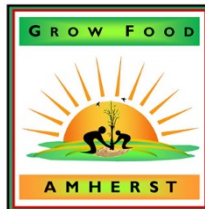


Is there an Upside to Genetically Modified Plants?

Amherst Town Hall
Nov 20, 2014

Elizabeth Vierling
Professor of Biochemistry & Molecular Biology
UMass Amherst

Co-Sponsored By:



What is my bias?

- Use knowledge-based processes to understand potential risk and rewards of new (and old) technologies
- Protect the right for farmers to farm in different sustainable ways (and make a living), and for consumers to choose foods of their preference
- Concern: Are we allowing extraordinary claims and over-heated rhetoric to blind ourselves to the real risks and rewards of *GMOs*?

My other bias - Not all GMOs are created equal and must be tested.

Before release into the environment, GM crops are subject to risk-assessment and risk-management measures to evaluate:

- Risks to human health (including toxicity and allergenicity)
- Risks of evolution of resistance in target pathogens or pests
- Risks to non-target organisms
- Risks from movement of transgenes



Safety regulators in the U.S.

FDA: U.S. Food and Drug Administration

– Determines if it is safe to eat

EPA: U.S. Environmental Protection Agency

– Determines if it is safe for the environment

USDA: U.S. Department of Agriculture

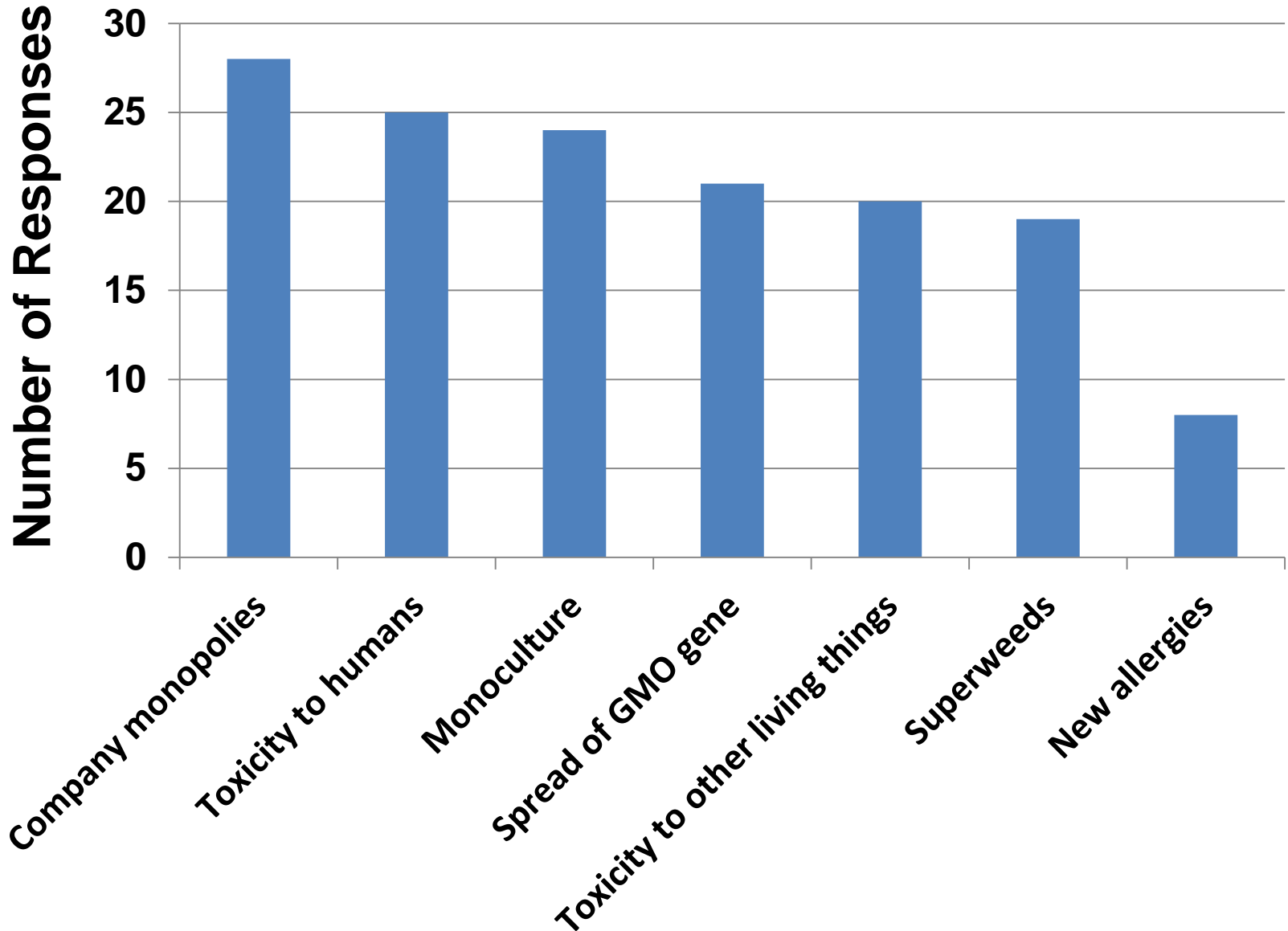
– Determines if it is safe to grow

What's the *GMO* debate about?

- Environmental and health risk of new technology
 - relationship to risks of existing technology
- 'Right to farm' (*GMO*-adopting, organic)
- Public concern about *GMOs* - sorting out facts from over-the-top rhetoric
 - *GMOs* will double yields and solve all agricultural problems
 - *GMOs* will kill you, or at least make you sick, and besides...it's **MONSANTO** (buy organic)

Concerns of the Audience

Amherst MA- April 2014



What I want to communicate

What are the major “transgenic crops” today?

How do we put genes into plants?

Address concerns from last time.

A “good” example and “good” possibilities

What I want to communicate

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Center for Environmental Risk Assessment

About Us

→ GM Crop Database

Bibliography Database

CERA Meetings & Events

CERA Publications

S. Asia Biosafety Program

<http://cera-gmc.org/s>

The Center for Environmental Risk Assessment (CERA) is dedicated to developing and applying sound science to the environmental risk assessment of agricultural biotechnologies so their contributions to the sustainable production of food, fuel and fiber may be safely realized.

Types of “Biotech” crops currently grown

Countries listed in order of number of acres

Country	Biotech Crops
USA*	Maize, soybean, cotton, canola, sugar beet, alfalfa, papaya, squash
Brazil*	Soybean, maize, cotton
Argentina*	Soybean, maize, cotton
India*	Cotton
Canada*	Canola, maize, soybean, sugar beet
China*	Cotton, papaya, poplar, tomato, sweet pepper

Types of "Biotech" crops currently grown

Countries listed in order of number of acres

Country	Note: There is NO "GMO" rice, wheat, peanut
USA*	Maize, soybean, cotton, canola, sugar beet, alfalfa, papaya, squash
Brazil*	Soybean, maize, cotton
Argentina*	Soybean, maize, cotton
India*	Cotton
Canada*	Canola, maize, soybean, sugar beet
China*	Cotton, papaya, poplar, tomato, sweet pepper

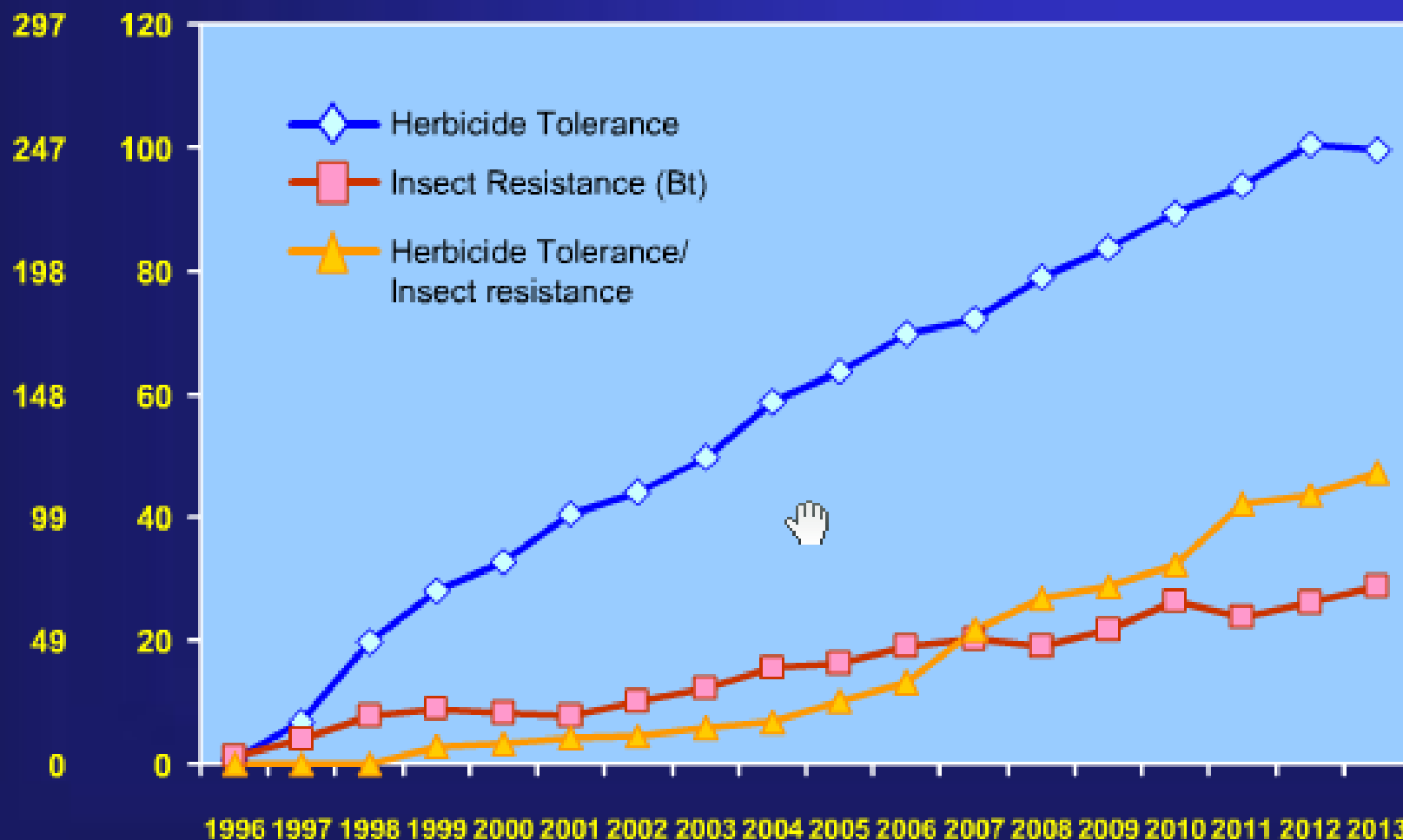
Genes currently in transgenic crops

- **Herbicide tolerance (HT):** Corn, soybean, canola, cotton, sugar beet, alfalfa
"Roundup Ready"
Gene: EPSP synthase
- **Insect Resistance (Bt):** Corn, Cotton
"Bacillus thuringensis toxin"
Gene: Bt toxin
- **Papaya ring spot virus resistance:** Papaya
Gene: RSV protein

Global Area of Biotech Crops, 1996 to 2013: By Trait (Million Hectares, Million Acres)



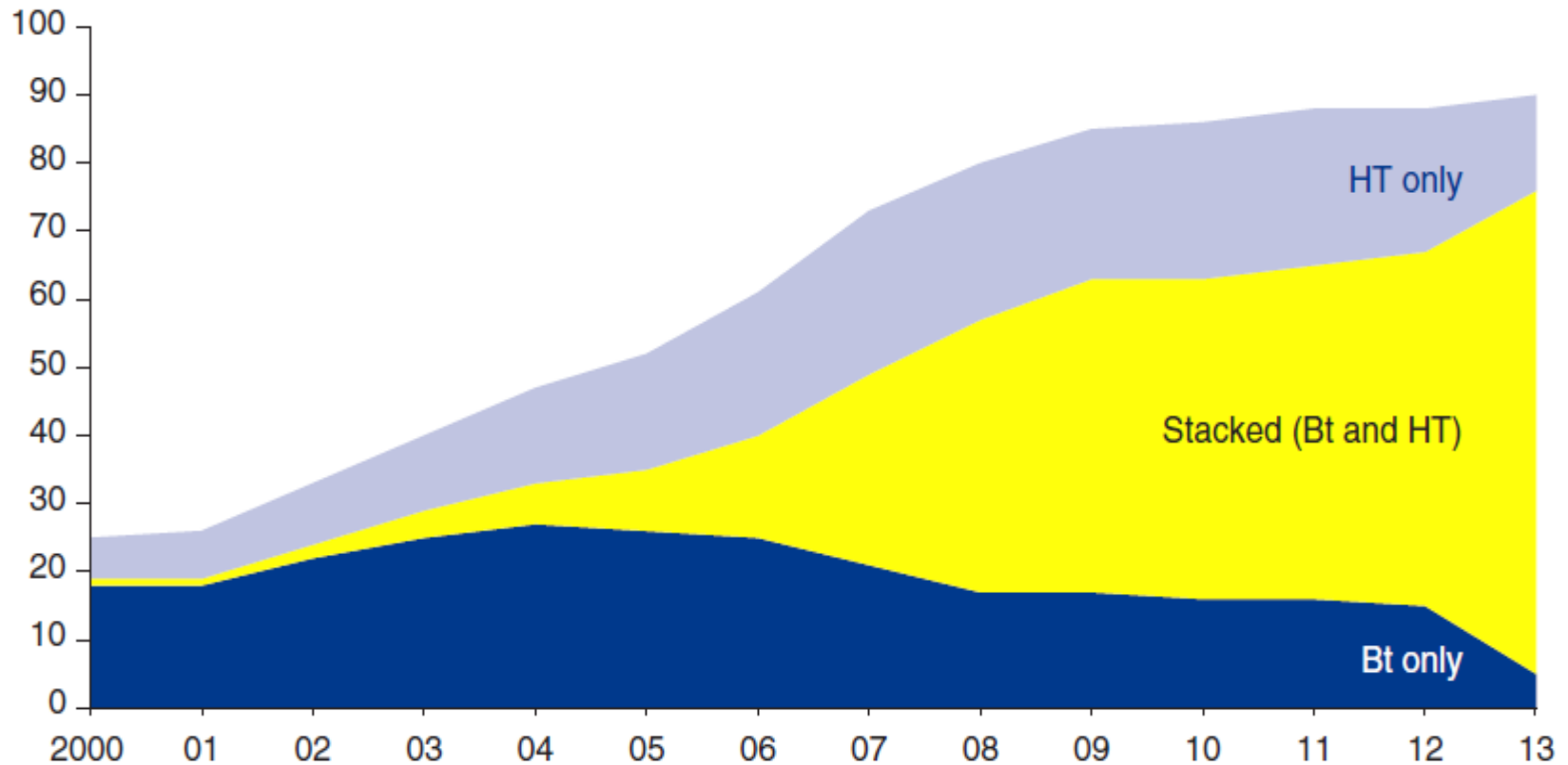
M Acres



Source: Clive James, 2013

Adoption of Genetically Engineered Corn in the US

Percent of Acres Planted

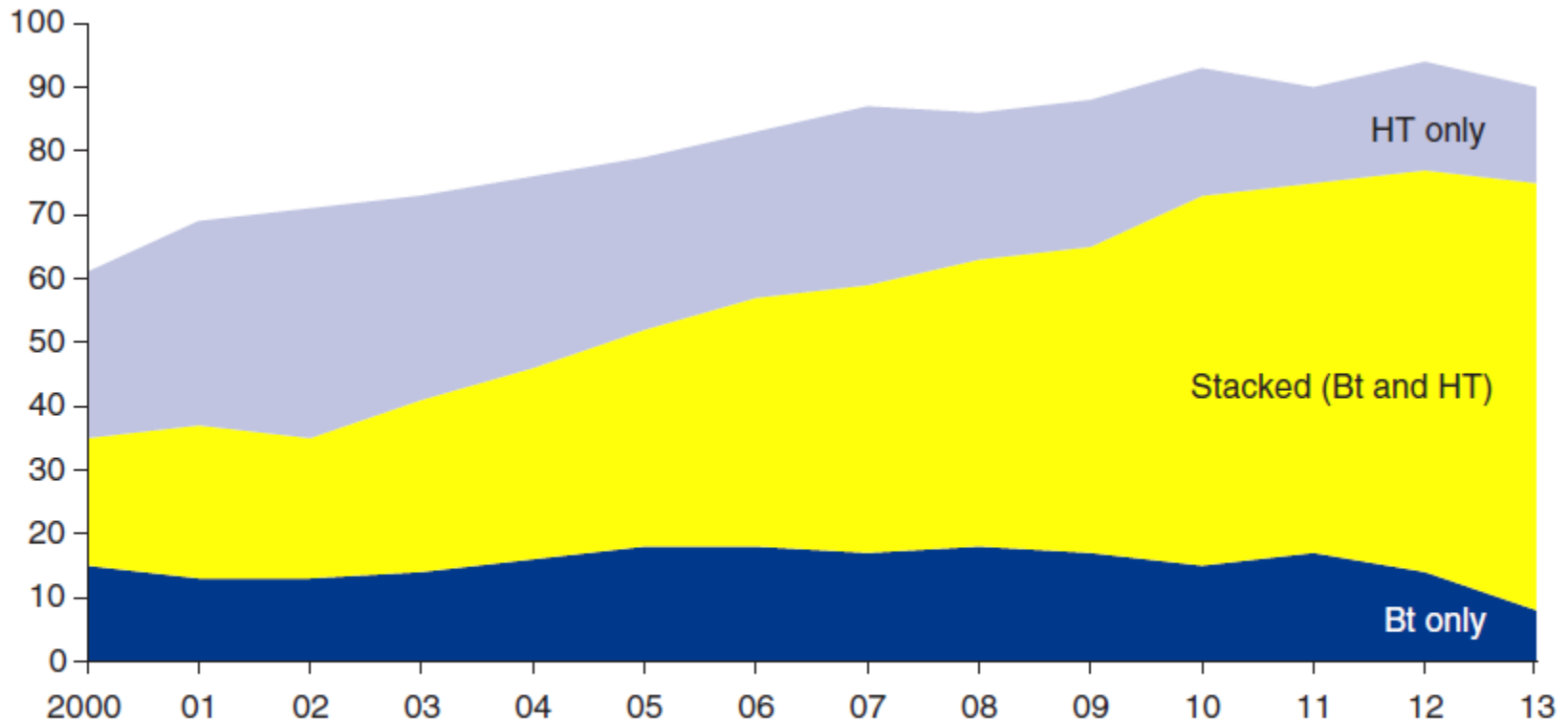


Bt crops have insect-resistant traits; HT crops have herbicide tolerance traits.

Source: U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2013. *Adoption of Genetically Engineered Crops in the United States*, data product.

Adoption of Genetically Engineered Cotton in the US

Percent of Acres Planted



Bt crops have insect-resistant traits; HT crops have herbicide tolerance traits.

Source: U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2013. *Adoption of Genetically Engineered Crops in the United States*, data product.

What I want to communicate

What are the major “transgenic crops” today?

How do we put genes into plants?

Address concerns from last time.

A “good” example and “good” possibilities

What is a *GENE*?

Let's start with DNA
and putting it in
context.

The four major Macromolecules of life:
(i.e. big stuff, e.g. relative to an atom)

Nucleic acids: DNA-Deoxyribonucleic acid
RNA-Ribonucleic acid
Store and transmit information

Proteins: Made of Amino acids (20 kinds) -
Workhorses of our cells/bodies

Lipids: Store energy (fat), lots of other functions

Carbohydrates: Store energy, other stuff too

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(i.e. the big stuff, e.g. relative to an atom)

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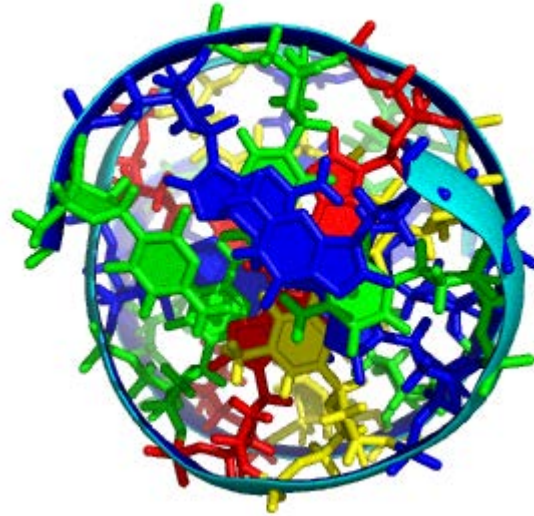
Carbohydrates: Store energy, other stuff too

DNA "Double Helix"

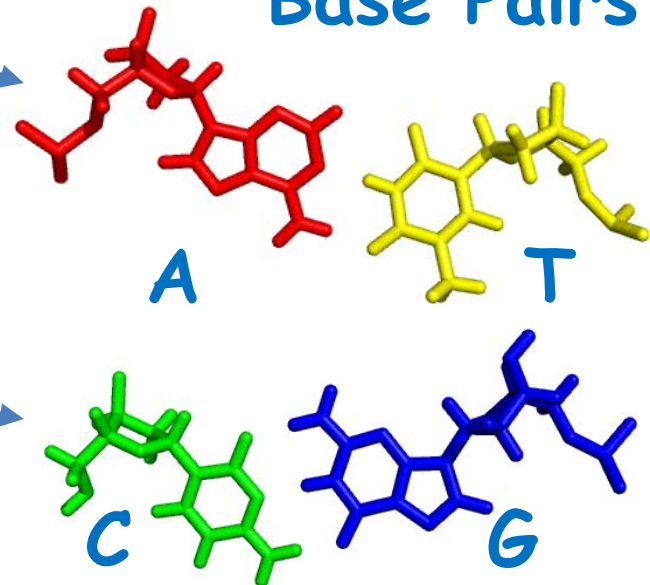
"Side" View



"Top" View

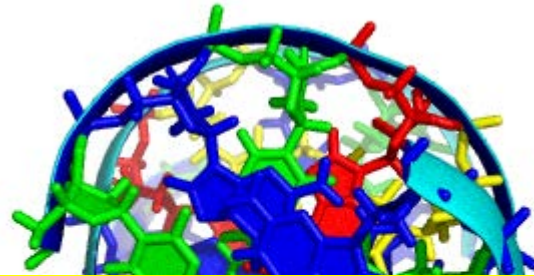


"Base Pairs"



DNA "Double Helix"

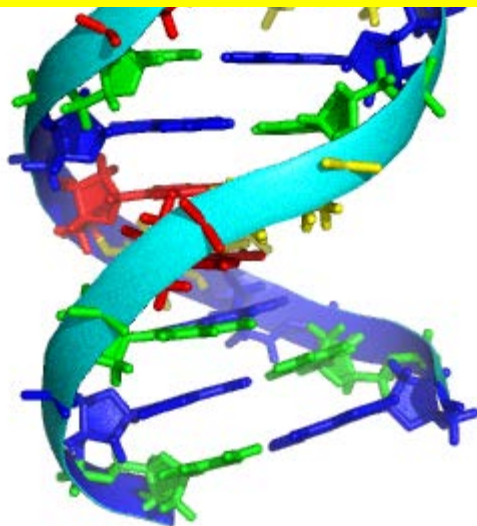
"Top" View



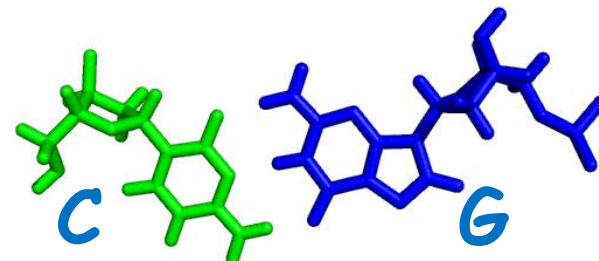
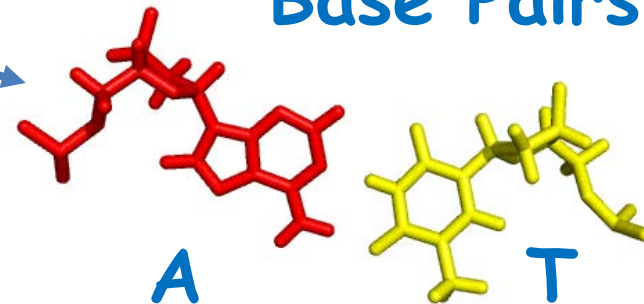
"Side" View



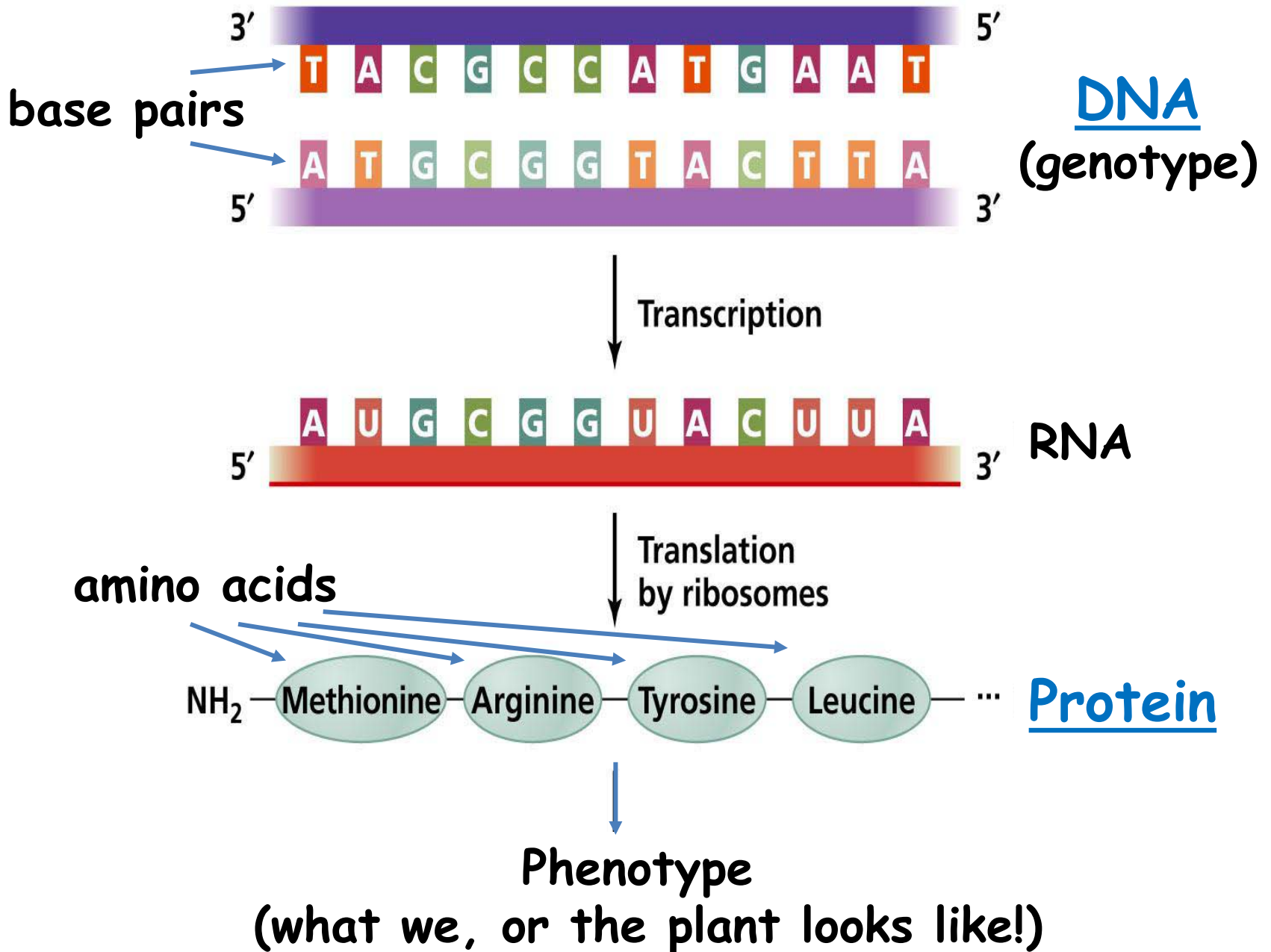
A **GENE** is a section of DNA with a specific sequence of "base pairs" that encodes the information required to make a protein

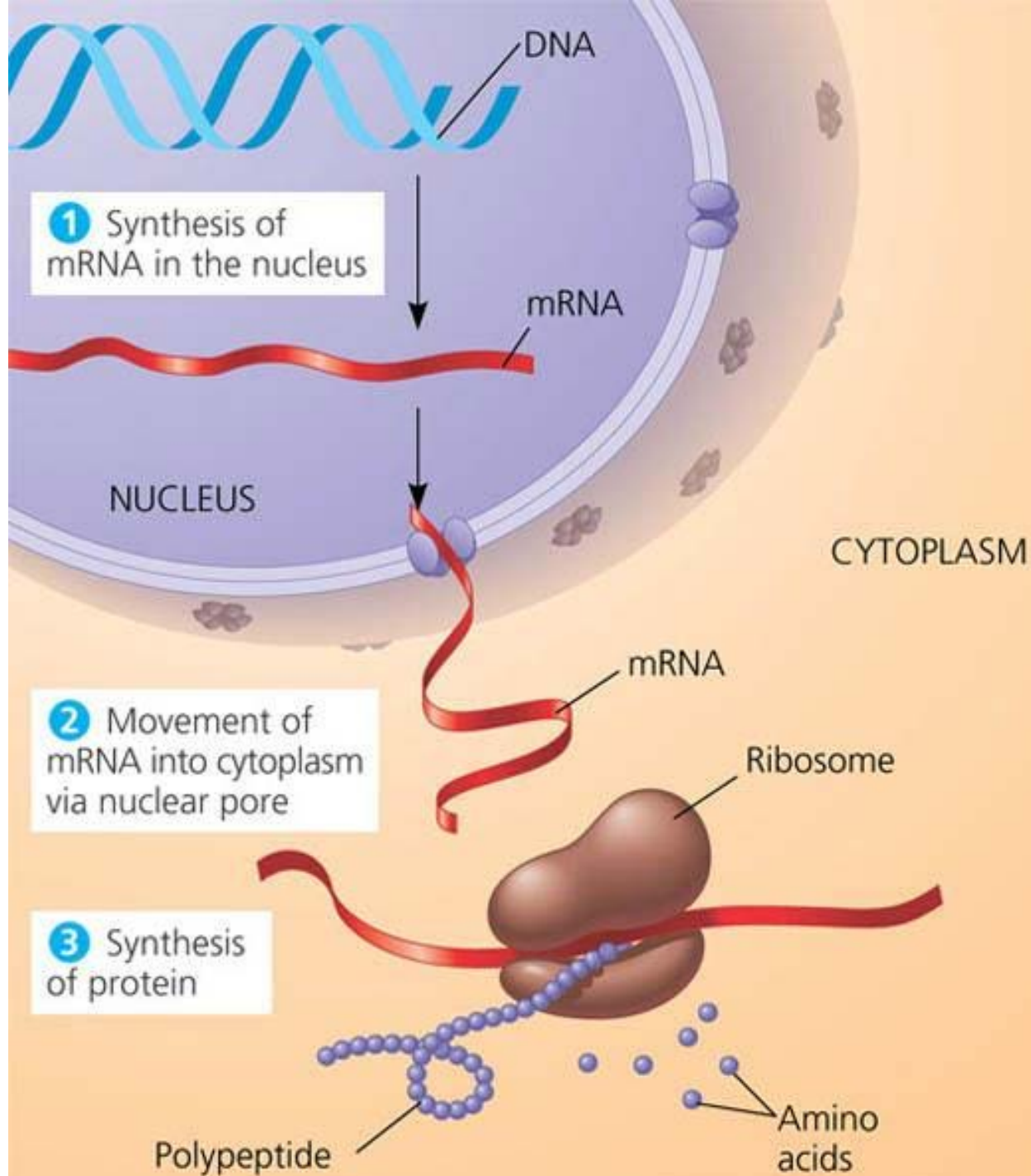


"Base Pairs"



From DNA to Protein - The Central Dogma





In my lab we put genes into plants for basic research and discovery.

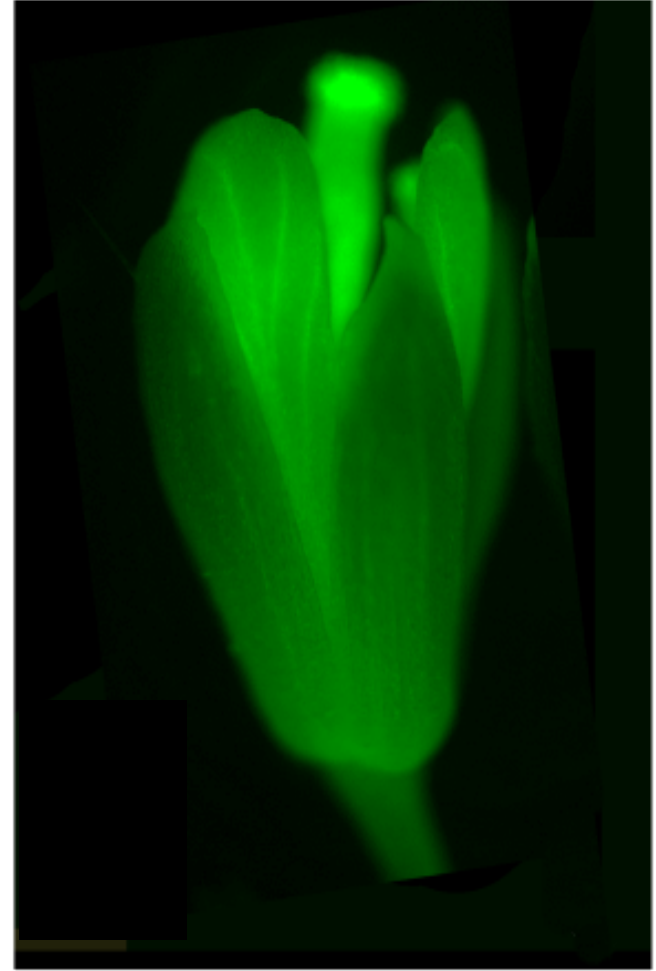


"Mouse-eared cress"
(*Arabidopsis thaliana*)

Mustard family
(Brassicaceae)

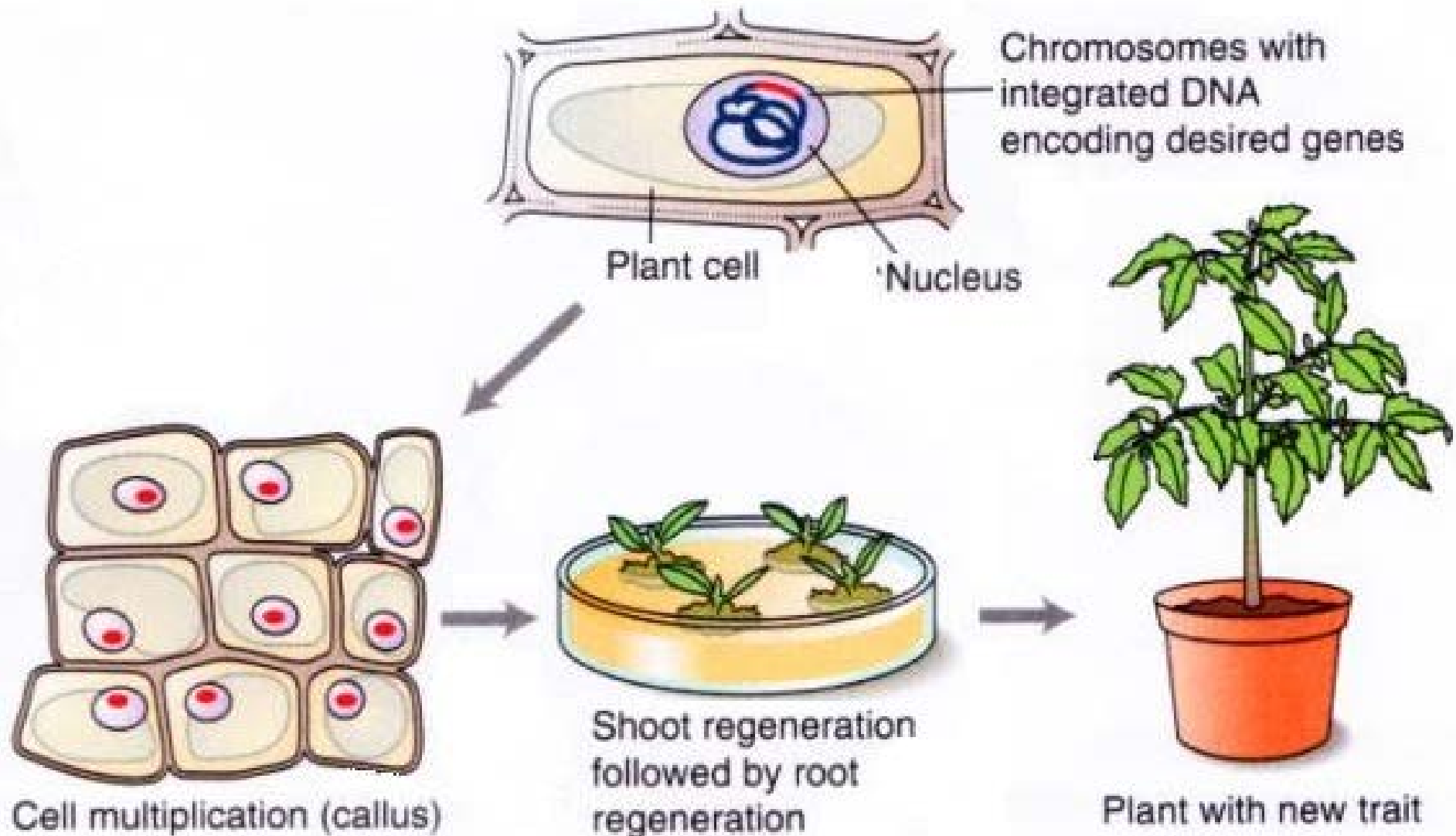
Related to Canola, Broccoli,
Cauliflower, Cabbage

Adding a Green Fluorescent "Tag" to Our Favorite Gene.



We can see where a protein is in the plant

We can introduce a gene into a plant cell and the "regenerate" a whole plant



So:

GMO plants can be made using DNA Technology by introducing a GENE (a small piece of DNA that specifies one protein) from any organism, including even a highly related or even the same plant.

What I want to communicate

What are the major “transgenic crops” today?

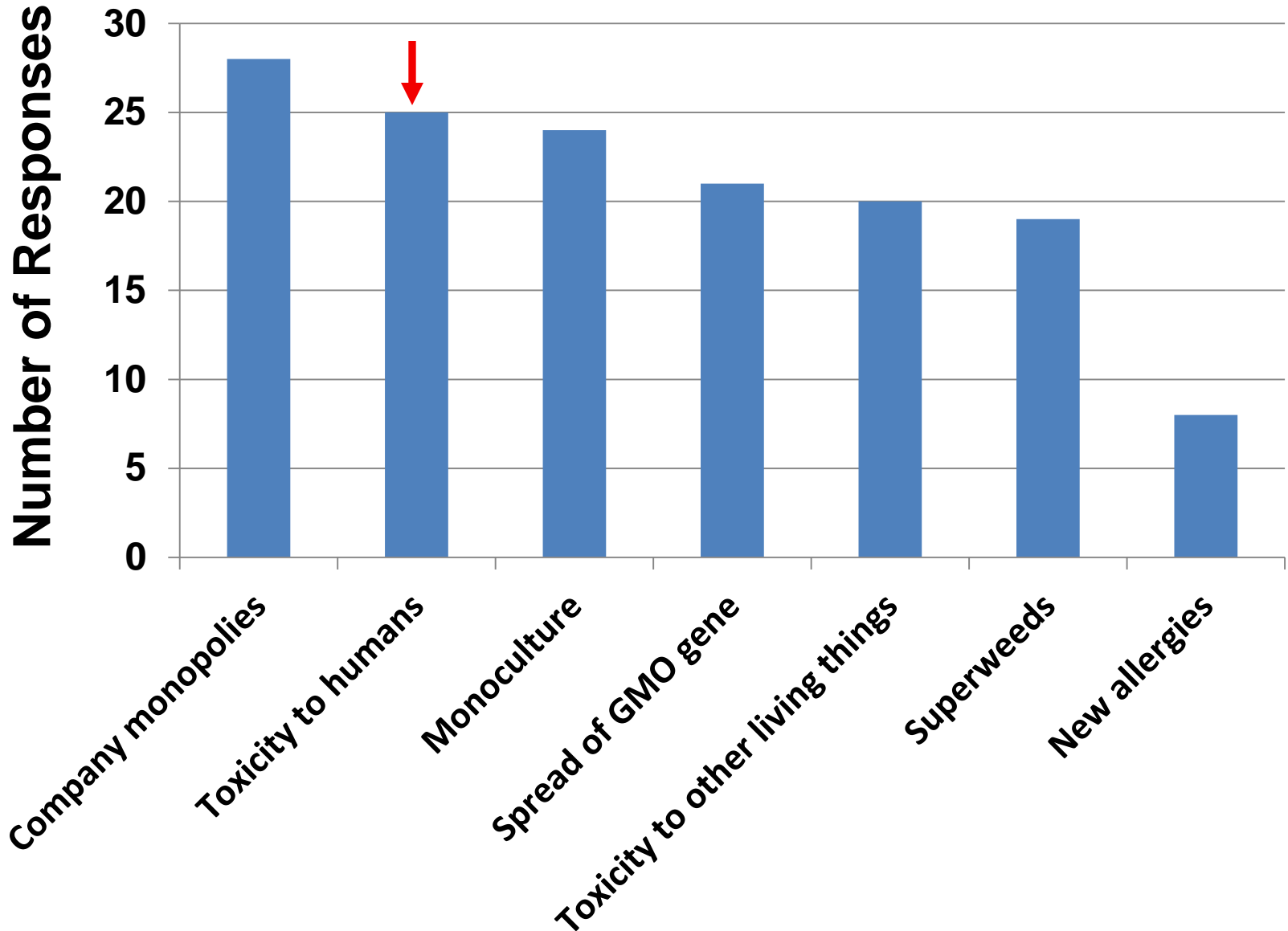
How do we put genes into plants?

Address concerns from last time.

A “good” example and “good” possibilities

Concerns of the Audience

Amherst MA- April 2014



➤ There is a lot of disagreement about the effects of existing GMOs on human health - **FALSE!!!**

➤ “No negative effects on human health”

- World Health Assoc.
- National Academy of Sciences
- American Assoc. Advancement of Sciences
- American Medical Assoc.
- European Food Safety Authority
- US EPA, US FDA, USDA
- Scientific Societies of UK, France, Brazil, etc.

INTERNATIONAL SCIENCE ORGANIZATIONS ON CROP BIOTECHNOLOGY SAFETY

GENETIC LITERACY PROJECT

WHERE SCIENCE TRUMPS IDEOLOGY

www.geneticliteracyproject.org



1

THE AMERICAN MEDICAL ASSOCIATION

(Chicago)

"There is no scientific justification for special labeling of genetically modified foods. Bioengineered foods have been consumed for close to 20 years, and during that time, no overt consequences on human health have been reported and/or substantiated in the peer-reviewed literature."

2

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

(Washington, D.C.)

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

3

THE NATIONAL ACADEMY OF SCIENCES

(Washington, D.C.)

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

4

FOOD STANDARDS AUSTRALIA NEW ZEALAND

(Australia & New Zealand)

"Gene technology has not been shown to introduce any new or altered hazards into the food supply, therefore the potential for long term risks associated with GM foods is considered to be no different to that for conventional foods already in the food supply."

5

THE FRENCH ACADEMY OF SCIENCE

(France)

"All criticisms against GMOs can be largely rejected on strictly scientific criteria."

6

THE ROYAL SOCIETY OF MEDICINE

(United Kingdom)

"Foods derived from GM crops have been consumed by hundreds of millions of people across the world for more than 15 years, with no reported ill effects (or legal cases related to human health), despite many of the consumers coming from that most litigious of countries, the USA."

7

THE EUROPEAN COMMISSION

(Belgium)

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

8

THE UNION OF GERMAN ACADEMICS OF SCIENCES AND HUMANITIES

(Germany)

"In consuming food derived from GM plants approved in the EU and in the USA, the risk is in no way higher than in the consumption of food from conventionally grown plants. On the contrary, in some cases food from GM plants appears to be superior in respect to health."

9

SEVEN OF THE WORLD'S ACADEMIES OF SCIENCES

(Brazil, China, India, Mexico, the Third World Academy of Sciences, the Royal Society, and the National Academy of Sciences of the U.S.)

"Foods can be produced through the use of GM technology that are more nutritious, stable in storage and in principle, health promoting—bringing benefits to consumers in both industrialized and developing nations."

10

WORLD HEALTH ORGANIZATION

(Switzerland)

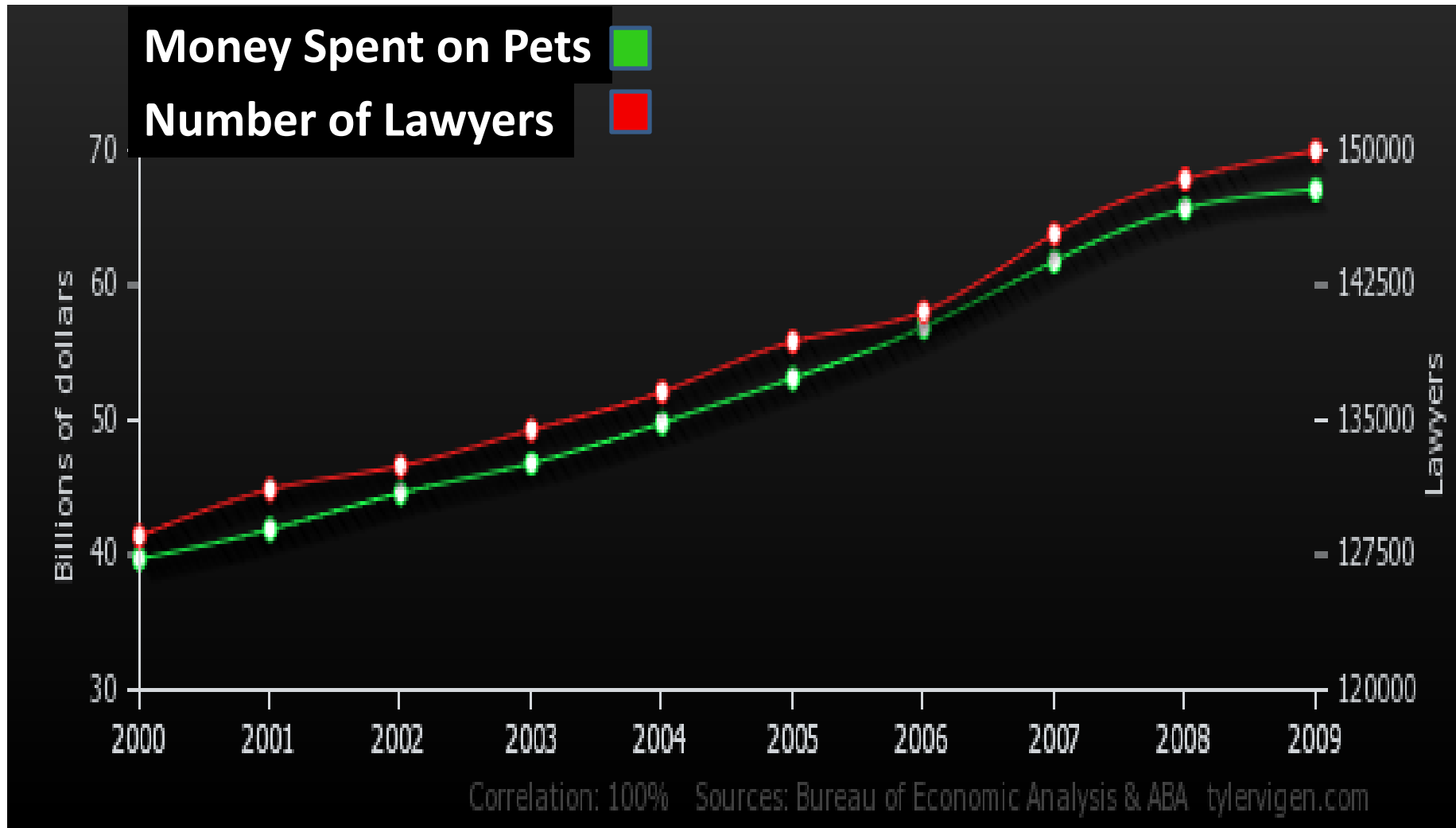
"No effects on human health have been shown as a result of the consumption of GM foods by the general population in the countries where they have been approved."

GMOs cause lots of public health problems such as autism, cancer, diabetes, etc.????

- When the stakes are high, people are more likely to jump to causal conclusions.
- In general, we should all be wary of our own bias; we like explanations. The media often concludes a causal relationship among correlated observances. Without clear reasons to accept causality, we should only accept correlation.
- Two events occurring in close proximity does not imply that one caused the other, even if it seems to make perfect sense.

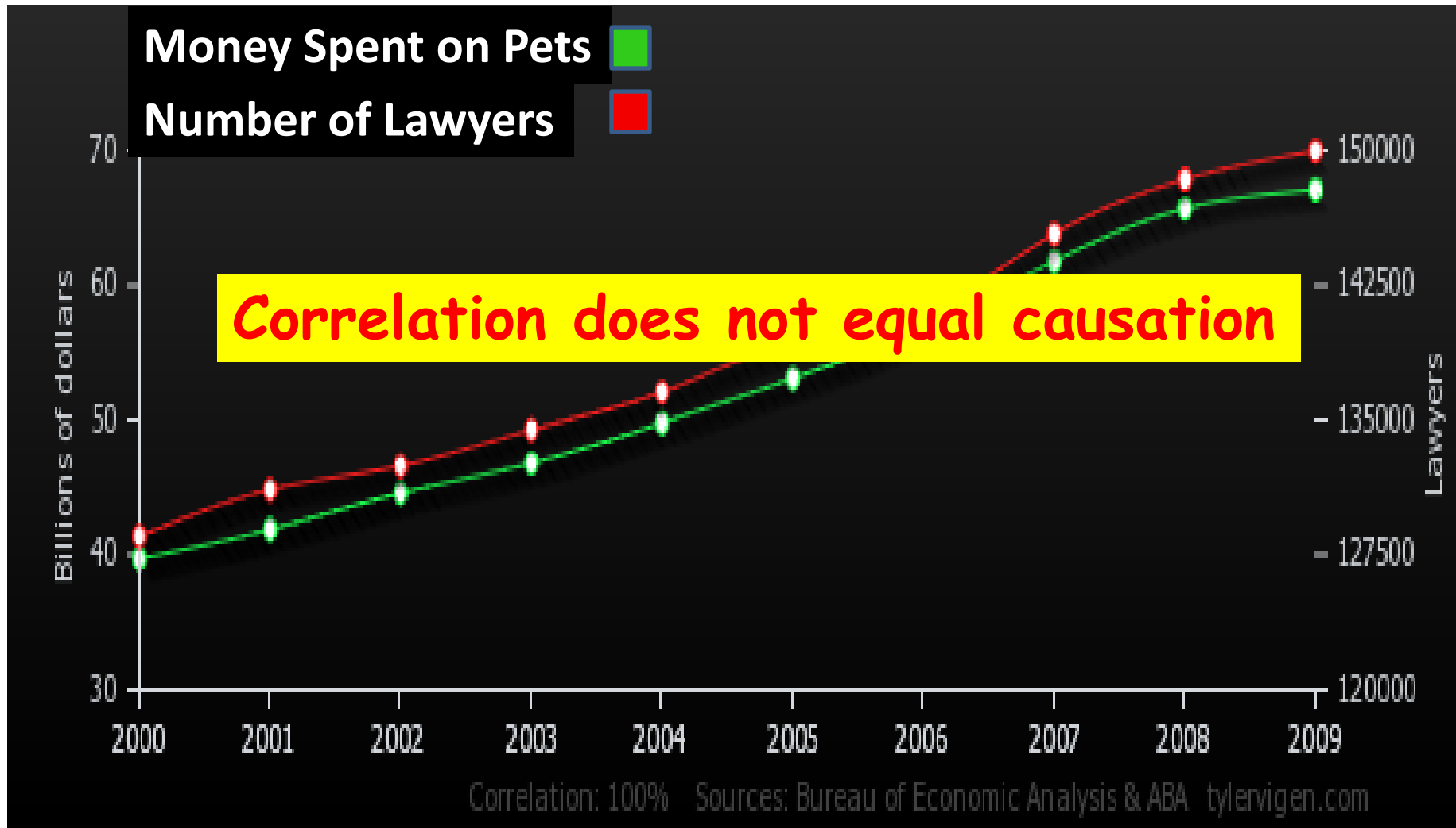
Money Spent on Pets (US)

Correlates with Number of Lawyers in CA

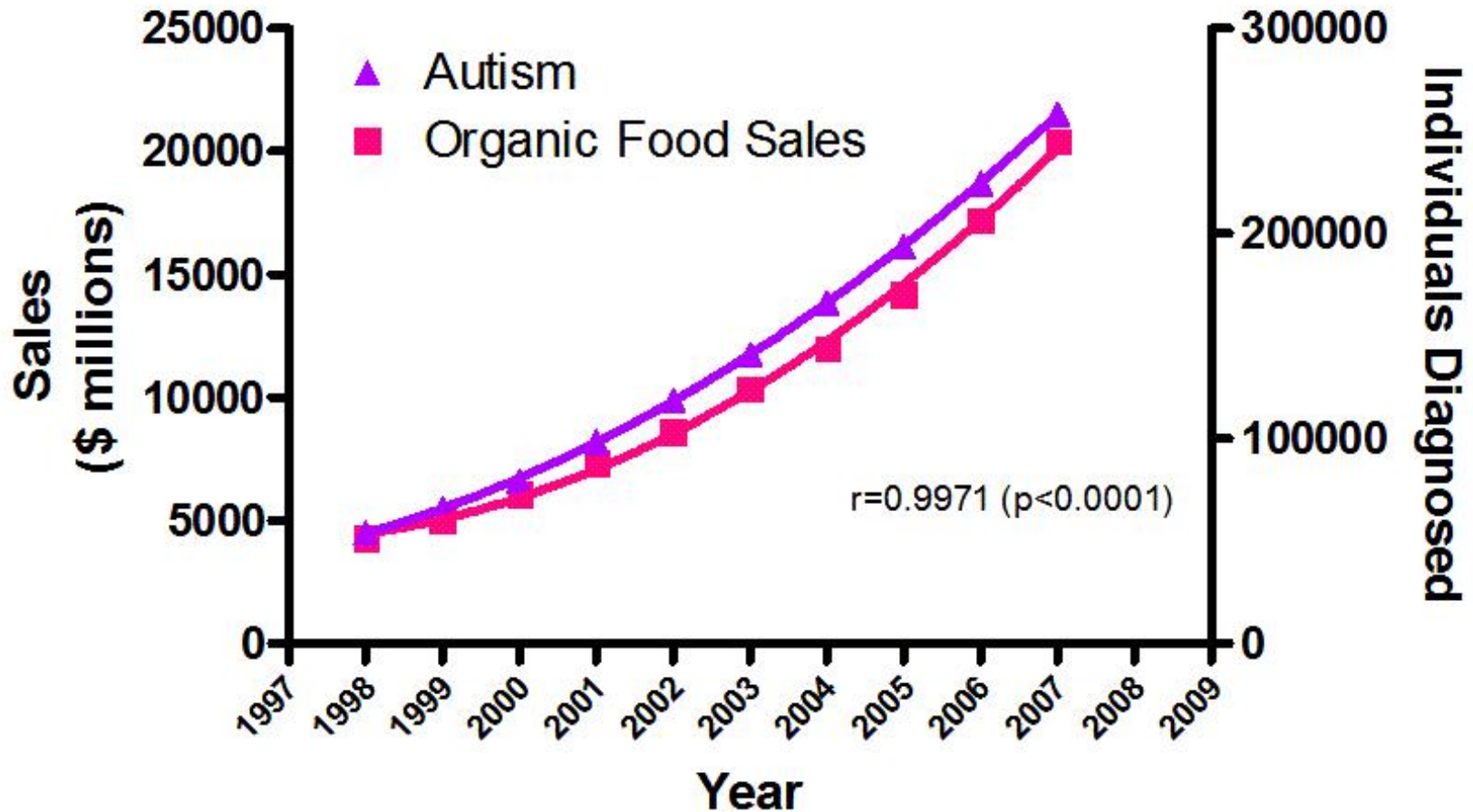


Money Spent on Pets (US)

Correlates with Number of Lawyers in CA



Bulletin: Rise in Organic Food closely related to rise in Autism



Sources: Organic Trade Association, 2011 Organic Industry Survey; U.S. Department of Education, Office of Special Education Programs, Data Analysis System (DANS), OMB# 1820-0043: "Children with Disabilities Receiving Special Education Under Part B of the Individuals with Disabilities Education Act"

Why I am perfectly happy eating herbicide tolerant plants!

The gene used specifies a protein found in all plants. We eat it all the time!

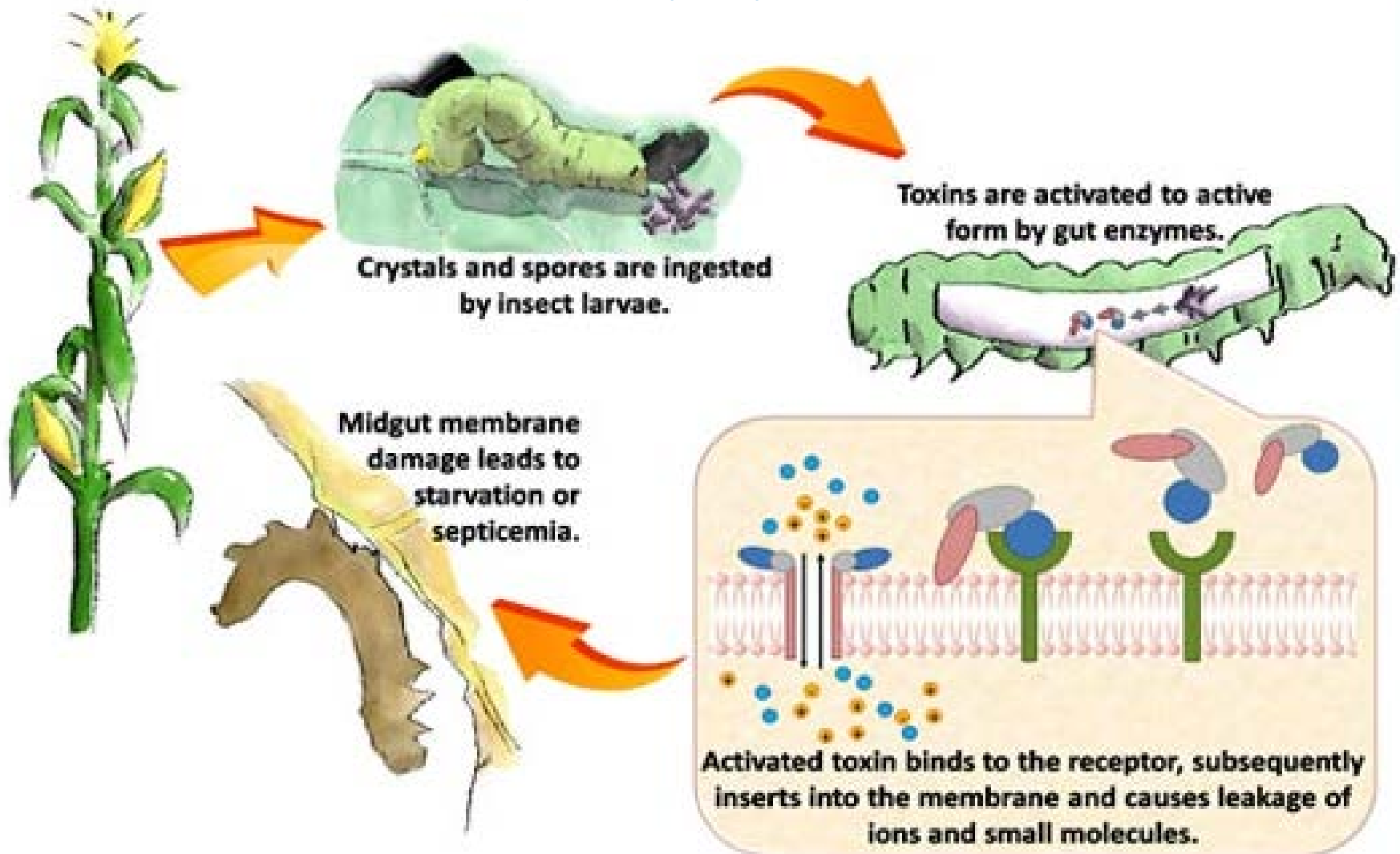
The change that makes the protein “herbicide tolerant” involves a few amino acids - less difference than there is between two different plants.

Why I am perfectly happy eating insect resistant plants!

The gene used (Bt toxin) specifies a protein that is digested in our stomach.

It is not digested by the insect, because, not surprisingly, they have very different "guts".

Bt toxin is very INSECT SPECIFIC, there are many types that affect only certain insects

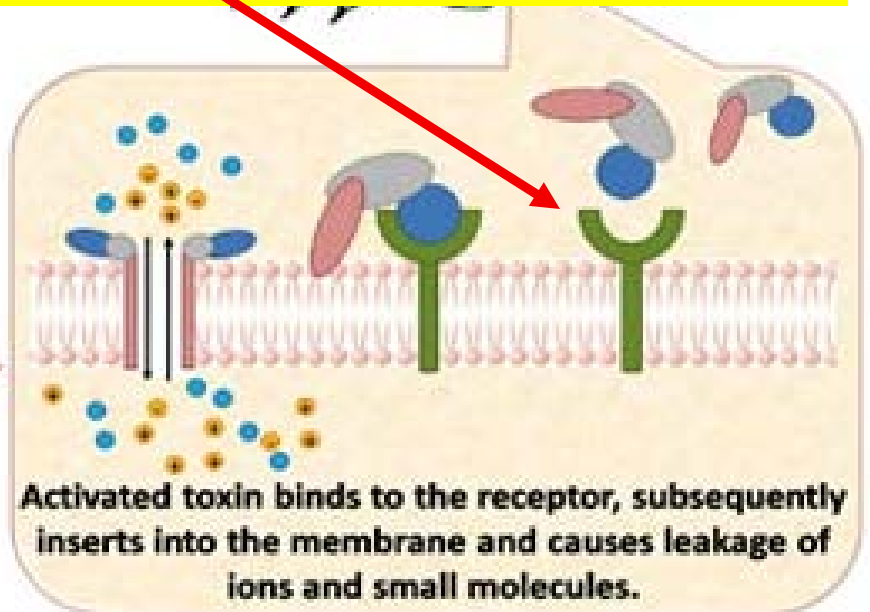


Bt toxin is very INSECT SPECIFIC, there are many types that affect only certain insects

In order to kill the insect, the Bt protein must be attached to a specific receptor found only in insects



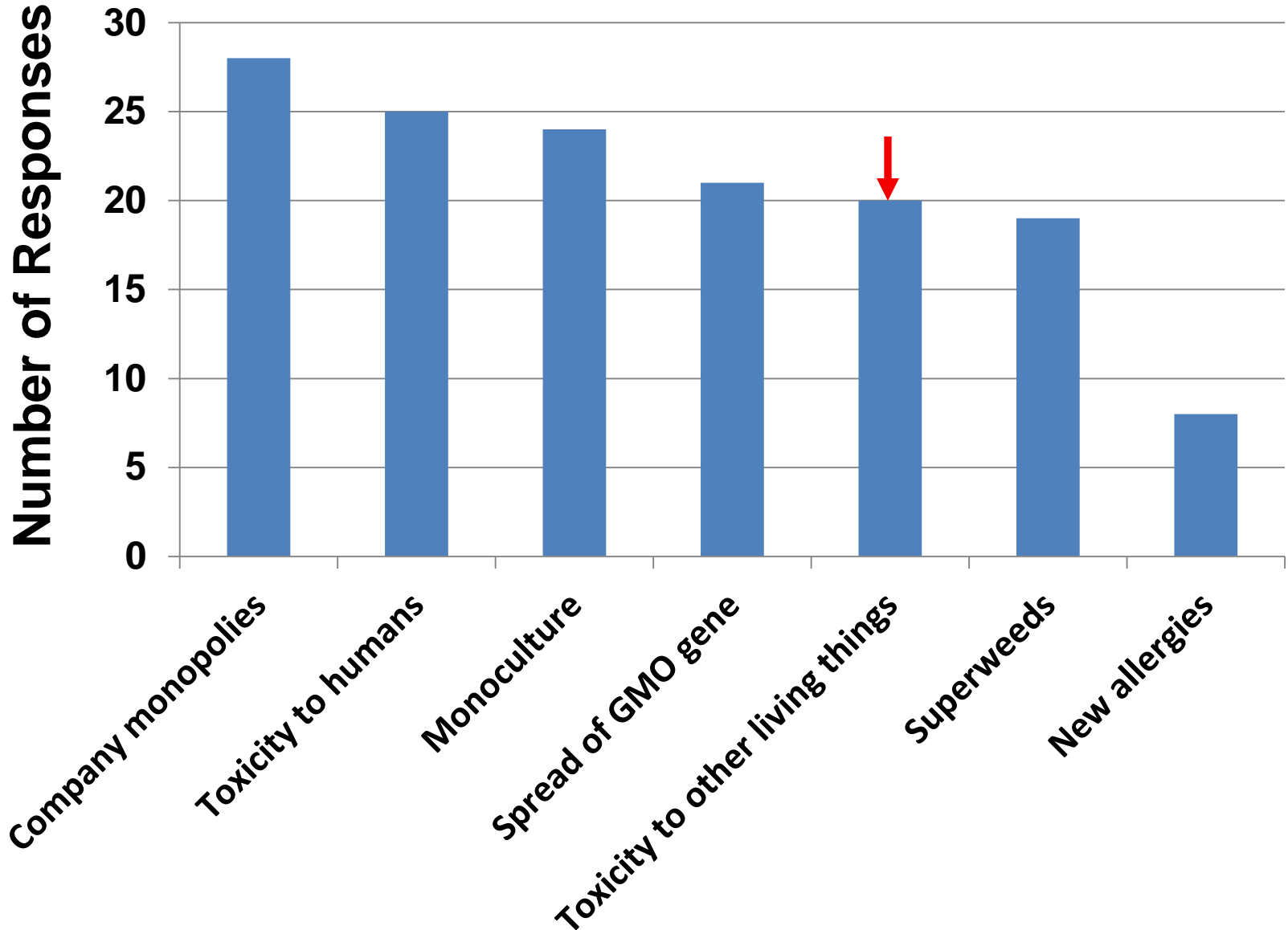
Midgut membrane damage leads to starvation or septicemia.



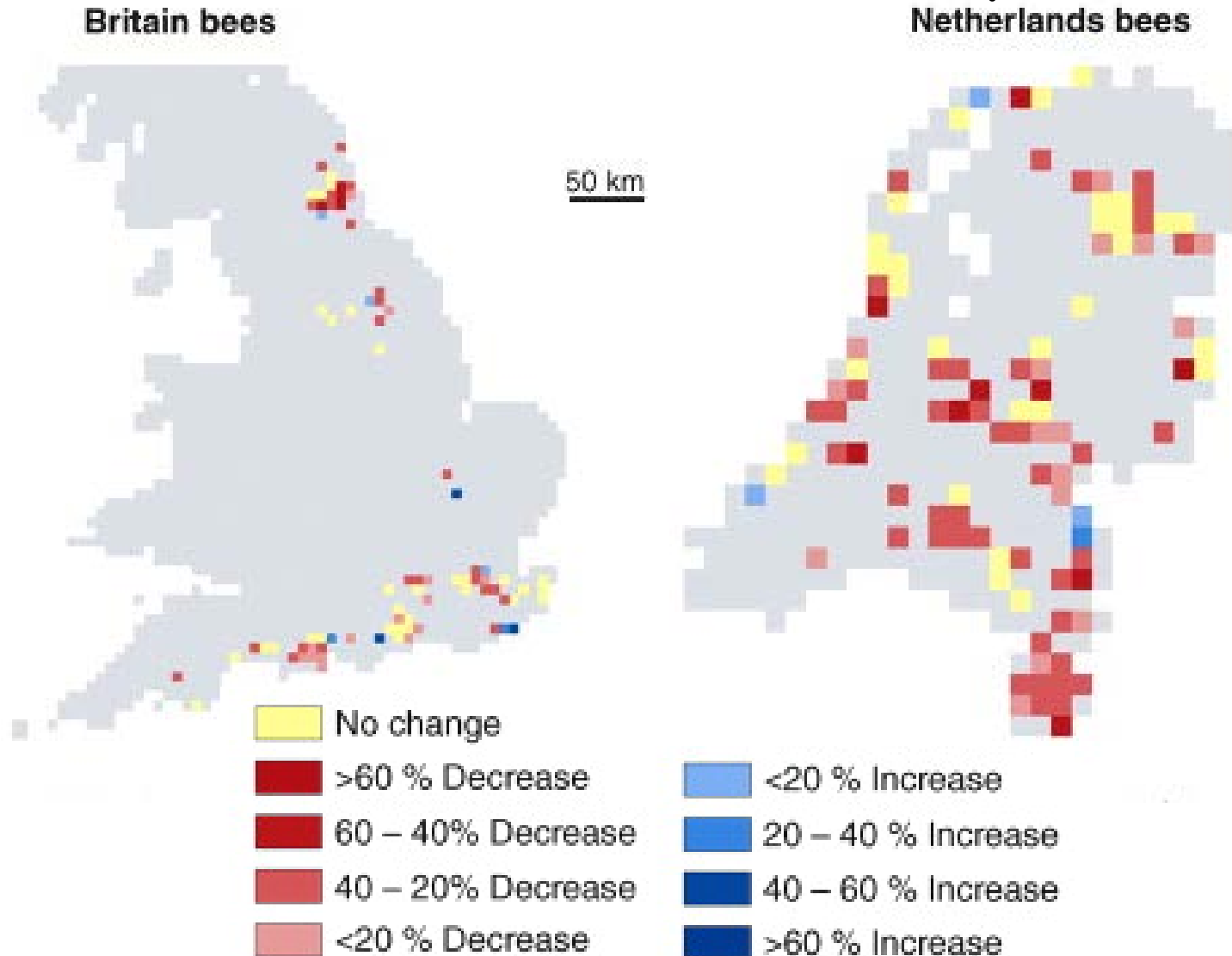
Activated toxin binds to the receptor, subsequently inserts into the membrane and causes leakage of ions and small molecules.

Concerns of the Audience

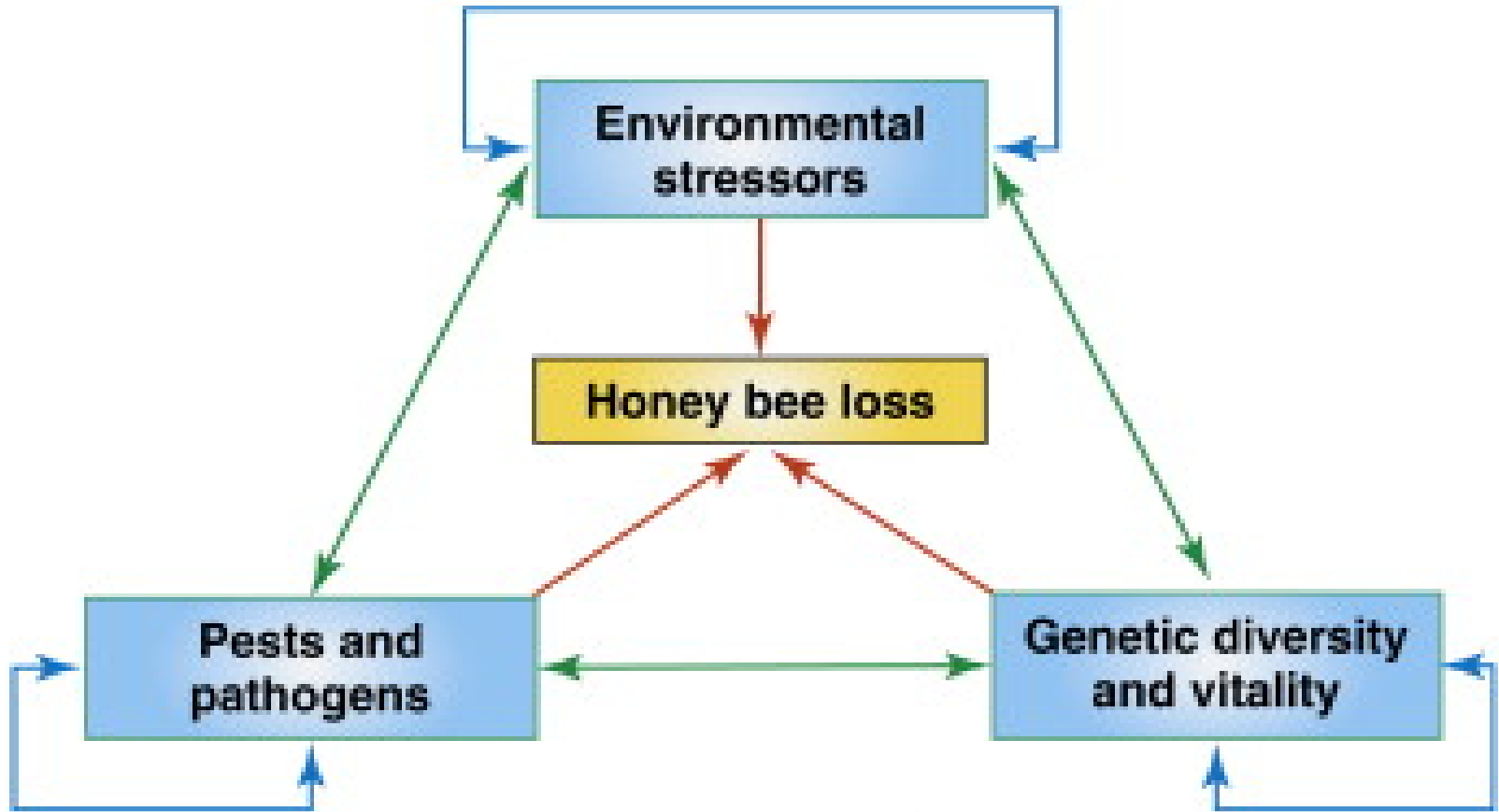
Amherst MA- April 2014



Decline in Bee Species: in Britain and the Netherlands, two countries without *GMO* crops



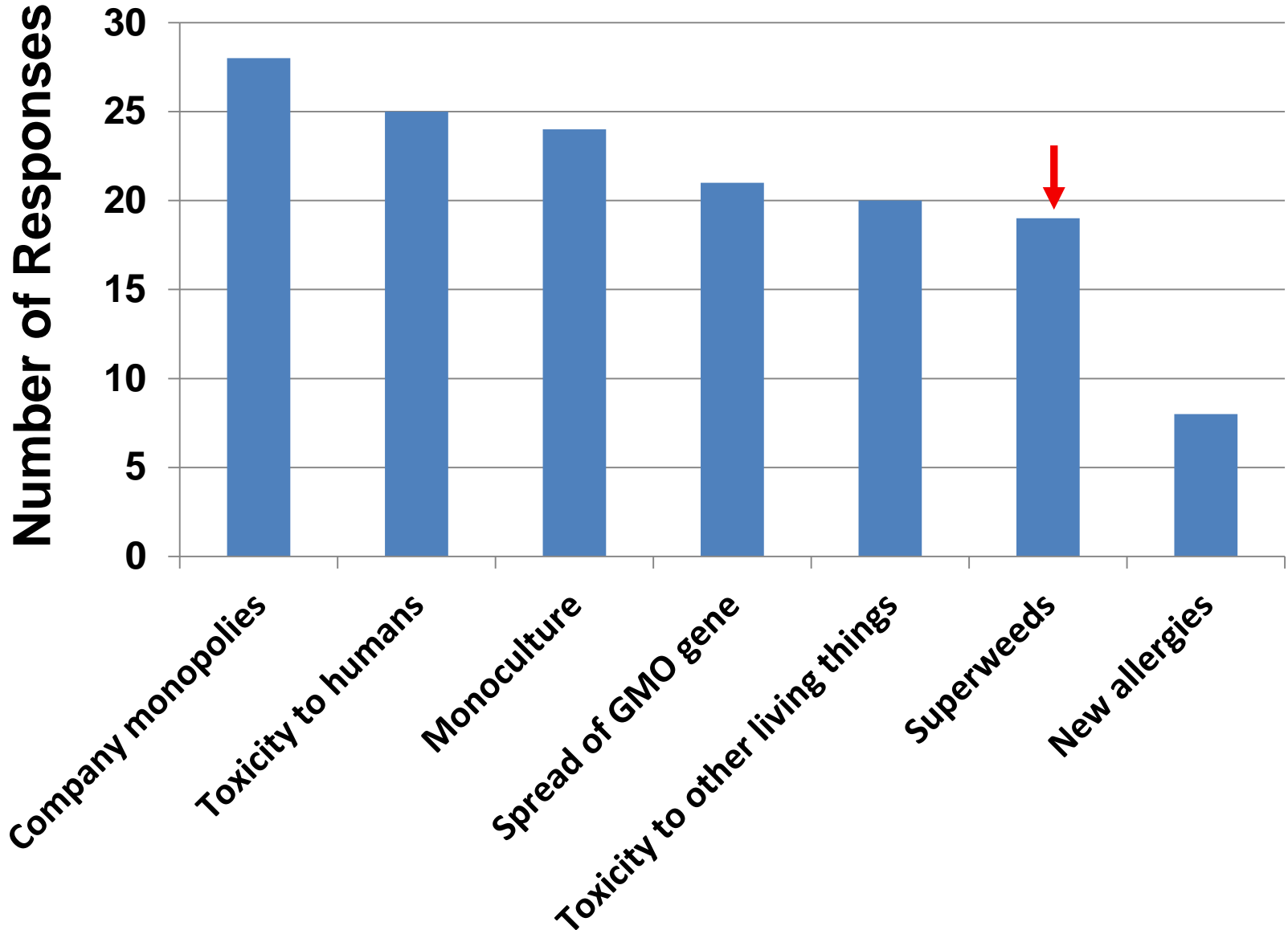
Causes of Decline in Bees:



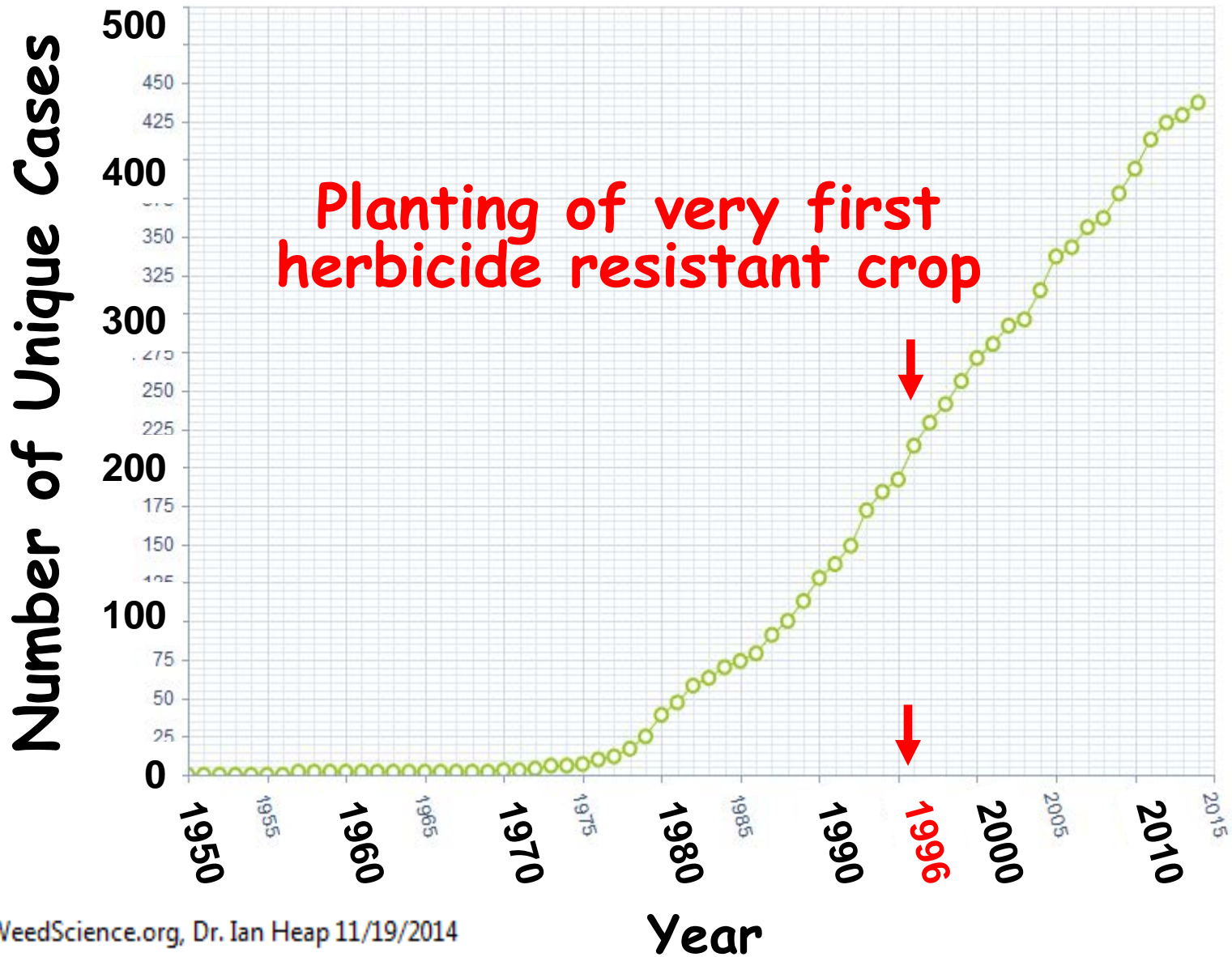
TRENDS in Ecology & Evolution

Concerns of the Audience

Amherst MA- April 2014



Chronological Increase in Number of Herbicide Resistant Weeds



GMOs Create "Superweeds"???

There are currently 436 unique cases of herbicide resistant weeds in 65 countries.

238 plant species
(22 herbicide
targets)

<u>Herbicide Target</u>	<u>Herbicide</u>	<u># Resistant Weeds</u>
Acetolactate Synthase	Chlorsulfuron	145
Photosystem II	Atrazine	72
Acetyl-CoA Carboxylase	Sethoxydim	46
PSI Electrons	Paraquat	31
EPSP synthase	Glyphosate	31
Synthetic Auxins	2,4-D	30

The only
GMO
herbicide
resistance



"Roundup Ready"



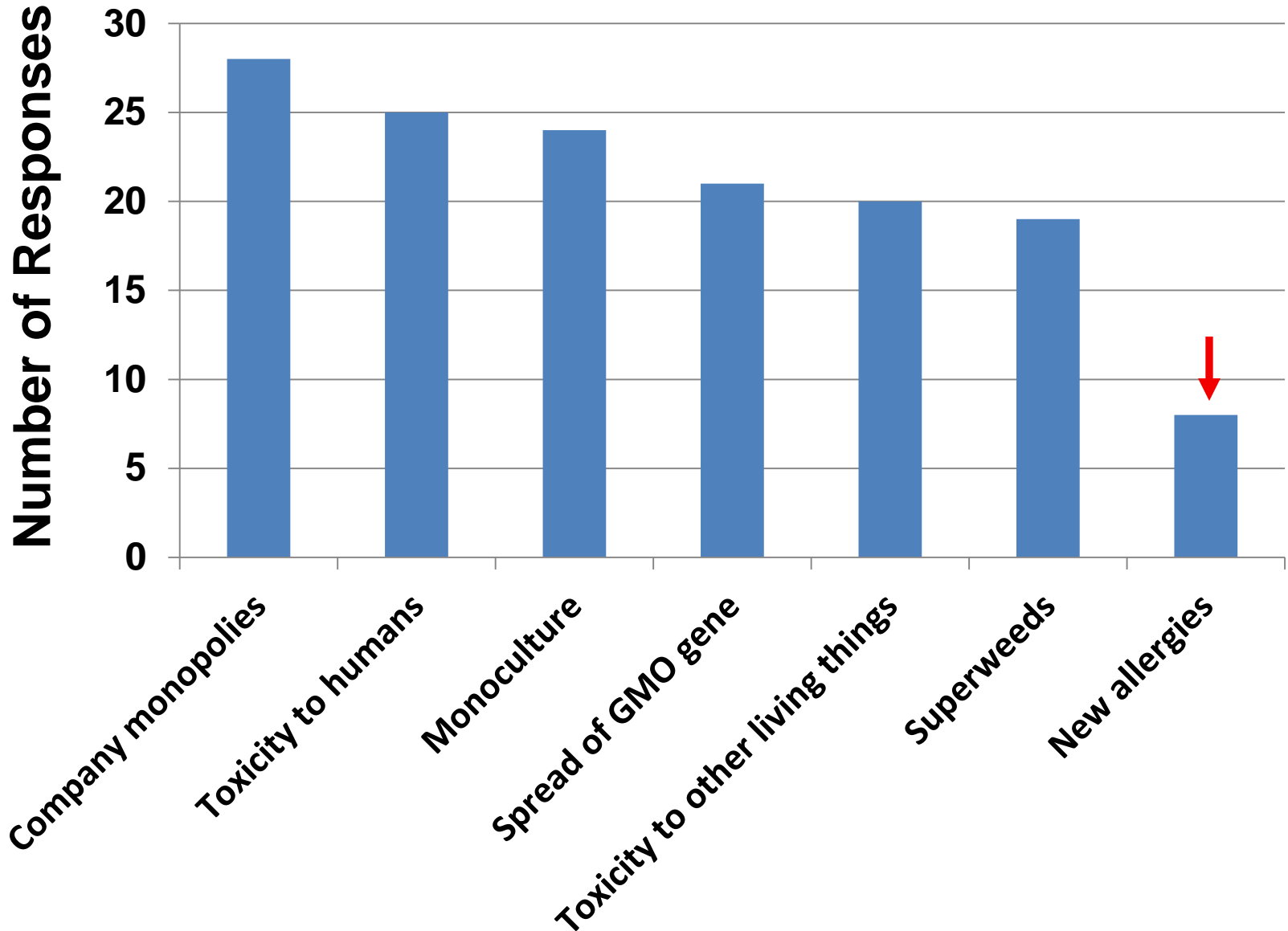
Data from 442 weed scientists around the world.

<http://www.weedscience.org/summary/home.aspx>

<http://www.weedscience.org/summary/SOASummary.aspx>

Concerns of the Audience

Amherst MA- April 2014



Can we use Genetic Engineering
to do "good things"???

Plant improvement that can't be done
by conventional breeding.

What needs to be done?

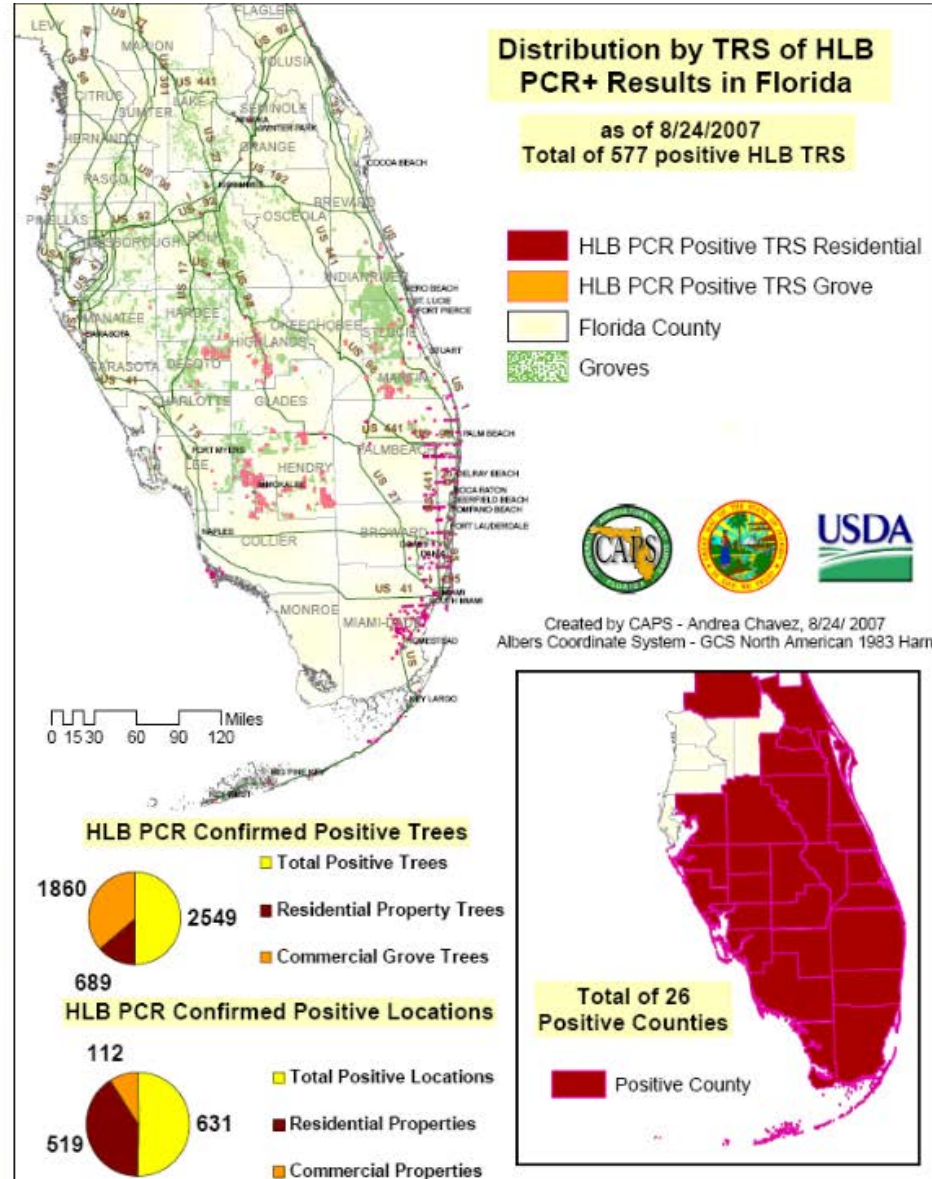
Worldwide, preharvest crop loss estimates:

- 13.8% due to insects and other arthropods
- 11.6% due to disease (fungi, bacteria, and viruses)
- 9.5% due to weeds

Total: 35%

Other losses due to stress:
drought, cold heat, salinization

The spread of Citrus Greening disease

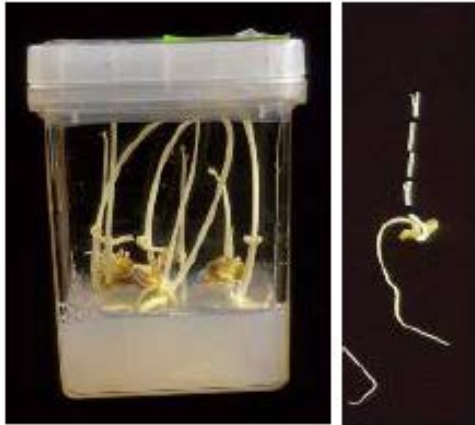


Unfortunately...
conventional breeding for Citrus Greening
resistance is not a viable option:

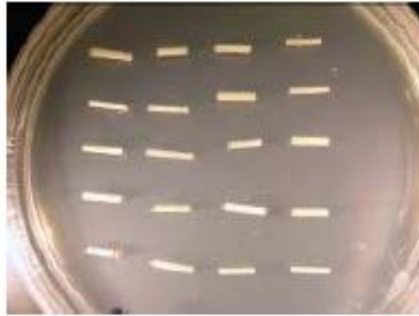
- No documented resistance to greening among edible citrus types
- *Citrus latipes* and *Citrus indica* may have some resistance - BUT THEY ARE NOT COMMERCIALY ACCEPTABLE

Citrus Transformation

Transformation



Selection



Regeneration



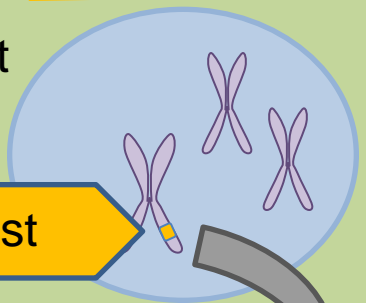
Evaluation





Source of gene
(disease-resistant
plant)

Gene of interest



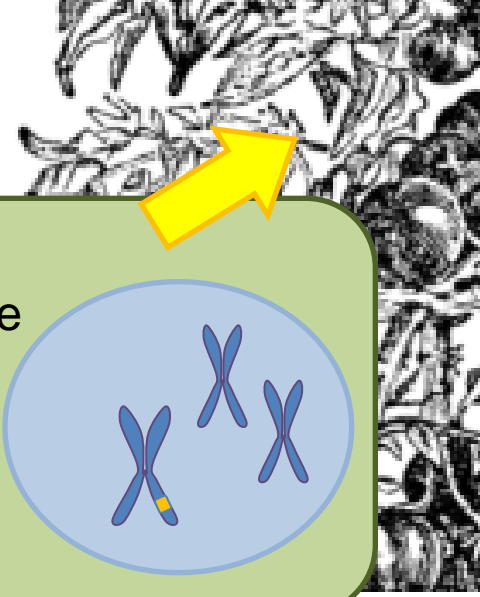
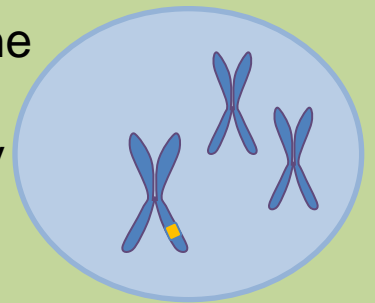
Isolate gene of
interest using
molecular
biology methods



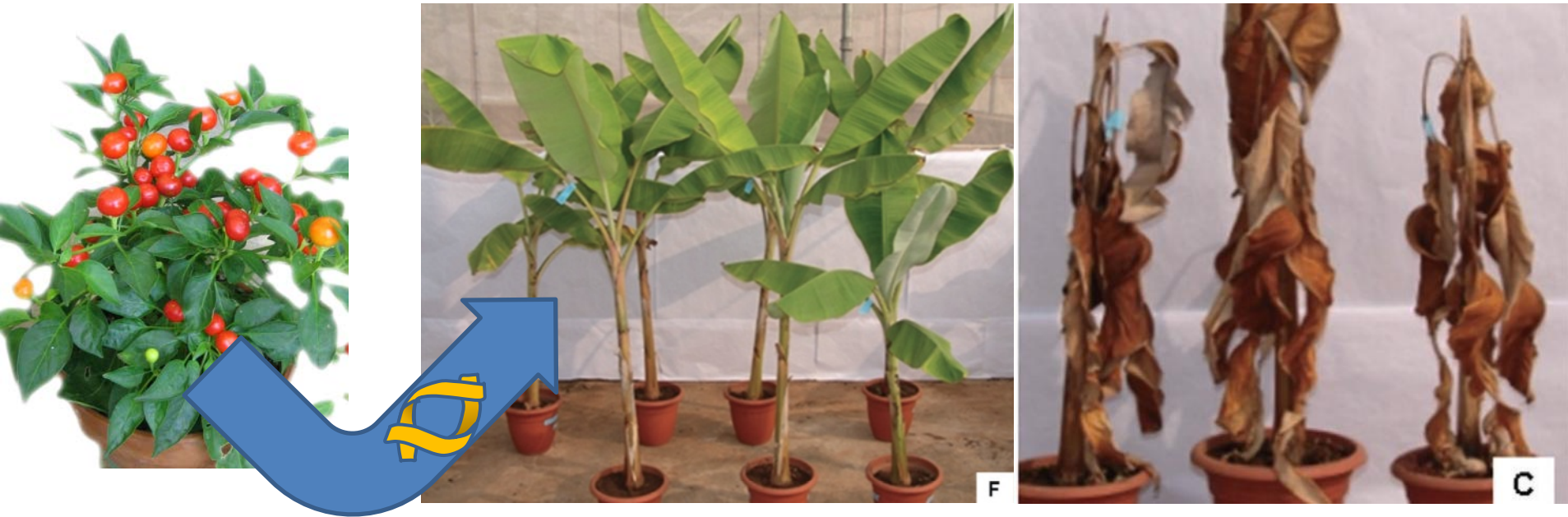
Recombine into
recipient plant DNA



Once a gene is
introduced into the
plant genome it
functions like any
other gene



GM Example: Disease resistant banana by introduction of a gene from pepper



Resistant

Susceptible

Banana bacterial wilt is destroying plants in eastern Africa. Transgenic plants carrying a resistance gene from pepper are resistant to the disease

GM Disease Resistant Papaya has replaced 80% of the Hawaiian Papaya crop

GM Crop Database

Database Product Description



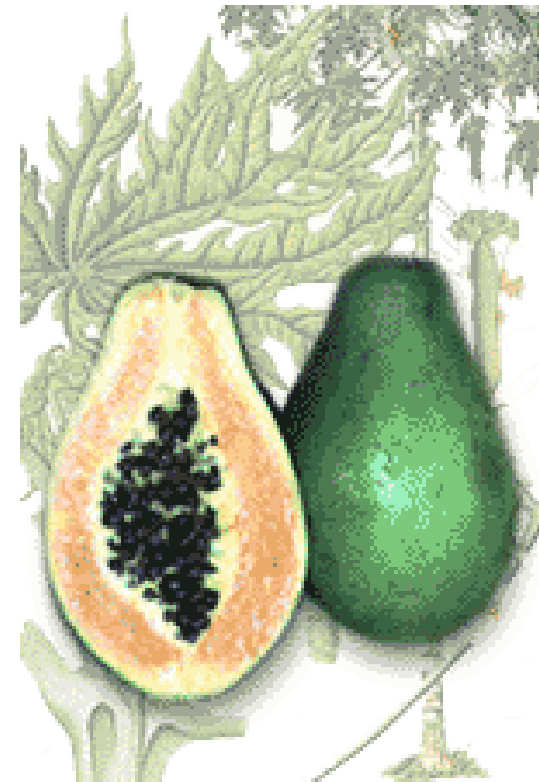
Show abstract



Print this page

UFL-X17CP-6 (X17-2)

Host Organism	<i>Carica papaya</i> L. (Papaya)
Trait	Resistance to viral infection, papaya ringspot virus (PRSV).
Trait Introduction	<i>Agrobacterium tumefaciens</i> -mediated plant transformation.
Proposed Use	Production of papaya for human consumption, either fresh or processed.
Company Information	University of Florida



http://cera-gmc.org/index.php?action=gm_crop_database

Transgenics have proven successful for other fruit crops



Papayas
Papaya ring spot
Viral disease



Apples
Fire blight
Bacterial disease



Plums
Plum pox
Viral disease

All commercial transgenic crops have been developed by large to mid-sized corporations.

Except:

Virus resistant papaya

Virus resistant plums (not yet commercial)

There has been, and continues to be significant research and discussion about the safety of *GMOs*, not only for human consumption, but also for the environment and the economy.

Some informative websites:



<http://www.biofortified.org/>



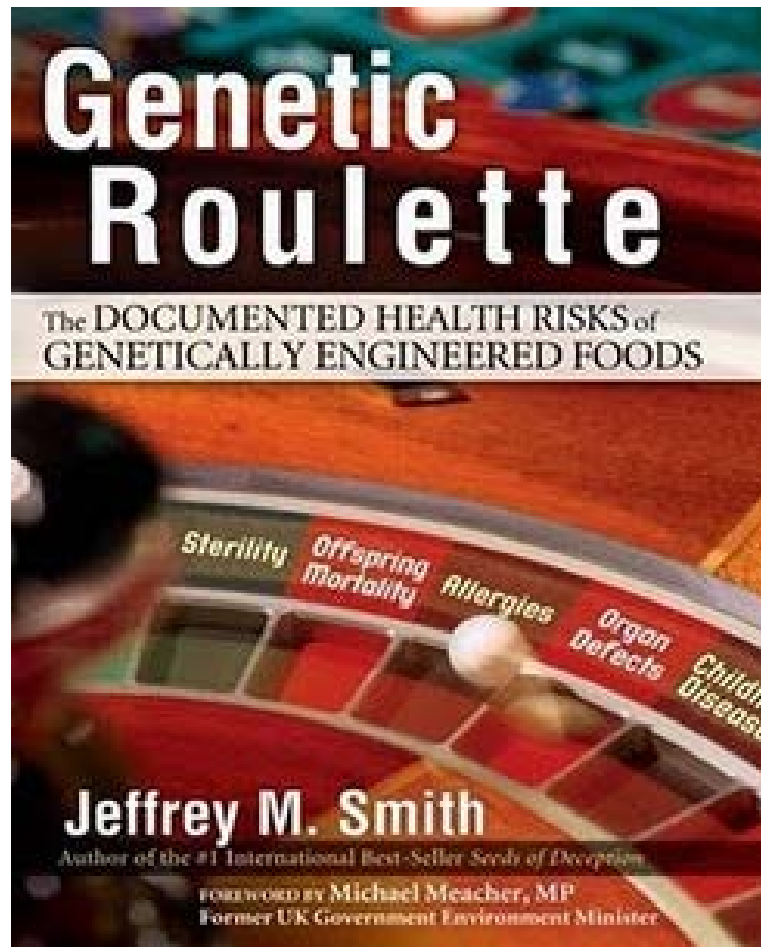
Center for
Environmental
Risk Assessment

http://cera-gmc.org/index.php?action=about_us



INTERNATIONAL SERVICE
FOR THE ACQUISITION
OF AGRI-BIOTECH
APPLICATIONS

<http://www.isaaa.org/inbrief/default.asp>



Please see the site below for a careful discussion of the misinformation presented in this book and video

<http://academicsreview.org/reviewed-content/genetic-roulette/>

Intellectual Property

Four firms (and subsidiaries):

- Bayer Cropscience
- DuPont
- Monsanto
- Syngenta

Own or co-own 80% of all biotech traits that have received regulatory approval.

- **Let's be passionate about the truth**

- **Don't accept everything you hear!**

- **Adhere to a scientific approach with important questions:**
 - **Are GMOs safe in your foods?**
 - **Are GMOs better or worse for the environment?**
 - **Are GMOs potentially helpful or hurtful to the future of agriculture?**
 - **Will GMOs put non-GE farmers out of business?**

Where to go from here?

- Each crop, each “trait” (modification) needs to be evaluated separately.
- We need more agricultural research
 - To understand how to combat pests and disease
 - To move away from monoculture towards sustainable practices

Genetic Modification Technology

Neil deGrasse Tyson—Astrophysicist, NOVA Host,
Science Communicator

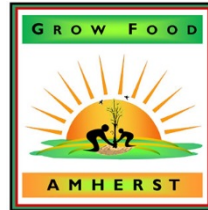
"If your objection to *GMOs* is the morality of selling non-perennial seed stocks, then focus on that.

If your objection to *GMOs* is the monopolistic conduct of agribusiness, then focus on that.

But to paint the entire concept of *GMO* with these particular issues is to blind yourself to the underlying truth of what humans have been doing -- and will continue to do -- to nature so that it best serves our survival.

That's what all organisms do when they can, or would do, if they could. Those that didn't, have gone extinct."

Thank you to my sponsors



Thanks to many members of my research lab over the last 29 years

Thank you for your attention!