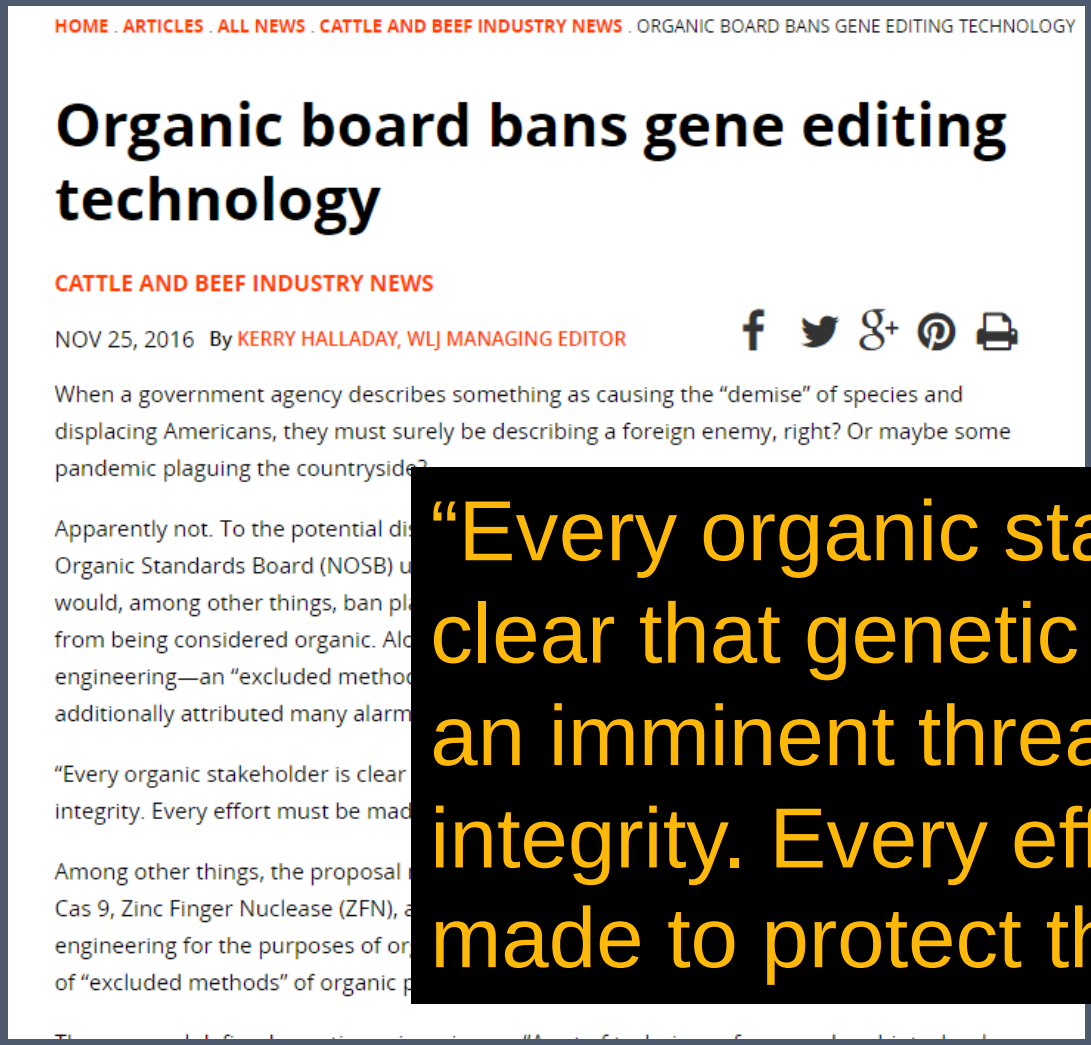
We are at the dawn of a new paradigm in plant breeding. Classical approaches to crop improvement based on hybridization and selection can now be complemented by targeted genome editing that exploits knowledge of specific gene sequences in a systematic way. Unlike conventional genetic modification that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



HOME . ARTICLES . ALL NEWS . CATTLE AND BEEF INDUSTRY NEWS . ORGANIC BOARD BANS GENE EDITING TECHNOLOGY

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 potential di
Organic Standards Board (NOSB) u
would, among other things, ban pl
from being considered organic. Alc
engineering—an "excluded metho
additionally attributed many alarm

"Every organic stakeholder is clear
integrity. Every effort must be mad

Among other things, the proposal
Cas 9, Zinc Finger Nuclease (ZFN), a
engineering for the purposes of or
of "excluded methods" of organic p

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

In conclusion....

Asilomar, CA meeting on rDNA research 1975

OPINION MEETINGS THAT C

ESSAY

Asilomar 19

The California meeting set st public health. Organizer Paul

Today, the benefits of genetic engi and the risks and ethical dilemm it presents, are part of everyday discourse, thrashed out in newspaper c and by politicians and commentators where. In the early 1970s, it was a very ent picture. Scientists were only just le how to manipulate DNA from various into combinations that were not kn exist naturally. Although they were co that the new technology offered co able opportunities, the potential hea environmental risks were unclear.

The people who sounded the alarm this new line of experimentation w

"Could an Asilomar-type conference help resolve some of the controversies now confronting scientists and the public — such as over fetal tissue, embryonic stem-cell research, somatic and germ-line gene therapy and the genetic modification of food crops? **I believe that it would be much more difficult to organize such an event today.**"

"In the 1970s, most of the scientists engaged in recombinant DNA research were working in public institutions and were therefore able to get together and voice opinions without having to look over their shoulders. This is no longer the case — as **many scientists now work for private companies where commercial considerations are paramount.**"

Asilomar, CA meeting on rDNA research 1975

ESSAY

Asilomar 1975: DNA modification secured

The California meeting set standards allowing geneticists to push research to its limits without endangering public health. Organizer Paul Berg asks if another such meeting could resolve today's controversies.

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"Related to this is that so many issues in science and technology today are beset by economic self-interest and, increasingly, by **nearly irreconcilable ethical and religious conflicts, as well as by challenges to deeply held social values**. A conference that sets out to find a consensus among such contentious views would, I believe, be **doomed to acrimony and policy stagnation**.."

THE NEW YORKER

ANNALS OF SCIENCE JANUARY 2, 2017 ISSUE

REWRITING THE CODE OF LIFE

Through DNA editing, researchers hope to alter the genetic destiny of species and eliminate diseases.

By Michael Specter

"We say if it's risky we just shouldn't do it. And that's fine, so long as you're standing on firm ground. But that's the thing: we're not standing on firm ground. And the greatest danger we could face is to assume that not doing anything to nature is the safest course."

-Kevin Esvelt, who directs the "sculpting evolution" group at M.I.T.

Forest stresses growing: "No-analog" scientific thinking should dominate today

Novel climates, no-analog communities, and ecological surprises

John W Williams[1*] and Stephen T Jackson[2]

No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future. The well documented no-analog plant communities of late-glacial North America are closely linked to "novel" climates also lacking modern analogs, characterized by high seasonality of temperature. In climate simulations for the Intergovernmental Panel on Climate Change A2 and B1 emission scenarios, novel climates arise by 2100 AD, primarily in tropical and subtropical regions. These future novel climates are warmer than any present climates globally, with spatially variable shifts in precipitation, and increase the risk of species reshuffling into future no-analog communities and other ecological surprises. Most ecological models are at least partially parameterized from modern observations and so may fail to accurately predict ecological responses to these novel climates. There is an urgent need to test the robustness of ecological models to climate conditions outside modern experience.

Front Ecol Environ 2007; 5(9): 475–482, doi:10.1890/070037

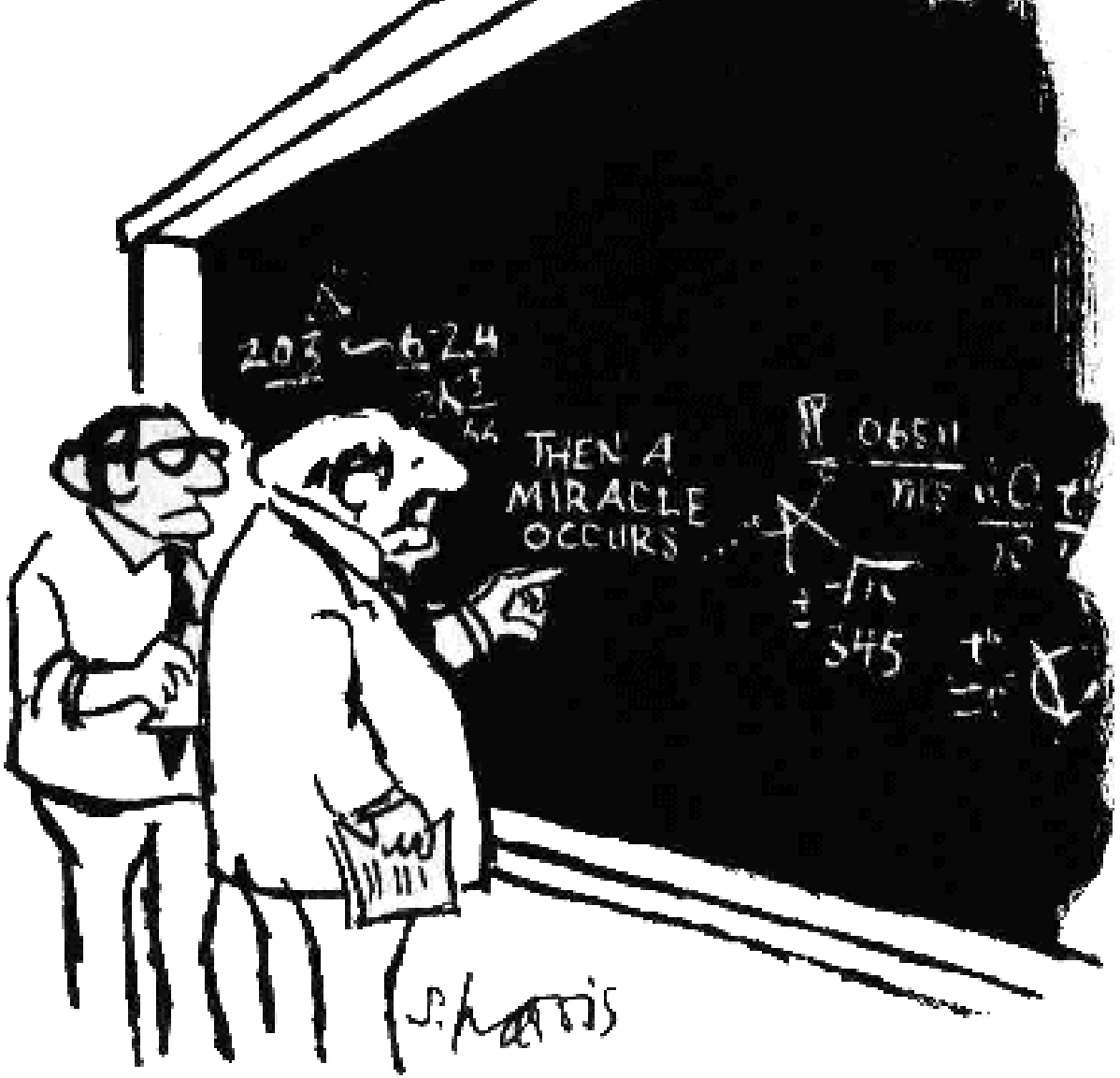
How do you study an ecosystem no ecologist has ever seen? This is a problem for both paleoecologists and global-change ecologists, who seek to understand ecolog- past or future, is heavily conditioned by our current observations and personal experience.

The further our explorations carry us from the present

"No-analog communities (communities that are compositionally unlike any found today) occurred frequently in the past and will develop in the greenhouse world of the future."

In summary

- We today live in, and have been witnessing the growth of for > 40 years, a “perfect storm” of resistance to GE in agriculture and forestry
- Novelty, unnaturalness of GE science and technology to an urban, skeptical, nature-loving, well-fed public
- Complexity / challenges of sustainable food production
- Method-focused, highly precautionary regulations
- Rise of numerous interest groups that profit from anti-GMO activism
- Corporate/private dominance and conflicts of interest
- Market restrictions and “clean” labels
- Power and speed of online information / social media amidst filter bubbles and fake / funky news



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