GMO crops
The science vs. the controversy

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Why do GMOs matter to you?

- Conflicting information about them is widespread – I want **truth**
- Not being **duped** by **costly** but unfounded greenwash and natural food claims
- Wish to see **wise use of a critical technology** for food, medicine, and energy production
- Urgent issue for the **poor** and under a **changing climate**
Fake news and fake science is widespread.

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

GENETICALLY MODIFIED FOOD IS EVIL.
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 of non-scientific reasons.

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 modifications, 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. There are occasional claims of foods to animals ranging from diarrhoea to sterility, tumours to death. Although such claims are often sensationalized and receive a

Approved by the AAAS Board of Directors on 20 October 2012
GMO warning labels common
Vicious anti-GMO messages widespread
There are numerous myths that are rampant and recycled in media.

- Confirmed food safety
- Confirmed insecticide reduction with pest resistant corn
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 a non-profit organization in the United States. It serves as a trusted source of information on scientific matters.

The National Academy of Sciences (NAS) is the premier scientific body in the United States. It is an independent organization that provides advice on scientific matters.

The Royal Society of Medicine is a professional body for doctors, dentists, scientists, and others involved in medicine and healthcare.

The World Health Organization (WHO) is the directing and coordinating authority for health within the United Nations system. It has been providing guidance on the safety of GM foods for many years.

The European Commission is the executive body of the European Union. It has been involved in the regulation of GM foods in Europe.

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

http://www.axismundionline.com/blog/the-new-is-gm-food-safe-meme/
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.
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.
Are GE/GMO foods safe? Are they good for the environment?

Are we asking the RIGHT questions?

www.mysaintfrancis.com
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
The more relevant questions:

• Is agriculture becoming more productive, sustainable, efficient, and resilient?

• If food becoming safer and healthier?

• There are no silver bullets: Are we 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?
Where did our crops come from?

Answer: All over the world
Most crops intensively bred, prior to GMOs.
Mutants are some of our best friends: Domestication of wild cabbage

- **Wild cabbage**
- **Kale, 500 BC**
- **Kohlrabi, Germany, 100 AD**
- **Ornamental kale, Late 1900's**
- **Cauliflower, 1400's**
- **Broccoli, Italy, 1500's**
- **Brussel sprouts, Belgium, 1700's**

Cabbage, 100 AD
Many plant varieties derived from randomly induced mutations

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

Calrose 76 semi-dwarf rice

Rio Red grapefruit

High oleic sunflower
Radical changes in domesticated animals

All dogs derived from the wolf by breeding
Bottom line: The crops we grow, and thus the food we eat, are not natural
What is genetic engineering (GE)

• Direct modification of DNA
  – s. 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

1. **Agrobacterium method**
   - **Agrobacterium tumefaciens**
   - Ti plasmid carrying desired genes
   - Cocultivation of Agrobacterium with plant pieces
   - DNA transferred to plant cells
   - Chromosomes with integrated DNA encoding desired genes
   - Cell multiplication (callus)
   - Shoot regeneration followed by root regeneration
   - Plant with new trait

2. **Particle gun method**
   - Particles coated with DNA encoding desired genes
   - Bombardment of plant pieces with particles

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**Diagram Description:**
- **Agrobacterium tumefaciens** carries a Ti plasmid with desired genes.
- Plant pieces are cocultivated with Agrobacterium.
- DNA from the plasmid is transferred to the plant cells.
- The DNA becomes integrated into the plant's chromosomes.
- Cell multiplication (callus) occurs.
- Shoot regeneration follows, eventually leading to a plant with the new trait.
Then plants are propagated normally (seeds, cuttings) and tested for health and new qualities.
Insect-resistant “Bt crops”
More efficient and less harmful to non-targets than sprays --
Bt sprays widely used in organic agriculture
The Gene Machine
What the CRISPR experiments mean for humanity
By Alice Park
Sandman CRISPR !
Markets are another thing....
The National Organic Standard Boards has banned gene editing technologies.

“Every organic stakeholder is clear that genetic engineering is an imminent threat to organic integrity. Every effort must be made to protect that integrity.”
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First generation herbicide and insect resistant crops were rapidly adopted by farmers, both in the developed and developing world.
Two traits dominate worldwide, increasingly “stacked” in combinations.
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

### Biotech Mega Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Million Hectares</th>
</tr>
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<tbody>
<tr>
<td>1. USA</td>
<td>70.9</td>
</tr>
<tr>
<td>2. Brazil*</td>
<td>44.2</td>
</tr>
<tr>
<td>3. Argentina*</td>
<td>24.5</td>
</tr>
<tr>
<td>4. India*</td>
<td>11.6</td>
</tr>
<tr>
<td>5. Canada</td>
<td>11.0</td>
</tr>
<tr>
<td>6. China*</td>
<td>3.7</td>
</tr>
<tr>
<td>7. Paraguay*</td>
<td>3.6</td>
</tr>
<tr>
<td>8. Pakistan*</td>
<td>2.9</td>
</tr>
<tr>
<td>9. South Africa*</td>
<td>2.3</td>
</tr>
<tr>
<td>10. Uruguay*</td>
<td>1.4</td>
</tr>
<tr>
<td>11. Bolivia*</td>
<td>1.1</td>
</tr>
<tr>
<td>12. Philippines*</td>
<td>0.7</td>
</tr>
<tr>
<td>13. Australia</td>
<td>0.7</td>
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<tr>
<td>14. Burkina Faso*</td>
<td>0.4</td>
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<tr>
<td>15. Myanmar*</td>
<td>0.3</td>
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<tr>
<td>16. Mexico*</td>
<td>0.1</td>
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<tr>
<td>17. Spain</td>
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<td>18. Colombia*</td>
<td>0.1</td>
</tr>
<tr>
<td>19. Sudan*</td>
<td>0.1</td>
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</tbody>
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**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.
Accidental mixing of GM and non-GM crops/food create great problems

Many costly cases of trade disruption and lawsuits with corn, soy, and rice
Local controversy too: GMO ban voted on in Benton County, Oregon in 2015

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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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
Global “meta-analysis” of early impacts: 2014

“147 original studies were included.”
“On average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68.”
• Major pesticide reductions - Bt
• Expanded conservation tillage
• Herbicide tolerant weeds

— Need more sustainable management
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.
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.
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.

**Herbicide class:**
- Acetolactate synthase inhibitor (including imazethapyr)
- Triazines (including atrazine)
- Glyphosate
- Ureas, amides
- Dinitroanilines

**Number of resistant species:**
- 125
- 100
- 75
- 50
- 25

**Years:**
- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010

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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)
- 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
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)
Potential Innate Potato benefits

• If all USA potatoes had its improved traits, each year:
  • Waste reduced by 5 billion pounds
  • CO₂ 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?
Diverse pipeline of biofortification products = enhancement of critical vitamins or nutrients
Why use breeding and biotechnology for β-carotene (pro-vitamin A) enrichment?
Deficiency is widespread, impacts severe, and decades of supplements are unable to overcome

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.

Sources: HarvestPlus; CIMMYT
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
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Why the GMO controversy?

• “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)
What are the 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
   - GMO-free food popular, creating mixture problems
   - 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?
More fun....

I'm no ordinary apple
I'm a genetically modified one that never rots

facebook.com/theorganicindian

TAKE A BITE

Pixleen
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

Trend of the Year: Clean Label

Industry answers the call for simple ingredients
GMO-free labels a significant feature of clean label movement
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, and trade problems
• Diverse pipeline of new products
• “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."