
Bob Goldberg
10/10/08
Today’s Headlines

The New York Times

A Global Need for Grain That Farms Can’t Fill
Published: March 9, 2008

High Rice Cost Creating Fears of Asia Unrest
By KEITH BRADSHER
Published: March 29, 2008

Economist.com

CNN.com

THE FOOD CHAIN
A Drought in Australia, a Global Shortage of Rice

Across Globe, Empty Bellies Bring Rising Anger

Newsweek

Riots, instability spread as food prices skyrocket
Updated 10:42 p.m. EDT, Mon April 14, 2008

The Washington Post
We Face Challenges In Agriculture Even Greater Than Those in Today’s Headlines

Over the next 50 years we will need to produce more food than in the whole of human history and do it with fewer inputs on less arable land!!

∴ Crop yields need to be increased significantly!!
Without Increases in Crop Yield We Will Need to Farm Every “Square Inch” of Land on the Earth To Satisfy Crop Demand

NOTE:
Only 35% of Earth’s Land Mass is Suitable For Agriculture... and 67% of that is used for Pasture & Range! Only ~8% is used for Crops Eaten Directly as Food!
And........There's Also A Problem With Using Land For Energy Production..............
There Were 18,000 Farms in Los Angeles County in 1930!!!

From 1901 to 1950 Los Angeles County Was the Largest Agricultural Producing County in the US!!!
How Will Crop Yields Be Increased?

As We Always Have

By Using State-of-the-Art Science & Technology
And by using a variety of approaches to identify genes and processes that will help increase crop yields and food production significantly in the 21st century.

**Yield (Developmental Traits)**
- Seed Number
- Seed Size
- Growth Rate
- Organ Size (*More Seeds*)
- Plant Architecture
- Flowering Time
- Senescence
- Maturity
- Stature

**Yield (Stress Traits)**
- Nutrient Uptake
- Drought Resistance
- Heat Resistance
- Cold Tolerance
- Salt Tolerance
- Shade Tolerance
- Disease Resistance

From “Low-Tech” Genetics to “High-Tech” Genomics

From Lab to Improved Seeds for Farmers
And Use Breeding and Genetic Engineering to Introduce These "Yield" Genes Into Existing Crops

- Optimal Flowering Time
- Seeds Without Fertilization
- Hybrids
- Reduced Pod Shattering
- Architecture Designed For Specific Growth Conditions

- High Photosynthetic Efficiency
- Drought Resistant
- Pathogen Resistant
- Efficient Uptake of Micronutrients
- High Yields Under Suboptimal Conditions
- More Seeds
- Bigger Seeds
- Seeds Optimal For Human/Animal Health & Nutrition
- Ability to Fix Nitrogen

What are the Other Major Challenges For the Future?
Major Challenges For 21st Century Agriculture

• **Increase Crop Yield** To Provide More Food And Save/Create More Open Space

• **Reduce Inputs** Required For Growing Crops (e.g., water, fertilizer) -- A Sustainable Agriculture

• **Reduce Environmental Impacts** of Intensive Agriculture (e.g., pesticides)

• **Optimize Crops** For Human Health and Nutrition

• **Use Crops as Factories** For Specialized Industrial and Pharmaceutical Applications (e.g., vaccines)

• **Facilitate the Conversion** From a Petroleum-Based Energy System to a Dedicated Plant-Based Renewable Energy System (e.g., cellulose to ethanol)

• **Help Reduce CO₂ Emissions** and Mitigate Effects of Climate Change (e.g., switch from coal to biomass)

Plant Genome Projects and Identifying Novel New Traits Can Help Meet This Challenge!!!!!!
Early Humans Faced Major Challenges Finding Food

Inventing Agriculture and "Domesticating" Plants and Animals 10,000 Years Ago Changed That & Everything Else!!!
The Invention Of Agriculture Led To Civilization

As We Know It!!!

Agriculture Dates Back 10,000 Years

Agriculture Dates Back 10,000 Years
Generating New Types Of Crops Is Not New To The 21st Century!!
**Most Major Food Crops Were “Engineered” By Breeding ~10,000 Years Ago**

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEEDS (cereals)</td>
<td>corn, rice, wheat, barley, millet, sorghum</td>
</tr>
<tr>
<td>SEEDS (legumes)</td>
<td>soybean, beans, peanut</td>
</tr>
<tr>
<td>ROOTS AND STEMS</td>
<td>potato, cassava, yam, sugar beet, sugar cane, radish</td>
</tr>
<tr>
<td>FRUITS</td>
<td>tomato, banana, coconut, papaya</td>
</tr>
<tr>
<td>LEAVES</td>
<td>cabbage, kale, lettuce, spinach</td>
</tr>
<tr>
<td>FLOWERS</td>
<td>broccoli, cauliflower, artichoke</td>
</tr>
</tbody>
</table>

Crops were selected by using pre-existing genetic variability in wild plant populations -- They Were Made by “Man” and Not by Nature!!

Breeding, By Definition, Means Manipulating Genes!!!!
Engineering Teosinte Into Domesticated Corn

Note: Architecture and Fruit (cob) Size
Modern Corn Was “Engineered” From Teosinte 10,000 Years Ago & Cannot Survive in “Nature!!”
Tomatoes Were Engineered From Small Wild Relatives
Broccoli, Cauliflower, Cabbage, and Brussels Sprouts Were “Engineered” As Well!

......Brassicas or Crucifers
Big Changes in the US Over The Past 100 Years
“We’ve Come a Long Way Baby”

<table>
<thead>
<tr>
<th></th>
<th>1900</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Expectancy (women)</td>
<td>48</td>
<td>79</td>
</tr>
<tr>
<td>Average Family Income</td>
<td>$8,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>(2008 Dollars)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline Use Per Capita</td>
<td>34 gallons</td>
<td>1,100 gallons</td>
</tr>
<tr>
<td>Flush Toilets Per Housing</td>
<td>10%</td>
<td>99%</td>
</tr>
<tr>
<td>High School Grads</td>
<td>13%</td>
<td>90%</td>
</tr>
<tr>
<td>Farm Workers</td>
<td>55%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

These statistics illustrate significant improvements in various aspects of life in the United States over the past century.
CROP YIELD INCREASES HAVE "ROCKETED UPWARDS" OVER THE LAST 100 YEARS AND CONTRIBUTED TO A LONGER AND "BETTER" LIFE

<table>
<thead>
<tr>
<th>Year</th>
<th>Crops (bushels/acre)</th>
<th>% Farm Workers</th>
<th>% Income on Food</th>
<th>Life Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>100</td>
<td>55%</td>
<td>50%</td>
<td>48 Years</td>
</tr>
<tr>
<td>1920</td>
<td>115</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940</td>
<td>145</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>300</td>
<td>1.5%</td>
<td>9%</td>
<td>79 Years</td>
</tr>
</tbody>
</table>

1930: 30 bushels/acre
1930: 1 farmer fed 10 people

2008: 150 bushels/acre
2008: 1 farmer feeds 200 people

Conclusion: Crop yield increased ~ 300% over the past 100 years and lead to a similar reduction in food costs!!!!!
But... World Food Production is Leveling Off on a Per Capita Basis!

Per Capita Cereal Production

Kg grain per capita

1965 Kcal a day

Green Revolution

Require a New Green Revolution......
The Genomics Era Will Be the Driver
How Was This Accomplished Over the Past 100 Years?

What Role Did Science & Technology Play?

What About in the Future When There are 400 Million People in the USA and 9 Billion in the World?
WHAT TECHNOLOGIES CAUSED AN INCREASE IN CROP YIELDS OVER THE PAST 100 YEARS?

- PLANT BREEDING (New Hybrids-Green Revolution)
- IRRIGATION
- FERTILIZERS
- PESTICIDES & HERBICIDES
- MECHANIZATION (e.g., Tractor)
- GLOBAL POSITIONING AND SATELLITE IMAGING
- GENOMICS & GENETIC ENGINEERING (New Traits)

These technologies have resulted in a 300% increase in US crop productivity during the 20th-21st century!

Need to sustain this yield increase by applying the best technology and agricultural practices!
Genetics Has Also Changed Dramatically Over the Past 100 Years!!

1900: Rediscovery of Mendel’s Work

DeVries, Correns and Tschermak independently rediscover Mendel’s work.

Three botanists - Hugo DeVries, Carl Correns and Erich von Tschermak - independently rediscovered Mendel’s work in the same year, a generation after Mendel published his papers. They helped expand awareness of the Mendelian laws of inheritance in the scientific world.

The three Europeans, unknown to each other, were working on different plant hybrids when they each worked out the laws of inheritance. When they reviewed the literature before publishing their own results, they were startled to find Mendel’s old papers spelling out those laws in detail. Each man announced Mendel’s discoveries and his own work as confirmation of them.

1909: The Word Gene Coined

Danish botanist Wilhelm Johannsen coined the word gene to describe the Mendelian units of heredity.

He also made the distinction between the outward appearance of an individual (phenotype) and its genetic traits (genotype).

Four years earlier, William Bateson, an early geneticist and a proponent of Mendel’s ideas, had used the word genetics in a letter; he felt the need for a new term to describe the study of heredity and inherited variations. But the term didn’t start spreading until Wilhelm Johannsen suggested that the Mendelian factors of inheritance be called genes.

The proposed word traced from the Greek word ‘genes’, meaning “birth”. The word spawned others, like genome.

1911: Fruit Flies Illuminate the Chromosome Theory

Using fruit flies as a model organism, Thomas Hunt Morgan and his group at Columbia University showed that genes, strung on chromosomes, are the units of heredity.

Morgan and his students made many important contributions to genetics. His students, who included such important geneticists as Alfred Sturtevant, Hermann Muller and Calvin Bridges, studied the fruit fly Drosophila melanogaster. They showed that chromosomes carry genes, discovered genetic linkage - the fact that genes are arrayed on linear chromosomes - and described chromosome recombination.

In 1933, Morgan received the Nobel Prize in Physiology or Medicine for helping establish the chromosome theory of inheritance.

2000: Drosophila and Arabidopsis genomes sequenced

Drosophila melanogaster (fruit fly) has been a primary tool for experiments since the early part of the twentieth century. The sequencing of its genome is the result of a collaborative effort between the Drosophila Genome Project Group, led by Gerald Fink at the University of California, Berkeley and researchers from Celera Genomics Corporation led by Craig Venter. The Drosophila genome is estimated to have approximately 13,600 genes as compared to 28,000–30,000 genes in humans. The popularity of Drosophila as an experimental organism ensures that its genome sequence will be of great scientific and practical value.

Drosophila melanogaster and Arabidopsis thaliana are two of the most extensively studied experimental organisms. Drosophila melanogaster has been conserved through evolution and have human counterparts. This means that scientists can perform experiments using flies and apply their findings to human biology.

Arabidopsis thaliana is the first plant to have its genome sequenced. This plant from the mustard family has become the plant biologists' equivalent of the laboratory mouse. Its genome was completed by the collective efforts of an international group of researchers called the Arabidopsis Genome Initiative. The Arabidopsis genome has an estimated 25,000 genes—apparently even more than humans. Although not a crop plant, Arabidopsis was chosen as a model organism because its genome is small and it has relatively little of the nonsensical, so-called junk, DNA. It does, however, share very similar (biochemically) to crop plants such as rice or barley. The study of its sequence is expected to have widespread applications for agriculture and medicine.

2004: Refined Analysis of Complete Human Genome Sequence

The International Human Genome Sequencing Consortium led in the United States by the National Human Genome Research Institute and the Department of Energy published a description of the finished human gene sequence. The analysis reduced the estimated number of genes (which as recently as the mid-1990s had been ~105,000) from 35,000 to only 20,000–25,000. The fact that the human genome has far fewer genes than was originally thought suggests that humans "get more" out of their genetic information than do other animals. For example, the average human gene is able to produce three different gene products.

The finished sequence contains 2.85 billion nucleotides interrupted by only 341 gaps. It covers 99 percent of the genome with an accuracy of 1 error per 100,000 bases. Researchers confirmed the existence of 15,599 protein-coding genes and identified 2,189 other DNA segments that are thought to be protein-coding genes. Although the genome sequence is described as "finished," it isn't perfect. The small gaps that remain cannot be sequenced by the industrial-scale methods used by the Human Genome Project. Filling in these gaps will have to await a series of small targeted efforts by researchers using other techniques and possibly new technologies. The finished genome sequence can be freely accessed through public databases and may be used by researchers without restrictions.
Modern Genetic Engineering Has Come a Long Way Since Its Origins in 1973!

Gene Transplants Seen Helping Farmers and Doctors;

By VICTOR K. McELHENY
May 20, 1974, Monday
Page 61, 1335 words

NY Times-1974

Biochemists working in California have developed a practical method of transplanting genes, the chemical units of heredity, from cells as complex as those of animals into the extremely simple, fast-multiplying cells known as bacteria. [END OF FIRST PARAGRAPH]
Unity in Biology

Has Lead to Genetic Engineering & Biotechnology

DNA is DNA is DNA!!!!
And is the “Same” in Plants and Humans

Translating The Genetic Code Into Proteins is a Conserved Process

Replication

Transcription (RNA synthesis)

Translation (protein synthesis)

Protein

DNA

RNA

Protein

Insulin, TPA, Growth Hormone, Other Drugs For Human Health in Bacterial Factories!!

Genetic Engineering

A Natural Process!!
Genetic Engineering in Plants Has Also Come a Long Way!

Engineering A Novel Crop By "Wide" Breeding

Cabbage (Brassica)  Radish (Raphanus)

"Head"  X

Storage Root

Karpechenko 1925

With Unpredictable Results in the Beginning...

Cabbage (*Brassica*)

"Head"

Radish (*Raphanus*)

Storage Root

Radish leaves!!!

*RaphanoBrassica*

Cabbage roots!!!

Karpechenko
1925 (R.I.P.!!)
Modern Plant Genetic Engineering is Less Than 30 Years Old!

June 30, 1981

Protein Gene Is Transplanted From Bean to Sunflower

UPI

August 29, 1986

GENE-ALTED PLANT TO GET TEST

AP

The crop will consist of only 20 plants, but experts say the tiny tobacco stand may lead to an inexpensive genetic way to fight costly plant-devastating insects.

The Rohm & Haas Company of Philadelphia, one of the world’s largest producers of chemicals, announced Wednesday that the United States Department of Agriculture had approved the world’s first field test of genetically altered caterpillar-resistant plants. The Agriculture Department confirmed that the approval had been granted.

Two other chemical companies, Ciba-Geigy and Agracetus, have been conducting similar tests with genetically altered plants resistant to weeds.

September 3, 1987

COMPANY NEWS; Insect-Resistant Plant Reported

REUTERS

LEAD: A Belgian company said it had made an important scientific breakthrough by altering plants genetically so they became poisonous to insects. Plant Genetic Systems of Ghent said its technique could result in a big reduction in the spraying of farm crops with insecticides.

A Belgian company said it had made an important scientific breakthrough by altering plants genetically so they became poisonous to insects. Plant Genetic Systems of Ghent said its technique could result in a big reduction in the spraying of farm crops with insecticides.

P.G.S. said field trials of tobacco plants altered with the gene of a natural, non-toxic insecticide showed that successive generations of the plants produced enough of the insecticide in their leaves to kill caterpillars.
Plants Can Be Regenerated From Cells in Culture

1. Leaf explant
2. Create single cells
3. Purify cells
4. Plate out cells
5. Callus formation
6. Shoot and root development
7. Transplant new plantlets

Plants → Cells → Fertile Plants

Before There Was Dolly the Sheep There Were Cloned Orange Carrots!!!!
Plant Genome Projects Are Identifying Genes Essential For Increasing Crop Yields!!

**Plant Genomes Sequenced To Date**

- **Arabidopsis**
- **Rice**
- **Poplar Tree**
- **Soybean**
- **Corn**
- **Medicago**
- **Papaya**
- **Grape**
- **Castor Bean**
Gene Engineering Techniques Can Also Be Used To Transfer Specific Genes Into Crops

**TRADITIONAL PLANT BREEDING**

Plant Breeding Combines Many Genes At Once

- **Traditional Line**
- **Commercial Variety**
  
  \[ X \]

- **Desired Gene**
- (Many Crosses)

\[ \text{Mutagenesis/Selection/Genetic Diversity} \]

- **New Variety**
- **Many Genes Transferred**

**PLANT BIOTECHNOLOGY**

Biotechnology Adds A Single Gene

- **Desired Gene**
- **Commercial Variety**
  
  \[ \xrightarrow{\text{Gene Transfer (one generation)}} \]

- **New Variety**
- **One Gene Transferred**

**Conclusion:** Plant Genome Projects & Genomics Allow Us to Identify Genes That Can Be Used to Improve Crops Plants Using Classical & Genetic Engineering Approaches
Genetic Engineering Has the Advantage of Allowing Everything That’s Possible Biologically To Be Achieved

We Are Only Limited By Our Imagination and Knowledge of Biological Processes
Specific Examples of Bioengineered Crops

Pest Resistance
How to Control Insects?

PROTECT CABBAGE CROPS. The minute you plant a brassica, squadrons of cabbage white butterflies seem to descend on it to lay their eggs. The easiest way to thwart them is to cover your cabbage crops with row covers right from the start. The next best option is spraying with Bacillus thuringiensis to kill the young caterpillar larvae.

Bt Has Been Used For Many Years To Control Pests by Conventional And Organic Farmers !!!
How to Make an Insect-Resistant Plant

1. Isolate bacterial gene that produces protein toxic against certain insects

2. Insert Bt gene and a "marker" gene into cells

3. Identify cells with Bt and "marker" genes

4. Allow cells to grow into plants. Plants now produce toxins against insect pests
INSECT RESISTANCE with Bt

CONTROL Bt
Max Smith, Iowa Farmer
Engineering Papaya For Resistance to Papaya Ringspot Virus

Saved Hawaiian Papaya Industry

Sensitive Non-Transgenic Control Papaya

Resistant Transgenic Papaya
Using a **Wild Potato Gene** to Engineer Potato Plants Resistant to Potato Blight Fungus

Gene RB Cloned From Solanum bulbocastanum Confers Broad Spectrum Resistance to Potato Late Blight” Song et al., PNAS 100, 9128-9133 (2003)

Potato Blight Caused the Irish Famine That Killed One Million People in the Late 19th Century and Resulted in a Large Migration of Irish People to the United States!!!
Specific Examples of Bioengineered Crops

Abiotic Stress
Identifying Genes For Drought and Freezing Tolerance

Major Factors in Lowering Crop Yield

Identifying Salt Tolerant Genes

Sanan-Mishra et al. PNAS 102, 509-514 (2005)
Specific Examples of Bioengineered Crops

Seeds
Seeds Are Used in Many Ways as Food, Beverages, Spices, and Fuels!

- Beans
- Peas
- Wheat
- Corn
- Coconut
- Cashew Nuts
- Peanuts
- Pecans
- Cocoa Beans
- Coffee Beans
- Nutmeg
- Mustard
Most Importantly..... Our Food is Derived From Fourteen Crops & Over Half Produce Seeds For Human and Animal Consumption

<table>
<thead>
<tr>
<th>Seed Crops</th>
<th>Non-Seed Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>Potato</td>
</tr>
<tr>
<td>Rice</td>
<td>Sweet Potato</td>
</tr>
<tr>
<td>Corn</td>
<td>Cassava</td>
</tr>
<tr>
<td>Barley</td>
<td>Sugar Beet</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Sugar Cane</td>
</tr>
<tr>
<td>Soybean</td>
<td>Banana</td>
</tr>
<tr>
<td>Common Bean</td>
<td></td>
</tr>
<tr>
<td>Coconut</td>
<td></td>
</tr>
</tbody>
</table>

In Some World Populations 75% of Calories Are Derived From Seeds!
Vitamin A Deficiency Causes 1,000,000 Deaths Per Year!

Other Nutritionally-Enhanced Seeds (e.g., Folates, Micronutrients, Vitamin E)

Engineering For Seed Size & Yield Is Not New!

Engineering Bigger Seeds 10,000 Years Ago

- Elder
- Sunflower
- Squash

Wild | Crop

Engineering Bigger Seeds Today

WT | ap2-10

But Need to Identify the Critical Genes

Our American Ancestors, 10,000 BC

Jofuku et al., PNAS, 2005
Specific Examples of Bioengineered Crops
Biofuels
A Perfect Storm for Energy Crops

Demand Trends
- Consumption outpacing discovery
- China & India

Supply Trends
- Nationalization of reserves
- High oil prices
- Peak production

Oil Security
- Little domestic supply
- Unrest in producing regions

Environmental
- Carbon emissions
- Drilling/mining

Pressure to create a significant, renewable, domestic source of liquid fuels
U.S. Ethanol Production

35 billion gallons of renewable and alternative fuels in 2017 (RFS)

Time is Short—Need Crops in the Ground By 2015!
Using Dedicated Energy Crops To Produce Biofuel

"With plausible technology developments, biofuels could supply some 30% of global demand in an environmentally responsible manner without affecting food production. To realize that goal, so-called advanced biofuels must be developed from dedicated energy crops, separately and distinctly from food."

Steven E. Koonin
Chief Scientist, British Petroleum
Biomass Yield Matters

- At 2 tons of biomass per acre, a 5,000-ton/day biorefinery would require a radius of about 50 miles to support it.
- A 20-ton dedicated energy crop would shrink that area by 90%
Potential Dedicated Energy Crops

- Switchgrass
- Sorghum
- Miscanthus
- Sugarcane
The “Perfect” Energy Crop

High biomass: increased growth rate, photosynthetic efficiency, delayed flowering

Improved composition & structure: higher fuel yield per ton

Disease and pest resistance

Optimized architecture: dense planting, no lodging, easier harvest

Salt, pH and Aluminum tolerance

Rapid and cost-effective propagation

Stand establishment: cold germination, cold growth

Perennial: multi-year crop, efficient nutrient use, high fossil energy ratio

Deep roots: drought tolerance, nutrient uptake, carbon sequestration

These Are All Yield Traits! Identify From Genome Projects!
Engineering Biomass
10,000 Years Ago

Foxtail Millet

Wild
Domesticated

Engineering Biomass
2008

35S:ANT

Bob Fischer
UC Berkeley
Plants Have Been Engineered For Large Numbers of Traits in Laboratories Around the World

Tens of Thousands of GE Experiments!!

**Genetically Engineered Traits**

- **Improving Pest and Weed Management**
  - Herbicide tolerance
  - Virus resistance
  - Insect resistance
  - Bacterial resistance
  - Fungal resistance

- **Improving Agronomic Properties**
  - Altering cold sensitivity
  - Improving water stress tolerance
  - Improving salt tolerance
  - Improving nutrient uptake
  - Drought Resistance*

- **Improving PostHarvest Qualities**
  - Delay of fruit ripening
  - Delay of flower senescence/timing
  - High-solids tomatoes
  - High-starch potatoes
  - Sweeter vegetables

- **Improving Plant Breeding**
  - Male sterility; production of hybrid seeds *(Canola)*

- **Improving Nutritional Quality**
  - High-methionine and high-lysine seeds
  - Decaffeinated Coffee*
  - Vitamin-enriched grains
  - Allergen-free seeds/grains*

- **Molecular Farming**
  - Oils
  - Starch
  - Plastic
  - Enzymes, Pharmaceuticals
  - Ethanol/Transportation Fuel*

- **Detoxifying Contaminated Soils**

But Only a Few Have Helped Generate New Crops!
The “Simple Ones With Economic Drivers”

- Crops in Desert & Drought
- *Chemical Free* Crops
- *Healthier* Crops
- Crops as Factories & *Vaccines*
- Crops to Clean Environment
- Longer Lasting Crops
One Way is to Use These New Traits in Engineered Crops That Farmers Have Adopted Faster Than Any New Agricultural Technology In the Past 100 Years!

Over 1.7 Billion Acres of Bioengineered Crops Have Been Grown World-Wide Since 1996 and 280 Million Acres in 2007

ISAAA Brief, 2007
Engineered Crops Have Increased Yields, Reduced Pesticide Use, and Increased Incomes of Farmers in the Developing World

WHAT ABOUT SAFETY?
How Many Genes Did You Eat Today?

- One lettuce leaf has two million cells
- Each lettuce cell has ~ 25,000 genes
- One lettuce leaf has fifty billion genes
- A small salad has 10 lettuce leaves or FIVE HUNDRED BILLION GENES!!!

What About the Carrots, Celery, Tomatoes, etc.? What Happens to the Genes That You Eat?
Safety Issues of Genetically Engineered Plants Have Been Investigated and Discussed For Almost 25 Years!!!
“The public has been told for several years that GM foods are inherently unsafe to eat. Most people would like to know what evidence exists to back up such claims. We have examined the results of published research and have found nothing to indicate that GM foods are inherently unsafe. If anybody has convincing evidence, get it out in the open so that it can be evaluated.”

Hundreds of millions of people have eaten GM foods with no ill effects!
However... There's a Battle Raging to Get Bioengineered Crops Adopted in Many Parts of the World
The GMO “Controversy” Has European Origins and is Complex and Not Science Based

- Ideology / Anti-Technology / Anti-Biotech/Anti-Science/Unnatural/Propaganda
- Lack of Confidence in Government -- No Strong USDA, FDA, or EPA Tradition in Europe (Protect Food Supply -- Mad Cow -- Dioxin!)
- Labeling -- Want to Know and Choose What is Eaten (Personal Liberty)!
- Experience of Europe in WWII -- Wary of Genetic Manipulation
- Small Farmer Tradition in Europe
- Production-Oriented Farming -- Subsidies/More Production/More Euros ($54B/2003)
- Organic Growers/Markets -- Gain Market Share (Follow the $!!)/Pollen Flow -- “Contamination”
- No “Obvious” Consumer Benefit -- First Generation AgBiotec/No Need
- Trade/Protectionism -- Keeping out US Farm Products -- GM Crops
- Large European Agrochemical Companies -- Lost First Biotec Round
- Ecological Issues -- Native Species “Contamination”
- Lack of Public Science Awareness
What Has Been Some of the Real Life Affects of the GMO Controversy?

AFRICAN COUNTRIES REJECT GM FOOD AID

Zimbabwe and Zambia have rejected genetically modified food donations intended to avert drought-induced food shortages. Wisdom Mzungraii reports for Harare that participants at an international conference on genetic engineering and sustainable agriculture in Lusaka, Zambia commended the countries’ decision to mill some of the donated food instead.

Dr. Luke Mumba, chairman of the Biosafety Council of Zambia and research of the University of Zambia, commented that while there was respect for the two countries’ decision, there was need to adopt safe biotechnological advances, and that the use of GM technology could contribute to the complex problems of alleviating poverty and malnutrition. Meanwhile, Zambian Minister of Science and Technology Judith Kapulimonga said the problem of food insecurity in Africa was a result of complex issues that required an integrated approach for sustainability.

See the article in http://allafrica.com/stories/200510110710.html.
Professor Frank Furedi, University of Kent, England
Times are Changing

The New York Times

April 21, 2008

In Lean Times, Biotech Grains Are Less Taboo

By ANDREW POLLACK

Soaring food prices and global grain shortages are bringing new pressures on governments, food companies and consumers to relax their longstanding resistance to genetically engineered crops.

In Japan and South Korea, some manufacturers for the first time have begun buying genetically engineered corn for use in soft drinks, snacks and other foods. Until now, to avoid consumer backlash, the companies have paid extra to buy conventionally grown corn. But with prices having tripled in two years, it has become too expensive to be so finicky.
The End

….or is it the Beginning?
So.....Why Seeds??

Seeds Protect and Disperse Plant Embryos and Come in Many Shapes and Sizes!
Science vs. Non-Science

• Non-Scientific Approach
  - Starts with conclusion, searches for evidence to support it ("cherry picking")
  - Discredits alternative views
  - Often lacks context
  - "Ideological" (whether GMOs, evolution, or stem cells)

• Scientific Approach
  - Tests hypotheses by experimentation
  - Collects and analyzes all available evidence before reaching conclusion (e.g., rejecting hypothesis)
  - Actively seeks alternative interpretations
  - Is his/her own greatest critic
  - Applies critical thinking skills - what is the basis for this?
## SIGNIFICANT NUMBERS

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Bioengineered Crop Field Trials</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Number of Countries Growing Bioengineered Crops</td>
<td>23</td>
</tr>
<tr>
<td>Proportion of World Crop Area</td>
<td>20%</td>
</tr>
<tr>
<td>Number of Bioengineered Plant Species Tested</td>
<td>41</td>
</tr>
<tr>
<td>Number of Significant Adverse Incidents</td>
<td>0</td>
</tr>
</tbody>
</table>
ADDING TO THE CHALLENGE TO PRODUCE SUFFICIENT FOOD......

More Than 90% of the World’s Land is Unsuitable for Growing Food Crops

Plants Require Water and Nutrients (e.g., Nitrogen) to Grow!!

Pests (insects, fungi, bacteria, & viruses) Make Farming Even More Difficult!!! And Foods Unsafe (e.g., mycotoxins)!!!

Growing Crops in Harsh Environments is not “Natural”!!