Paweł Golik
Institute of Genetics and Biotechnology

Genetic modification

Friend or foe?

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UNIVERSITY'S INTEGRATED DEVELOPMENT PROGRAMME

The state of public knowledge

- Over 50% of EU citizens (Eurostat poll) believe that only genetically modified plants contain genes
- 80% of Americans think that any food containing DNA should be labeled as such
- The facts:
  - Everything we eat contains DNA and genes
  - It doesn't matter - DNA is quickly degraded in acid solutions, no DNA from food can be transferred to our cells

New study confirms that 80 percent of Americans support labeling of foods containing DNA

Europ Funds Knowledge Education Development
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The Washington Post Democracy Dies in Darkness

Fear tactics

Should we modify genomes?

- It's a philosophical and ethical questions. Is natural necessarily superior? Are we obliged to respect the genetic integrity of other beings?
- But it's a bit too late
  - Most of our crop plants, and farm and companion animals were transformed by us and are very far from their wild ancestors
- We were transforming animals as long, as 20 000 years ago (and plant as long as 10 000 years ago)!

"Conventional" methods

- Crossing and selection
  - "evolutionary engineering
- Controlled crosses (artificial pollination in plants ~1000 BCE)
- Interspecific hybrids
- Chemical and physical mutagenesis, manipulating chromosome division

The power of selection

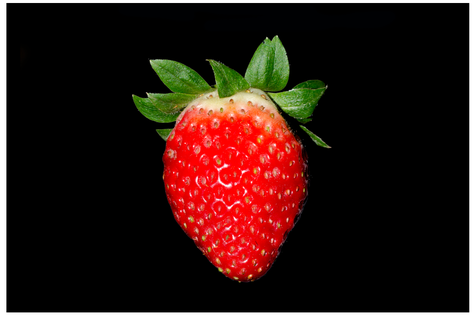
Brassica oleracea var. *silvestris* (brzoskiew)

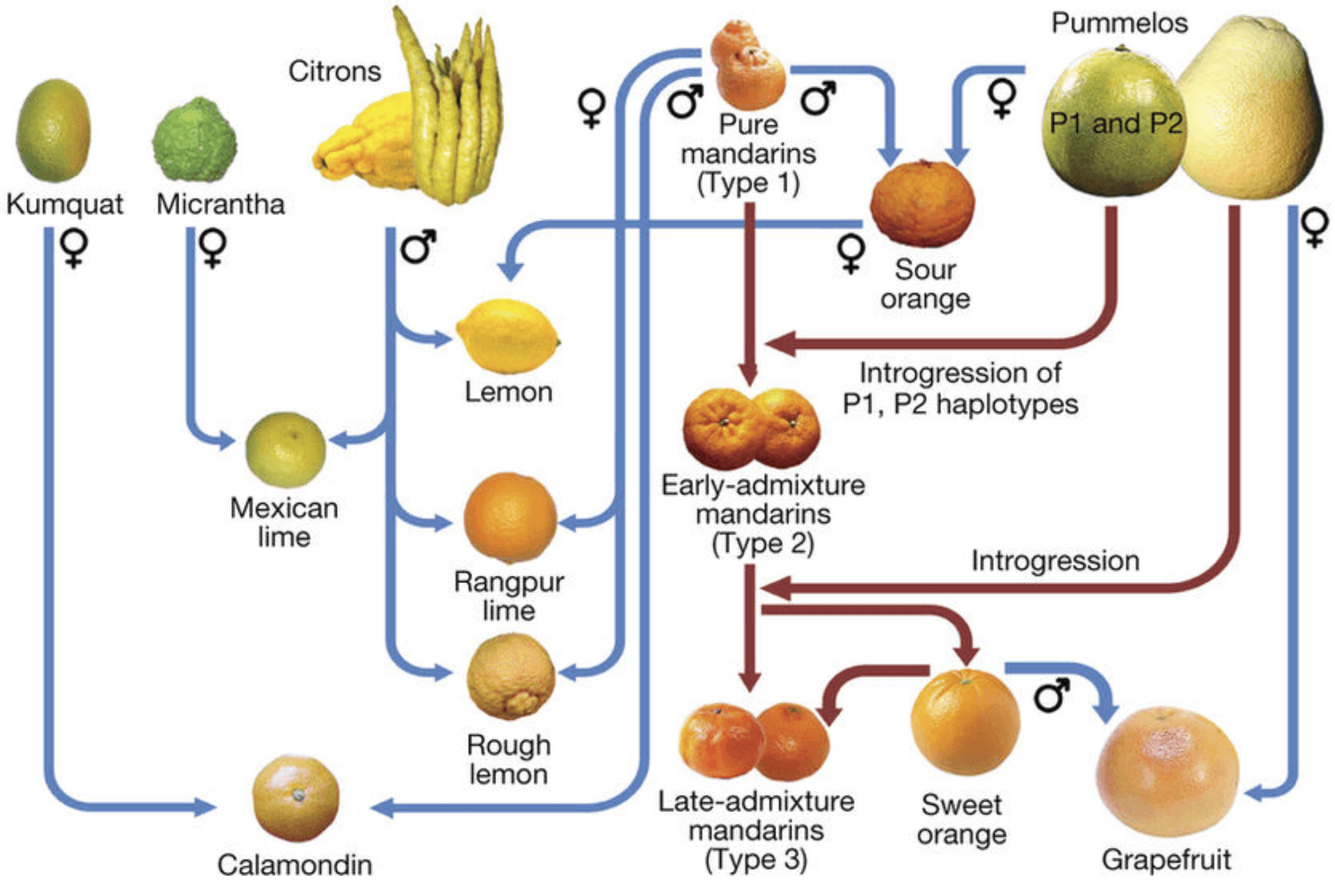
Brassica oleracea odmiany uprawne

Selection acting upon random variation is very powerful

Hybrids

- E.g. strawberry - grown in France in the XVIIIth century
- A cross of *Fragaria virginiana* (eastern USA) and *Fragaria chiloensis* (Chile)
- There are no “natural” strawberries
- Also, most of edible citrus fruits are hybrids





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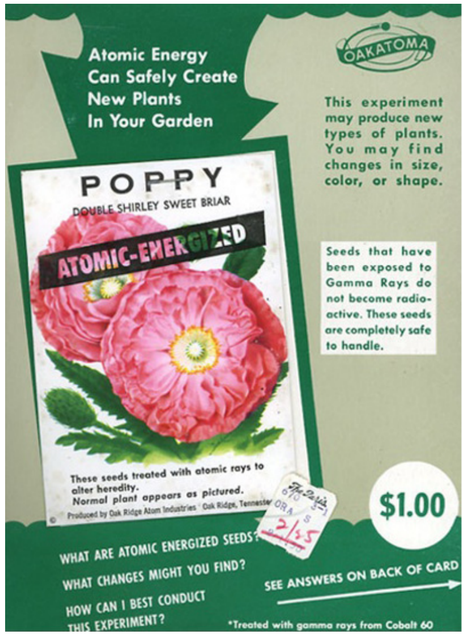
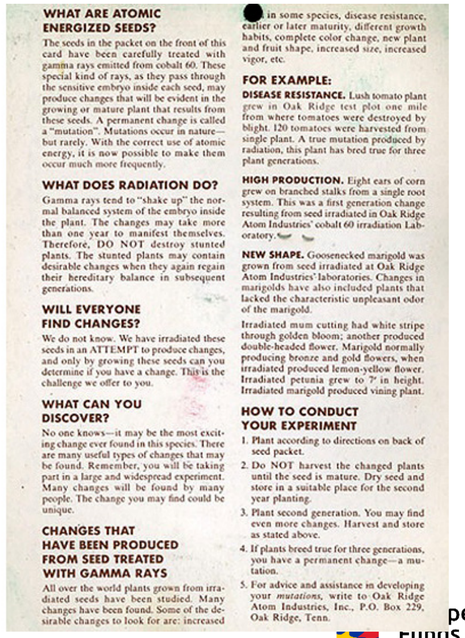
Atomic gardens

- Seeds mutagenized by ionizing (mostly gamma) radiation
- Used to be sold in gardening stores
- Atomic Gardening Society (1959)





WHAT ARE ATOMIC ENERGIZED SEEDS?

The seeds in the packet on the front of this card have been carefully treated with gamma rays emitted from cobalt 60. These special kind of rays, as they pass through the sensitive embryo inside each seed, may produce changes that will be evident in the growing or mature plant that results from these seeds. A permanent change is called a "mutation". Mutations occur in nature—but rarely. With the correct use of atomic energy, it is now possible to make them occur much more frequently.

WHAT DOES RADIATION DO?

Gamma rays tend to "shake up" the normal balanced system of the embryo inside the plant. The changes may take more than one year to manifest themselves. Therefore, DO NOT destroy stunted plants. The stunted plants may contain desirable changes when they again regain their hereditary balance in subsequent generations.

WILL EVERYONE FIND CHANGES?

We do not know. We have irradiated these seeds in an ATTEMPT to produce changes, and only by growing these seeds can you determine if you have a change. This is the challenge we offer to you.

WHAT CAN YOU DISCOVER?

No one knows—it may be the most exciting change ever found in this species. There are many useful types of changes that may be found. Remember, you will be taking part in a large and widespread experiment. Many changes will be found by many people. The change you may find could be unique.

CHANGES THAT HAVE BEEN PRODUCED FROM SEED TREATED WITH GAMMA RAYS

All over the world plants grown from irradiated seeds have been studied. Many changes have been found. Some of the desirable changes to look for are: increased [redacted] in some species, disease resistance, earlier or later maturity, different growth habits, complete color change, new plant and fruit shape, increased size, increased vigor, etc.

FOR EXAMPLE:

DISEASE RESISTANCE. Lush tomato plant grew in Oak Ridge test plot one mile from where tomatoes were destroyed by blight. 120 tomatoes were harvested from single plant. A true mutation produced by radiation, this plant has bred true for three plant generations.

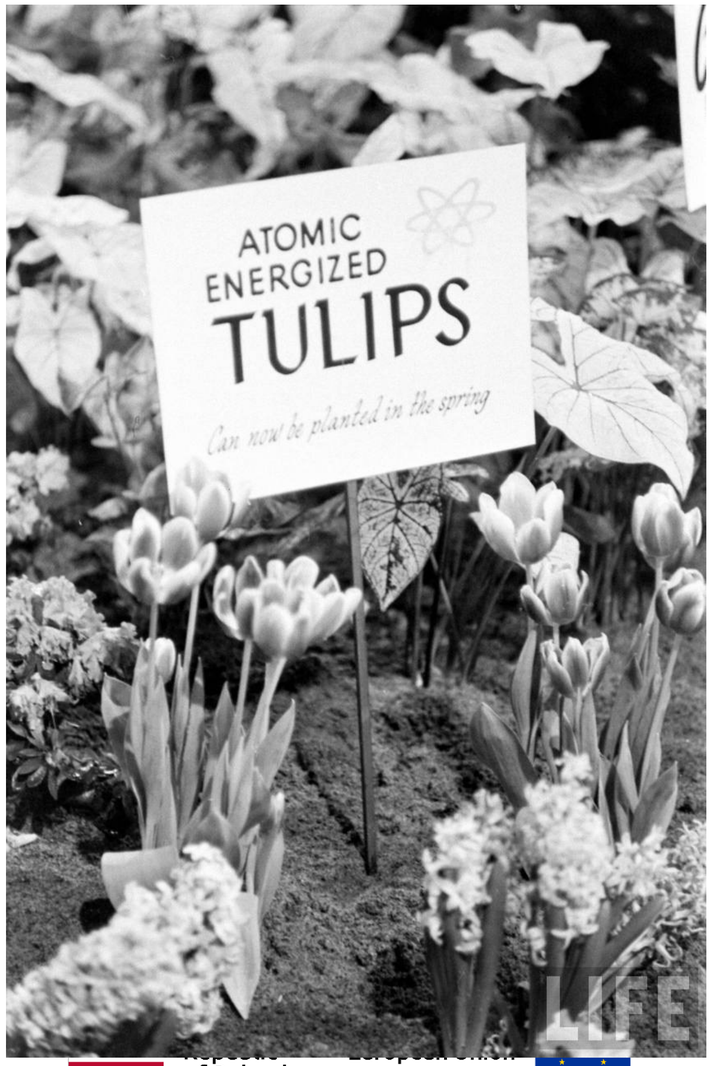
HIGH PRODUCTION. Eight ears of corn grew on branched stalks from a single root system. This was a first generation change resulting from seed irradiated in Oak Ridge Atom Industries' cobalt 60 irradiation Laboratory.

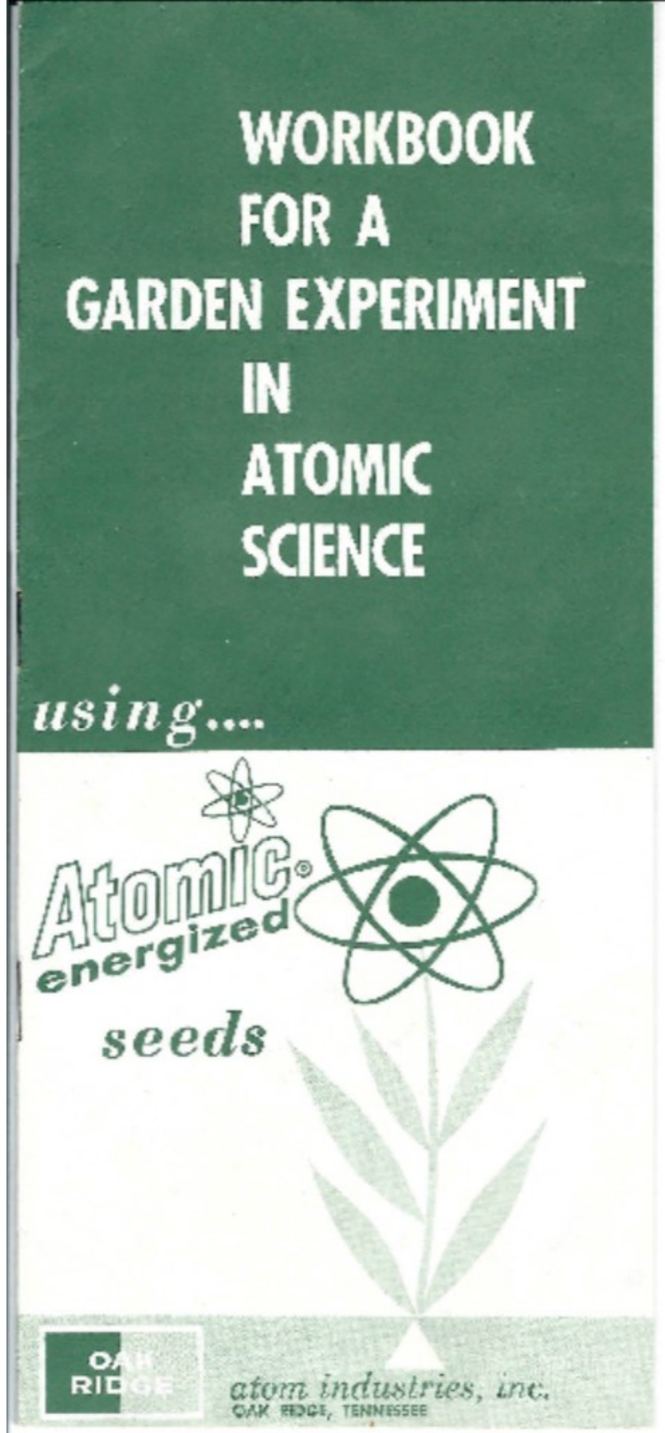
NEW SHAPE. Goosenecked marigold was grown from seed irradiated at Oak Ridge Atom Industries' laboratories. Changes in marigolds have also included plants that lacked the characteristic unpleasant odor of the marigold.

Irradiated mum cutting had white stripe through golden bloom; another produced double-headed flower. Marigold normally producing bronze and gold flowers, when irradiated produced lemon-yellow flower. Irradiated petunia grew to 7" in height. Irradiated marigold produced vining plant.

HOW TO CONDUCT YOUR EXPERIMENT

1. Plant according to directions on back of seed packet.
2. Do NOT harvest the changed plants until the seed is mature. Dry seed and store in a suitable place for the second year planting.
3. Plant second generation. You may find even more changes. Harvest and store as stated above.
4. If plants breed true for three generations, you have a permanent change—a mutation.
5. For advice and assistance in developing your *mutations*, write to Oak Ridge Atom Industries, Inc., P.O. Box 229, Oak Ridge, Tenn.





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Atomic food

SHANGRI-LA TOWERS
ATOMIC INDUSTRIES

Atomically Energized

STAR RUBY PINK GRAPEFRUIT

The mutant variety Star Ruby was officialy approved in 1970. It was developed by treatment with thermal neutrons (thN). Main improved attributes of mutant variety are red flesh like parent variety, but almost seedless (0-9 seeds instead of 40-60).

GUERILLA SCIENCE

GRAPEFRUIT STAR RUBY EKOLOGICZNY

So, what is the problem

- What is this “genetic engineering”
- Recombinant DNA – *in vitro* manipulation of DNA
  - Experimental: since 1972, commercial since 1992
- The basic concept: isolate DNA, introduce changes, transform back into the organism
- There are methods of changing genomes that are not considered genetic engineering
  - e.g. radiation mutagenesis, creation of hybrids
- According to the law: there is a list of methods that are “genetic modification”

Genetic engineering - a very brief history

- 1972 - first experimental gene isolation and transfer in bacteria (Paul Berg)
- 1974 - a letter of scientists (published in *Science*) proposing a moratorium
- 1975 - the Asilomar conference - setting the safety rules and regulations for genetic engineering
- The regulations were proposed by scientists themselves!

Plant modification

- First experiments - 1983, first field tests 1986
- First commercial application (virus resistant tobacco) - 1992
- First modified food (FlavrSavr tomato) -1994
  - success at first, but not viable economically

Not only plants

- Microorganisms - commonly used, with little controversy
  - many drugs (human insulin produced in bacteria, etc.)
  - rennet used to make hard cheese suitable for lactovegetarians
- Animals - mostly in biomedical research, few commercial attempts (AquaAdvantage fast-growing salmon)

The fundamental application

- Since the 70s genetic modification is one of the main tools in research
- Very significant developments in the knowledge of gene function
- Action against genetic modification affects research and education as well
  - for example in Poland

Can we discuss a method?

- The problem is that the discussion is about allowing or disallowing a **method**, not particular products or applications

- Does it make sense?

Can we discuss a method, not particular applications?

- The debate is about a **method**, not about its applications
- Does it make sense?
- It's not about modification: other methods (selection, hybrids, radiation mutagenesis) are not disputed and not limited by law
  - Even if the results are equivalent (e.g. traditionally selected herbicide-resistant crops)
- What is special about genetic engineering?

Can we discuss a method, not particular applications?

- The debate is about a **method**, not about its applications
- Does it make sense?
- Only if there are properties or problems that are
  - **common for all the applications of this method**
  - **absent for applications of different methods**

Does the dispute make sense?

- Are there problems that are
  - **common for all the applications of genetic engineering, and**
  - **absent for applications of traditional methods?**
- There are no such problems
  - it does not mean that there are no problems, just that they occur also with conventional plants!

Common modifications used today

- The Bt trait- a gene from a common soil bacterium Bacillus thuringensis encoding a protein that is toxic to insects that eat it
  - Not toxic to humans (or other vertebrates), nor to many insects (e.g. bees)
  - It acts when eaten by an insect (so it will not harm insects that do not eat the plant)
  - Isolated Bt protein can also be used (sprayed) - this is allowed in organic farming!
  - Plants: corn (MON810 - allowed in the EU), cotton, eggplant, and others

© Wikipedia

Common modifications used today

- Herbicide resistance, e.g. glyphosate (Roundup)
- The most controversial, but remember that:
  - glyphosate is also used with conventional plants
  - used in recommended amounts it is not more dangerous that other herbicides
  - there are glyphosate-resistant crops obtained using conventional selection
  - the patent has already expired

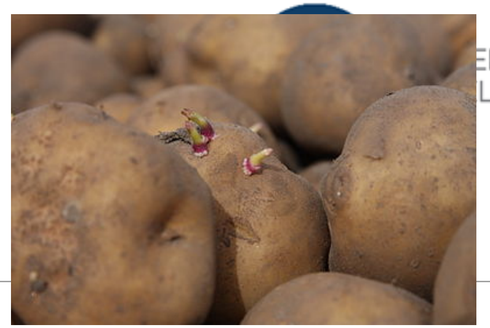
The original error

- "Roundup Ready" plants were the first widely introduced GMO plants
- The company that introduced them also makes Roundup
- If we started with other modifications (like the Bt trait), that **reduce** the use of chemical pesticides, would we have so many people against it now?
- Would it be better if the first applications were non-commercial?
  - in the 80s and 90s - neoliberal transformation, privatization and reduction of public projects (Reagan, Thatcher) - is it related to the loss of trust in science and technology?

Other modifications

- Plants resistant to bacterial and viral pathogens
  - papaya (grown in Hawaii)
  - banana - currently endangered by a viral disease
  - oranges - in Florida endangered by a bacterial pathogen

Other modifications



- Drought resistant plants and reduction of water usage
- Amflora potato - used in industrial starch production (paper making etc.), not for consumption
  - waxy starch - composed only of amylopectin, no amylose
  - better quality starch for paper, uses **less water and energy** to produce starch
  - due to action by environmental NGOs banned in the EU in 2013

Future possibilities

- Enhanced photosythesis
- Currently by up to 40%, possibly more
- Less area for the same yield

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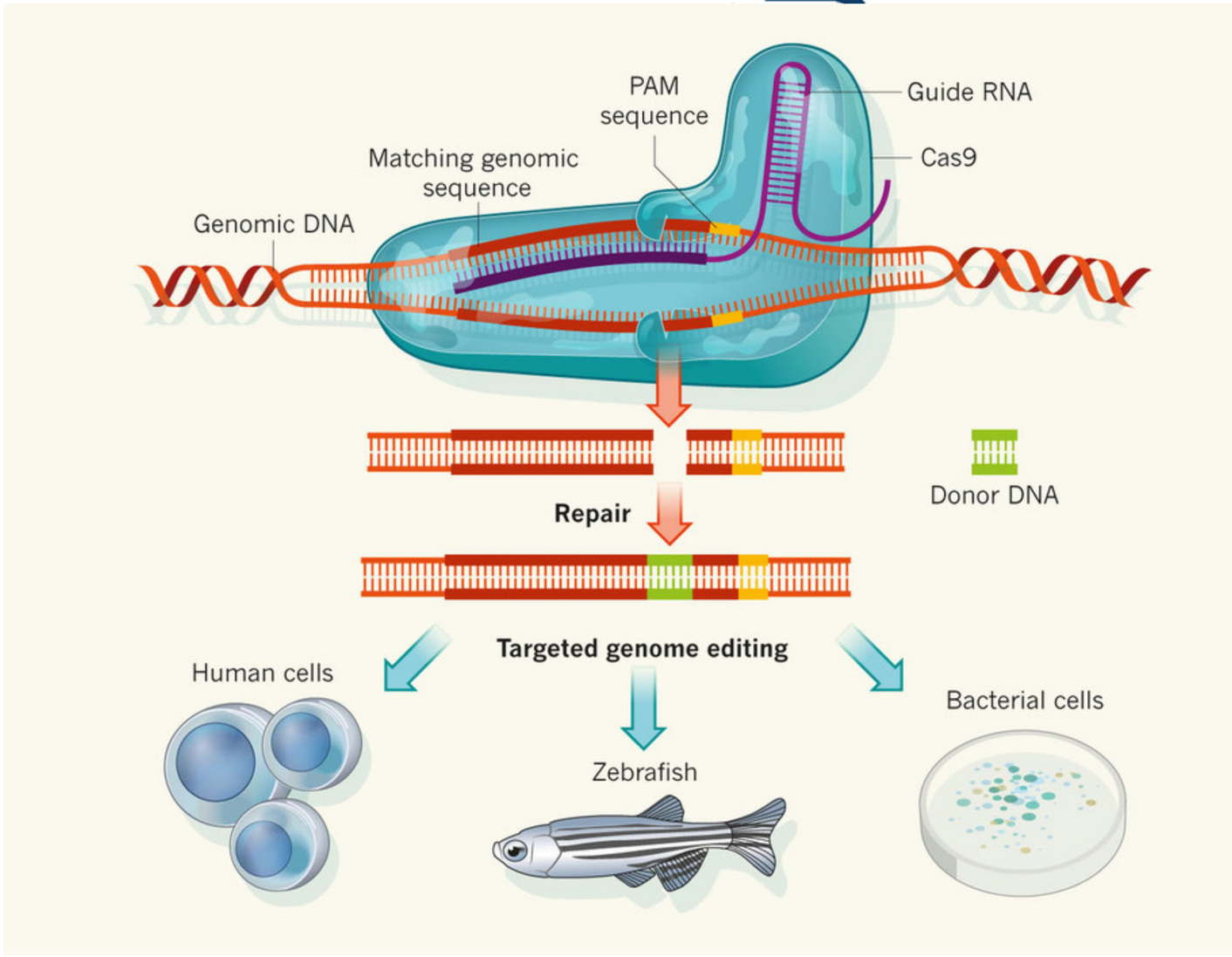
Genome editing

- In use since 2015-2016 - a method to introduce changes in DNA *in situ*, no need to isolate and reintroduce DNA
- Easily adapted to different species and cultivars, relatively cheap and easy
- Can leave no trace in the DNA and no alien inserts, indistinguishable from a spontaneous mutation
- CRISPR/Cas9 - one of the methods
- Since 2018 considered GMO according to the EU law



Nature 495, 50–51 (07 March 2013) doi:10.1038/495050a

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The debate

- Human health (food safety)
- Environmental impact
- Socio-economical impact (food sovereignty)
- Philosophical and ethical issues

Science and opinion

- Whether we should use genetic modification is an opinion, but opinions should be based in fact. Yet different people will reach different opinions from the same facts - it's normal.

- But whether a particular crop is dangerous to humans or environment is a question that can be answered by the scientific method

- The influence of a technology on a society and economics is more difficult to assess, but still can be researched by sociology and anthropology

GMO safety?

- Are GMOs safe (for humans or for the planet)?
- Wrong question - no activity is 100% safe, never!1
- A better question: are they **less safe** than conventional crops (grown in a similar way)?
- Are there any problems **specific** for GMOs?

Health

- Thousands of studies, summarized in meta-analyses, including decades-long studies
- The consensus: no ill effects specific to GMOs
- Bad diet can hurt or kill
  - with conventional foods just as much
- Remember: DNA from food does not get introduced in the genome
  - meat or eggs from animals fed GMO plants is indistinguishable from that of animals fed conventional diet

Environment

- Humans are bad for the planet.
- Agriculture is bad for the environment - there are many problems
- Are any of these problems specific to GMOs?
  - no
  - herbicides and insecticides are used in conventional (and even in organic) farming
  - some modification can reduce the use of pesticides (e.g. Bt)

Critical Reviews in Biotechnology

http://informahealthcare.com/bty
ISSN: 0738-8551 (print), 1549-7801 (electronic)

Crit Rev Biotechnol, Early Online: 1–12
 DOI: 10.3109/07388551.2013.823595

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REVIEW ARTICLE

An overview of the last 10 years of genetically engineered crop safety research

Alessandro Nicolia[1]*, Alberto Manzo[2], Fabio Veronesi[1], and Daniele Rosellini[1]

Table 1. Classification of 1783 scientific records on GE crop safety published between 2002 and 2012.

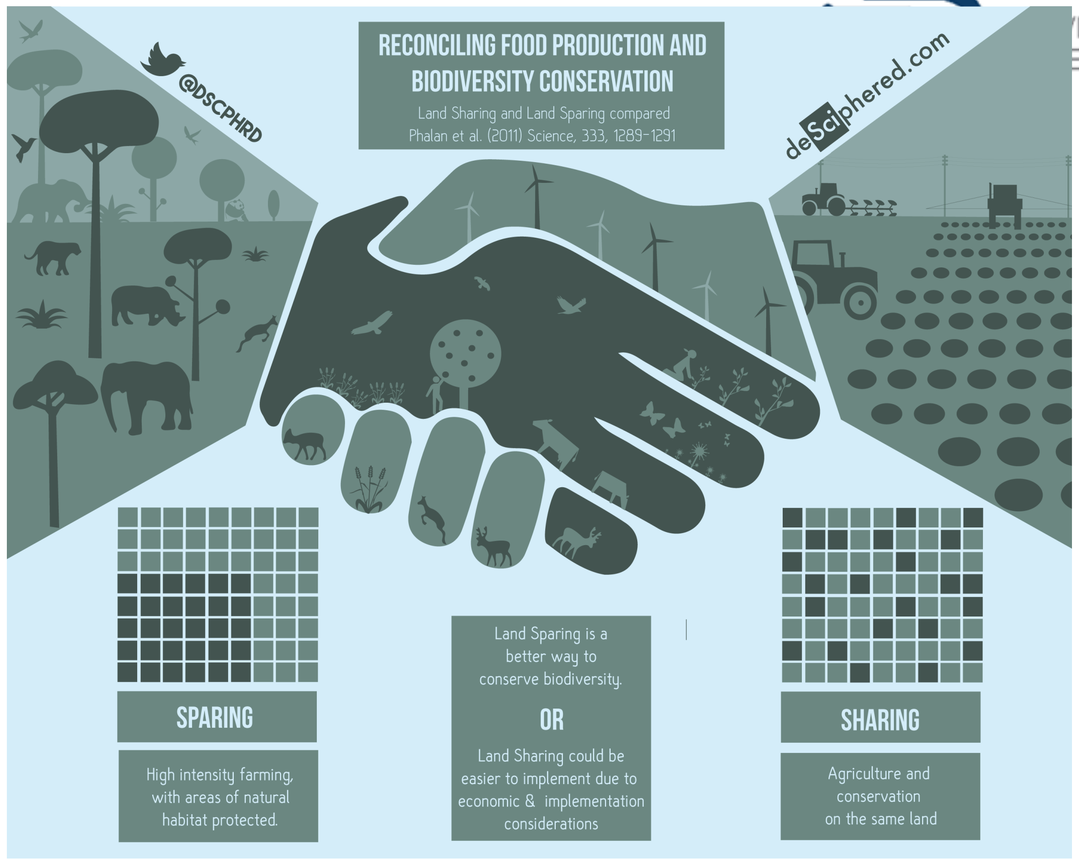
Topic	No. of papers	%*
General literature (GE gen)	166	9.3
Interaction of GE crops with the environment (GE env)	847	47.5
Biodiversity	579	32.5
Gene flow	268	15
Gf – Wild relatives	113	6.3
Gf – Coexistence	96	5.4
Gf – Horizontal gene transfer in soil	59	3.3
Interaction of GE crops with humans and animals (GE food&feed)	770	43.2
Substantial equivalence	46	2.6
Non-targeted approaches to equivalence assessment	107	6
GE food/feed consumption	312	17.5
Traceability	305	17.1

*Percentage of the total number of collected papers.

We have reviewed the scientific literature on GE crop safety for the last 10 years that catches the scientific consensus matured since GE plants became widely cultivated worldwide, and we can conclude that the scientific research conducted so far has not detected any significant hazard directly connected with the use of GM crops. The analysis of the record list shows that the Biodiversity topic dominated, followed by Traceability and GE food/feed consumption, which contributed equally in terms of the number of records (Table 1; Figure 3).

What model of food production

- *Land sparing*
  - high intensity, thus less area used
  - the spared area used for conservation
- *Land sharing*
  - lower intensity, but can partially coexist with conservation on the same area (eco-friendly farming)
  - but will need more area
- No easy solution, depends on many conditions
- Genetically engineered plants can be used in any type of farming, the obstacles are only fear and regulation (certificates, labels)



Reconciling Food Production and Biodiversity Conservation: Land Sharing and Land Sparing Compared

Ben Phalan,[1] Malvika Onial,[1] Andrew Balmford,[1] Rhys E. Green[1,2]

The question of how to meet rising food demand at the least cost to biodiversity requires the evaluation of two contrasting alternatives: land sharing, which integrates both objectives on the same land; and land sparing, in which high-yield farming is combined with protecting natural habitats from conversion to agriculture. To test these alternatives, we compared crop yields and densities of bird and tree species across gradients of agricultural intensity in southwest Ghana and northern India. More species were negatively affected by agriculture than benefited from it, particularly among species with small global ranges. For both taxa in both countries, land sparing is a more promising strategy for minimizing negative impacts of food production, at both current and anticipated future levels of production.

SCIENCE VOL 333 2 SEPTEMBER 2011

Crop diversity

- Does genetic engineering result in a loss of traditional varieties?
- Not now - current methods allow to easily introduce a modification into many different varieties
  - ~900 varieties of Bt cotton, more than 200 Bt corn varieties
- We can benefit from genetic modification while preserving traditional varieties
  - it becomes easier with the progress of technology (e.g. genome editing)

Socio-economical issues

- Control of food production by big corporations
- The most serious problem, but not limited to GMO crops!
  - patents and intellectual property laws apply also to conventional crops
  - legal contracts between farmers and seed companies - also with conventional crops
- "Healthy" or "organic" food is also a large business

Patents

- There are “open source” and non-profit GMOs
- The issues with intellectual property apply also to conventional crops
- In the USA plant varieties that reproduce asexually can be patented since 1930
  - Other varieties protected by Plant Variety Protection Act of 1970 (PVPA), 7 U.S.C. §§ 2321-2582
- In the EU: International Union for the Protection of New Varieties of Plants (UPOV)

Honeycrisp™ apple
patent 1988, University of Minnesota - not a GMO

http://www.nature.com/nbt/journal/v17/n2/full/nbt0299_197.html

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Non profit GMOS

- Rainbow Papaya - virus resistant, saved the papaya farming in Hawaii
  - Cornell University, technology transferred free of charge
- Bt Eggplant in Balngladesh
  - University of Agricultural Sciences in Dharwad, and Tamil Nadu Agricultural University, technology from Cornell U. and others
  - distributed to small farmers free of charge by the Bangladesh Agricultural Research Institute
  - 5x increase in small farmer profit
  - significant reduction in chemical pesticide use

http://bteggplant.cornell.edu/

frontiers in Bioengineering and Biotechnology

PERSPECTIVE
published: 03 August 2018
doi: 10.3389/fbioe.2018.00106

Check for updates

Bt Eggplant Project in Bangladesh: History, Present Status, and Future Direction

A. M. Shelton[1], M. J. Hossain[2], V. Paranjape[3], A. K. Azad[4], M. L. Rahman[4], A. S. M. M. R. Khan[4], M. Z. H. Prodhan[4], M. A. Rashid[4], R. Majumder[3], M. A. Hossain[2], S. S. Hussain[2], J. E. Huesing[5] and L. McCandless[6]*

[1] Department of Entomology, Cornell/NYSAES, Geneva, NY, United States, [2] Feed the Future South Asia Eggplant Improvement Partnership, Dhaka, Bangladesh, [3] Sathguru Management Consultants Pvt. Ltd., Hyderabad, India, [4] Bangladesh Agricultural Research Institute, Gazipur, Bangladesh, [5] USAID/BFS USDA/ARS OIRP, Research Division, Office of Agriculture Research & Policy, Washington, DC, United States, [6] International Programs, Cornell University, Ithaca, NY, United States

“Bangladesh-based anti-GMO groups, who are all funded by the way from sources right here in Europe, travelled around telling these same farmers that their children would become paralyzed if they ate the GM aubergines (eggplant), and that they should instead go back to spraying insecticides.”

Non-profit GMO research

- The WEMA project (*Water Efficient Maize for Africa*)
- African Agricultural Technology Foundation (AATF)
- seeds distributed without a license

https://wema.aatf-africa.org

Non-profit GMOs

- "Golden rice"
  - Produces β-carotene in seeds
  - Designed to combat vitamin A deficiency
  - ~1,7 million of children <5 years in the Philippines alone (Helen Keller International)
- Flax used for antibacterial linen wound dressings (University of Wrocław)
  - abandoned due to the lack of authorization for field tests (due to activist protests)

Anti-GMO activists: "let them eat carrots instead"

New reality, old resistance

- In the XX century genetic engineering was difficult and expensive - top research institutions and big business money
- Currently it is routine (an average university or a startup)
  - particularly genome editing
  - Soon: amateurs at home?
    - like computers and electronics
    - biohacking

New reality, old resistance

- Do continued resistance and bureaucratic barriers to genetic engineering benefit the big corporations that:
  - already have the technology
  - have legal means and lobbying power
  - are global and can transfer farming to countries with weak regulations
- At the cost of potential competition?
- By blocking genetic engineering in the EU (with good consumer protection laws) we outsource it to other parts of the world (with weak worker and consumer protections) - its that reasonable?

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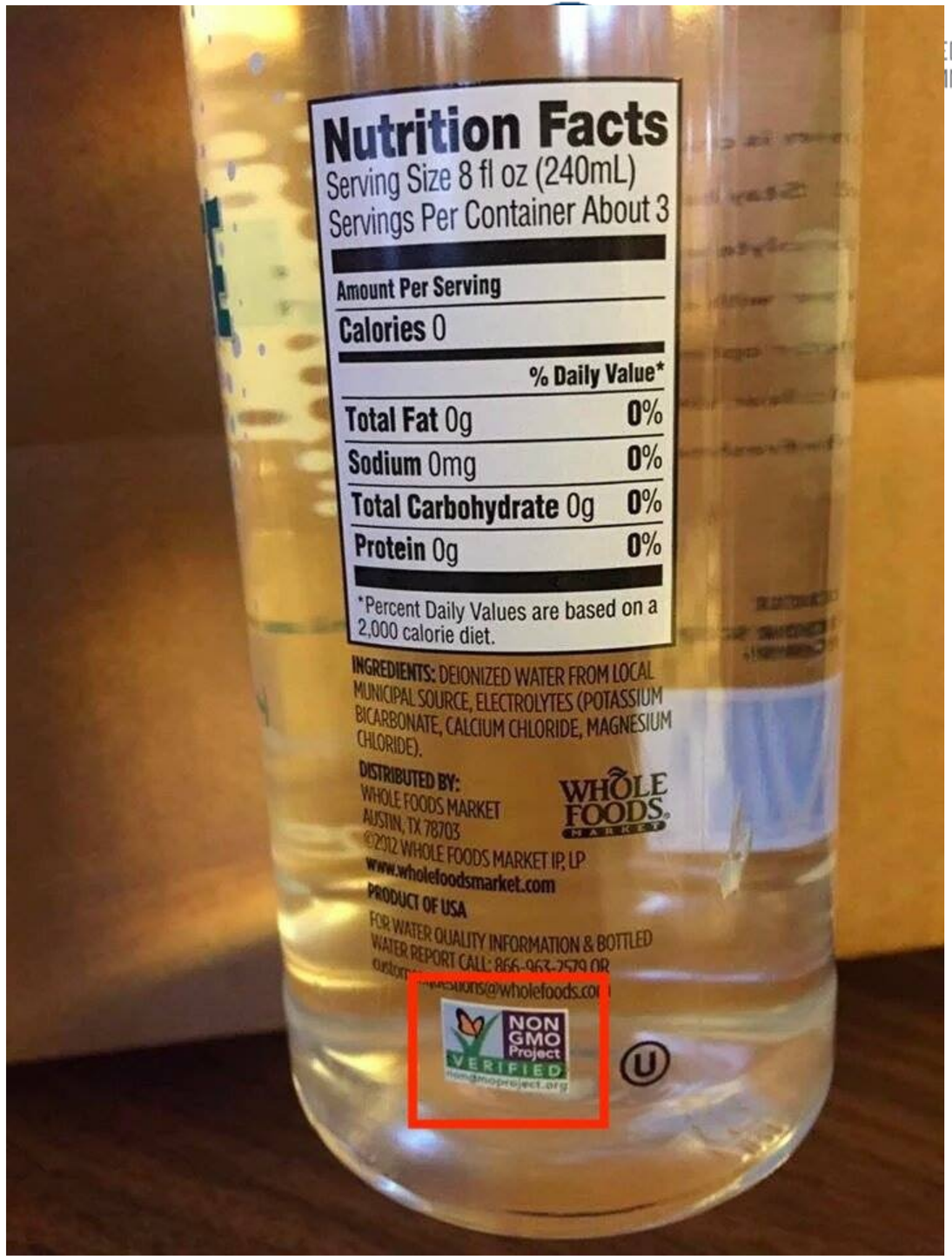
“Non GMO” business

- E.g. “Whole Foods Market” (one of the principal founders of anti-GMO campaign in the USA) - yearly income comparable to Monsanto
- “Non GMO verified” bottled water
  - in a plastic bottle…



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Non GMO advertising

- There are no GMO hens
- DNA in the feed does not go into the egg
- There is no way to distinguish an egg from a hen fed GMO and non-GMO in a blind test
- These eggs are type 3 (cage farming)

Roll over image to zoom in

Salt Himalayan Pink Gourmet FDA No Chemicals Non-gmo Organic Halall Kosher 2 Lbs Fine Grind (.5mm) (2 Pounds)

by Pure Himalayan Salt

★★★★☆ 157 customer reviews | 10 answered questions

$8.25 & FREE Shipping

In Stock.

Ships from and sold by Old World Salt Company.

This item does not ship to **Warsaw, Poland**. Please check other sellers who may ship internationally.

Size: **2 Pounds**

1 Pound | 2 Pounds | 5 Pounds

- FDA#: 15073930442 completely chemical and pesticide free
- Gourmet Pure Himalayan Salt
- Same minerals as present in our bodies all easily absorbed
- No additives or chemicals including fumigation or irradiation, FDA approved
- Organic, Natural, Non-gmo, Halall & Kosher

9 new from $4.00

Conspiracy theories

- In pseudoscience any critique is a conspiracy
  - anti vaccine - “big pharma”
  - anti-GMO - Monsanto, “big Ag”
  - climate deniers - “big green”, “ecologists”

The scientific consensus: climate and GMO

Organization	Statement on Climate Change	Statement on GMOs
American Association for the Advancement of Science	"The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society." (AAAS Board Statement on Climate Change, 2006)	"The science is quite clear: crop improvement by the modern molecular techniques of biotechnology is safe." (AAAS Board Statement on Labeling of Genetically Modified Foods, 2012)
American Medical Association	"Our AMA ... supports the findings of the Intergovernmental Panel on Climate Change's fourth assessment report and concurs with the scientific consensus that the Earth is undergoing adverse global climate change and that anthropogenic contributions are significant." (Global Climate Change and Human Health, 2013)	"Our AMA recognizes that there is no evidence that unique hazards exist either in the use of rDNA (GE) techniques or in the movement of genes between unrelated organisms." "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." "To date, no evidence has supported an increased degree of allergenicity of bioengineered foods compared to their non-bioengineered counterparts." (Report of the Council on Science and Public Health, 2012)

http://www.geneticliteracyproject.org/2014/07/08/climate-change-vs-gmos-comparing-the-independent-global-scientific-consensus/

Conspiracy theories

- The scientific consensus: **global climate catastrophe is anthropogenic**
  - despite documented lobbying (Koch Brothers) and strong denialism (including the president of the USA)
    - yearly income: BP 25 billion $, Exxon Mobil 90 billion $
- The scientific consensus: **GMO plants are not a danger to health and environment**
  - yearly income: Monsanto 7.5 billion $
- Are geneticists that cheap?

The hard question

- Can new technologies benefit the environment and humanity?
  - Is there an alternative, is “return to nature” an option?
- What needs to change?
    - The idea of constant growth (economy and population)
- Is it OK to lie (e.g. about GMOs causing cancer) for a good cause?

We need dialog

- Most environmentalists are not anti-science
  - they are not the same as antivaxxers or flat-earthers
- We have common goals, but disagree on solutions
- We need to discuss, with respect to facts and each other
  - no “crazy tree-huggers” or “Monsanto shills”
  - it’s not religion, it’s OK to change an opinion

What next?

- Promote modern genetic technologies that
  - increase yield
  - reduce pesticide use
  - mitigate climate changes (e.g. economize water)
  - are less commercial: move technological progress to academia away from big corporations and share it with the people
    - activists: please, don't protest in such cases