Genetic Engineering and the Seed Science

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Monsanto Company

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Agenda

• Introductions
• Anticipatory Set
• Hands On Demo
• Presentation
• Helpful Resources
Anticipatory Set
Which is a “GMO”?

Let’s find out...
Lateral Flow Strip Activity

Positive

Control line

Sample

Labeled specific antibodies

Antigen complex to conjugated antibody

Sandwich formation with capturing antibody

Unbound conjugated antibody with anti conjugate antibody

Antibody Conjugate Pad

Nitrocellulose Membrane

Test Line

Control Line
Rising Population

Growing enough for a growing world

Global Population

Source: http://www.fao.org/3/a-I6881e.pdf

Source: The World Bank, Food and Agriculture Organization of the United Nations (FAO-STAT), Monsanto Internal Calculations

Limited Farmland

Farmers will need to produce enough food with fewer resources to support our world population

Acres per Person

Source: The World Bank, Food and Agriculture Organization of the United Nations (FAO-STAT), Monsanto Internal Calculations
Sustainable Agriculture
Where We Have Been and Where We Are Going

Historic U.S. Average Corn Yields

- Early 1900's: 30 bu/a  10' X 73'
- Ca. 1980: 100 bu/a  10' X 44'
- Modern Day: 150 bu/a  10' X 29'
- 200 bu/a  10' X 22'
- 250 bu/a  10' X 17.5'
- 300 bu/a  10' X 14.5'
- 400 bu/a  10' X 11'

Future Corn Yields

bu/a = Bushels per Acre

Source: USDA Averages
Monsanto is a Global Leader in Modern Agriculture

• **We produce seeds**
  for key crops and vegetables that help farmers have better harvests while using energy, water and land more efficiently

• **We provide solutions**
  that help farmers around the world maintain soil health, improve practices and minimize damage from pests and disease

• **We drive innovation**
  through collaborations and partnerships that tackle some of the world’s biggest challenges
Developing Solutions for Farmers

A grower makes 40+ key decisions each growing season.
Dunning-Kruger Effect

Confidence

Experience

High

Valley of Despair

Slope of Enlightenment

Low

None

Expert
Methods of Crop Modification

- Cross-Breeding
- Mutagenesis
- Polyploidy
- Transgenics (GMO/Biotech)
- Gene Editing
Cross-Breeding

**Crop Example**

Norman Borlaug crossed two different types of wheat to produce a short statured variety which prevented tipping, increased yield and disease tolerance contributing to the “Green Revolution”.

**Technique**

**Breeding:** Combining two sexually compatible sub-species to create a variety with the desired characteristics of the parents.

Want the infographics? Visit Monsanto.com/STEM (resources tab)
Dilemma in corn breeding: Finding new sources of useful genetic variation

Global Germplasm Diversity
Plant breeding is a powerful tool in improving crops and creating new varieties.
Mutagenesis

Ruby Sweet® grapefruits were created by exposing seeds to radiation causing a mutation resulting in a deep red fruit color.

**Mutagenesis:** Use of physical or chemical mutagens to induce random mutations, creating the desired characteristic.

Want the infographics? Visit Monsanto.com/STEM (resources tab)
**Polyploidy**

Seedless watermelons are a result of combining two varieties of watermelons with a different number of chromosomes.

**Polyploidy:** An uneven pairing of chromosomes sets occurring after cell division.
Transgenics

Rainbow Papaya is modified with an added gene that gives it resistance to the Papaya Ringspot Virus.

**Transgenesis:** Addition of genes from another species resulting in a plant with desired new characteristics.

Want the infographics? Visit Monsanto.com/STEM (resources tab)
Gene Editing

A precise deletion in a specific gene prevents the mushroom from browning but all other characteristics remain the same.

Gene Editing: Use of a DNA editing tool such as CRISPR-Cas9 targeting a deletion or edit at a precise location within the cell’s DNA.

Want the infographics? Visit Monsanto.com/STEM (resources tab)
Methods of Crop Modification

- Cross-Breeding
- Mutagenesis
- Polyploidy
- Transgenics (GMO/Biotech)
- Gene Editing

Want the infographics? Visit Monsanto.com/STEM (resources tab)
Little Cranberry Island, Maine
Genetic Modification Happens in Nature

Recently, scientists discovered what may be the world’s first GMO—a sweet potato that was naturally improved by bacteria in the soil.

Centuries ago, some wild sweet potato plants “borrowed” a natural bacterial gene in the environment. These plants ended up growing larger and stronger than other sweet potatoes.

Today, plant scientists are making similar efforts to adapt desirable traits to new plants. This process, known commonly as “genetic modification” or “GMO,” helps plants thrive in their environment—which helps farmers have better harvests while using resources more efficiently.

For more information: http://bit.ly/washpost042915
For the full study: http://bit.ly/sciencedaily42815
Methods for making a new GMO

1. Extraction of embryos (explants)
2. Particle bombardment
3. Agrobacterium
   - Gene transfer to corn genome (new event)
4. Selection of transformed callus
5. Regeneration
6. Generation of multiple events per trait
7. Creation of seed with trait
How many transgenic ("GMO") crops are on the market today?
GMO Foods

Only 10 GMO crops exist on the market today, offering consumer and farmer benefits

<table>
<thead>
<tr>
<th>Insect Resistance</th>
<th>Herbicide Tolerance</th>
<th>Virus Resistance</th>
<th>Non-Browning</th>
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</thead>
<tbody>
<tr>
<td>Drought Tolerance</td>
<td>Sustainable Production</td>
<td>Disease Resistance</td>
<td></td>
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</tbody>
</table>

- Corn
- Soy
- Cotton
- Alfalfa
- Sugar Beets
- Canola
- Papaya
- Apple
- Potato
- Squash
What is not a GMO?

• These crops (among many) are not the result of biotechnology
### Enzymes

Nearly all cheese is made using rennin produced through biotechnology.

### Yeast

Scientists use biotechnology to create unique yeast strains for use in brewing beer and making bread.

### Medicine

Most insulin, supplements, and vitamins are produced through biotechnology.
GMO testing and regulation is similar to clinical trials for medicine.

<table>
<thead>
<tr>
<th></th>
<th>Discovery</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gene/trait identification</td>
<td>Proof of concept</td>
<td>Early development</td>
<td>Advanced development</td>
<td>Prelaunch</td>
</tr>
<tr>
<td>Average duration</td>
<td>54 months</td>
<td>27 months</td>
<td>30 months</td>
<td>37 months</td>
<td>49 months</td>
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<tr>
<td>Average cost</td>
<td>USD 31 million</td>
<td>USD 28.3 million</td>
<td>USD 13.6 million</td>
<td>USD 45.9 million</td>
<td>USD 17.2 million</td>
</tr>
<tr>
<td>Key activity</td>
<td>• High-throughput screening • Model crop testing</td>
<td>• Gene optimization • Crop transformation</td>
<td>• Trait development • Preregulatory data • Large-scale transformation</td>
<td>• Trait integration • Field testing • Regulatory data generation • Product development</td>
<td>• Regulatory submission • Seed bulk-up • Premarketing • Product development</td>
</tr>
</tbody>
</table>

- **Discovery and collaborative partners**
  - Thousands of genes are often tested
  - A few genes are advanced for optimization
  - Products combine vector and breeding stacks
Biotechnology, from an idea to the field

- Product concept
- Gene discovery
- Evaluation
- Event selection
- Variety development
- Regulatory process
- Field production
- Market

<table>
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<tr>
<th>Choice of genes/proteins</th>
<th>Agronomic assessment</th>
<th>Characterization of gene product and comparative analysis</th>
<th>Postmarket assessment</th>
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<tbody>
<tr>
<td>Source</td>
<td>Greenhouse to field</td>
<td>Toxicity</td>
<td>Postmarket surveillance</td>
</tr>
<tr>
<td>Initial molecular</td>
<td>Agronomic</td>
<td>Allergenicity</td>
<td>Supplemental food/feed studies, as needed</td>
</tr>
<tr>
<td>characterization</td>
<td>performance</td>
<td>Nutrition</td>
<td></td>
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<tr>
<td>History of safe use</td>
<td>Phenotypic screening</td>
<td>Compositional analysis</td>
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<tr>
<td>Mode of action</td>
<td>of events</td>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Event selection (&lt;1%)</td>
<td>Further molecular characterization</td>
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Monsanto GMO Traits

1. Bt Products
2. Roundup Ready® Crops
3. Disease resistant Squash
4. Drought Tolerant Corn
5. Soybeans – reducing Trans/Saturated fats
   • SDA Omega-3 soybeans
   • Vistive® Gold soybeans

Industrial/non toxic benefits of replacing petroleum-based products and synthetic oils

• The bacterium, *Bacillus thuringiensis*, makes several proteins that are toxic to specific insects (*Coleoptera* and *Lepidoptera*). These protein toxins are activated in the insect gut and bind to specific receptors in the insect.

• Humans and other animals have acidic stomachs and thus the protein is digested.

• Mammals lack the receptor to bind the protein making it completely non-toxic to humans and other animals.
Roundup Ready® Crops
(tolerant to the herbicide glyphosate)

5-EnolPyruvylShikimate-3-Phosphate Synthase

- Glyphosate binds to EPSPS and disrupts amino acid synthesis pathway
- Monsanto discovered an *epsp* gene from a bacterium that was not sensitive to glyphosate but still performed the same function.
Environmental Benefits

The reduction in pesticides from 1996 to 2014 was estimated at 1.3 billion lbs. or 8.2% reduction.

In 2014 alone, biotech helped prevent an estimated 49.4 billion lbs. of CO₂ emissions, equivalent to removing 10 million cars from the road for a year.

Without biotech, it would take an additional 44.7 million acres (1 acre roughly size of football field) to produce the same amount of food produced during 1996 to 2014.
Other Industry Products

Golden Rice/Super Banana – Vitamin A (2020)
- to cure Vitamin A deficiency in developing countries which kills 670,000 children each year.

Citrus Greening Resistant Oranges
- gene from spinach for resistance to the bacterium, Liberibacter.

Aphid Resistant Wheat
- Natural defense to Aphids which require repeat pesticide usage to combat pests.

Potato – resist bruising (gene taken from wild variety)
- Lowers Acrylamide in high temperature cooking
- Lowers bruises

- Mosquitoes (Eliminates transmission of Malaria)
  - GMO mosquito blocks malaria parasite infection
  - Could be used for Zika virus?

- Arctic Apples (Apples that don’t brown)
  - Reduction in production of one protein- Polyphenol oxidase (PPO)
Lesson Plans & Kit

agclassroomstore.com

https://agclassroomstore.com/gm-soybean-seed/
Documentary Highlight

Food Evolution

- See where the film will be showing in your community: http://www.foodevolutionmovie.com/screenings/
- Watch the trailer and share it: https://www.foodevolutionmovie.com/#trailer
- Follow the producers on Twitter: https://twitter.com/foodevomovie
- Rent and see the film, through Hulu and these services: Amazon Video, iTunes, YouTube, Google Play Movies & TV
## Check it out!

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<td>Food and Farm Discussion Lab</td>
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<td>Grow Next Gen</td>
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