Innovation in Agricultural Science

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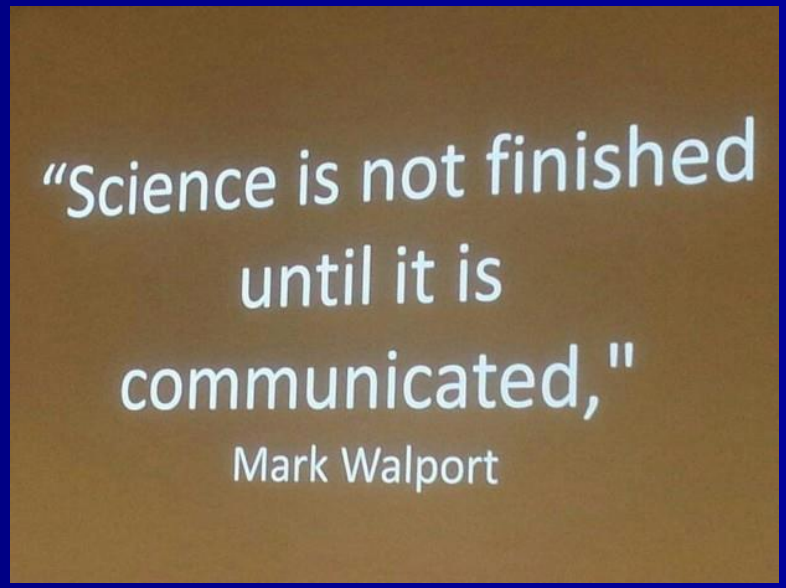

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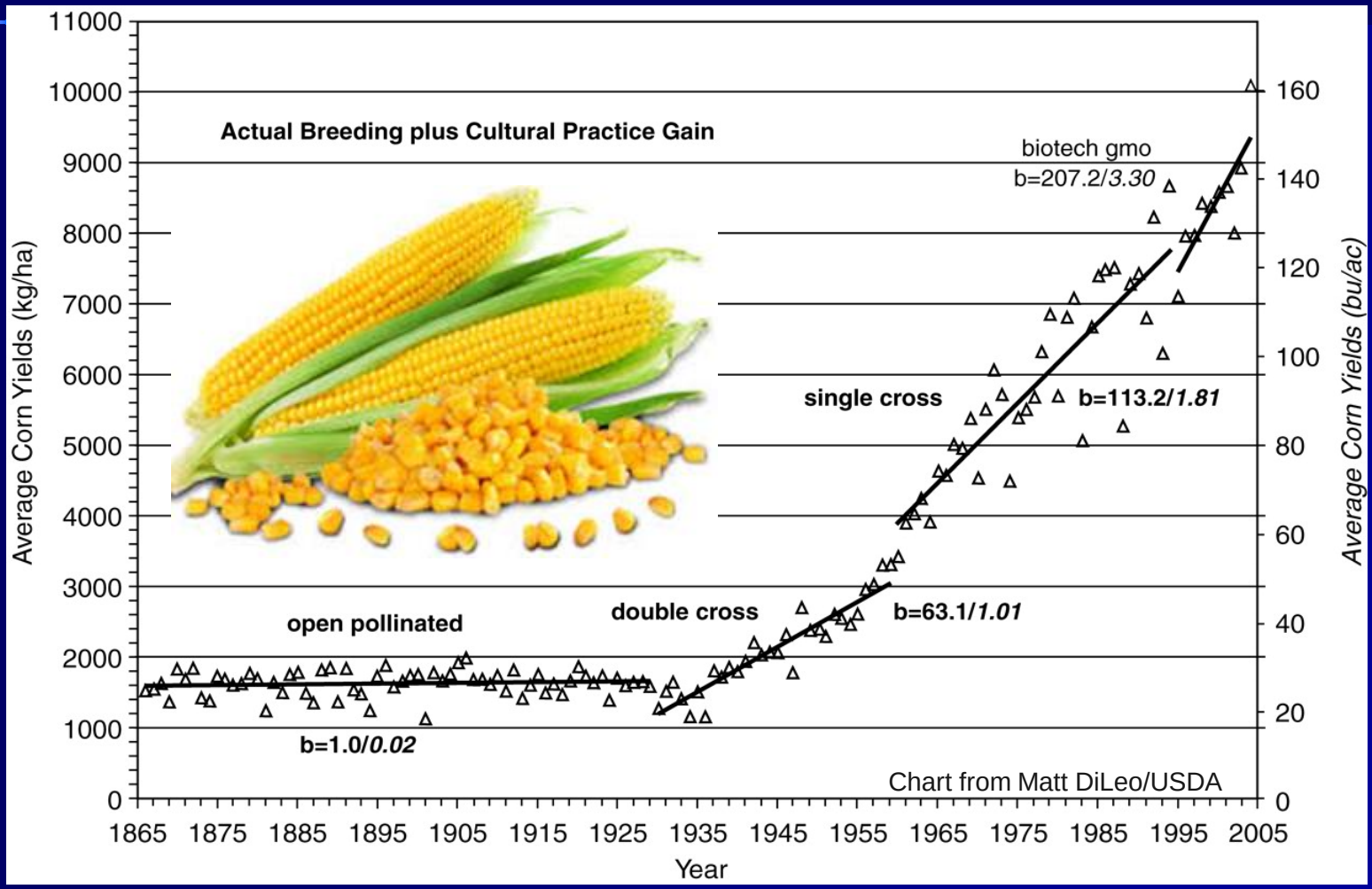
http://animalscience.ucdavis.edu/animalbiotech

Image credit: John Wood

Animal breeders have made remarkable genetic progress based solely on "conventional" selection

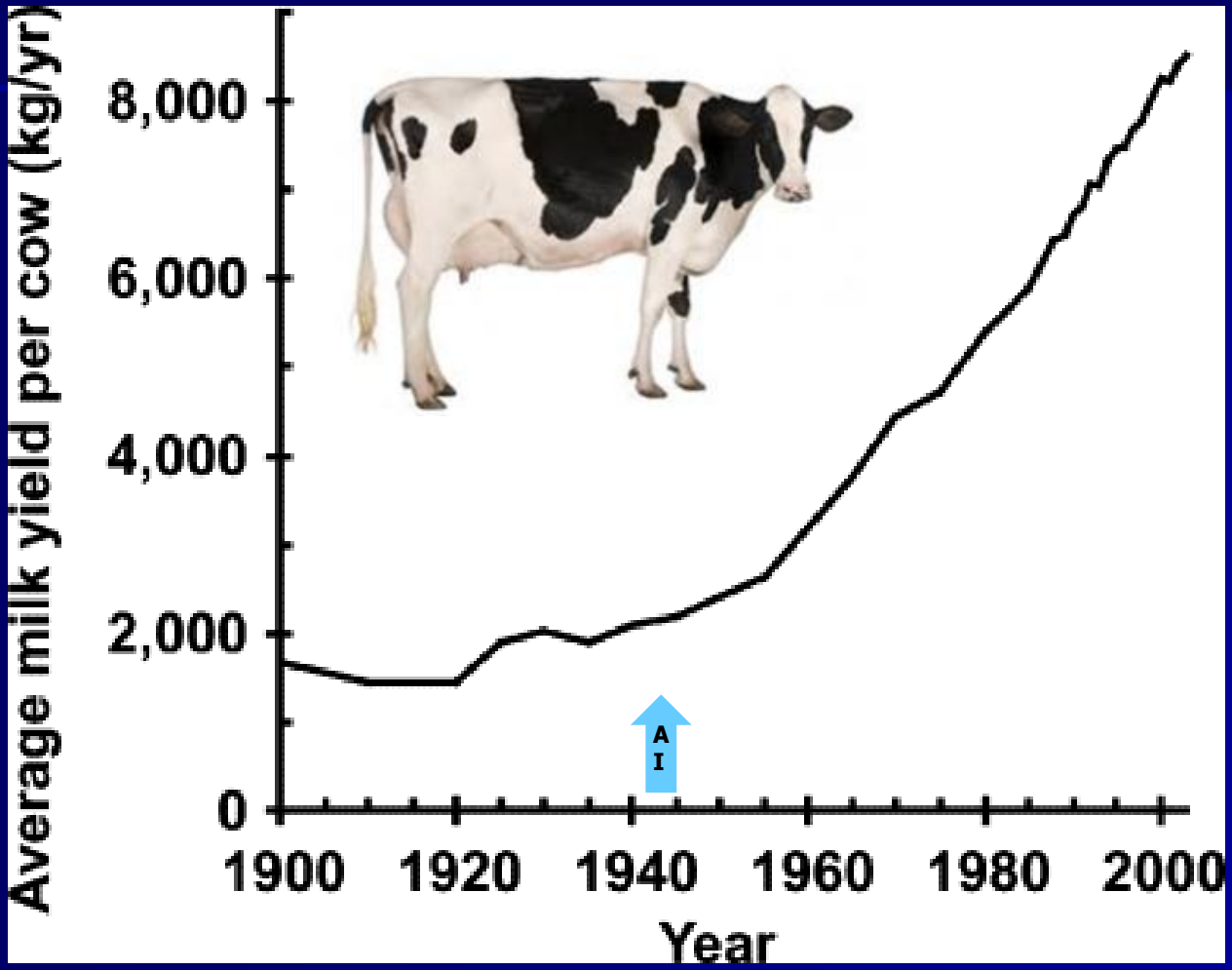
Plant and animal breeders have perhaps the most compelling sustainability story of all time



https://grist.files.wordpress.com/2015/12/corn-hybrid-yields.jpeg

1944: 25.6 million animals; total annual milk production of 53.1 billion kg.
1997: 9.2 million animals; total annual milk production of 84.2 billion kg.

About half of this 369% increase in production efficiency is attributable to genetic improvement enabled by AI



VandeHaar, M.J. and St-Pierre, N. (2006). **Major Advances in Nutrition: Relevance to the Sustainability of the Dairy Industry.** *Journal of Dairy Science* 89, 1280-1291.

Artificial insemination was initially a controversial technology

"In the initial stages of attempting to develop AI there were several obstacles. The general public was against research that had anything to do with sex. Associated with this was the fear that AI would lead to abnormalities. Finally, it was difficult to secure funds to support research because influential cattle breeders opposed AI, believing that this would destroy their bull market."

Foote, R.H. 2002. The history of artificial insemination: Selected notes and notables. J. Anim. Sci., 80 (E. Suppl.) (2002), pp. E22–E32

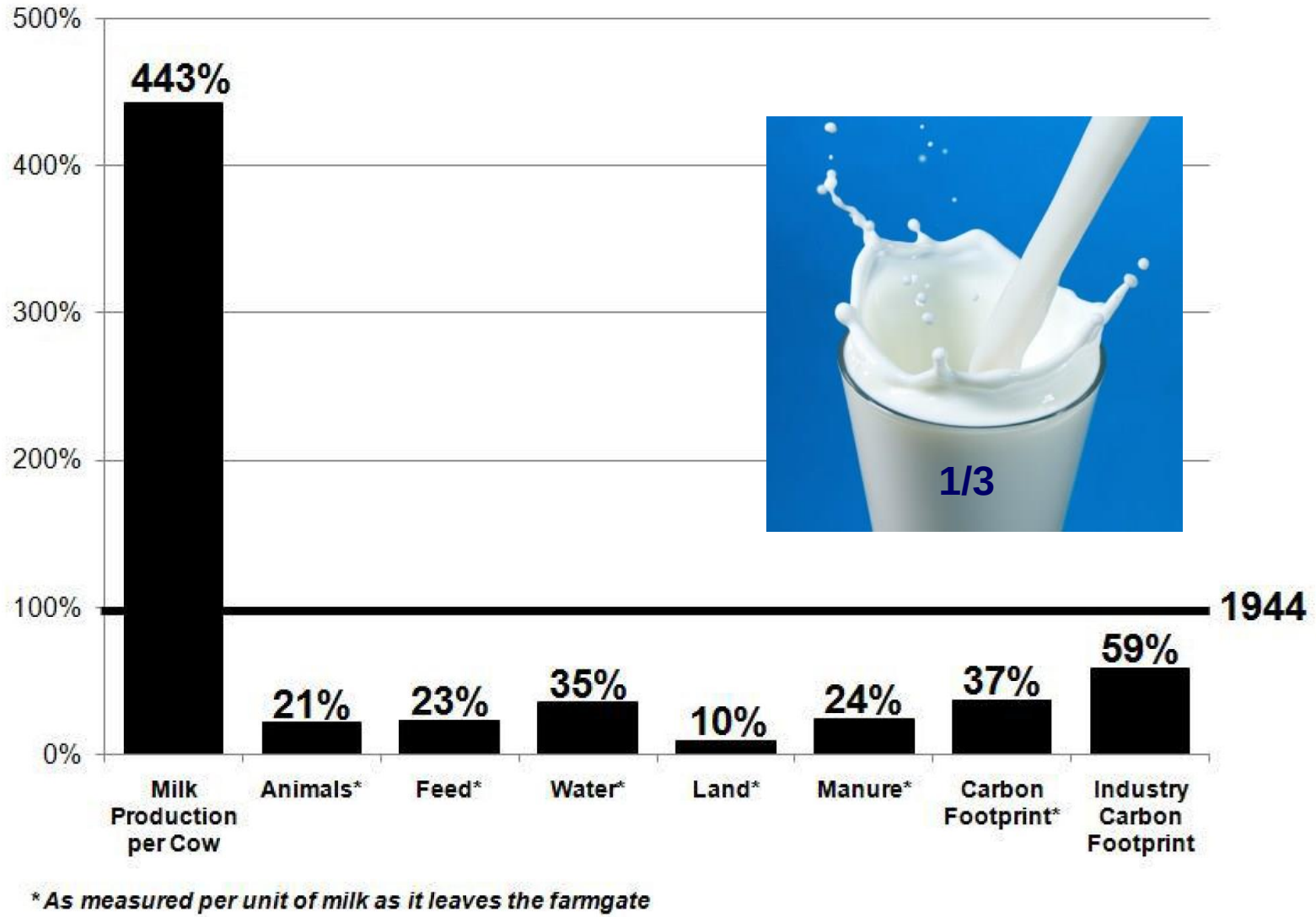


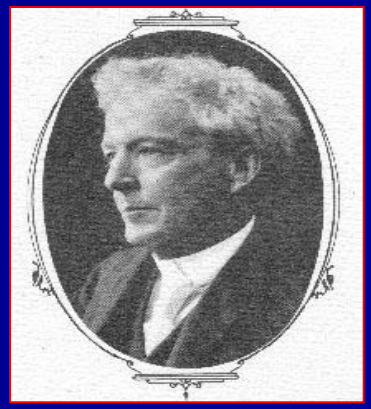
Figure 3. The 2007 U.S. milk production, resource use and emissions expressed as a percentage of the 1944 dairy production system. Adapted from Capper et al. (2009).

Capper, JL and DE Bauman, 2013. The Role of Productivity in Improving the Environmental Sustainability of Ruminant Production Systems. Annual Review of Animal Biosciences. 1 pp. 9.1–9.21

Concerns around breeding not new
Who said this? and when?

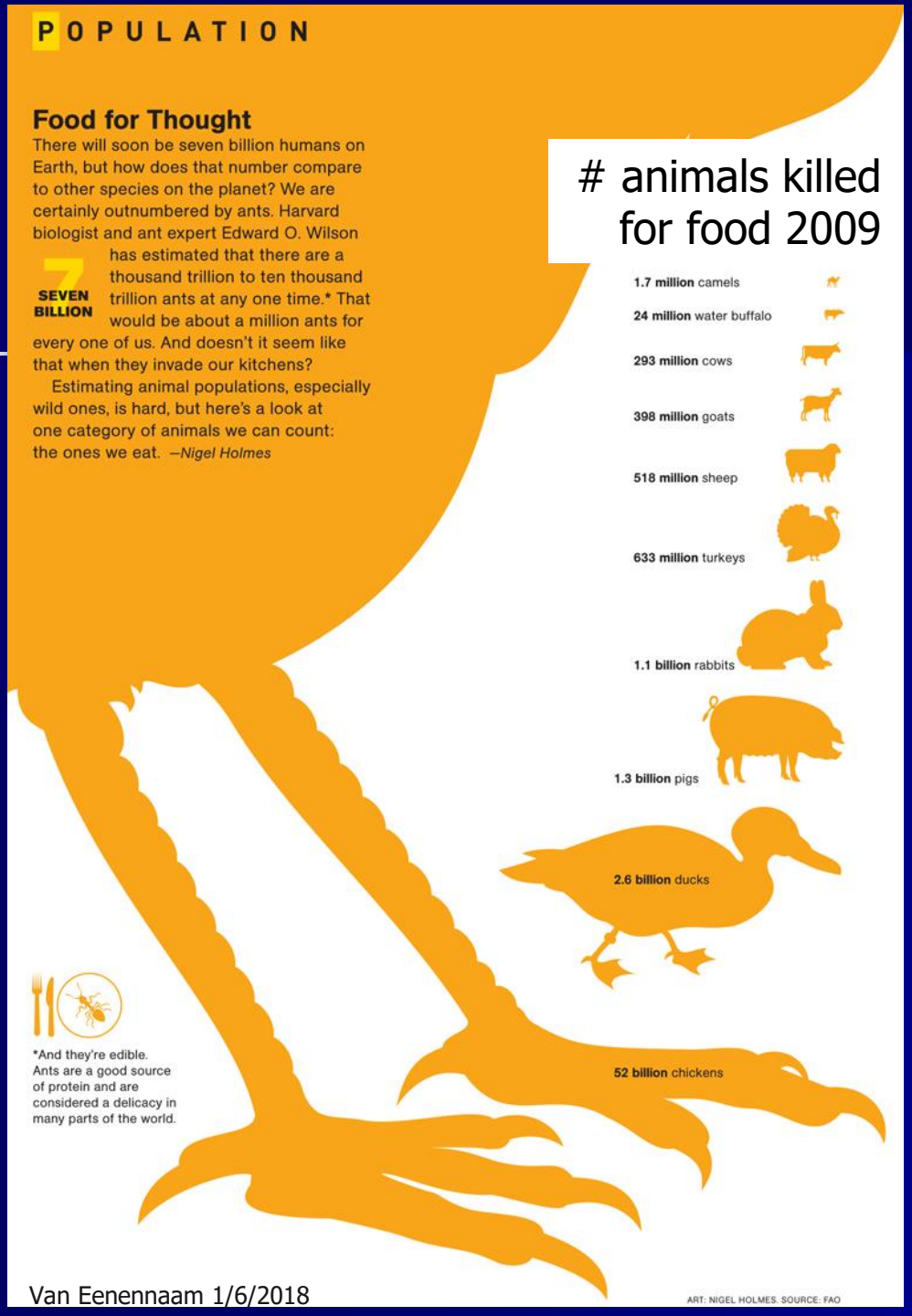
"We have recently advanced our knowledge of genetics to the point where we can manipulate life in a way never intended by nature. We must proceed with the utmost caution in the application of this new found knowledge."

LUTHER BURBANK
Creator of over 800 new plant varieties through plant breeding
1906



The 8-week old body weight of broiler (meat) chickens has increased from 0.81 kg to 3.14 kg over the period 1957 to 2001, and approximately 80% of this four-fold increase has been the result of genetic selection.

Havenstein, G., et al. (2003). **Growth, livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets.** *Poultry Science* 82, 1500-1508.



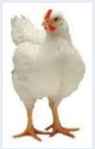
What if we had not genetically improved our food animals?

1.3 billion pigs

2.6 billion ducks

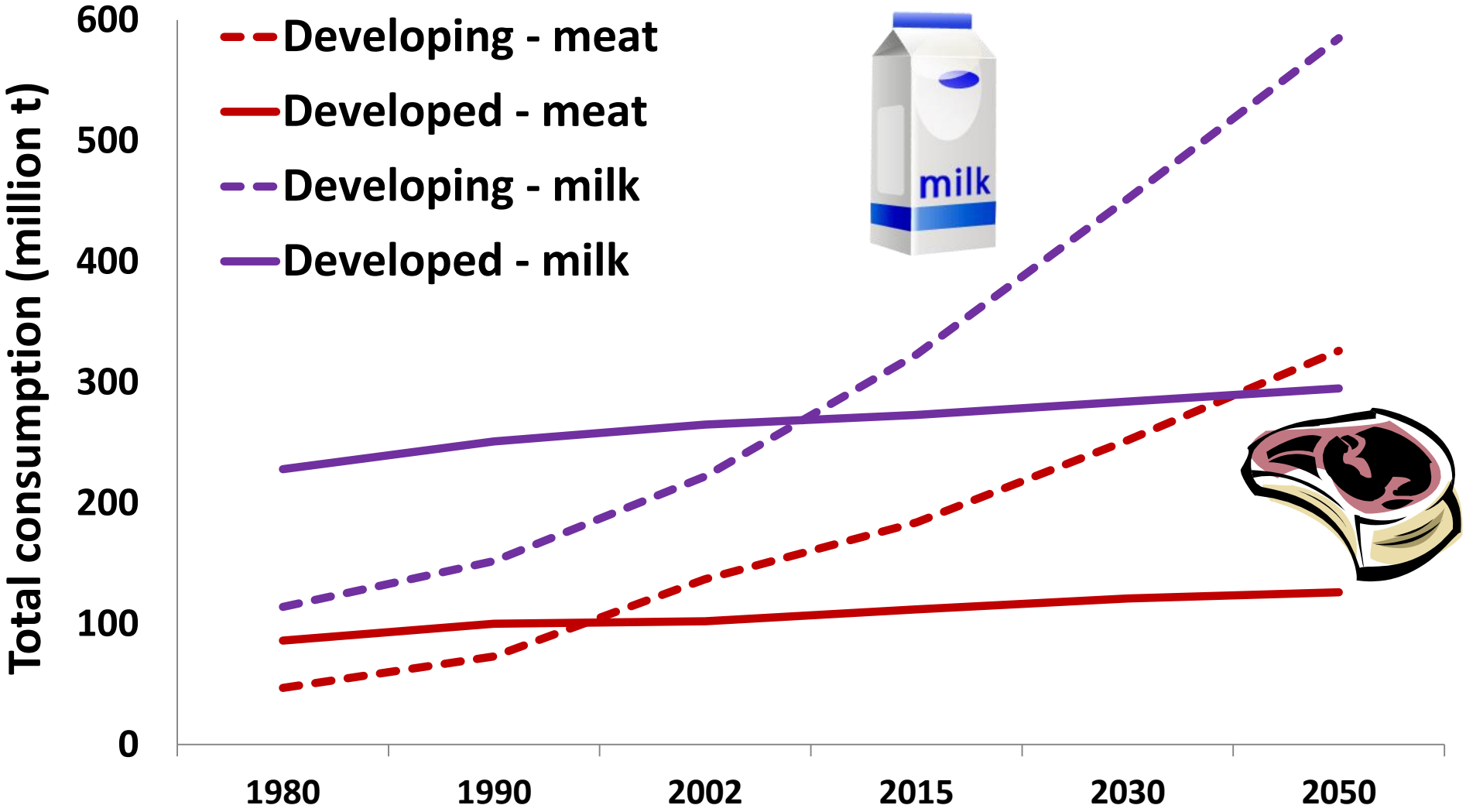
52 billion chickens

- 59 million tons eggs
- 90 million tons meat

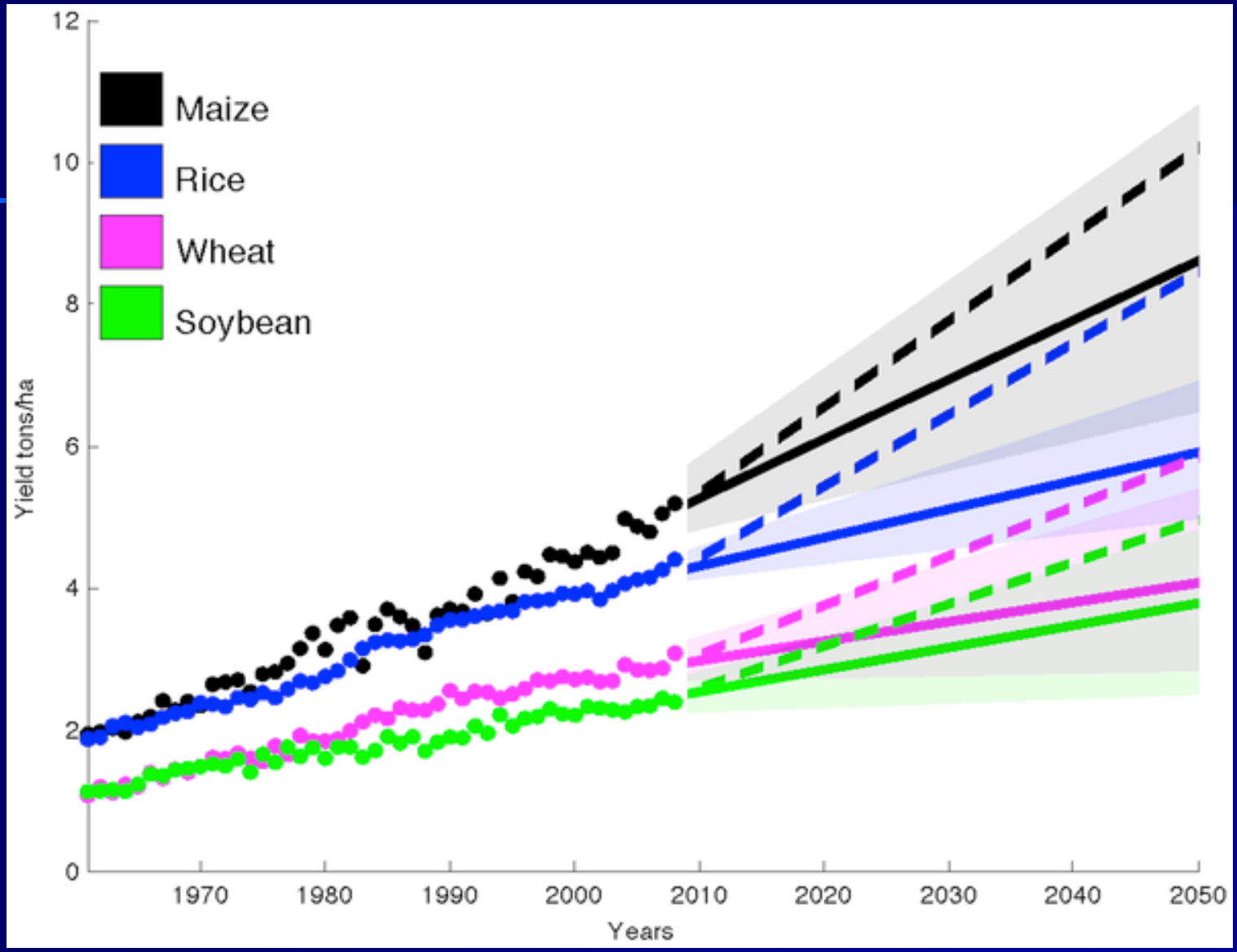
	2014 total production	2014	Amount needed at 1950s rate	Additional needed
Soybeans 	3,927,090,000 BU (235,562,540,000 lb) (106,849,370,802 kg)	82,591,000 Acres (33,423,392 ha)	180,971,889 Acres (73,236,725 ha)	**~ 98 million Acres**  (~40 million ha)
Corn 	14,215,532,000 BU (796,069,979,000 lb) (361,091,268,460 kg)	83,136,000 Acres (33,643,946 ha)	372,134,346 Acres (150,597,427 ha)	**~ 289 million Acres**  (~120 million ha)
Dairy cattle 	206,046,000,000 lbs milk (93,460,893,469 kg)	9,257,166 head	38,774,181 head	**~ 30 million head** 
Broilers 	51,373,100,000 lbs meat (23,302,446,000 kg)	8,544,100,000 head	16,679,545,455 head	**~ 8 billion head** + an additional **81.5 billion lbs** feed due to less efficient FCR

Past and projected trends in consumption of meat and milk in developing and developed countries

(Thornton, P.K. 2010 Livestock production: recent trends, future prospects. Philosophical Transactions of the Royal Society B: Biological Sciences 365:2853-2867).



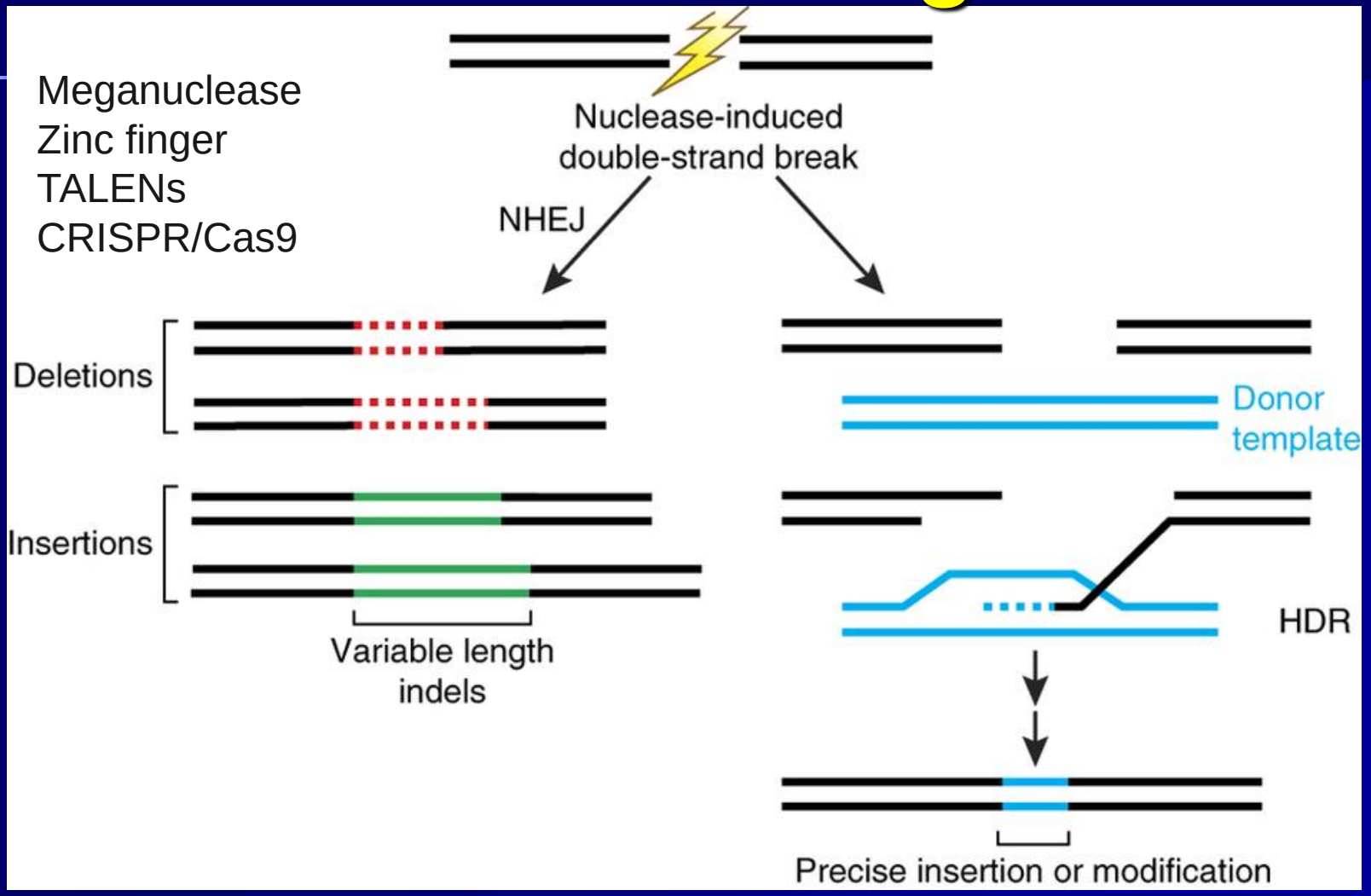
Yield Trends Are Insufficient to Double Global Crop Production by 2050



Ray DK, Mueller ND, West PC, Foley JA (2013) Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6): e66428. doi:10.1371/journal.pone.0066428 http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0066428

Gene or Genome Editing What are we talking about?

Meganuclease
Zinc finger
TALENs
CRISPR/Cas9



Sander JD, Joung JK. CRISPR-Cas systems for editing, regulating and targeting genomes. *Nat Biotech* 2014;32:347-355.

How might gene editing be used in animal breeding?

Species	Target	TargetedTrait/Goal
Cattle	**POLLED allele from beef cows into dairy cows**	**No horns**
	Myostatin gene knockout	30% increased muscle yield
	Beta-lactoglobulin gene knockout	Elimination of milk allergen
	Insertion of lysostaphin transgene	Disease resistance
	Insertion of lysozyme transgene	Disease resistance
	Insertion of SP110 transgene	Resistance to tuberculosis
Chicken	Ovalbumin gene knockout	Elimination of ovalbumin in egg
	Insertion of Immunoglobulin heavy chain locus	Germline gene editing
Goat	Myostatin gene knockout Prion protein gene knockout Beta-lactoglobulin gene knockout	Increased muscle growth Elimination of prion protein Elimination of milk allergen
Pig	**CD163 gene knockout**	**PRRS Virus Resistance**
	Interspecies RELA allele substitution	African Swine Fever Resistance
	Myostatin gene knockout	Increased muscle yield
Sheep	Myostatin gene knockout	Increased muscle yield

Van Eenennaam, A. L. 2017. **Genetic Modification of Food Animals.** Current Opinion in Biotechnology. 44:27-34.

The Telegraph

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Companies Comment Personal Finance ISAs Economy Markets Property Enterprise Fi

When we work as one,
the insight to achieve t
athenahealth

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Genus breeds first pigs resistant to major infection

The genetically-enhanced porkers are a "potential game-changer" for the industry

27 0 14 41 Email

Genus helps farmers breed high quality livestock by supplying them with semen from genetically superior animals Photo: EPA

- African Swine Fever
- Porcine Reproductive and Respiratory Syndrome (PRRSV) virus

Lillico et al. 2016. **Mammalian interspecies substitution of immune modulatory alleles by genome editing**. Sci Rep 6:21645.

Whitworth et al. 2016. **Gene-edited pigs are protected from porcine reproductive and respiratory syndrome virus (PRRSV).** Nature Biotechnology 34:20-22.

Genetic improvement (permanent, cumulative) as a solution to animal disease rather than antibiotics/chemicals

Gene Edited Polled Calves

Intraspecies allele substitution at polled locus

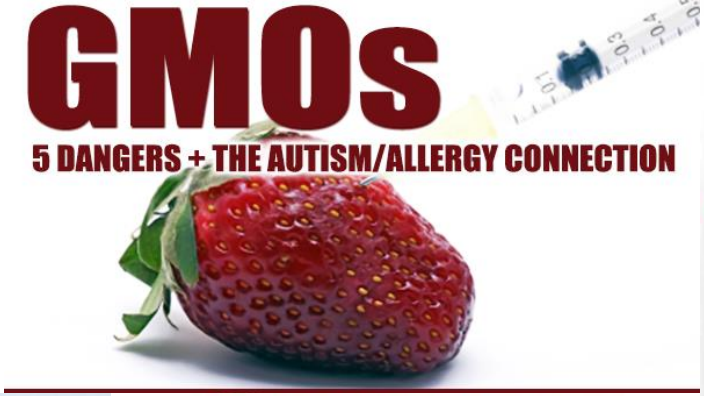
recombinetics

Carlson DF, Lancto CA, Zang B, Kim E-S, Walton M, et al. 2016. **Production of hornless dairy cattle from genome-edited cell lines**. Nat Biotech 34: 479-81

https://www.youtube.com/watch?v=-Qks_LMmodw

Will breeders be able to use gene editing or will it go the way of genetic engineering (GE) aka GMOs?


Orange Juice
May Soon
Contain
Pig Genes


GMOs
5 DANGERS + THE AUTISM/ALLERGY CONNECTION


400%
increase
in allergies since GMOs were introduced.
Coalition Powered by Green America
GMO INSIDE!
#SimilacNoGMO


Genetically Modified
Oranges
gene spliced with
Frogs
Coming soon to a grocery store near you.


One New Apple Product
Your Family Doesn't Need.
Just say "know" to
genetically engineered apples.


Pro-GMO organizations argue that in a world where food is scarce, they are helping to feed the hungry. Feeding people untested lab modified food (GMOs) is like one giant science experiment gone bad! You can feed rice mixed with a little rat poison to a starving African child each day and claim, "I am feeding this child!" The ability to stave off starvation does not counteract the poisonous side-effects!
GMO FOOD IS DANGEROUS!
United Nations Photo
homecuresthatwork.com


CONTAMINATED


GMO FREE USA
Will Roundup rob him of someday having babies of his own?
Gerber uses RoundUp Ready GMOs in its Good Starts for American babies. But a new study published in the journal Free Radical Medicine & Biology implicates Roundup in male infertility at concentration levels well within the EPA's "safe levels" for food.
That's NOT a Good Start, Gerber!

Name the technological innovation

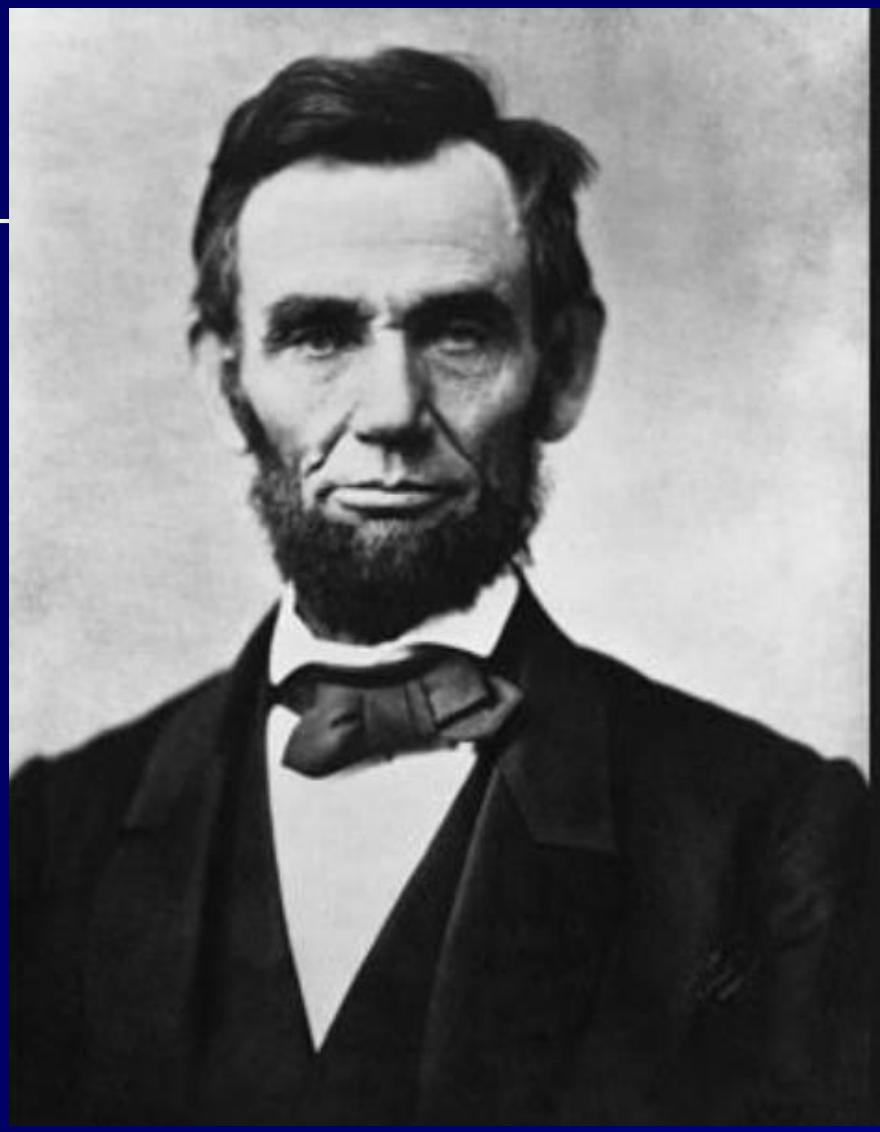
"It is unknown what long term health consequences may unfold. The studies are not adequate. Furthermore, this will likely not be available or cost effective for small farmers, it will decrease product acceptance and consumption."

Quote from the introduction of the Pasteurized Milk Ordinance

1924

There is a special place in hell reserved for the pandering marketers that developed these misleading “absence” labels

Gluten Free
Non-GMO
Water



"Don't believe everything you read on the Internet just because there's a picture with a quote next to it."

—Abraham Lincoln

http://weknowmemes.com/2012/07/dont-believe-everything-you-read-on-the-internet

In 2016 185.1 million hectares of GE crops were planted by ~18 million farmers in 26 countries. ~110-fold increase since 1996. GE is the fastest adopted crop technology in the history of modern agriculture.

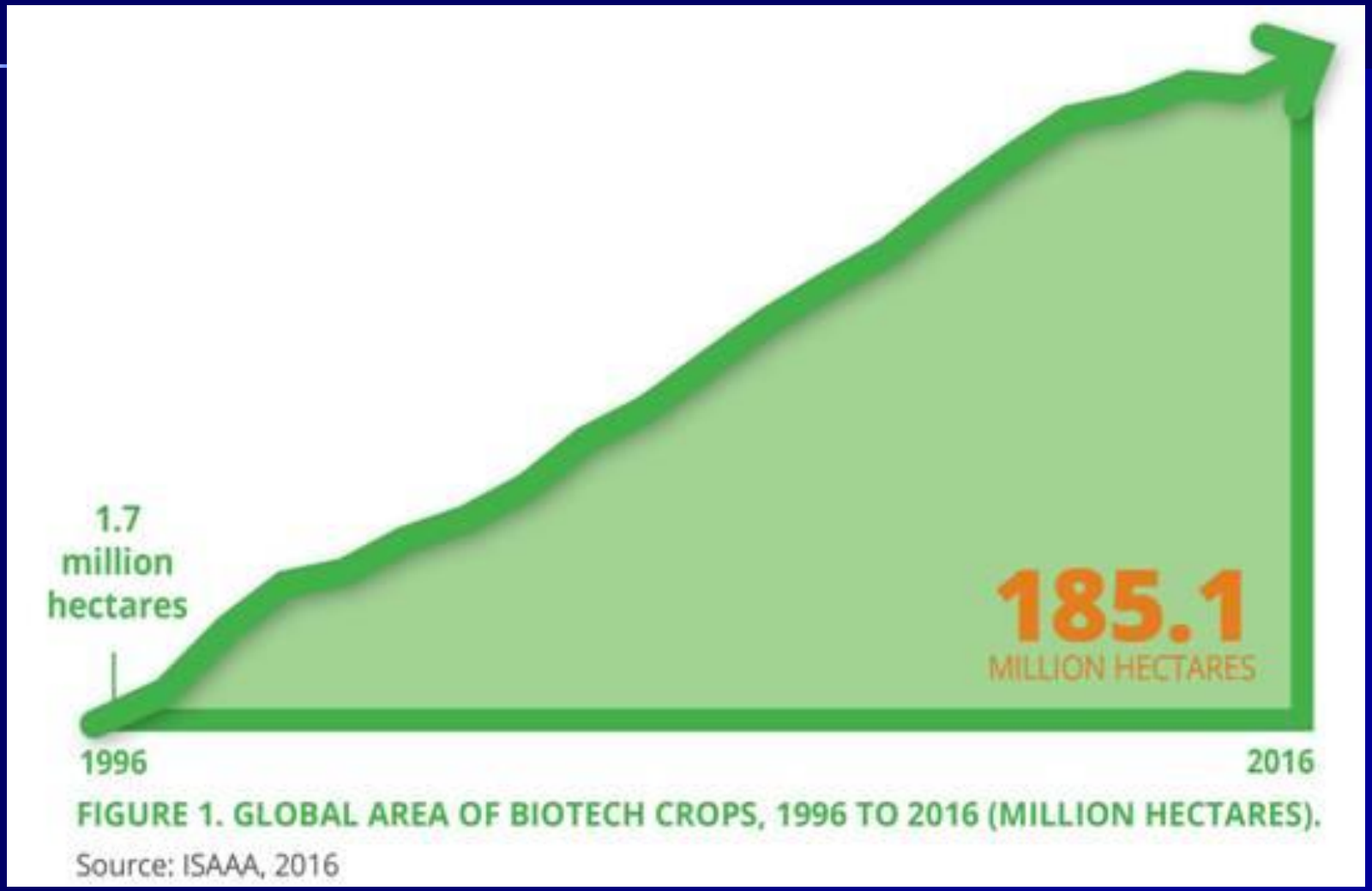


FIGURE 1. GLOBAL AREA OF BIOTECH CROPS, 1996 TO 2016 (MILLION HECTARES).

Source: ISAAA, 2016

Source: Clive James, 2016 ISAAA Brief Pocket K No. 16: Biotech Crop Highlights in 2016

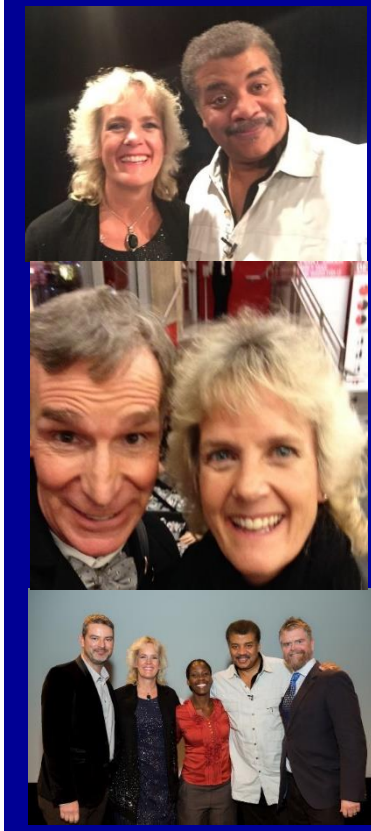
Why is this important? Because GE has facilitated huge reduction in environmental footprint of ag production

*"The adoption of GE insect resistant and herbicide tolerant technology has **reduced GLOBAL pesticide spraying by 618.7 million kg (~8.1%)** and, as a result, decreased the environmental impact associated with (less toxic) herbicide and insecticide use on these crops by 18.6%. The technology has also facilitated important **cuts in fuel use and tillage changes**, resulting in a significant reduction in the release of greenhouse gas emissions from the GE cropping area. In 2015, this was equivalent to **removing 11.9 million cars from the roads**."*

Graham Brookes & Peter Barfoot (2017): Environmental impacts of genetically modified (GM) crop use 1996–2015: Impacts on pesticide use and carbon emissions. GM Crops & Food, DOI: 10.1080/21645698.2017.1309490

Food Evolution – foodevolutionmovie.com

Showing TONIGHT, 9 pm Salon 2 & 3



@foodevomovie

Available on demand at Hulu; and for rent on itunes, Amazon, YouTube

Approved commercially-available Genetically Engineered (GE) food animals in the United States

0

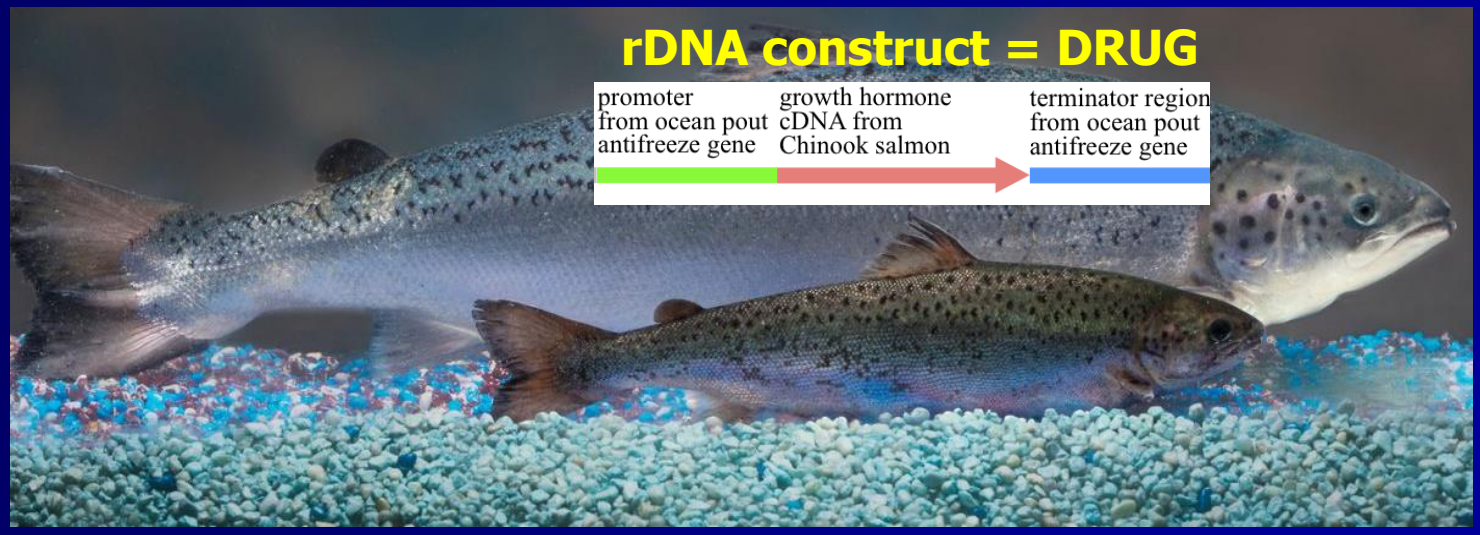
Genetically engineered fast growing AquAdvantage salmon – founder fish produced in 1989 – still not for US sale

AquAdvantage salmon: Transgenic and conventional sibling at the same age

Approved by FDA on November 19, 2015

The Food and Drug administration mandatory premarket evaluation of GE animals as new animal drugs

The Food and Drug Administration's Center for Veterinary Medicine evaluates GE animals under the new animal drug provisions of the Federal Food Drug and Cosmetic Act (FFDCA). The act defines drugs as "articles (other than food) intended to affect the structure or any function of the body of man or other animals." **The rDNA construct in the resulting GE animal is thus a regulated article that meets the drug definition**; the GE animal itself is not a drug.



January 18th, 2017 FDA draft guidance considers all animals whose genomes have been "altered intentionally" using modern molecular techniques to be drugs

Image by Aleksandra Domanović and Spencer Lowell

http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM113903.pdf

Are Gene Edited Horn-less calves a drug?

Naturally-occurring bovine DNA sequence at Polled locus

What is the "new animal drug" in this case?

Animals were 20X sequenced to look for off target mutations and none were found - only the intended edit (where the polled allele replaced the horned allele) mapped to within 10 bp of any of the identified degenerate targets supporting the high specificity of TALENs for this locus.

Does it really make sense to regulate polled dairy calves differently to polled (hornless) beef calves?

Carroll D, Van Eenennaam AL, Taylor JF, Seger J, Voytas DF. 2016. **Regulate genome-edited products, not genome editing itself.** *Nat Biotech* 34: 477-9 rdcu.be/hUVn

A. Van Eenennaam

Laboratory

Prior Authorization and
Training Required Before Using
Any Equipment In This Lab

Thanks for inviting me!

UCDAVIS ANIMAL SCIENCE

My laboratory receives public funding support from the National Institute of Food and Agriculture and the Biotechnology Risk Assessment Grant (BRAG) program, U.S. Department of Agriculture, under award numbers 2011-68004-30367, 2013-68004-20364, 2015-67015-23316, 2015-33522-24106 and 2017-33522-27097.

USDA United States Department of Agriculture National Institute of Food and Agriculture