Gene Editing and the Future of Agriculture

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About ITIF

- Independent, nonpartisan research and education institute focusing on intersection of technological innovation and public policy, including:
  - Innovation and competitiveness
  - IT and data
  - Telecommunications
  - Trade and globalization
  - Life sciences, agricultural biotech, and energy

- Mission to formulate and promote policy solutions that accelerate innovation and boost productivity

- Ranked by University of Pennsylvania as top science and technology think tank in United States and number two in world
“A truly extraordinary variety of alternatives to the chemical control of insects is available. All have this in common: They are *biological* solutions, based on understanding of the living organisms they seek to control. ...Some of the most interesting of the recent work is concerned with ways of forging weapons from the insects’ own life processes.”

--Rachel Carson, Silent Spring, 1962

Chapter 17, para 3
“Rarely does a discovery come along that could revolutionize medicine...

“...the most surprising discovery, and the most consequential discovery in this century so far...

“Critics say ‘You’re Playing God.’ God gave us brains so we could find a way to eliminate suffering of human beings and if that’s playing God, I guess that’s the way it is.”

https://www.cbs.com/shows/60_minutes/video/dIdyXroziO4KUSRu_98VLALNMxtt7cXg/crispr-the-gene-editing-tool-revolutionizing-biomedical-research/
What is a “GMO”?

“organisms (i.e. plants, animals or microorganisms) in which the genetic material (DNA) has been altered in a way that does not occur naturally by mating and/or natural recombination”


Definition describes something that does not exist. (Sweet potatoes, monarch butterflies, every living thing)
Corn/maize

Teosinte

Modern Corn
Hate how common **GMOs** seem to be nowadays?

*Just remember...*

...by one means or another, humans have **always** loved screwing with nature.

And we made all the really big changes AGES ago.

CRACKED.COM
Global Area of Biotech Crops, 1996 to 2017: Industrial and Developing Countries (Million Hectares, Million Acres)
Economic &
Environmental Impacts

- $18.2 billion in AV in 2016—186.1B since 1996
  - soybeans +213MT
  - maize +405MT
- Pesticide use -671.4 M kg
- CO2 reductions ~ -16.7 million autos for 1yr
- EIQ = -18.4%

Source: https://www.tandfonline.com/doi/full/10.1080/21645698.2018.1464866 &
What Is “Gene Editing” ("New Breeding Techniques")?

- ZFN = Zinc Finger Nucleases
- TALENS = Transcription activator-like effector nucleases
- ODM = Oligonucleotide directed mutagenesis
- MEGA = meganucleases
- RdDM = RNA dependent DNA methylation
- RNAi/PTGS = small, interfering RNAs/Post translational gene silencing
- CRISPR-Cas9 = Clustered regularly interspaced short palindromic repeats
- (Gene drives/reversal drives...)

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The History of CRISPR

- CRISPR discovered in 1987 (Yoshizumi Ishino)
- An unusual repeating DNA sequence (24-48bp) that was accidentally cloned
- Similar repeating sequences found in all bacteria, archaea examined
- It is an adaptive immune system for defense against viruses
- “RNA derived from... CRISPR loci direct large ribonucleoprotein complexes (cas) to destroy invading bacteriophage and plasmids”
- Identifies viral DNA and cuts it
Where Do We Find CRISPR In The Wild?

- There are at least 45 families of CAS genes/proteins
- “Libraries of tens of thousands of guide RNAs are available...”

How CRISPR Works

- The CRISPR portion is the post office wall full of mug shots
- The CAS protein is the U.S. Marshall
How CRISPR really Works...
Copyediting genomes at will...

- “My initial gut reaction was 'Oh my god, this is terrible. It's so scary... But when you give it more thought and weigh it against the environmental changes that we have already made and continue to make, it would be a drop in the ocean.”
  -- Micky Eubanks, Texas A&M

- “A dream come true for plant breeders…”
  --A. Gal-On
Gene Editing Publications

![Gene Editing Publications Chart]

*Projected total for 2016 based on data up to 10.3.16

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Why Is CRISPR Important? What Can We Do With It?

- Researchers have tweaked CRISPR so it can be used to target any specific DNA sequence (via “guide RNAs” – make your own!)
- It enables researchers to manage any DNA sequence of choice by changing, deleting, or inserting specific nucleotides or nucleotide sequences
- If you can imagine a change you’d like to make to a DNA sequence, CRISPR allows you to make it.
Gene Editing Timeline

- **2012**: Hornless milk cows
- **2015**: TALENs used to fight leukemia in two infant girls
- **2016**: In vitro CRISPR trials to cure HIV
- **2016**: CRISPR clinical study to cure lung cancer in China
- **2017**: CRISPR clinical trials to cure var. cancer in the US
- **2020**: Farm animals with var. resistances against virus and bacterial diseases
- **2015**: Herbicide resistant canola
- **2016**: Soybean with reduced trans-fats
- **2016**: Non-browning mushroom
- **2017**: Virus-resistant cucumber
- **2020**: Gluten-free wheat
- **2015**: Powdery mildew-resistant wheat
- **2016**: High yield waxy corn
- **2017**: Potatoes with altered starch
- **2017**: High yield rice
- **2020**: Non-allergenic apples and peanuts
- **2020**: Improved abiotic behaviour
- **2012**: Blight-resistant rice
How Researchers Already Have Used CRISPR

- Genetically “poll” dairy cattle
- Gene therapy: curing tyrosinaemia in mice; β-thalassaemia
- Make programmable transcription factors to turn genes on/off
- Disease resistance or HT in canola, wheat, rice, soy, potato, sorghum, tomato, mice, goats, pigs, sheep, cattle
- Drought tolerant crops (corn, rice, sugar cane, soy, tomatoes, barley, wheat...)
- Vitamin enriched oranges; micronutrient enhanced grains; oil-profile modified oilseeds
- Enhance product quality in mushrooms, apples, potatoes, tomatoes
- CRISPR gene drives (2015) targeting mosquitoes, ticks, invasive plants, weeds
- PERV deletion in pigs
- CRISPR used to gene edit human embryos (2015)
- T-cell augmented cancer therapy clinical trial (2016)
What Else Could We Do?

- Cure HIV
- Cure genetic diseases like CF, MD, Huntington's... (OMIM = 23,714)
- Cure cancer (restore p53-mediated tumor suppression)
- Improved N fixation; Nitrogen fixation in non legumes; enhanced photosynthesis (C3 plants to C4)
- Make mosquitoes immune to malaria/Dengue/Yellow Fever/Zika
- Drive mosquito species to extinction
- Rescue endangered species (Hawaiian honeycreepers; alala)
- Eradicate invasive species
- What else can you think of?
GMOs vs CRISPR: Same or different?

- Some have tried to draw a bright line between GMOs & CRISPR
- Earliest CRISPR uses were simple edits, usually deleting one or several nucleotides (letters)
- Using CRISPR to import exogenous DNA is increasingly common; now almost routine in animals, becoming easier in plants.
- In the near future we will be able to do with CRISPR whatever we could with GMOs, and much more.
- The specific technique we use is much less important than what we do with it.
- All techniques are used to improve plants, animals, diagnose and treat disease, use resources more efficiently and sustainably.
- Risks derive from results (phenotypes) more than specific techniques.
Further Reading

- Lluís Montoliu, The CRISPR page at CNB.
- Jennifer Doudna, “CRISPR systems in prokaryotic immunity” and “How CRISPR lets us edit our DNA.”
Thank You!

Val Giddings  |  @PrometheusGreen
If the only way to sell your product is to scare people with lies about your competitors’ products, that speaks volumes about the uselessness of your product.

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