



INTEGRATED PEST MANAGEMENT

Unit 2 Section 3 Lesson 8 "GM"... It's Not Just a Car Anymore!

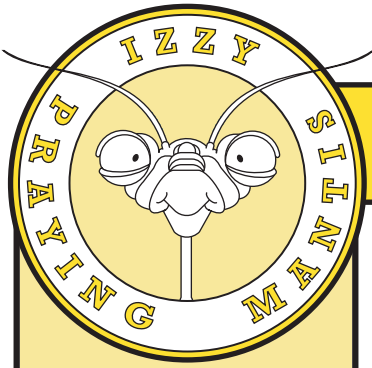
Focus Areas: Pest Control Methods -
Cultural; Science, Computer
Technology, Language Arts

Focus Skills: Presenting evidence to
persuade

Level of Involvement: AVERAGE

Unit 2 Section 3 Lesson 8: "GM"... It's Not Just a Car
Anymore!





**Dedicated
to Reducing
Pesticides**



**University of
Connecticut**
College of Agriculture
and Natural Resources
Cooperative Extension System

Unit 2 Section 3 Lesson 8: "GM"...It's Not Just a Car Anymore!

Focus Areas: Pest Control Methods - Cultural; Science, Computer Technology, Language Arts

Focus Skills: Presenting evidence to persuade

Level of Involvement: AVERAGE

Objectives

- * To research a current scientific topic
- * To formulate an opinion on a current scientific dilemma
- * To defend that opinion using a debate format

Essential Question

Should genetic modification continue to be used as a viable method to increase a food supply?

Essential Understanding

GM, genetic modification of agricultural products is possible, but it is controversial.

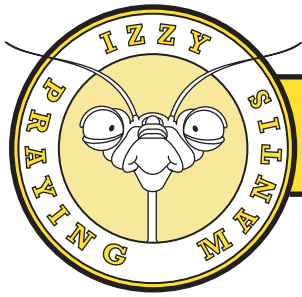
Background

- * Preview the PBS video *Harvest of Fear* and read *Harvest of Fear Synopsis*
- * Handout 1 *Food Fright*
- * Article *Genetically Modified Foods: Are They Safe?*
- * ARS News Service web page on *Bt corn risk to monarch butterflies*

Vocabulary



GM acronym for genetically modified plants or animals



Unit 2 Section 3 Lesson 8: "GM"...It's Not Just a Car Anymore!

Challenge

Form a pro or con opinion about genetically modified agricultural products!

Logistics

Time: three classes:

1. a 45-minute class period to research online and print resources
2. a 45-minute class period to explain debate format, and allow teams to prepare for debate
3. a 45-minute class period for debate

Group size: 4 to 24 (the group should be divisible by 4 or 5 to accommodate team needs in the debate segment of lesson)

Space: a computer lab for research and a room with group seating for debate

Materials



Harvest of Fear video

Harvest of Fear Synopsis *

article Genetically Modified Foods: Are They Safe? *

computers with Internet access

ARS News web page on *Bt* Corn and risk to monarch butterflies *

access to recent publications

Handout 1 Food Fright *

Handout 2 Slow Peaches *

Handout 3 Procedure for Debate *

Handout 4 Student Evaluation of a Debate *

Assessment for a Position Paper *

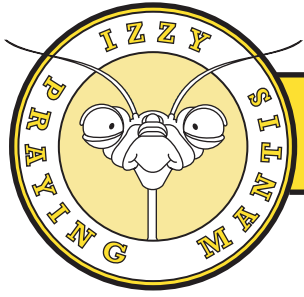
Assessment for an Editorial or Debate *

Assessment for a Graph *

* single copy provided

Preparations

1. Prepare copies of related articles, rules of debate and evaluation sheets (one per individual).



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Preparations (continued)

2. Arrange for use of computer lab if necessary.

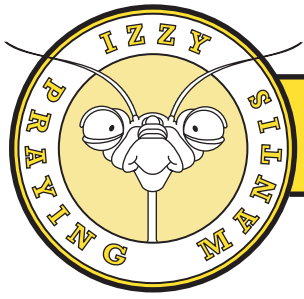
Activity

Introduction

1. Introduce the term GM as it applies to genetically modified agricultural products.
2. Have participants share their personal background knowledge of topic.
3. Distribute background readings and allow time to read.
4. Distribute the debate rules for both opposing teams.
5. Divide group into teams of 4 or 5 and have them select (or assign) which side they will represent.

Involvement

1. Participants search websites and take notes to support their positions: pro or con GM usage in agriculture.
2. Review rules and procedure for debate.
3. Distribute evaluation sheets and have individuals fill out biographical information.
4. The group works to develop presentation with arguments and rebuttals two minutes in length. The group assigns members to debate order.
5. Collect evaluation sheets.
6. Review Handout 3 Procedure for Debate, particularly #5 and #6 of **Preparation** Section.



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Activity

Involvement (continued)

- Option #1** Hold debate(s). **Note:** If you have more than 1 team per position, number pro and con teams and draw numbers to determine which teams debate each other.
- Option #2** Hold an informal debate in which pro (P) and con (C) take turns presenting evidence to support their positions. **Note:** An argument must be refuted prior to a new argument being introduced. Therefore, the pattern is support (Pro or Con) followed by rebuttal, followed by new argument by side that rebutted, etc. (pattern P-C-C-P-P-C-C, etc.). Record the arguments on chart paper.

Follow Up

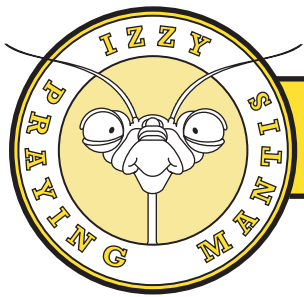
1. Discuss with group which side presented the stronger case. Be sure participants defend their choice with reasons.
2. Poll the group to determine if they are still opposed or supportive of GM foods in the products they use. How many people have changed their opinion after the research/debate process?

Follow Through

Focus Areas: Math

Focus Skills: Taking a poll, creating a graph

1. Have participants (with leader or parent) poll shoppers at a local supermarket to determine how many of them are:
 - a) Aware of GM ingredients in the foods they eat
 - b) Aware but unconcerned about the use of GM ingredients in the foods they eat
 - c) Aware and concerned about the use of GM ingredients in the foods they eat



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Follow Through (continued)

2. Record the reasons.
3. Graph the results.

Answer Key

None Needed

Assessment

1. Use the evaluation sheets for the debate and/or resulting graphs from **Follow Through** activities.
2. Have each participant write a position paper.

Resources



Internet Websites

<http://www.foodfuture.org.uk/gmcrops/regulation.htm>

<http://www.foodfuture.org.uk/gmcrops/benefits.htm>

<http://www.foodfuture.org.uk/gmcrops/therisks.htm>

<http://www.foodfuture.org.uk/whataregmcrops/.htm>

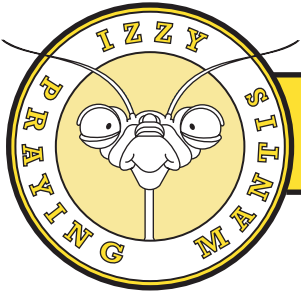
<http://www.pbs.org/wgbh/harvest/viewpoints/benefits.html>

<http://www.pbs.org/wgbh/harvest/viewpoints/risks.html>

<http://www.pbs.org/wgbh/harvest/exist/> [interactive excellent]

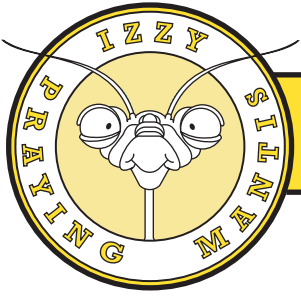
http://dailynews.yahoo.com/fc/Science/Genetically_Modified_Food/

<http://www.newscientist.com/hottopics/gm/> (multiple listings)



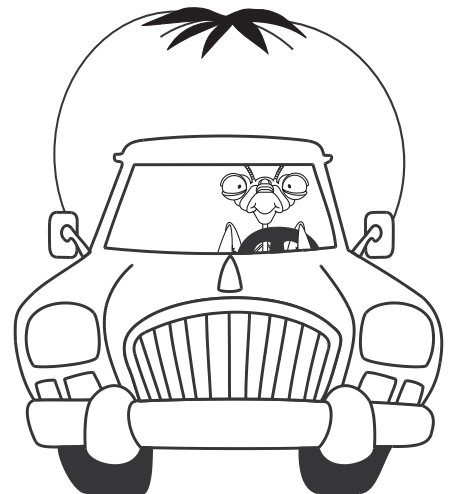
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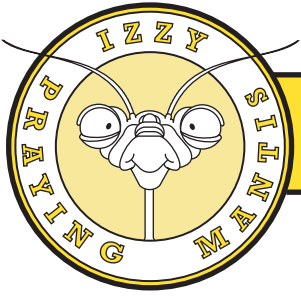
Notes



Unit 2 Section 3 Lesson 8: "GM"...It's Not Just a Car Anymore!

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Synopsis

Harvest of Fear

In "Harvest of Fear," FRONTLINE and NOVA explore the intensifying debate over genetically-modified (GM) food crops. Interviewing scientists, farmers, biotech and food industry representatives, U.S. regulators, and critics of biotechnology, this two-hour report presents both sides of the debate - exploring the risks and benefits, the hopes and fears, of this new technology.

Hugh Grant, an executive with Monsanto - the leader in agricultural biotechnology-- and farmers like Gerald Tumbleson in Minnesota, tout the benefits of GM crops. They say they can help feed the world and preserve the environment by reducing the need for pesticides. One example: by inserting a gene from the organic pesticide *Bacillus thuringiensis* (*Bt*) into crops such as cotton, corn, and apples, farmers can grow these crops using very little pesticide.

Even more promising is the hope that GM technology can save lives. Scientists like Charles Arntzen are working on GM techniques to make edible vaccines - inside bananas and other foods - to combat viruses in developing countries.

But others aren't so sure. Organic farmer Paul Muller argues that GM crops can increase pest resistance and have other bad consequences for sustainable agriculture. And opposition groups such as Greenpeace, Friends of the Earth and the Union of Concerned Scientists are concerned that in redesigning plants using genes from other organisms - even other species - a new, possibly reckless experiment is underway with unforeseen impacts (video) on nature and the environment.

"Harvest of Fear" chronicles how in Europe, opponents like Charles Margulis with Greenpeace, campaigned and nearly halted, the development and use of genetically-modified foods. However, in the U.S., genetically modified crops like corn and soybeans have been in the food supply since 1996 - in everything from cereals to sodas. Interviewing scientists like Martina McGloughlin and U.S. regulators such as Jim Maryanski with the FDA, this report asks the key question: Is GM food safe to eat?

This FRONTLINE/NOVA report also examines the contrasting public perceptions about GM foods and what explains it. In Europe, there is skittishness about this new technology. But in the U.S., focus group research reveals that American consumers' top priority is 'choice' - if GM foods are labeled, it will help reduce fear.



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Synopsis

Harvest of Fear

Throughout this FRONTLINE/NOVA report, cameras take viewers inside the laboratories of scientists developing the latest applications of GM technology, and show anti-GM demonstrations in Europe and the U.S., including violent tactics employed by some opponents. Some farmers had genetically-modified crops hacked away during the night by "eco-terrorists." And members of the Earth Liberation Front claimed responsibility for a fire at Michigan State University that destroyed a building being used for work related to agricultural biotechnology.

Such demonstrations and protests, however, haven't deterred the technology's supporters. Pandora's box has been opened, they say. No amount of protests or violent tactics can put the lid back on. "We'll not be able to stop this technology," USDA Secretary Dan Glickman says. "Science will march forward."

<http://www.pbs.org/wgbh/harvest/etc/synopsis.html>



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Handout 1

Food Fright

By Melanie LeTourneau

New Frankenstein foods have become the target of protests in Europe. Why are they so controversial?

At public school cafeterias in Berkeley, Calif. students can order prune burgers, rice cakes, and other tasty treats. What they can't order is anything made from products that have been genetically modified. In a genetically modified (GM) plant, the DNA has been altered to give the plant new characteristics.

The Berkeley Unified School Board is not the only group that has taken a stand against genetically modified foods. Anti-GM food protests have sprouted up elsewhere, particularly in Europe, where genetically modified crops are called Frankenstein foods.

So what's all the fuss about? Here are two sides of the issue:

More than 28 million hectares (70 million acres) of GM crops now grow in eight different countries, including the United States. GM crops are harvested and turned into everything from potato chips to taco shells to soft drinks.

Why are GM foods so popular? Many GM crops have been developed to help farmers cut down on the amount of poisonous pesticides they need to use on crops.





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Handout 1

Food Fright (continued)

Scientists studying a common soil bacterium (*Bacillus thuringiensis*, *Bt*) found that the bacterium makes its own pesticide, a toxic protein that kills insects but doesn't harm people. The scientists then pin-pointed the *Bt* gene that controls production of the toxic protein. A gene is a segment of an organism's DNA.

Scientists removed the *Bt* gene from the bacterium and put it in the DNA of several crop plants, including potatoes, cotton, and corn. When a bug takes a bite out of those genetically modified crops, the bug keels over and dies.

By manipulating other plant genes, biotechnology engineers have also created soybean and corn crops that are resistant to a popular weed killer called Roundup. Now farmers can spray their fields with Roundup to wipe out weeds without harming their crops.

Tastier Food

Experiments under way in several labs aim to create other beneficial types of GM foods, including starchier potatoes and caffeine-free coffee beans. Genetic engineers are even trying to transfer genes from a coldwater fish to make a frost-resistant tomato.

A low-sugar GM strawberry now in the works might one day allow people with health problems such as diabetes to enjoy the little juicy red fruits again. Diabetes is an inability to produce insulin, a hormone that helps regulate blood sugar levels. GM beans and grains supercharged with protein might help people at risk of developing kwashiorkor. Kwashiorkor, a disease caused by a severe lack of protein, is common in parts of the world where there are severe food shortages.

Commenting on GM foods, Jonathon Jones, a British researcher, said: The future benefits will be enormous, and the best is yet to come.

To some people, GM foods are no different from unmodified foods. A tomato is a tomato is a tomato, said Brian Sansoni, a representative of the Grocery Manufacturers of America.

Critics of GM food dispute Sansoni's opinion. They worry about the harm that GM crops might do to people, other animals, and plants.



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Handout 1

Food Fright (continued)

In a recent lab study conducted at Cornell University, scientists tested pollen made by *Bt* corn, which makes up one-fourth of the U.S. corn crop. The scientists sprinkled the pollen onto milkweed, a plant that makes a milky juice and is the only known food source of the monarch butterfly caterpillar. Within four days of munching on the milkweed leaves, almost half of a test group of caterpillars had died. Monarchs are considered to be a flagship species for conservation, said Cornell researcher Linda Raynor, "This is a warning bell."

In a similar experiment done by the the Scottish Crop Research Institute, scientists studied ladybugs feeding on aphids that had eaten GM potatoes. The ladybugs laid fewer eggs than normal and died sooner than usual.

Another nontarget insect affected by *Bt* crops in lab experiments was the lacewing caterpillar. In one experiment, more than half of a group of lacewings died after eating corn borer insects that had consumed *Bt* corn.

Tougher Bugs

Some insects that aren't killed by GM foods might find themselves made stronger. How so? The insecticides used to protect most of today's crops are sprayed on the crops when needed and decay quickly in the environment. But GM plants produce a continuous level of insecticide. Insect species feeding on those crops may develop resistance to the plants and could do so in a hurry, say the critics. Insects may also develop a resistance to the insecticide *Bt*.

At a forum on GM food held last year in Canada, scientists raised yet another concern. GM crops that have been made resistant to the Roundup herbicide might crossbreed with wild plants, creating superweeds that could take over whole fields.

So where do you stand? Should GM foods be banned in the United States, as they are in parts of Europe? Or do their benefits outweigh any of the risks they might carry?



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ARS News Service

Agricultural Research Service, USDA

Kim Kaplan, (301) 504-1637, Kaplan@ars.usda.gov

October 5, 2001

Information about *Bt* corn's impact on monarch butterflies is now available on a web page (<http://www.ars.usda.gov/is/br/btcorn/>) from the Agricultural Research Service. The core of the web page is research coordinated by ARS and recently published in the Proceedings of the National Academy of Sciences.

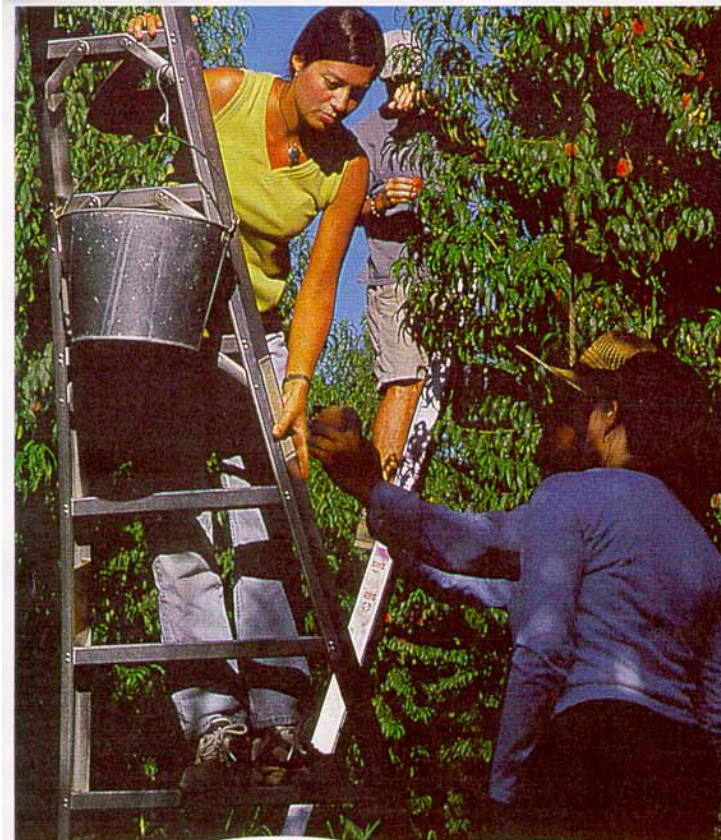
That *Bt* corn might present a risk became a matter of scientific and public concern when a small study in 1999 indicated caterpillars suffered when given no choice but to feed on milkweed leaves heavily dusted with *Bt* corn pollen. *Bacillus thuringiensis* (*Bt*) is a soil bacterium used as an effective alternative to chemical insecticides for controlling moth pests.

Two major questions needed to be scientifically answered to establish whether *Bt* corn actually posed a threat to monarch caterpillars - the direct toxicity of *Bt* pollen for caterpillars and the likelihood that caterpillars might be exposed to that much pollen, according to entomologist Richard L. Hellmich with the ARS Corn Insects and Crops Genetics Research Unit in Ames, Iowa. (<http://cicgr.agron.iastate.edu/CICGR/home.html>)

The studies found monarch caterpillars are not very sensitive to pollen from most types of *Bt* corn, and that caterpillar exposure to *Bt* pollen is low. It took pollen levels greater than 1,000 grains of pollen per square centimeter (cm^2) before there were any toxic effects in monarch caterpillars, and even greater levels before the effect was significant.

Caterpillars were found on milkweed in cornfields during the 1-2 weeks pollen is shed by corn, but corn pollen levels on these plants were found to average only about 170 pollen grains per cm^2 . Less than 1% of the milkweed leaves in cornfields had pollen levels exceeding 1,000 grains per cm^2 during pollen shed.

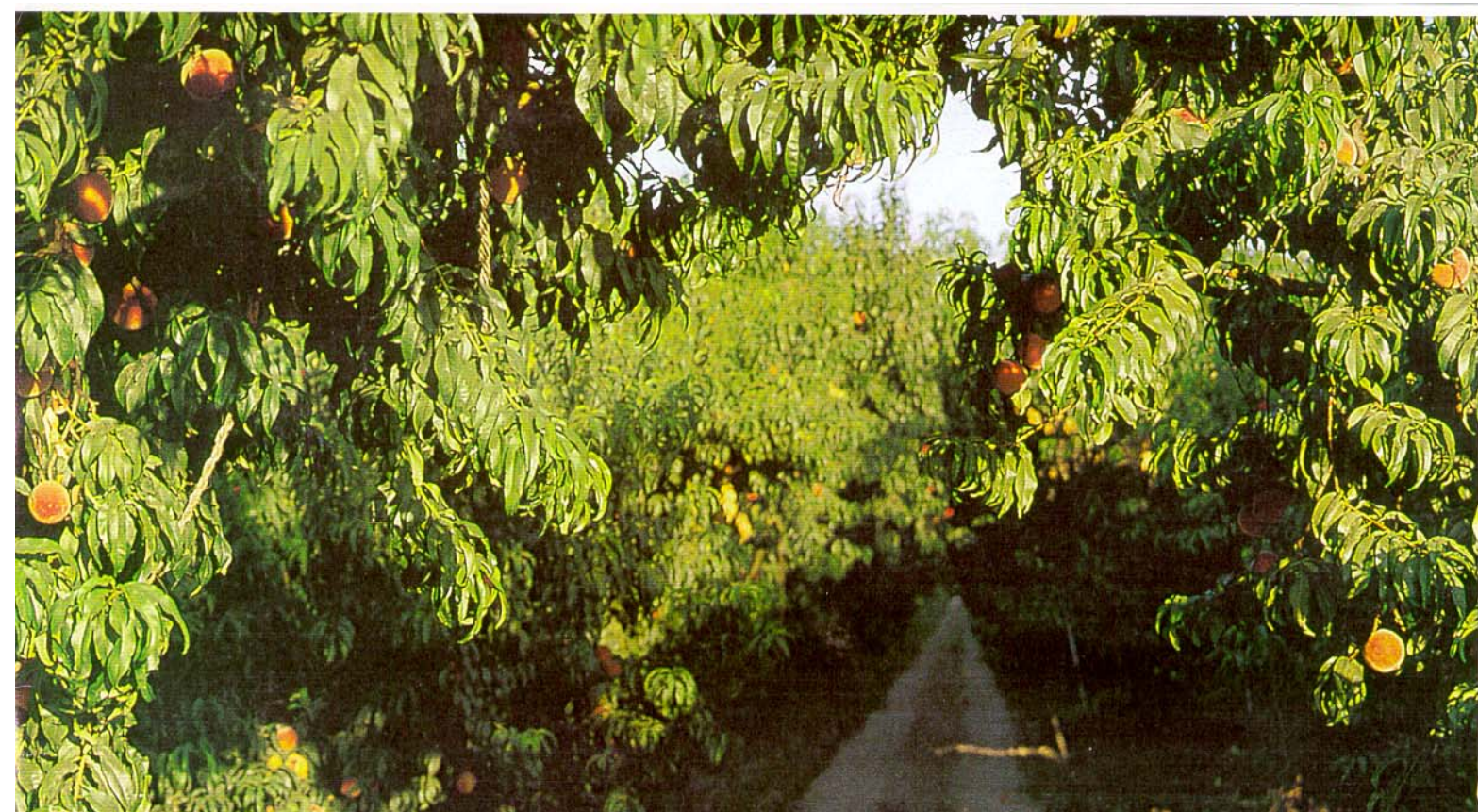
One variety of *Bt* corn - *Bt* 176 - did have a toxic effect with pollen doses as small as 10 pollen grains per cm^2 . *Bt* 176 is one of the earliest forms of *Bt* corn and has never been planted on more than 2% of the corn acres. It will be completely phased out by 2003.



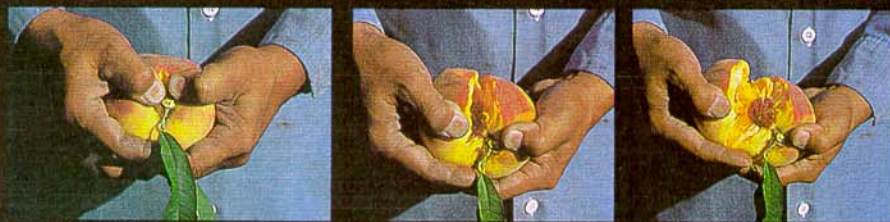
SLOW

peaches





by David Mas Masumoto



● **David Mas Masumoto** is an organic farmer of peaches and grapes and the author of *Epitaph for a Peach*, *Four Seasons on My Family Farm*, and *Harvest Son*, *Planting Roots in American Soil*. He works and writes on his 80-acre family farm near Fresno, California.

Does fast food come from fast farms?

I want my fruits to carry the aroma of a summer harvest. When you bite into one, I want the juices to trickle down your cheeks and dangle on your chin; the nectar exploding on your taste buds and the meat enveloping your tongue. I want the moment to stay with you forever. This is my perfect peach.

It's a challenge to raise such a treasure because great peaches are grown, not made. It's about working with nature and farming organically – relying on natural methods. It's not about efficiency, mass production and assembly line procedures. The best fruits are raised on a small, personal scale employing all the senses. I have only enough land that I can walk daily, seeing, smelling, touching and tasting. I glean lessons with gradual accrual. Each season I continue my practice at farming with the dream of one day getting it right. Formula recipes have no place in my fields. I farm slow and it works for me on my piece of this earth.

I can't, nor do I want to try and control nature. After decades I've learned that no matter what I do, after a mild winter, peaches will still wake up grumpy; lacking proper dormant sleep, their storage quality will not be the best. A series of summer rains will fall like a cold shower, giving peaches a bad attitude; their flesh will grow with an uneven texture. I honor nature, accepting what's

out of my control; I respond to what she gives, living with her pace.

But during the last hundred years agriculture has faced challenges to this sacred and precarious balance of nature and humans. In the name of efficiency, mechanization has swept through the farm landscape. While I value my equipment, which has saved my weary back and tired arms, I still sigh because each major invention has driven millions from the land and I question if this is necessarily an improvement for rural communities. The promise of pesticides resulted in silent springs: chemicals kill more than pests, they destroy ecosystems and habitat. Short term increases in productivity often leave behind long-term disasters. The farm walk has turned into a sprint: farmers forced to chase elusive profits as if the new goal is to farm faster.

Now, new missionaries bring another panacea: genetically modified organisms with the promises of even higher productivity, better control and good business. Problems with weeds? Splice in a gene to make a crop resistant to an herbicide; then simply spray everything to get rid of the problem. Got worms? Implant a bacterium and start growing plants with their own built-in pesticide.

The work of agriculture then shifts from the fields and into research and development facilities. The farmer, rather than farming, is just carrying out protocol. With these new technologies, I become a

manager and business man, and my land is transformed into a giant working laboratory. I no longer need to trust my senses – they don't belong on a genetically modified factory farm.

Genetic engineering steals life from my fields; my harvests are drained of humanity. Yet most importantly, genetic engineering takes the fun out of farming and replaces it with the folly of believing we can exclude nature in the process. I'd like to think nature has something to do with my best fruits. Something wild remains in juicy peaches when flavor explodes in your mouth and taste creates stories and memories.

I believe many in our world share my values. Most of us do not want a formula experience – it's the unexpected that gives us the rush.

So let me keep practicing at growing my perfect peach. I want to farm slow and enjoy this slow dance with nature.

WHERE WE STAND

Patagonia's position on genetic engineering is that genetically modified organisms must be kept in a contained environment until independent safety testing proves they are safe; products containing GMOs must be labeled as such, and companies that produce GMOs must be held responsible for any environmental damage they cause.

WHAT YOU CAN DO

Take action online! Send a message to the U.S. Food and Drug Administration at www.gefoodalert.org



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Handout 3

Procedure for Debate

Determining the Proposition

1. The sides Pro and Con are determined by a coin toss in the following manner; the side who wins the toss chooses which side of the issue it wishes to support and becomes the PRO side. The debate proposition is worded accordingly. For example:

- a) GM foods should be included in the human diet.
- b) GM foods should be banned from the human diet.

Note: The debate proposition must be worded in the positive. No negative words may be used. Therefore, GM foods should not be included in the human diet is incorrect.

Preparation

1. Combine the notes taken by all the team members to create a master list that supports your position.
2. Using the master list created in #1, determine the strategies and order your team will use to present their arguments. **Note:** As your team will probably not have the opportunity to present every supportive argument, choose the strongest reasons and make sure your plan assures that they are used.
3. Brainstorm with team members to create a list of reasons the opposing side will probably use.
4. Develop rebuttals for each reason the team believes the opposition will use to argue its position.
5. Based on the directions for the debate given below, decide the order in which each team member will speak in the debate. **Note:** The team members who are responsible for rebuttal must be able to speak spontaneously as their presentation will be in direct response to what the opposition says.
6. Each team member prepares a brief opening statement that establishes the team's position. Obviously each statement needs to be different. Their content, form and presentation are part of the team's strategy.



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Handout 3

Procedure for Debate

Debate Format

1. The debate proposition is read and the participants are introduced by the monitor. (PRO followed by CON). Throughout the debate NO ONE speaks until recognized by the monitor.
2. Each participant gives an opening statement. The order alternates between PRO (in favor) and CON (opposed to).
3. PRO #1 presents an argument to support the debate proposition.
4. CON #1 presents a rebuttal to the argument of PRO #1.
5. CON #2 presents an argument against the debate proposition.
6. PRO #2 presents a rebuttal to the argument of CON #2.
7. PRO #3 presents a new argument to support the debate proposition.
8. CON #3 presents a rebuttal to the argument of PRO #3.
9. CON #4 presents a new argument against the debate proposition.
10. PRO #4 presents a rebuttal to the argument of CON #4.
11. Each side gives a summation of its position. This may be done by the 5th member of each team or if teams consist of 4 members only, by any preselected team member.
12. Questions from the floor (audience) are optional and directed by the monitor.



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Handout 4

Student Evaluation of a Debate

Name: _____

Date: _____

	Excellent	Average	Fair	Poor
Shows an understanding of the issue	_____	_____	_____	_____
Presents relevant information	_____	_____	_____	_____
Strengthens team's position with either additional evidence or rebuttal	_____	_____	_____	_____
Clarity, pace and volume are correct	_____	_____	_____	_____
Presentation is well-organized	_____	_____	_____	_____
Observes the time restrictions	_____	_____	_____	_____

Student Evaluation of a Debate

Name: _____

Date: _____

	Excellent	Average	Fair	Poor
Shows an understanding of the issue	_____	_____	_____	_____
Presents relevant information	_____	_____	_____	_____
Strengthens team's position with either additional evidence or rebuttal	_____	_____	_____	_____
Clarity, pace and volume are correct	_____	_____	_____	_____
Presentation is well-organized	_____	_____	_____	_____
Observes the time restrictions	_____	_____	_____	_____



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Assessment for a Position Paper

Criteria	Possible Points	Points Earned
1. The problem is identified in a strong opening statement.	_____	_____
2. Relevant scientific concepts are included and used correctly.	_____	_____
3. Scientific vocabulary is explained.	_____	_____
4. Information is accurate.	_____	_____
5. The causes of the problem are summarized.	_____	_____
6. Recommendations for the solution are made.	_____	_____
7. Recommendations are logical and plausible.	_____	_____
8. Visual aids are used effectively.	_____	_____
9. There is a strong closing position statement.	_____	_____
10. Mechanics, spelling and neatness is exemplary.	_____	_____

Comments:



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Assessment for an Editorial or Debate

Criteria	Possible Points	Points Earned
1. Shows an understanding of the issue(s).	_____	_____
2. Presentation has both a strong opening and closing.	_____	_____
3. Opposing arguments are anticipated and refuted.	_____	_____
4. Clearly addresses the main ideas.	_____	_____
5. Tone is both rational and logical.	_____	_____
6. a. Mechanics are correct (if written).	_____	_____
b. Delivery; clarity, volume and pace (if oral).	_____	_____
7. Presentation is well organized.	_____	_____

Comments:



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Assessment for a Graph

Criteria	Possible Points	Points Earned
1. There is an explanatory main title.	_____	_____
2. Starting points and intervals are appropriate.	_____	_____
3. Axes are clearly and correctly labeled.	_____	_____
4. The data is plotted correctly.	_____	_____
5. The graph is easily understood.	_____	_____
6. Space is used well.	_____	_____
7. The graph is neatly done.	_____	_____

Comments:

Assessment for a Graph

Criteria	Possible Points	Points Earned
1. There is an explanatory main title.	_____	_____
2. Starting points and intervals are appropriate.	_____	_____
3. Axes are clearly and correctly labeled.	_____	_____
4. The data is plotted correctly.	_____	_____
5. The graph is easily understood.	_____	_____
6. Space is used well.	_____	_____
7. The graph is neatly done.	_____	_____

Comments:

"The field of genetic engineering is rapidly changing. Some statistics—and even experimental findings—mentioned in this story are probably out of date, replaced with more recent information. Still, this story offers a sense of the scientific issues in genetic engineering that continue today." Used with permission by Kathryn Brown.

Seeds of Concern

Are genetically modified crops an environmental dream come true or a disaster in the making? Scientists are looking for answers

By Kathryn Brown

Two years ago in Edinburgh, Scotland, eco-vandals stormed a field, crushing canola plants.

Last year in Maine, midnight raiders hacked down more than 3,000 experimental poplar trees. And in San Diego, protesters smashed sorghum and sprayed paint over greenhouse walls.

This far-flung outrage took aim at genetically modified crops. But the protests backfired: all the destroyed plants were conventionally bred. In each case, activists mistook ordinary plants for GM varieties.

It's easy to understand why. In a way, GM crops—now on some 109 million acres of farmland worldwide—are invisible. You can't see, taste or touch a gene inserted into a plant or sense its effects on the environment. You can't tell, just by looking, whether pollen containing a foreign gene can poison butterflies or fertilize plants miles away. That invisibility is precisely what worries people. How, exactly, will GM crops affect the environment—and when will we notice?

Advocates of GM, or transgenic, crops say the plants will benefit the environment by requiring fewer toxic pesticides than conventional crops. But critics fear the potential risks and wonder how big the benefits really are. "We have so many questions about these plants," remarks Guenther Stotzky, a soil microbiologist at New York University. "There's a lot we don't know and need to find out."

As GM crops multiply in the landscape, unprecedented numbers of researchers have started fanning into the fields to get the missing information. Some of their recent findings are reassuring; others suggest a need for vigilance.

Fewer Poisons in the Soil?

EVERY YEAR U.S. GROWERS shower crops with an estimated 971 million pounds of pesticides, mostly to kill insects, weeds and fungi. But pesticide residues linger on crops and the surrounding soil, leaching into groundwater, running into streams and getting gobbled up by wildlife. The constant chemical trickle is an old worry for environmentalists.

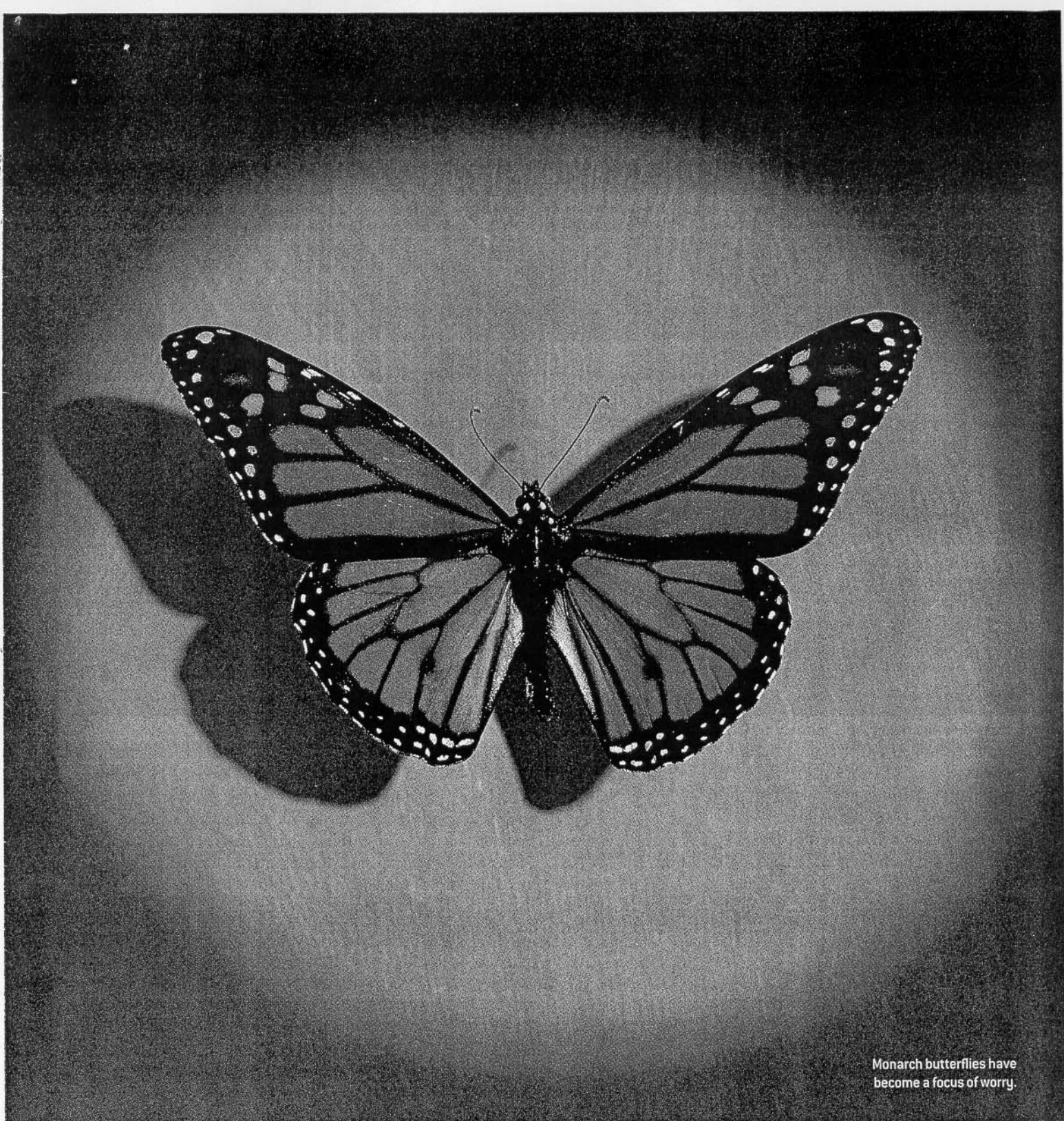
In the mid-1990s agribusinesses began advertising GM seeds that promised to reduce a farmer's use of toxic pesticides. Today most GM crops—mainly soybean, corn, cotton and

canola—contain genes enabling them to either resist insect pests or tolerate weed-killing herbicides [see box on page 56]. The insect-resistant varieties make their own insecticide, a property meant to reduce the need for chemical sprays. The herbicide-tolerant types survive when exposed to broad-spectrum weed killers, potentially allowing farmers to forgo more poisonous chemicals that target specific weed species. Farmers like to limit the use of more hazardous pesticides when they can, but GM crops also hold appeal because they simplify operations (reducing the frequency and complexity of pesticide applications) and, in some cases, increase yields.

But confirming environmental benefit is tricky. Virtually no peer-reviewed papers have addressed such advantages, which would be expected to vary from plant to plant and place to place. Some information is available, however. According to the U.S. Department of Agriculture, farmers who plant herbicide-tolerant crops do not necessarily use fewer sprays, but they do apply a more benign mix of chemicals. For instance, those who grow herbicide-tolerant soybeans typically avoid the most noxious weed killer, turning instead to glyphosate herbicides, which are less toxic and degrade more quickly.

Insect-resistant crops also bring mixed benefits. To date, insect resistance has been provided by a gene from the soil bacterium *Bacillus thuringiensis* (Bt). This gene directs cells to manufacture a crystalline protein that is toxic to certain insects—especially caterpillars and beetles that gnaw on crops—but does not harm other organisms. The toxin gene in different strains of *B. thuringiensis* can affect different mixes of insects, so seed makers can select the version that seems best suited to a particular crop.

Of all the crops carrying Bt genes, cotton has brought the biggest drop in pesticide use. According to the Environmental Protection Agency, in 1999 growers in states using high amounts of Bt cotton sprayed 21 percent less insecticide than usual on the crop. That's a "dramatic and impressive" reduction, says Stephen Johnson, an administrator in the EPA's Office of Pesticide Programs. Typically, Johnson says, a farmer might spray



Monarch butterflies have become a focus of worry.

insecticides on a cotton field seven to 14 times during a single growing season. "If you choose a Bt cotton product, you may have little or no use for these pretty harsh chemicals," he notes. Growers of Bt corn and potatoes report less of a pesticide reduction, partly because those plants normally require fewer pesticides and face fluctuating numbers of pests.

Defining the environmental risks of GM crops seems even harder than calculating their benefits. At the moment, public attention is most trained on Bt crops, thanks to several negative

studies. Regulators, too, are surveying the risks intensely. This spring or summer the EPA is expected to issue major new guidelines for Bt crops, ordering seed producers to show more thoroughly that the crops can be planted safely and monitored in farm fields.

In the face of mounting consumer concern, scientists are stepping up research into the consequences of Bt and other GM crops. Among their questions: How do Bt crops affect "non-target" organisms—the innocent bugs, birds, worms and other

creatures that happen to pass by the modified plants? Will GM crops pollinate nearby plants, casting their genes into the wild to create superweeds that grow unchecked? What are the odds that the genetically engineered traits will lose their ability to protect against insects and invasive weeds, leaving GM plants suddenly vulnerable?

At What Cost to Wildlife?

IN 1998 A SWISS STUDY provoked widespread worry that Bt plants can inadvertently harm unlucky creatures. In this laboratory experiment, green lacewing caterpillars proved more likely to die after eating European corn-borer caterpillars that had fed on Bt corn instead of regular corn. The flames of fear erupted again a year later, when Cornell University entomologist John Losey and his colleagues reported that they had fed milkweed leaves dusted with Bt corn pollen to monarch butterfly larvae in the lab and that those larvae, too, had died.

"That was the straw that broke the camel's back," says David

from plots of GM corn, estimating how much of it drifts onto plants such as milkweed and, finally, determining the exposure of butterfly and moth larvae to the protein. Much of that work, done during the 2000 growing season, is slated to be reported to the EPA shortly.

According to the agency, however, preliminary studies evaluating the two most common Bt corn plants (from Novartis and Monsanto) already indicate that monarch larvae encounter Bt corn pollen on milkweed plants—but at levels too low to be toxic. What is toxic? The EPA estimates that the insects face no observable harm when consuming milkweed leaves laden with up to 150 corn pollen grains per square centimeter of leaf surface. Recent studies of milkweed plants in and around the cornfields of Maryland, Nebraska and Ontario report far lower levels of Bt pollen, ranging from just six to 78 grains of Bt corn pollen per square centimeter of milkweed leaf surface. "The weight of the evidence suggests Bt corn pollen in the field does not pose a hazard to monarch larvae," concludes EPA scientist

The weight of evidence suggests that pollen from insect-resistant corn plants in the field does not pose a hazard to the larvae of monarch butterflies. But the jury is still out.

Pimentel, also an entomologist at Cornell. Suddenly, all eyes turned to the organisms munching GM plant leaves, nipping modified pollen or wriggling around in the soil below the plants—organisms that play vital roles in sustaining plant populations. Another alarming study relating to monarch butterflies appeared last August.

But the lab bench is not a farm field, and many scientists question the usefulness of these early experiments. The lab insects, they note, consumed far higher doses of Bt toxin than they would outside, in the real world. So researchers have headed into nature themselves, measuring the toxin in pollen

Zigfridas Vaituzis, who heads the agency's team studying the ecological effects of Bt crops.

But the jury is still out. "There's not much evidence to weigh," notes Jane Rissler of the Union of Concerned Scientists. "This issue of nontarget effects is just a black hole, and EPA has very little good data at this point to conclude whether the monarch butterfly problem is real, particularly in the long term."

In an EPA meeting on GM crops last fall, Vaituzis acknowledged the lack of long-term data on Bt crops and insect populations. Such studies "require more time than has been available since the registration of Bt crops," Vaituzis remarked. The EPA,

THREE WORRIES

1 INNOCENT CREATURES WILL BE HURT by insecticides built into many GM crops.

What the research says: Laboratory studies indicate that nontarget insects, such as monarch butterflies, could be harmed, but field studies suggest that the risk is small.

2 SUPERWEEDS WILL ARISE as genes that give crops the ability to kill insect pests or to withstand herbicides find their way into weeds.

What the research says: Studies have found no superweeds, but anecdotal reports have surfaced. Because pollen from GM plants can often fertilize weedy relatives of those plants, GM crops should not be grown near such relatives.

3 GM CROPS WILL SUDDENLY FAIL because insect pests will evolve tolerance to built-in insecticides and because weeds will evolve immunity to herbicides sprayed over fields of herbicide-tolerant GM plants.

What the research says: No failures have been documented, but they are likely to occur. Critics and proponents of GM crops disagree over the adequacy of current preventive measures.

HOW TO MAKE A GENETICALLY MODIFIED PLANT

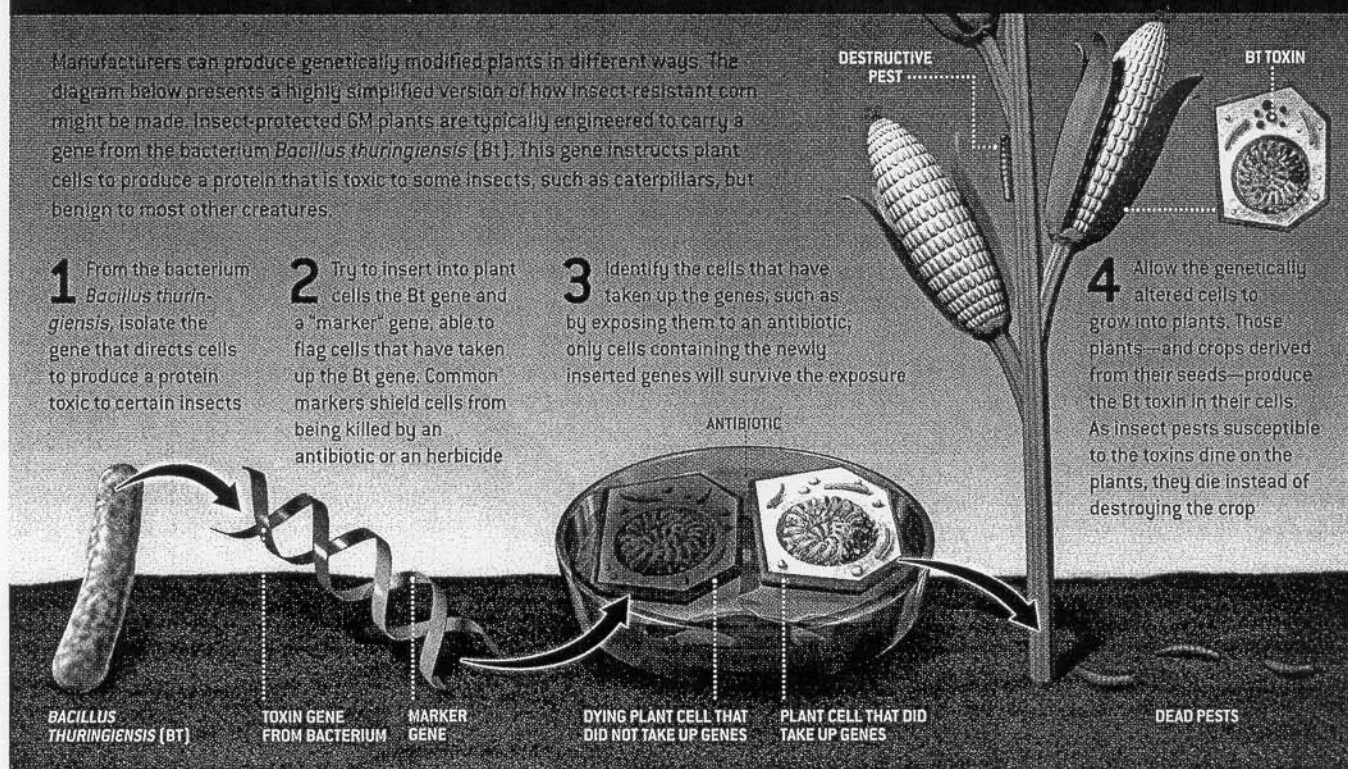
Manufacturers can produce genetically modified plants in different ways. The diagram below presents a highly simplified version of how insect-resistant corn might be made. Insect-protected GM plants are typically engineered to carry a gene from the bacterium *Bacillus thuringiensis* (Bt). This gene instructs plant cells to produce a protein that is toxic to some insects, such as caterpillars, but benign to most other creatures.

1 From the bacterium *Bacillus thuringiensis*, isolate the gene that directs cells to produce a protein toxic to certain insects

2 Try to insert into plant cells the Bt gene and a "marker" gene, able to flag cells that have taken up the Bt gene. Common markers shield cells from being killed by an antibiotic or an herbicide

3 Identify the cells that have taken up the genes, such as by exposing them to an antibiotic; only cells containing the newly inserted genes will survive the exposure

4 Allow the genetically altered cells to grow into plants. Those plants—and crops derived from their seeds—produce the Bt toxin in their cells. As insect pests susceptible to the toxins dine on the plants, they die instead of destroying the crop



he added, continues to collect Bt crop data—but so far without evidence of “unreasonable adverse effects” on insects in the field.

Seeding Superweeds?

WORRIES ABOUT THE FLOW of genes from the original plant to others also surround GM crops. Unwitting insects or the right wind might carry GM crop pollen to weedy plant relatives, fertilizing them. And if that happens, the newly endowed plants could break ecological rank, becoming “superweeds” that are unusually resistant to eradication by natural predators or pesticides. Scientists have stopped asking if such gene flow is possible. “In many cases,” says Cornell ecologist Allison Power, “we know gene flow will occur. The question now is, What will the consequences be?”

So far no scientific studies have found evidence of GM crops causing superweeds, and a 10-year study reported in *Nature* in February found no weedlike behavior by GM potatoes, beets, corn or canola planted in England. But worrisome anecdotes have appeared. Canadian farmers, in particular, have described GM canola escaping from farm fields and invading wheat crops like a weed. This canola also resisted pesticide sprays.

Power’s studies of gene flow from virus-resistant GM plants give further reason for precaution. For now, virus-resistant crops stake a small share of the GM landscape, but they are likely to become more prevalent, particularly in the developing world. Power investigates gene flow in cultivated grain crops—wheat, barley and oats—engineered to contain genes that make the plants resistant to the barley yellow dwarf virus (which

damages some 100 grass species). These GM grain crops could be on the market within the next decade.

Power’s work, carried out in the laboratory, indicates that wild oats—a weedy relative of cultivated oats—can “catch” the genes conferring resistance to barley yellow dwarf virus. If that happened in the field, she says, wild oats might run amok in the western U.S., outcompeting native grasses with kudzu-like intensity. Every GM crop, Power cautions, brings its own environmental personality and its own risks.

In the U.S., at least, landscape logistics make it rather unlikely that herbicide-tolerant or Bt crops will spread their biotech genes to weeds. That’s because the GM crops sown in this country have no close relatives in the regions where they grow; most plants can pollinate others only if the recipients and the donors have certain features in common, such as the same chromosome number, life cycle or preferred habitat. A known exception to the “no relatives” rule in the U.S. is wild cotton growing in Hawaii and southern Florida, which, by virtue of its unusual similarity to GM cotton, can accept the GM pollen. To separate the wild and biotech plants from each other, the EPA has ordered companies not to sell GM cotton south of Florida’s Interstate 60 or in Hawaii.

But it may prove harder to avoid creating superweeds outside North America, where weedy relatives of cultivated crops are common. Wild cotton, for instance, creeps past the Florida Keys, across the Gulf of Mexico and into Mexico. In South America, a weedy corn relative, teosinte, dresses the edges of domesticated cornfields. Either plant would readily

THE LATEST CROP OF NUMBERS

COUNTRIES PRODUCING GM CROPS IN 2000

■ INDUSTRIAL NATIONS ■ DEVELOPING NATIONS

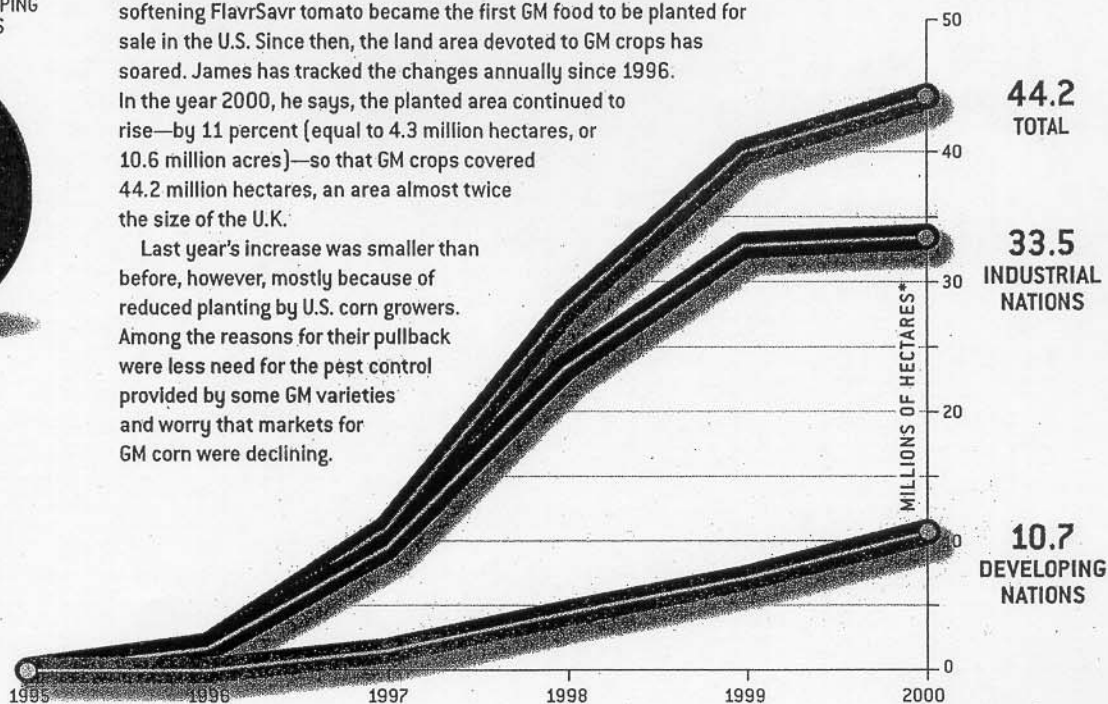


- IN DESCENDING ORDER:
- SOUTH AFRICA
 - AUSTRALIA
 - ROMANIA
 - MEXICO
 - BULGARIA
 - SPAIN
 - GERMANY
 - FRANCE
 - URUGUAY

Commercial planting of genetically modified crops began in China with tobacco in 1992, according to Clive James of the International Service for the Acquisition of Agri-biotech Applications. In 1994, the slow-softening FlavrSavr tomato became the first GM food to be planted for sale in the U.S. Since then, the land area devoted to GM crops has soared. James has tracked the changes annually since 1996. In the year 2000, he says, the planted area continued to rise—by 11 percent (equal to 4.3 million hectares, or 10.6 million acres)—so that GM crops covered 44.2 million hectares, an area almost twice the size of the U.K.

Last year's increase was smaller than before, however, mostly because of reduced planting by U.S. corn growers. Among the reasons for their pullback were less need for the pest control provided by some GM varieties and worry that markets for GM corn were declining.

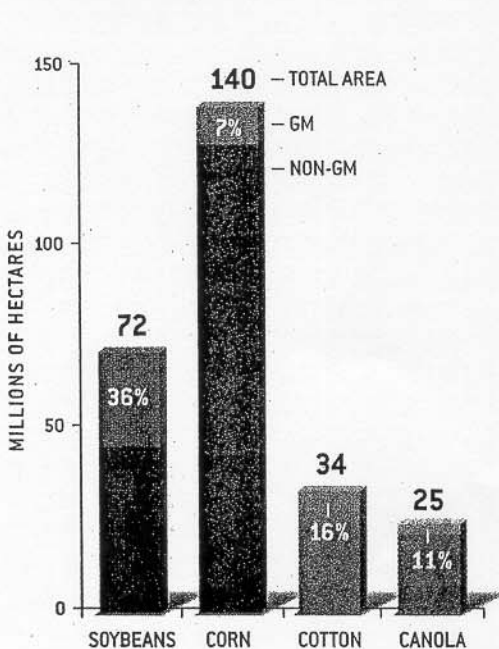
GLOBAL AREA OF GM CROPS



*Data were rounded to the nearest 100,000 hectares. 1 hectare = 2.471 acres

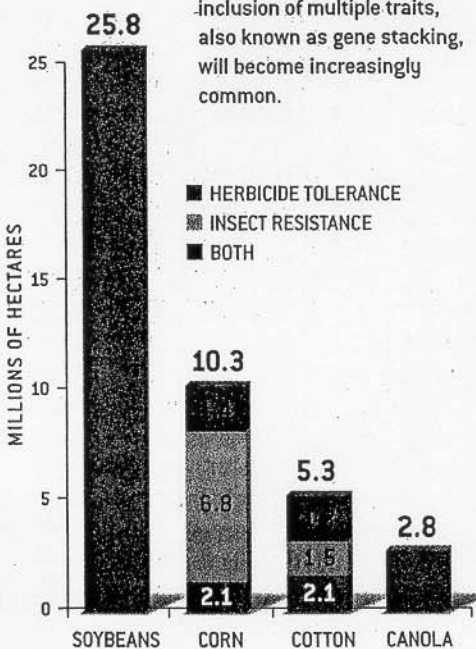
THE MOST COMMON GM CROPS ...

Soybeans, corn, cotton and canola were the dominant GM crops in 2000, covering 16 percent of the 271 million hectares devoted to those four commodities.



... AND HOW THEY'RE MODIFIED

Virtually all GM soybeans and canola planted in 2000 were herbicide-tolerant; corn and cotton were herbicide-tolerant or insect-resistant, or both. James predicts that inclusion of multiple traits, also known as gene stacking, will become increasingly common.



PERCENT OF TOTAL GM AREA

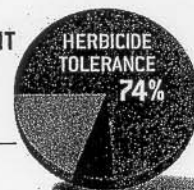
BY TYPE ...

- CANOLA 6%
- CORN 23%
- COTTON 12%
- SOYBEANS 58%



... AND TRAIT

- HERBICIDE TOLERANCE 74%
- INSECT RESISTANCE 19%
- BOTH 7%



Figures may not add up to 100% because of rounding.

Farmers cultivated other GM crops as well, but these essentially dropped off the data screen when James rounded his figures to the nearest 100,000 hectares. Among them were potatoes, squash, papayas, melons, tomatoes and plants engineered for such traits as virus resistance, delayed spoilage and improved nutrition.

accept the pollen from a GM relative. Indeed, scientists say, GM crops in many countries could end up growing near their ancestral plants—and sharing more than the sunshine overhead. “Almost every crop has weedy relatives somewhere in the world,” says Stephen Duke, a USDA plant physiologist in Oxford, Miss. “How do you keep GM crops out of places where they’re not supposed to be?”

Taking Refuge

FINALLY, ONE RISK follows GM crops wherever they’re planted: evolution. Over time, insect pests and weeds can become resistant to killing by routine chemical sprays. The same is bound to happen in the biotech age: eventually, impervious insects will munch away on GM insect-resistant plants, and the weeds surrounding herbicide-tolerant crops will shrug off the herbicide of choice. “Agriculture is an evolutionary arms race between plant protections and pests,” comments botanist Jonathan Wendel of Iowa State University. “And GM crops are just one more way that we’re trying to outsmart pests—temporarily.”

After five years of commercial Bt crop use, no reports of insect resistance to the crops have emerged, according to Monsanto. The company contends that roughly 90 percent of Bt corn and cotton growers comply with refuge requirements.

But some environmentalists question that rosy scenario and also argue that non-Bt refuges are either too small or too poorly designed to keep insect resistance at bay for long. “At the EPA meeting last fall, scientists seemed to agree that bigger, better refuges were the way to go but that cotton farmers would never agree to big refuges,” says Rebecca Goldberg, a senior scientist at Environmental Defense, a nonprofit organization based in New York City. More broadly, Goldberg questions how much GM crops really do for the environment. “In however many years,” she says, “we’ll lose Bt as an effective control against insects, and then we’ll be on to another chemical control. Many of us view this current generation of biotech crops as a kind of diversion, rather than a substantive gain for agriculture.” She favors sustainable agriculture alternatives, including careful crop rotation and organic farming methods, over pesticides sprayed on or engineered into plants.

U.S. landscape logistics make it unlikely that herbicide-tolerant or Bt crops will spread their biotech genes. It may be harder to avoid creating superweeds elsewhere.

To keep weeds vulnerable to herbicides, Monsanto and other companies urge growers to use the sprays responsibly, only when necessary. To slow insect resistance to the Bt toxin, the EPA requires Bt crop growers to set aside some part of their farmland for crops that have not been genetically modified. These “refuges” may be a corner of a field outside a Bt crop, for instance, or rows of standard plants that break up a Bt plot. Inside the refuges, insects that have acquired some Bt resistance breed with those that have not, diluting the resistance trait.

MORE TO EXPLORE

Transgenic Plants and World Agriculture. Royal Society of London, U.S. National Academy of Sciences, Brazilian Academy of Sciences, Chinese Academy of Sciences, Indian National Science Academy, Mexican Academy of Sciences, Third World Academy of Sciences. National Academy Press, July 2000.

The Ecological Risks and Benefits of Genetically Engineered Plants. L. L. Wolfenbarger and P. R. Phifer in *Science*, Vol. 290, pages 2088–2093; December 15, 2000.

Genetically Modified Pest-Protected Plants: Science and Regulation. National Research Council. National Academy Press, 2000.

Transgenic Crops in Natural Habitats. M. J. Crawley and R. S. Chails et al. in *Nature*, Vol. 409, pages 682–683; February 8, 2001.

Royal Society of Canada Expert Panel Report on the Future of Food Biotechnology. February 5, 2001. Available at www.rsc.ca

Information generally favorable to agricultural biotechnology, and extensive links, can be found at the Agbioworld Web site at www.agbioworld.org/

Information generally skeptical of agricultural biotechnology, and extensive links, can be found at the Union of Concerned Scientists Web site at www.ucsusa.org/food/0biotechnology.html

Virus-resistant GM crops have escaped widespread public concern, but they, too, pose some of the same risks as other GM crops. Some scientists worry that viruses will pick up resistance traits from virus-fighting GM crops and evolve into hard-to-beat strains that infect a newly expanded repertoire of plants. Some critics also question the ecological safety of emerging crops designed to resist drought, tolerate salt or deliver an extra nutritional punch. For example, Margaret Mellon of the Union of Concerned Scientists notes that salt-tolerant rice could potentially behave like a disruptive weed if it found its way into vulnerable wetlands.

“I don’t think it’s fair to say that every single GM crop is going to be a problem,” Rissler remarks. “But we need to devote the research to risks now, rather than deal with repercussions later.”

Still, some farmers are confident that GM technology can revolutionize agriculture for the better. For 30 years, Ryland Utlaut of Grand Pass, Mo., has been sowing and reaping 3,500 acres along the Missouri River. Last year, for the first time, he planted only herbicide-tolerant corn and soybeans across his entire, soil-friendly, no-till farm. As a result, he claims, he sprayed the crops half as often as he did before and got bigger yields. “If even the strongest environmentalist could see my farming practices now, I think they’d understand the benefits,” Utlaut says. “I’m a fervent believer in this technology.” Now he has to wait and see whether science confirms that belief.

Kathryn Brown is a science writer based in Alexandria, Va.

By Karen Hopkin

The Risks on the Table

More than half the foods
in U.S. supermarkets contain
genetically modified ingredients.
Have they been proved safe
for human consumption?



A farmworker crouches in the hot Texas sun, harvesting celery for market. That evening, painful

red blisters erupt across his forearms. The celery—a newly developed variety prized for its resistance to disease—unexpectedly produces a chemical able to trigger severe skin reactions.

Traditional breeding methods generated this noxious vegetable. But opponents of genetically modified foods worry that splicing foreign genes (often from bacteria) into food plants through recombinant-DNA technology could lead to even nastier health surprises. The stakes are high: GM foods are sold in many countries. In the U.S., an estimated 60 percent of processed foods in supermarkets—from breakfast cereals to soft drinks—contain a GM ingredient, especially soy, corn or canola; some fresh vegetables are genetically altered as well.

Detractors cite several reasons for concern. Perhaps proteins made from the foreign genes will be directly toxic to humans. Maybe the genes will alter the functioning of a plant in ways that make its food component less nutritious or more prone to carrying elevated levels of the natural poisons that many plants contain in small amounts. Or perhaps the modified plant will synthesize proteins able to elicit allergic reactions.

Allergy was the big worry last year when StarLink corn—

genetically modified to produce an insecticidal protein from the bacterium *Bacillus thuringiensis* (Bt)—turned up in taco shells, corn chips and other foods. Before the corn was ever planted commercially, U.S. regulators saw signs that its particular version of the Bt protein could be allergenic; they therefore approved StarLink for use only in animal feed, not in grocery products. They are examining claims of allergic reactions to foods harboring that corn, but a scientific advisory committee has determined that the amounts in consumer products were quite low and thus unlikely to provoke allergic reactions.

Proponents offer a number of defenses for genetically engineered foods. Inserting carefully selected genes into a plant is safer than introducing thousands of genes at once, as commonly occurs when plants are crossbred in the standard way. GM crops designed to limit the need for toxic pesticides can potentially benefit health indirectly, by reducing human exposure to those chemicals. More directly, foods under study are being designed to be more nutritious than their standard counterparts. Further, GM crops that produced extra nutrients or that grew well in poor conditions could provide critical help

to people in developing nations who suffer from malnutrition.

Advocates note, too, that every genetically engineered food crop has been thoroughly tested for possible health effects. Relatively few independent studies have been published, but manufacturers have conducted extensive analyses, because they are legally required to ensure that the foods they sell meet federal safety standards. In the past, the companies have submitted test results to the U.S. Food and Drug Administration voluntarily in advance of sale. But an FDA rule proposed in January should make such review mandatory.

The manufacturers' studies typically begin by comparing the GM version under consideration with conventionally bred plants of the same variety, to see whether the addition of a foreign gene significantly alters the GM plant's chemical makeup and nutritional value. If the proteins made from the inserted genes are the only discernible differences, those proteins are checked for toxicity by feeding them to animals in quantities thousands of times higher than humans would ever consume. If the genetic modification leads to more extensive changes, toxicity testers may feed the complete GM food to lab animals.

To assess the allergy-inducing potential, scientists check the

to be abandoned before they had a chance to hit grocery shelves. "I don't know of any evidence that any product on the market is unsafe," says Peter Day, director of the Institute of Biomolecular Research at Rutgers University.

The safety tests are not necessarily foolproof, though. For example, GM plants often cannot make enough of the foreign protein for use in feeding studies. So researchers have bacteria churn out the proteins. But a protein made by plants, the form people would consume, might be slightly different from the one made by microbes—a difference that might theoretically affect the safety assessment of that protein. And studies using whole GM foods are limited by the amount of any food that can be introduced into an animal's diet without generating nutritional imbalances that can confound the test results. This effect is one reason that scientists have criticized a controversial 1999 study claiming that the foreign DNA in GM potatoes led to abnormalities in the intestinal lining in rats.

Beyond the acute safety considerations, some critics fear that GM foods will do harm more insidiously, by hastening the spread of antibiotic resistance in disease-causing bacteria. When food designers genetically alter a plant, they couple the

Detractors cite several reasons for concern.

Perhaps proteins made from the foreign genes will be directly toxic to humans. Perhaps GM plants will elicit allergic reactions.

chemical makeup of each novel protein produced by the genetically altered plant against those of 500 or so known allergens; having a similar chemistry would raise a red flag. Proteins are also treated with acid to mimic the environment they will encounter in the stomach; most known allergens are quite stable and survive such treatment unscathed. Finally, investigators consider the original source of the protein. "There is no way that a peanut gene will ever be allowed into a strawberry," observes T. J. Higgins of the Commonwealth Scientific and Industrial Research Organization in Australia: too many people are allergic to proteins in peanuts.

Arguably, the testing system has worked well so far. It showed that the protein in StarLink corn might be allergenic (hence the animal-feed-only approval) and led other products—such as soybeans that contained a protein from Brazil nuts—

selected genetic material with a "marker" gene that reveals which plants have taken up foreign genes. Often the marker genes render plant cells resistant to antibiotics that typically kill them. At issue is the possibility that resistance genes might somehow jump from GM foods to bacteria in a consumer's gut, thereby aggravating the already troubling rise of antibiotic resistance among disease-causing bacteria.

The chances of such transfer are reportedly remote—"less likely than winning a national lottery three times in a row," notes Hans Günter Gassen of the Institute of Biochemistry at the University of Technology in Darmstadt, Germany. Even so, to allay public concern, the use of antibiotic resistance genes will probably be phased out in the next five years.

Meanwhile many consumers remain disturbed that most safety tests are performed by the very corporations that produce GM foods. Steve L. Taylor, head of the department of food science and technology at the University of Nebraska, admits that some may view the practice as unseemly. But, he asks, who else should shoulder the burden—and the expense? "I'd rather see the companies spend the money than have the government use my tax dollars," he adds. "I don't care if we're talking about bicycles or GM corn, it's their obligation to prove that their products are safe." No doubt concerned scientists and citizens will continue watching to see that they do so. ■

Karen Hopkin is a science writer based in Somerville, Mass.

MORE TO EXPLORE

Adequacy of Methods for Testing the Safety of Genetically Modified Foods. H. A. Kuiper et al. in *Lancet*, Vol. 354, No. 9187, pages 1315–1316; Oct. 16, 1999.

Effect of Diets Containing Genetically Modified Potatoes Expressing Galanthus Nivalis Lectin on Rat Small Intestine. S.W.B. Ewan and A. Pusztai in *Lancet*, Vol. 354, No. 9187, pages 1353–1354; Oct. 16, 1999.

Safety Aspects of Genetically Modified Foods of Plant Origin. Report of a joint FAO/WHO expert consultation on foods derived from biotechnology. Geneva, June 2000. Available at www.who.int/fsf/gmfood/fao-who_consultation_report_2000.pdf

Possible Health Risks of GM Foods. H. G. Gassen. Available from the OECD Web site at www.oecd.org/subject/biotech/Gassen.pdf

Two leading figures in the debate over genetic engineering defend their stances

Interviews by Sasha Nemecek

Used with permission by Sasha Nemecek.

Does the World Need GM Foods?

ROBERT B. HORSCH, vice president of product and technology cooperation at Monsanto Company, received the 1998 National Medal of Technology for his pioneering experiments in the genetic modification of plant cells. He talks about the promise of GM crops.

How did you become interested in the genetic modification of plants?

I started in this field with a strong interest in plants but with what you might call an academic interest in agriculture. I had this vague, naive notion that if we could genetically improve plants with the new tools of molecular biology, we would find a way to make biotechnology relevant to agriculture.

That has now happened. Biotechnology is a great tool that will allow us to produce more food on less land and with less depletion or damage to water resources and biodiversity. I am convinced that biotechnology is not just relevant but imperative for helping us meet the rapidly

growing demand for food and other agricultural products. The combination of more people and rising incomes will increase the demand for food by at least 50 percent in the next 25 years.

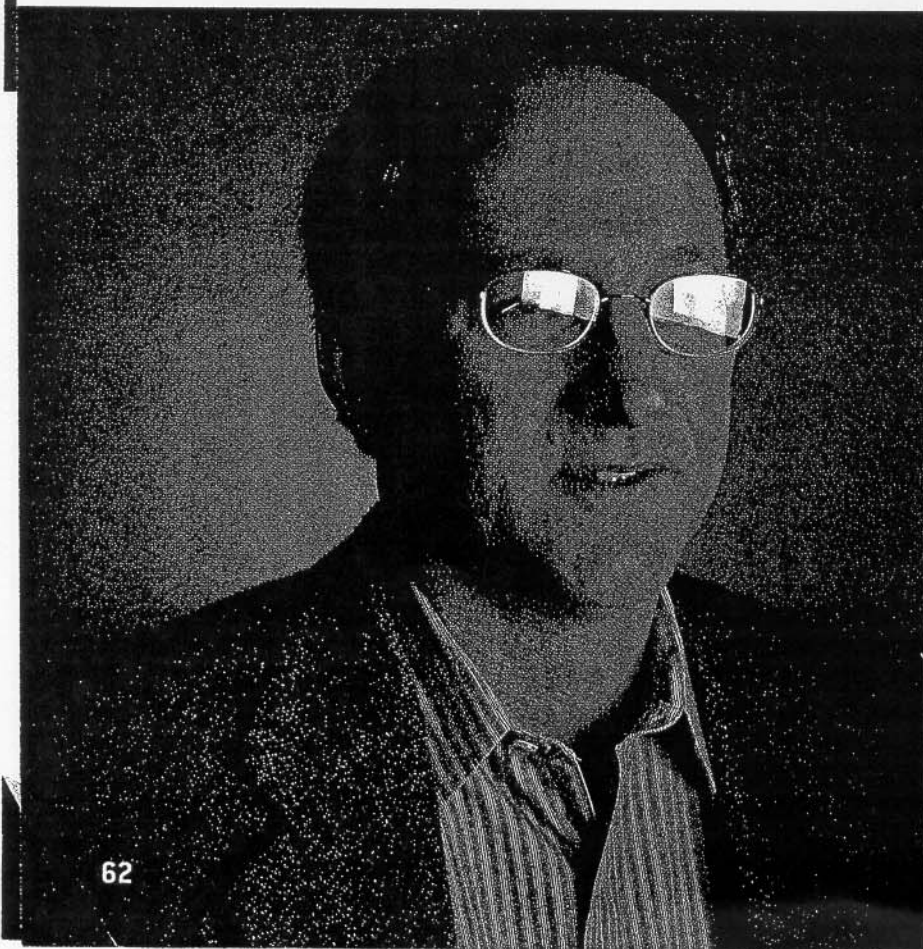
But critics of genetically modified foods point out that companies are not going to start giving products away. Can a corporation like Monsanto make biotechnology affordable for farmers in the developing world?

Cultivating commercial markets and applying technology to help the developing world are not mutually exclusive at all. One approach that works very well is to segment the market into three different areas. One is the pure commercial market. It makes economic sense, as a for-profit company, for us to invest in products and market developments in places where we can sell our products and where we think we can make a profit.

The other end of the spectrum is noncommercial technology transfer, which is largely focused on public-sector collaboration. Take, for example, our collaboration to put virus-resistance genes in the sweet potato. We will never have a commercial business in the sweet potato because it's just not a market economy crop. But by sharing our intellectual property and our technical knowledge with scientists from Kenya, we have helped them develop sweet potatoes that show resistance to the most serious sweet potato disease in Africa, which can cause the loss of 20 to 80 percent of the crop.

Then there's a third area, what I call a transitional market, where we have less experience related to biotechnology but that in the long run I think may be more powerful and beneficial for development efforts. We have used this approach with our older, nonbiotech products,

PHOTOGRAPHS BY TOM WOLFF



such as high-yielding corn hybrids, and I think we can use it in the future with biotech products. Small farmers can see results in a demonstration plot and, if they want, try it themselves on a portion of their farm. If it works for them, they can expand or repeat it the next year. We have programs like this in Mexico, India and parts of Africa. By the third or fourth year, if it's working, the farmers will have made enough money from the experimentation phase to be able to run essentially on their own.

And what about profits for Monsanto?

We sell the seeds and the herbicide at market prices, and we subsidize the learning, the testing and the development of distribution channels so that we don't actually make a profit in the first several years. Only if the project is successful enough to become self-sustaining will we start making a profit. At this point, we haven't gotten that far with any of these programs.

Let's turn to the environmental effects of GM crops. What do you consider the most important benefits of the technology?

Lower use of pesticides is the environmental benefit that people relate to immediately, and it's huge for a product like Bt cotton. [Editors' note: Bt crops have been genetically modified to produce a bacterial protein that kills certain insect pests.] According to a recent report, 2.7 million pounds of pesticides have not been used in the past four years, and many, many more won't be used in the future as biotech expands in acreage and in traits.

Beyond that there are also yield benefits. The Bt corn we have today doesn't displace a whole lot of insecticides, but what it does do is boost the yields by a noticeable margin. It depends on the year and on the region, but the increase in yield can range from 5 to 15 percent. If you think about it, that leverages land use, water use, fertilizer use and all the pesticides that go into growing corn. You get a 10 percent greater corn harvest with the same resources that you were going to use anyway. You're getting more out of your resources.

Getting more from really good farmland, then setting aside land that is of marginal quality and returning it to habitat for wildlife is very beneficial to the environment. We can't continue to indefinitely expand our old practices—of chemical use, of water diversion, of plowing wild lands and converting them to farms, of nonagricultural sprawl and of the production of industrial waste.

One of the benefits of biotech that we first heard about was nutritionally enhanced foods. But despite promises of healthier broccoli, we have Bt corn. The famous "golden rice" is not available to consumers yet and is still in very early stages of testing. Will we ever have nutritionally enhanced foods?

We're seeing progress across industry, academia and the non-profit community. For example, we are collaborating with a non-profit group, TERA [Tata Energy Research Institute] in India, on development of a product related to golden rice—golden mustard oil—that, like golden rice, is high in beta-carotene, a pre-

cursor of vitamin A. This may help alleviate vitamin A deficiencies in places where mustard oil is a staple in the local diet.

While making improvements to food for the industrial world is not a priority for Monsanto, other companies and university researchers are working hard in this area. For example, Du Pont has developed a modified oil with an increased amount of the fatty acid oleic acid. This product has reduced levels of polyunsaturated fatty acids and is more stable upon storage. Efforts are under way to modify other fatty acids to make oils more healthy for consumers. Also, there is research ongoing elsewhere to increase the amount of vitamin D in soybean oil.

Monsanto and other scientists have also been involved in research that may help reduce the likelihood of allergic responses to foods. We have been able to take a protein that is currently an allergen and modify specific amino acids in the protein to dramatically reduce the allergenic nature of the protein. Other scientists are using this and other methods to reduce the allergenic nature of some foods, such as peanuts and soybeans, which cause allergic reactions in a significant number of people.

Monsanto has been one of the most criticized, even despised, corporations because of its role in the development of genetically modified foods. Has it ever been hard to tell people you're an employee of Monsanto?

I've had a few people react negatively, but my experience is that when people meet you as a person, their reactions are very different than when they are commenting on the big nameless, faceless company.

I think the company is making an effort to address people's concerns about GM foods more openly. We've recognized that some genetic modifications are particularly bothersome. Among vegetarians, for instance, the idea of eating a vegetable that has an animal gene in it might raise questions. For certain cultures or religious groups, there could be similar concerns. So we decided it was better to avoid using animal genes in food crops.

I don't think it serves anybody's interest—including Monsanto's—to discount the potential risks of biotechnology. But for where we are today, and for what I see in the pipeline for the next few years, I really don't see a measurable risk from the GM products we are selling or developing. There have been numerous national and international scientific organizations that have reached this same conclusion, including the American Medical Association, the National Academy of Sciences, the World Health Organization and many others.

We at Monsanto have recently pledged to listen better to and engage in dialogue with concerned groups, to be more transparent in the methods we use and the data we have about safety, to respect the cultural and ethical concerns of others, to share our technology with developing countries, and to make sure we deliver real benefits to our customers and to the environment. I think this new attitude and new set of commitments will help improve both our company's image and the acceptance of this new technology.

Does the World Need GM Foods?

MARGARET MELLON, director of the agricultural and biotechnology program of the Union of Concerned Scientists in Washington, D.C., holds a law degree and a Ph.D. in molecular biology. She explains her concerns about the effects of GM foods on human health and the environment.

How did you become interested in genetically modified foods?

I became aware of genetic engineering while running a program on toxic chemicals at the Environmental Law Institute in the 1980s. I was initially more positively disposed toward biotechnology than I came to be over the years. Like a lot of folks, I wasn't very critical. But the more I knew about the technology and the deeper the questions I asked about it, the less likely I was to accept at face value the extravagant promises made on its behalf.

I should also say, however, that my colleagues and I at the Union of Concerned Scientists are not opposed to biotechnology. We

think its use in drug manufacture, for example, makes a lot of sense. The therapeutic benefits of the new drugs outweigh the risks, and often there aren't any alternatives. But in agriculture, it's different. So far, at least, there are only modest benefits associated with biotechnology products, and it has yet to be shown that the benefits outweigh the risks. And there are exciting alternatives to solving agricultural problems that we are simply ignoring.

Agriculture isn't like medicine. We in the U.S. produce far more food than we need. And we are so wealthy that whatever we can't produce we can buy from somebody else. As a result, there are about 300,000 food products on our grocery shelves and 10,000 new ones added every year. The notion that consumers in the U.S. fundamentally need new biotechnology foods isn't persuasive.

But, of course, many scientists and policy experts argue that we *do* need biotechnology to feed the world, especially the developing world. That is an important question to ask because so many people—about 800 million—are undernourished or hungry. But is genetic engineering the best or only solution? We have sufficient food now, but it doesn't get to those who need it. Most hungry people simply can't afford to buy what's already out there even though commodity prices are at all-time lows. How does genetic engineering address the problems of income disparity?

The real tragedy is that the debate about biotechnology is diverting attention from solving the problem of world hunger. I'd like to see people seriously asking the question, "What can we do to help the world's hungry feed themselves?" and then make a list of answers. Better



technology, including genetic engineering, would be somewhere on the list, but it would not be at the top. Trade policy, infrastructure and land reform are much more important, yet they are barely mentioned.

Genetic engineering has a place and should not be taken off the table, but I don't believe it is a panacea for world hunger. Treating it as if it is distorts this important debate. It is also amazing to me how quickly some have dismissed the virtues of traditional breeding—the technology that, after all, made us into an agricultural powerhouse.

Can we turn to another potential benefit that people claim for GM foods: agriculture that is more environmentally friendly?

Let's ask a question: What is a green agriculture? Is it one that doesn't depend on pesticides? I think it's a lot more than that, actually. But if we just consider avoiding pesticide use, we now have some data on the impacts of engineered crops. Surveys of American farmers by the Department of Agriculture show that the use of Bt [pest-resistant] corn aimed at the corn borer, for example, hasn't done much to reduce the application of pesticides to corn, because the vast majority of corn acreage isn't treated with pesticide to control that pest.

The introduction of Bt cotton, however, has resulted in a measurable drop in pesticide use. That's good for the environment and good for the farmers who cut their input costs. But this benefit will last only as long as the Bt trait keeps working. I think most scientists expect that the way Bt crops are being deployed will lead—sooner rather than later—to the evolution of resistance in the target pests, which means that the Bt cotton won't work anymore. We are likely to run through Bt cotton just like we ran through all the pesticides before it. So it isn't a durable path to a greener agriculture.

And there are environmental risks out there. Most scientists agree now that gene flow will occur—genes *will* go from engineered crops to nearby relatives. That means pollen will carry novel genes from the agricultural settings into neighbors' fields or into the wild. Gene flow from herbicide-resistant GM crops into the wild is already leading to the creation of herbicide-resistant weeds in Canada.

What about the health risks of GM foods? Do you see any looming problems?

I know of no reason to say the foods currently on the market are not safe to consume. But I don't have as much confidence as I should in that statement. There was a letter published in the journal *Science* last June from someone who had searched the literature for peer-reviewed studies comparing GM food to non-GM food. The researcher found something like five studies. That's not enough of a basis on which to claim, from a scientific standpoint, that we know enough to assure ourselves that these foods are going to be safe.

With the little we know about the food safety issue, I would say the biggest concern is allergenicity. Introducing new tox-

ins into food is also a risk. Of course, breeders are going to try to avoid doing that, but plants have lots of toxins in them; as scientists manipulate systems that they don't completely understand, one of the unexpected effects could be turning on genes for toxins. There are rules that govern how genes come together and come apart in traditional breeding. We're not obeying those rules.

So you don't see genetic engineering of crops to be an extension of traditional breeding?

No, not at all. You just can't get an elephant to mate with a corn plant. Scientists are making combinations of genes that are not found in nature.

From a scientific standpoint, there is no dispute that this is fundamentally different from what has been done before. And that it is unnatural. Now, because it's new and unnatural doesn't *necessarily* mean that it will prove to be more risky. But it is certainly a big enough break with what we have done before to demand an extra measure of caution.

And caution is particularly appropriate where the technology involves our food supply. Lots and lots of people—virtually the whole population—could be exposed to genetically engineered foods, and yet we have only a handful of studies in the peer-reviewed literature addressing their safety. The question is, do we *assume* the technology is safe based on an argument that it's just a minor extension of traditional breeding, or do we *prove* it? The scientist in me wants to prove it's safe. Why rest on assumptions when you can go into the lab?

Science can never prove that any technology is 100 percent safe. Will you ever be satisfied that we've tested GM foods enough? And how much risk is acceptable?

Sure, I could be satisfied that GM foods have been adequately tested. But it's premature to address that question now. Nobody is saying, "Look, we've got this large body of peer-reviewed experimental data comparing GM with non-GM foods on a number of criteria that demonstrate the food is safe."

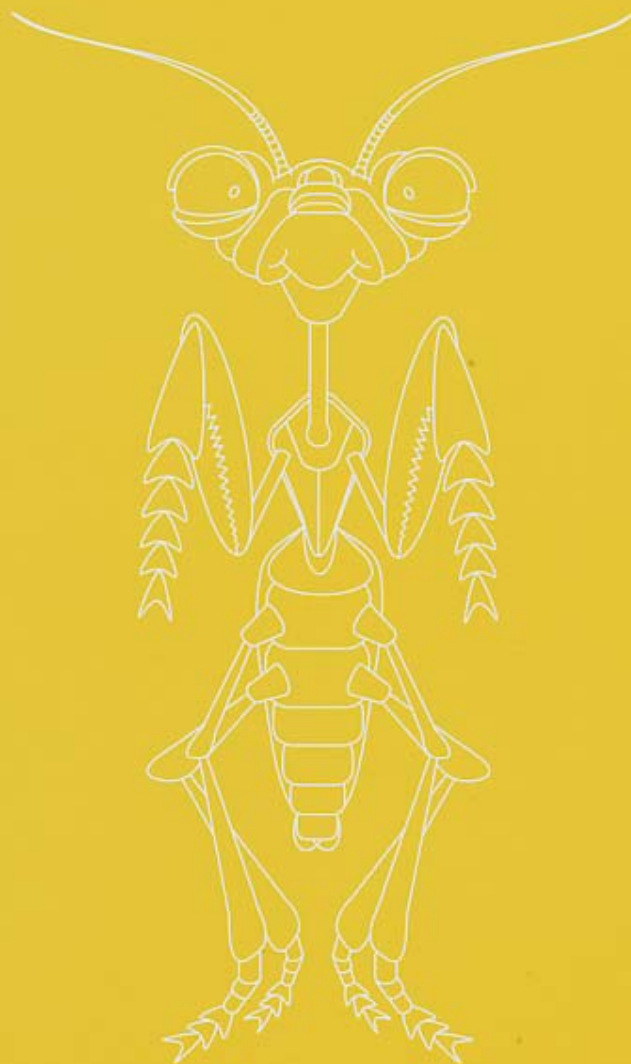
When we have generated such a body of evidence, *then* there will be an issue of whether what we have is enough. And eventually, if things go well, we'll get to a point where we say, we've been cautious, but now we're going to move ahead—we need to fish or cut bait. But we're nowhere near that point now.

Obviously, we take risks all the time. But why are we taking these risks? If we didn't have an abundant food supply, if we didn't have something like 300,000 food products on our shelves already, then we would have an argument for taking this society-wide risk. But we've got plenty of food. In fact, we've got too much. And although we have many problems associated with our food system, they are not going to be solved by biotechnology.

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