The importance of genetic innovations to sustainability

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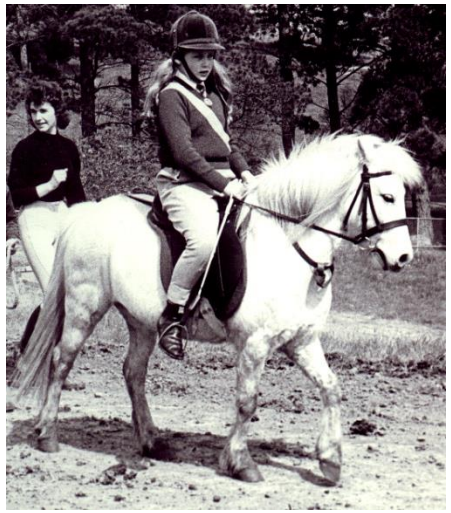
"The Next New Food" Panel CFA Conference

Have spent my whole career around agriculture, livestock and science



AUSTRALIA	1963
Population	11
Number sheep	159
Number cattle	17

UNITED STATES	1963	2019
Population	190	328
Number sheep	30	5

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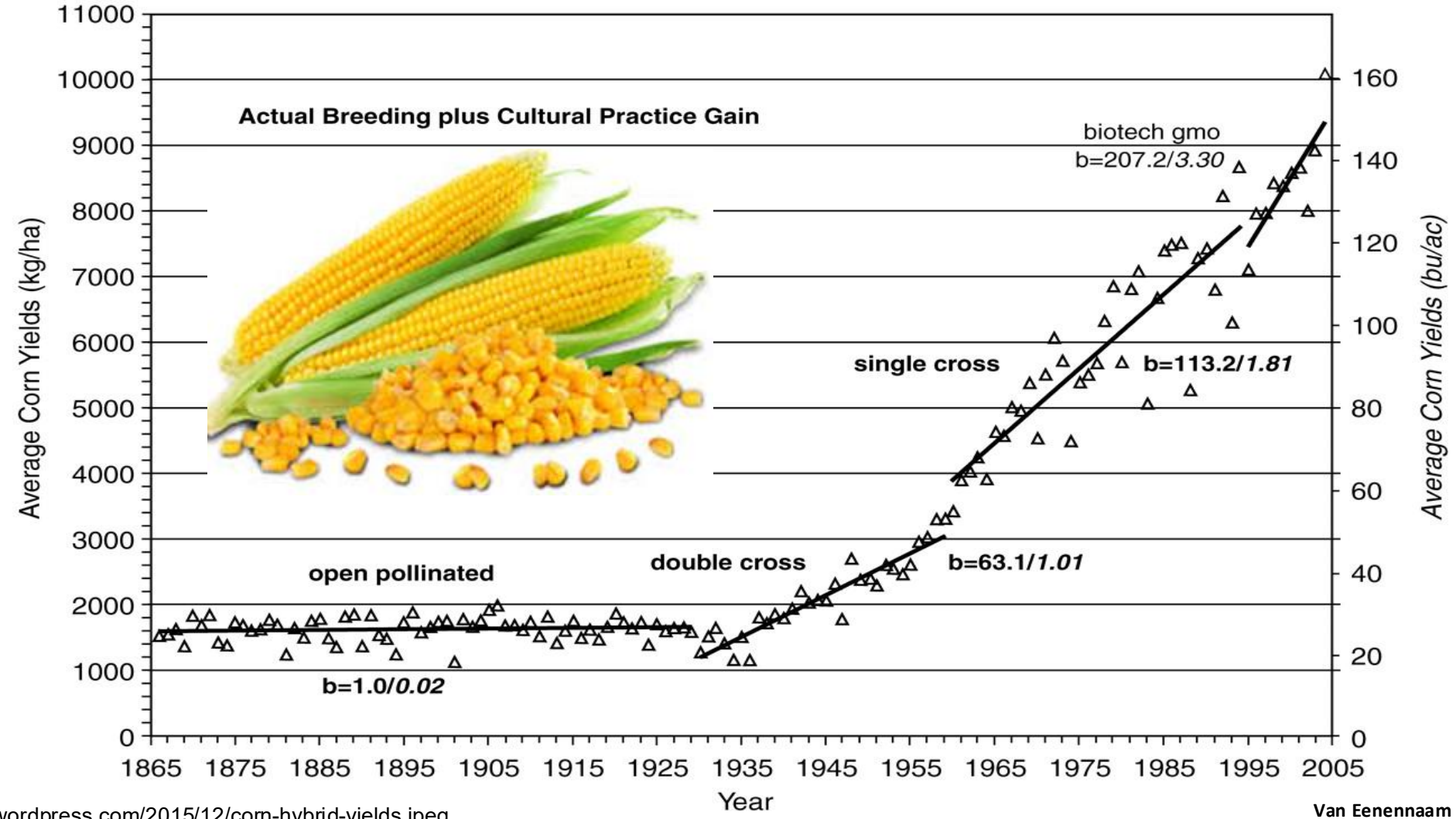
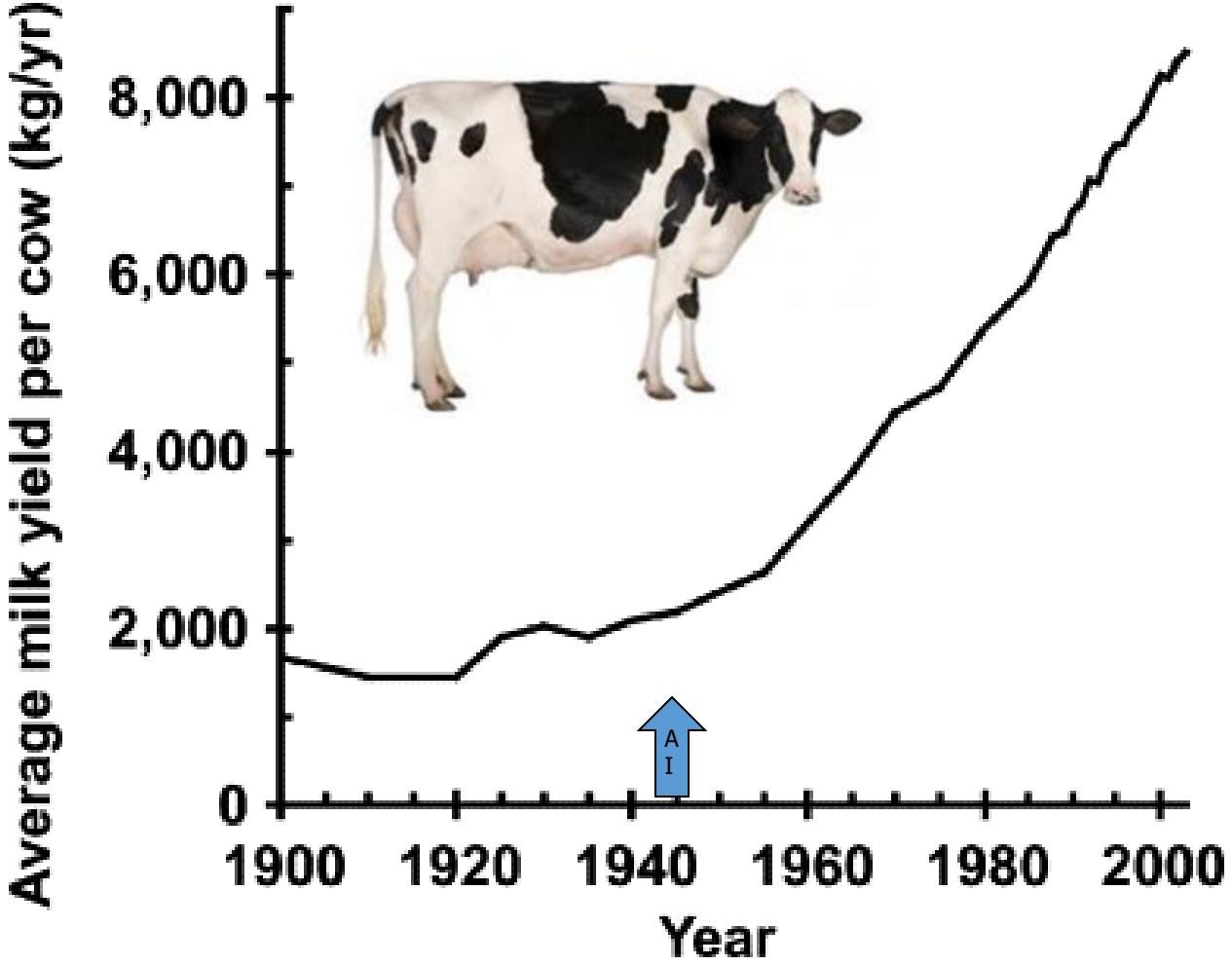
Plant and animal breeders have perhaps the most compelling sustainability story of all time



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

Improvement in efficiencies have been associated with inflection points enabled by new breeding methods



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.

US Dairy Cattle Inventory 1944; 1964 – 2019

Number of Cows Down (Million head; blue, left) vs. Milk Production Up (Million Tonnes; red, right)

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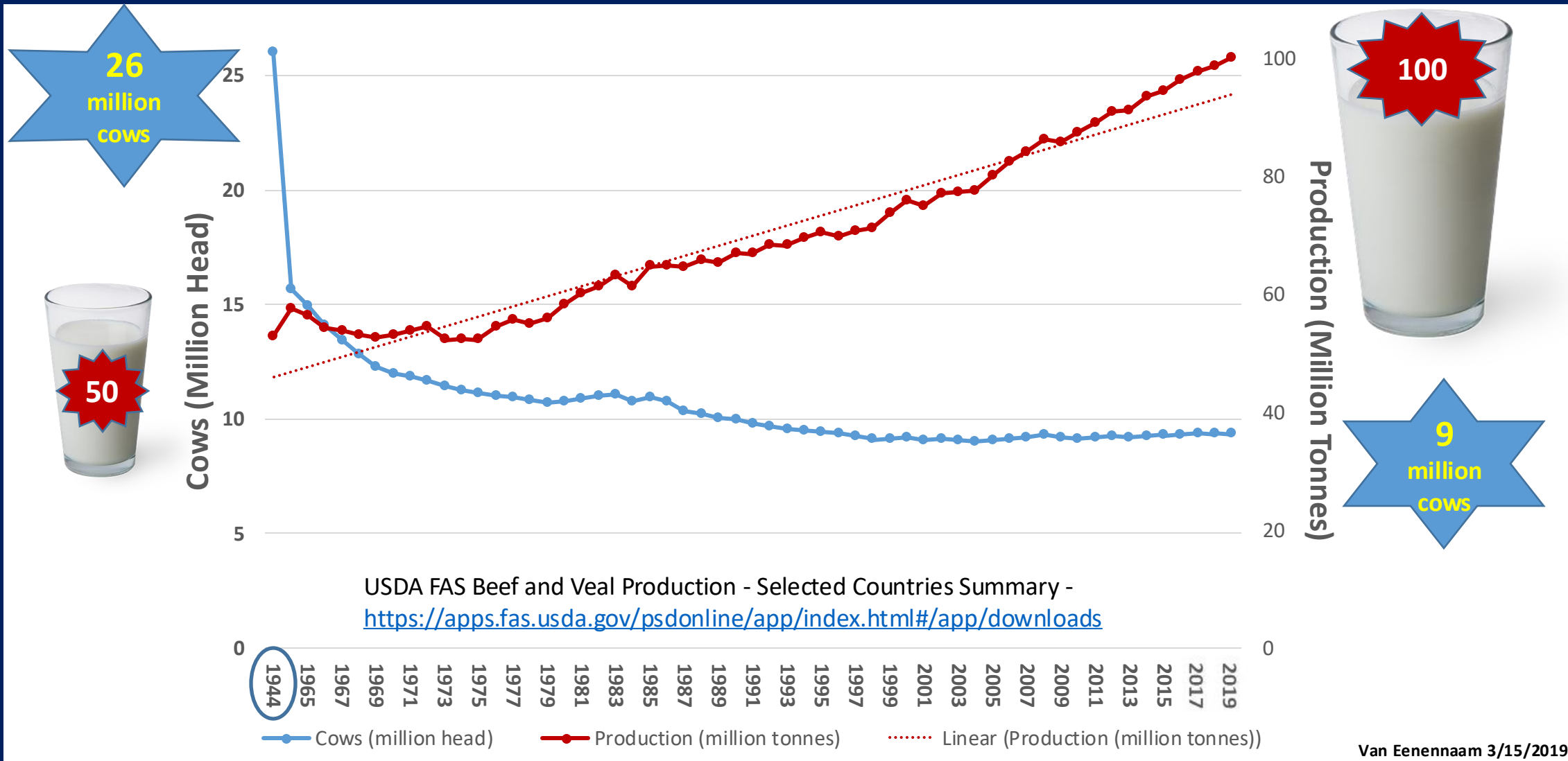
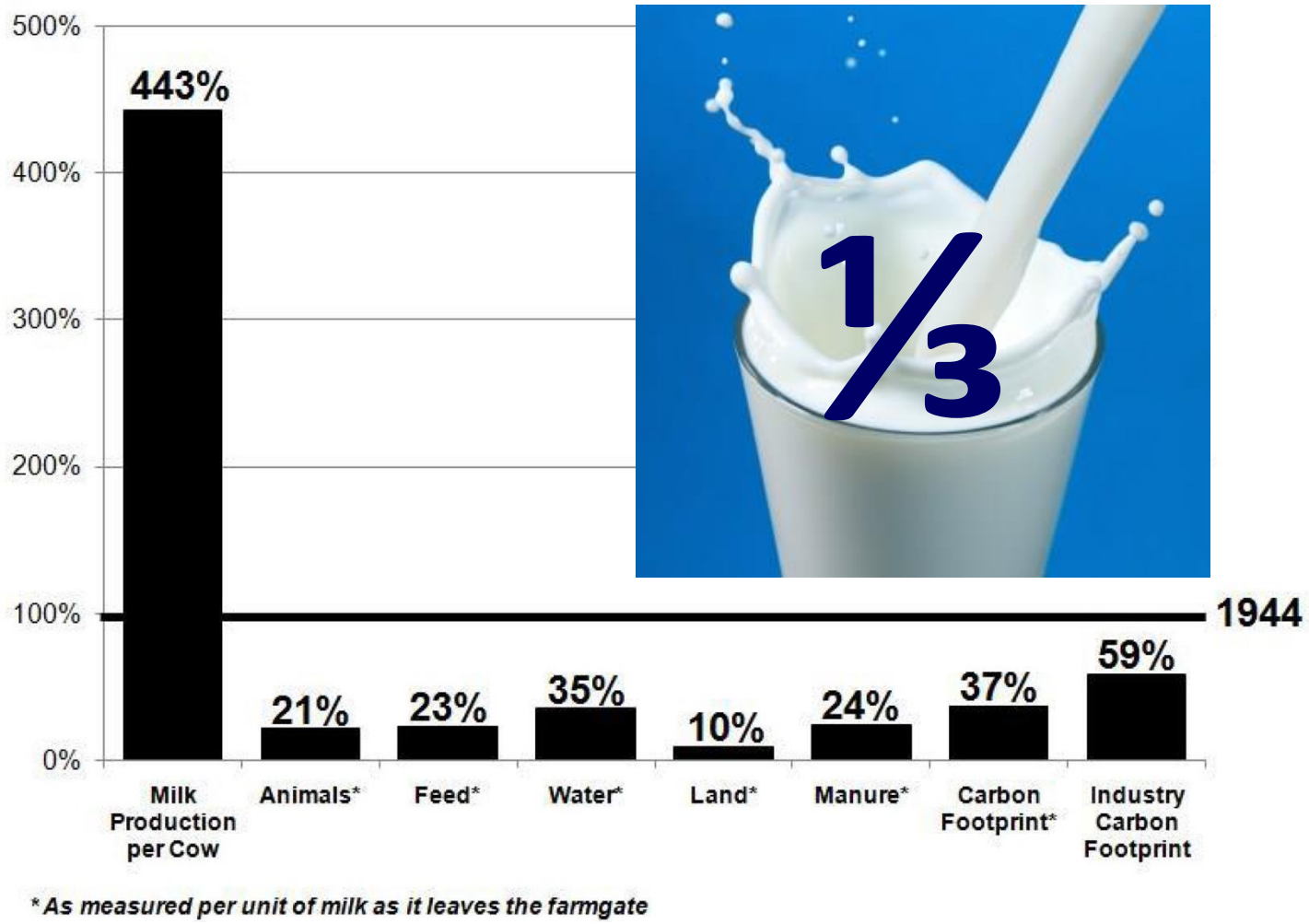


USDA FAS Beef and Veal Production - Selected Countries Summary - https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads

Van Eenennaam 3/15/2019

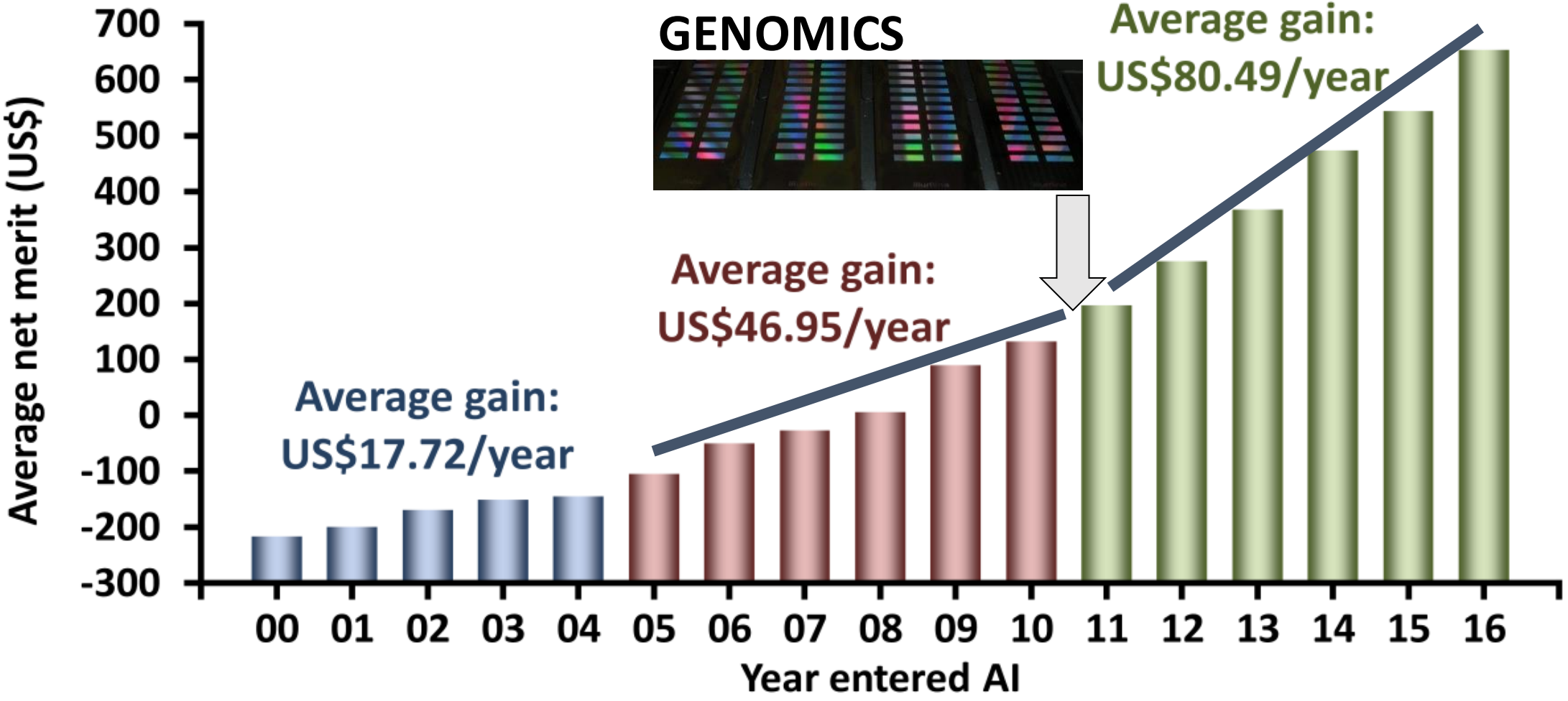
The GHG emissions associated with a glass of milk in the US today is ⅓ the 1944 value



*As measured per unit of milk as it leaves the farmgate

Capper, JL and DE Bauman, 2013. Annual Review of Animal Biosciences. 1 pp. 9.1–9.21

Rate of genetic gain in dairy bulls has doubled since 2009 genomic selection introduction



http://www.farms.com/news/two-million-genotypes-in-u-s-dairy-database-125448.aspx

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Gene editing could be the next inflection point

"We have ways now to use gene editing to separately modify fruit size, weight, the branches that make flowers, and the amount of flowers, as well as the architecture of a plant from a compact bush to one that keeps on growing."

Rodríguez-Leal D, Lemmon ZH, Man J, Bartlett ME, Lippman ZB. **Engineering Quantitative Trait Variation for Crop Improvement by Genome Editing.** Cell. 2017 Oct 5;171(2):470-480.e8. doi: 10.1016/j.cell.2017.08.030. Epub 2017 Sep 14. PubMed PMID: 28919077.Cell.

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Will gene editing produce the next new food? Or will it be thwarted by "new food" hesitancy

CROP	TRAIT	Method
Wheat/Tomato	Powdery Mildew Resistance	Silence gene
Grapefruit/ Orange	Citrus canker resistance	Silence gene
Rice	Bacterial Blight Resistance	Silence gene
Pepper, Lettuce, Pea, Tomato, Barley, Melon, etc	Turnip Mosaic Virus resistance	Silence gene
Cucumber	Zucchini yellow & Papaya ring spot mosaic virus	Silence gene
Soybean	Reduced trans-fatty acids	Silence gene
Wheat	Low Gluten	Silence gene
Tomato	High GABA (g-aminobutyric acid)	Silence gene
Tomato	Long shelf life	Silence gene
Grapes	Fungus resistance	Silence gene
Cacoa/Banana/Oranges	Disease resistance	Silence gene
Maize	Northern leaf blight resistance	Silence gene

Gene editing to produce Porcine Reproductive and Respiratory Syndrome (PRRS) virus resistant pigs

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Genus breeds first pigs resistant to major infection

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

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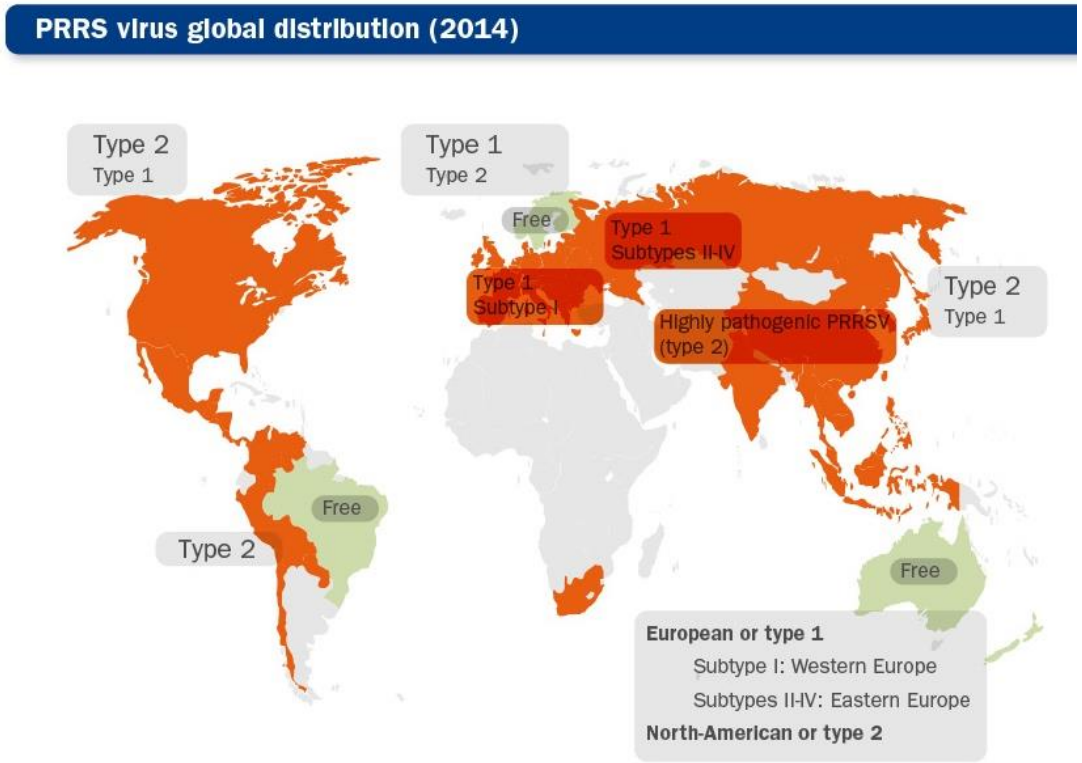
Genus helps farmers breed high quality livestock by supplying them with semen from genetically superior animals Photo: EPA



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

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Many animal applications are disease resistance and welfare traits

SPECIES	TRAIT	TRAIT/GOAL	Method
CATTLE	Beta-lactoglobulin gene knockout	Elimination of milk allergen	Silence gene
	Prion protein (PRNP) knockout	Resistance to BSE (mad cow disease)	Silence gene
	CD18 gene edit	Resistance to BRD (bovine respiratory disease)	Silence gene
	Intraspecies *POLLED* allele substitution	No horns/welfare trait	Between breed allele swap
	Intraspecies *SLICK* allele substitution	Heat tolerance	Between breed allele swap
GOAT	Prion protein gene knockout	Elimination of prion protein	Silence gene
	Beta-lactoglobulin gene knockout	Elimination of milk allergen	Silence gene
PIG	CD163 gene knockout	PRRS Virus Resistance	Silence gene
	RELA allele substitution	African Swine Fever Resistance	Interspecies allele swap
	Knockout of sexual maturity pathway	No need for castration/welfare trait	Silence gene
SHEEP	Scrapie resistance PrP allele substitution	Scrapie resistance	Between breed allele swap
	FGF5 gene knockout	Increased wool length & yield	Silence gene
CHICKEN	Inactivate genes required for virus infection	Avian influenza (bird flu) resistance	Silence gene
	Identify eggs with male chickens before hatch	All female chicks for egg industry/welfare trait	Marker gene

Funding disclosure

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