



Were Those the Days? Animal Agriculture Then & Now

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<http://blogs.ehu.eu/network/palaeoblog/files/2012/10/science.jpg>

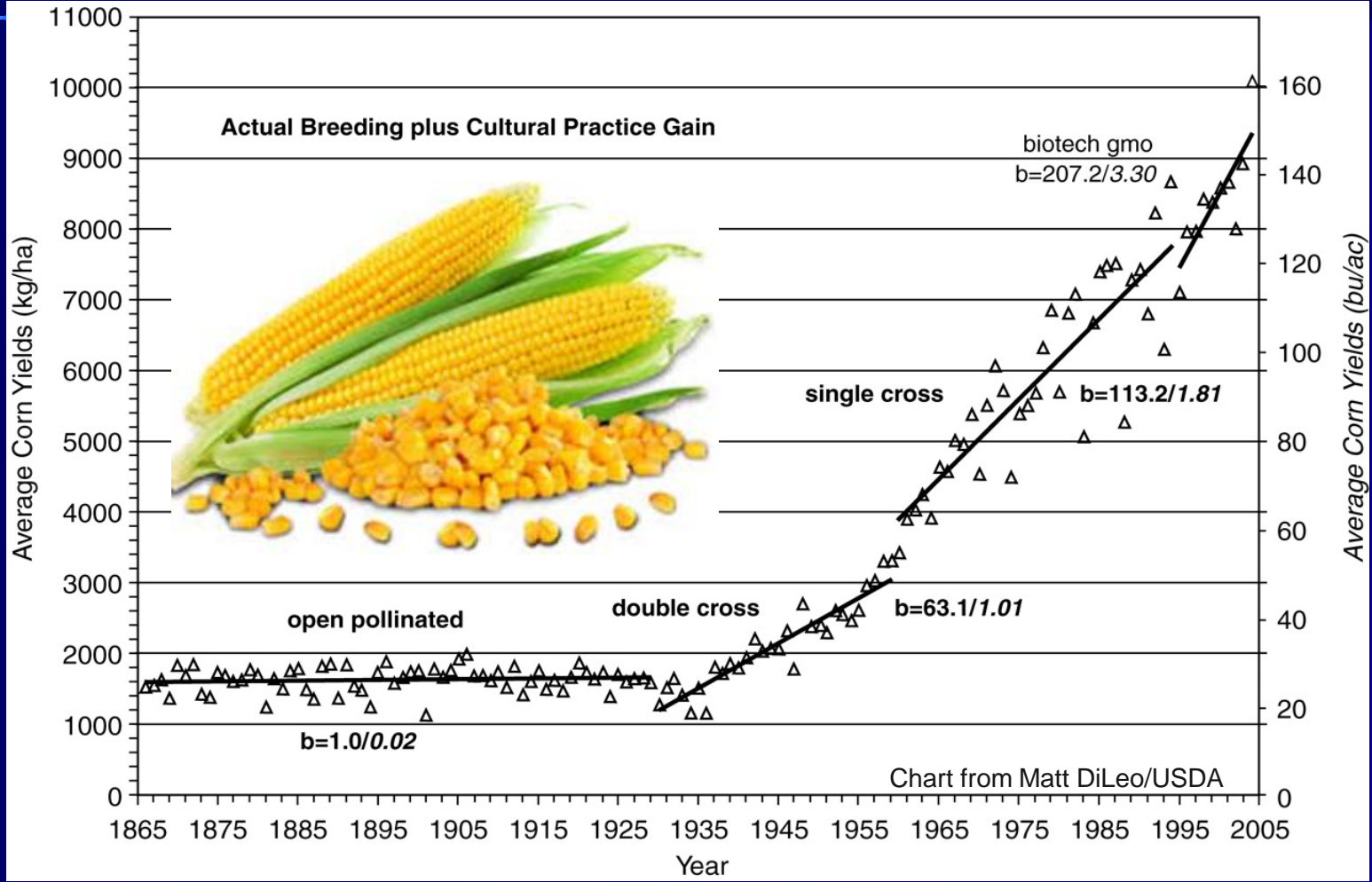


Animal breeders have made remarkable genetic modifications based solely on conventional breeding methods





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>



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.

1957 vs. 2001 chickens

1957



2001



43

57

71

85 d.

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.



How did chicken breeders achieve these remarkable improvements?

Balanced conventional selection

Conventional selection (aka science)

- Acts on naturally occurring genetic variation in the population
- Utilize hybrid vigor by implementing 4 way cross
- Very large number of progeny derive from elite breeding stock
- Large pedigrees
- Sophisticated techniques such as genomic selection
- Very comprehensive performance recording for a number of traits
 - e.g. Cobb-Vantress records 56 individual observations per each pedigree candidate
 - More than 50% of these 56 individual traits are some measure of health and fitness of an individual.





Broiler breeding - Striking a balance between economic and well-being traits



Current breeding programs:

- Improving the efficiency of meat production **2–3%/yr**
- Decreasing time to market for 5 lb bird by **0.74 days/yr**
- Increasing breast meat yields for 5 lb bird by **0.5%/yr**
- Decreasing feed-conversion (lb feed:lb gain) **0.025 /yr**

At the same time

- Livability (survival) is improving **0.22%/yr**
- Condemnation rates are decreasing **0.7%/yr.**

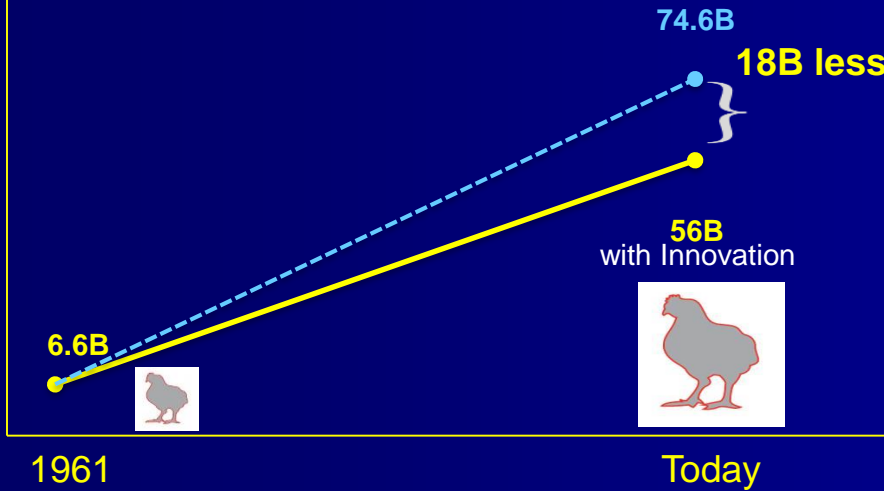
M. N. Katanbaf, J. W. Hardiman; Primary broiler breeding—Striking a balance between economic and well-being traits, *Poultry Science*, Volume 89, Issue 4, 1 April 2010, Pages 822–824, <https://doi.org/10.3382/ps.2009-00439>



Globally approximately 56 Billion broilers grown annually



Number of Animals (In billions)

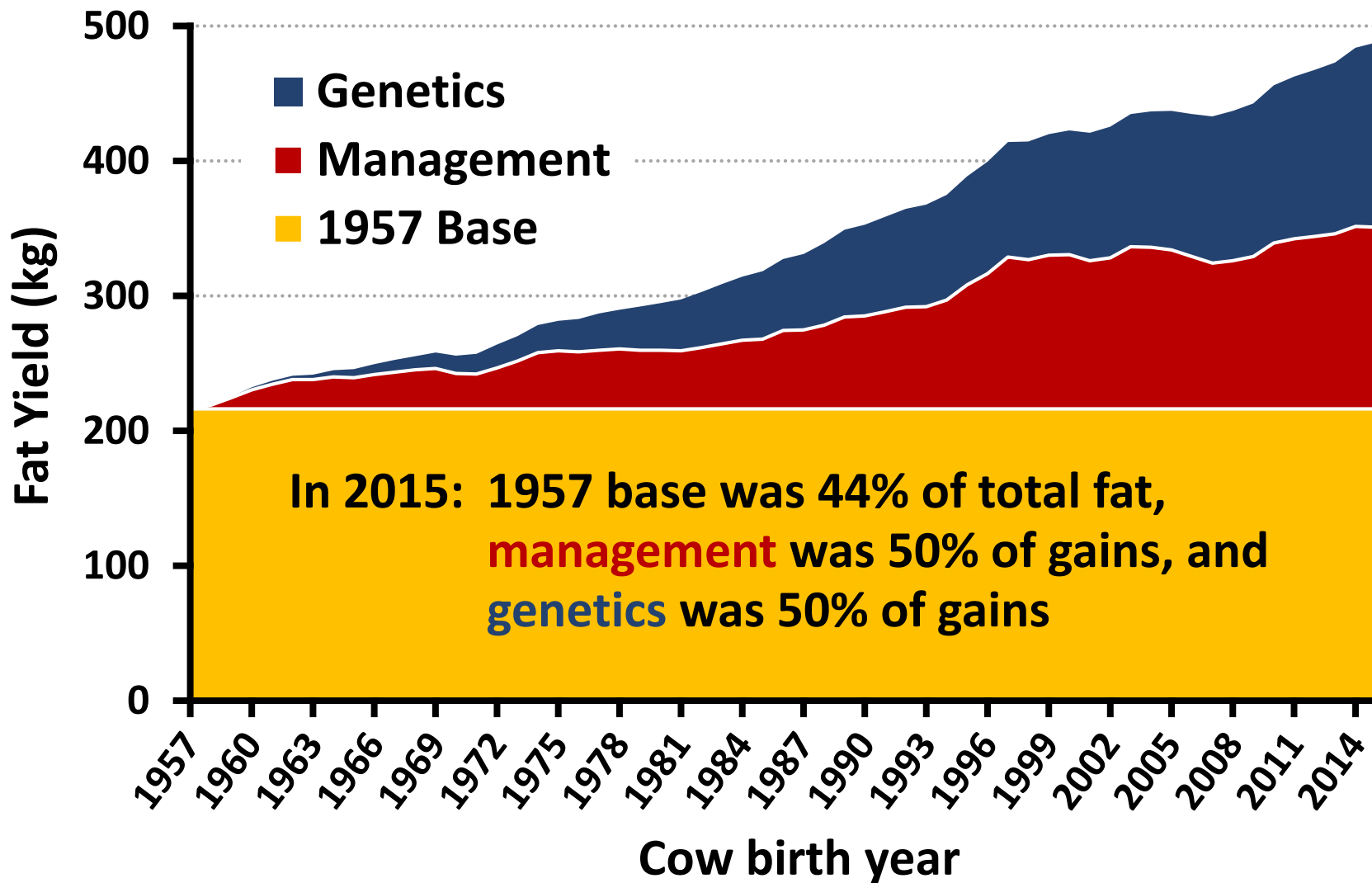


1958: 13.25 lbs feed/5 lb broiler
 2008: 8.25 lbs feed/5 lb broiler

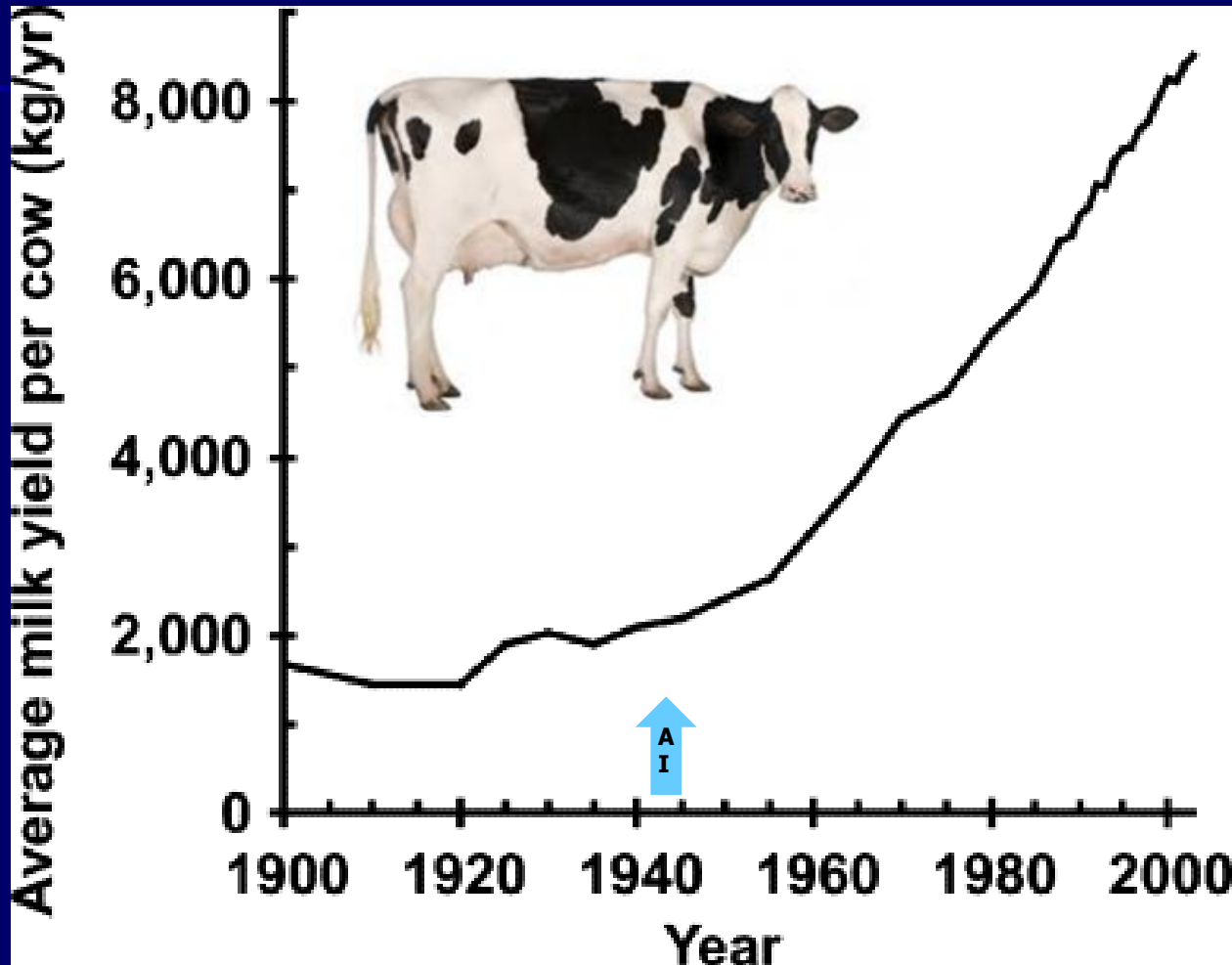


—●— Without innovation = no productivity increase
 —●— Current rate of genetic improvement

Dairy has a similar story to tell



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



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



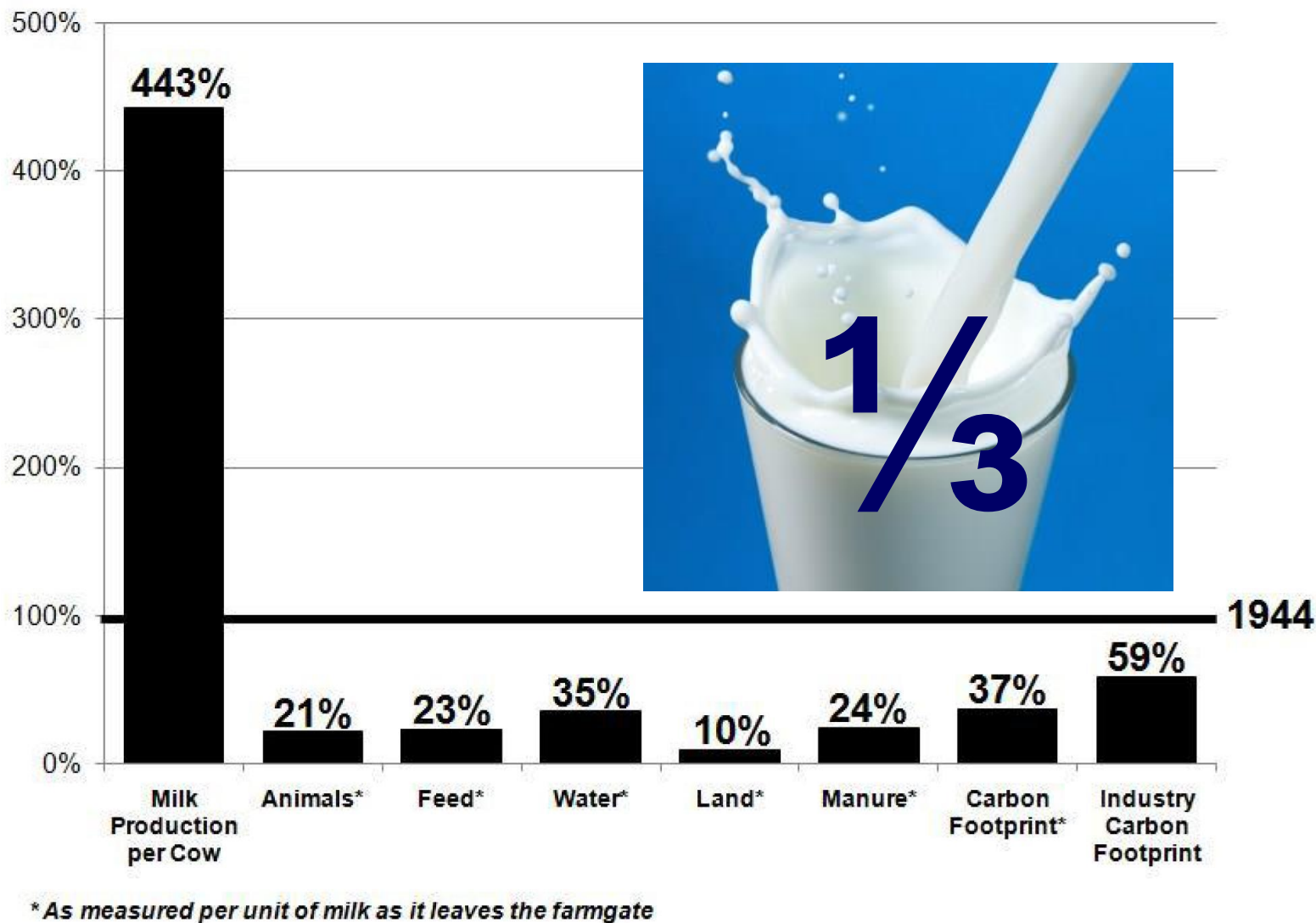
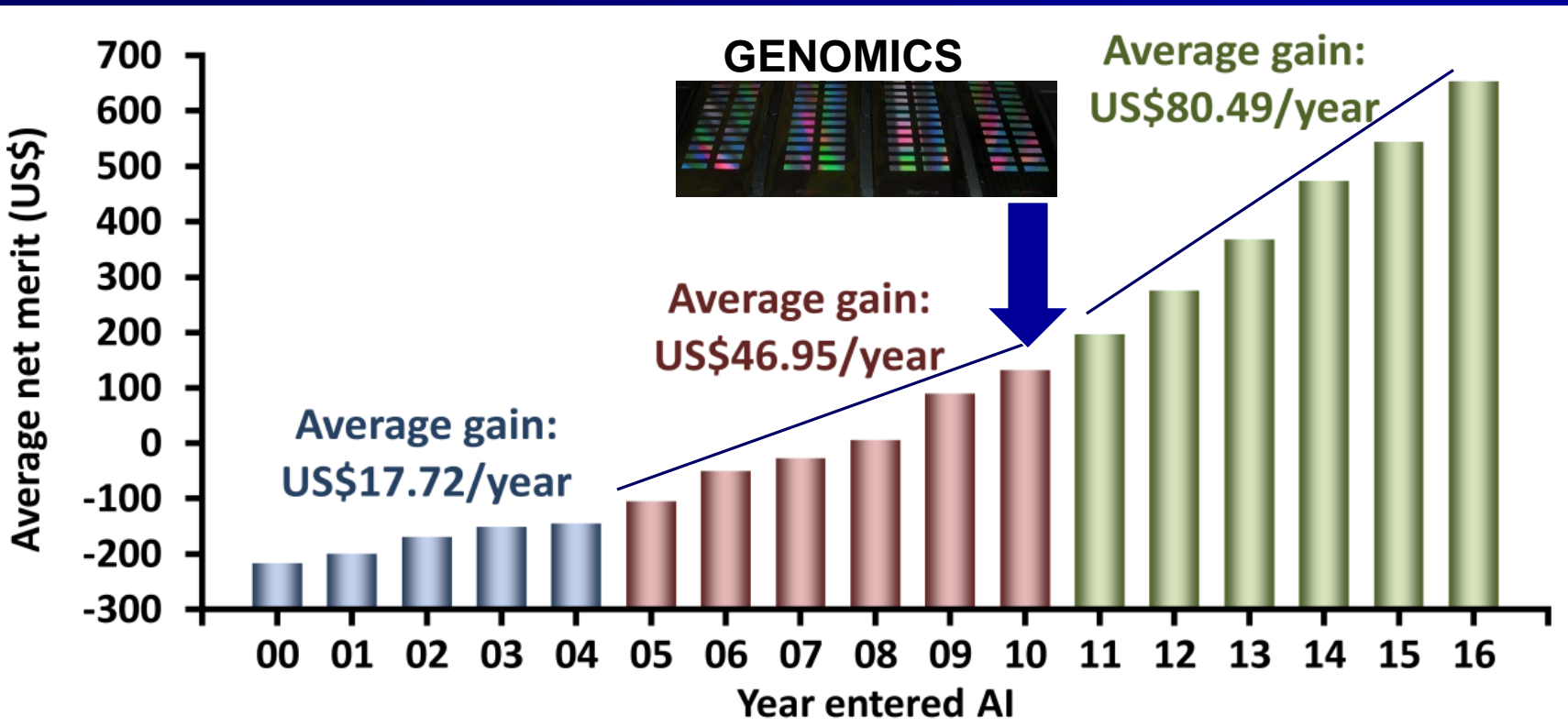


Figure 3. The 2007 U.S. milk production, resource use and emissions expressed as a percentage of the 1944 dairy production system. Adapted from Capper et al. (2009).

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



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



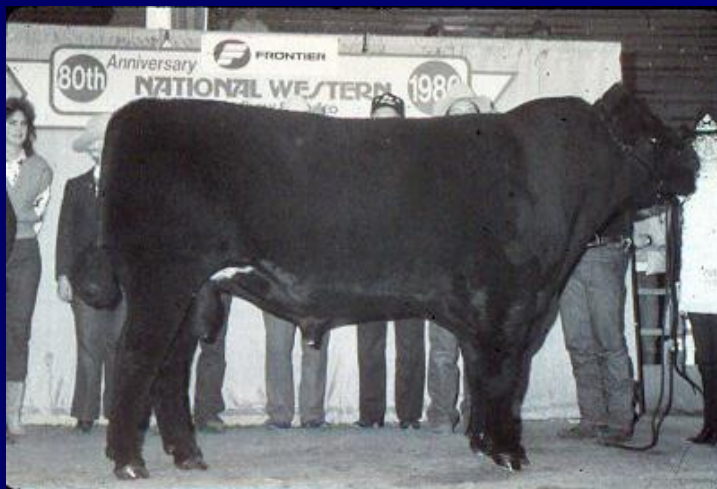
<http://www.farms.com/news/two-million-genotypes-in-u-s-dairy-database-125448.aspx>



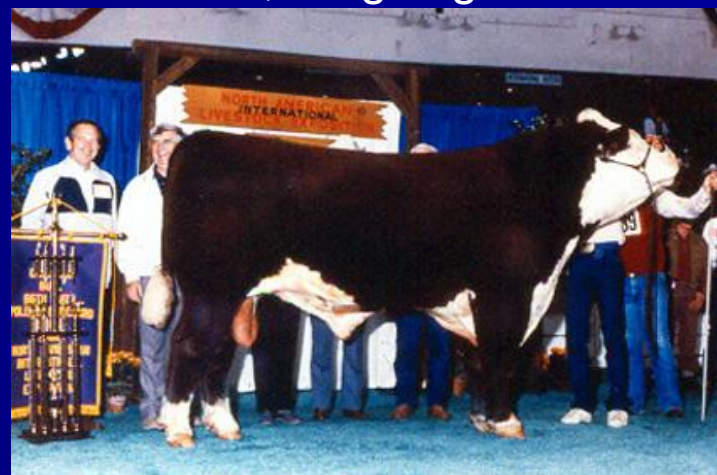
1953. Grand Champion Angus Female, International, 1953



1950. Grand Champion Steer, International, weighing 1025 lbs



1986. "Coblepond New Yorker" weighed 2529 lbs and measured 65 inches tall at 35 mos. (Frame 10) when he was Denver Champion.



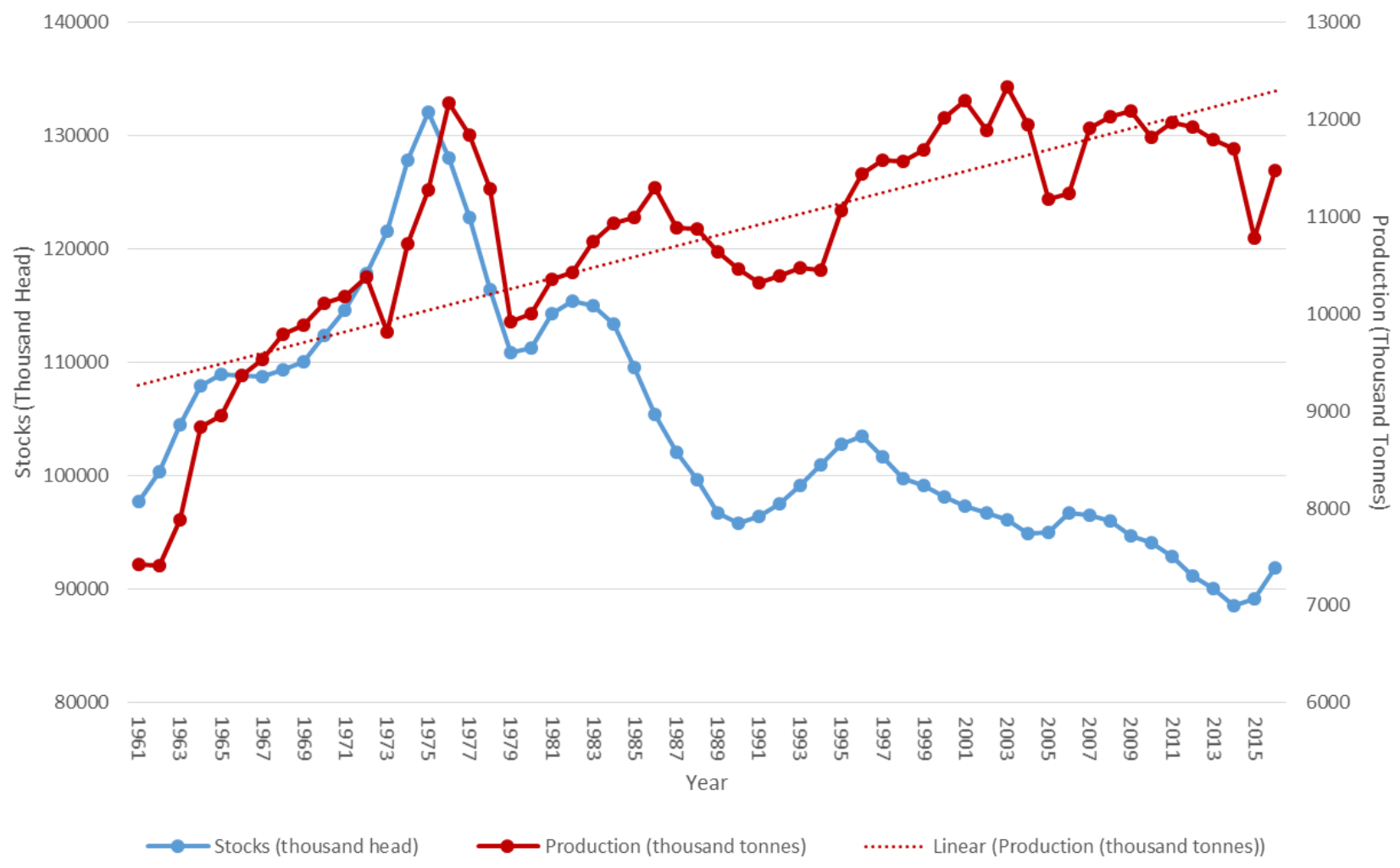
1988 Grand Champion Bull, National Polled Hereford Show (frame 10).

Images from Harlan Ritchie's historical review of type
<https://www.msu.edu/~ritchih/historical/cattletype.html>



US Cattle Inventory 1961 – 2015

Stocks (Thousand Head; blue, left) vs. Production (Thousand Tonnes; red, right)

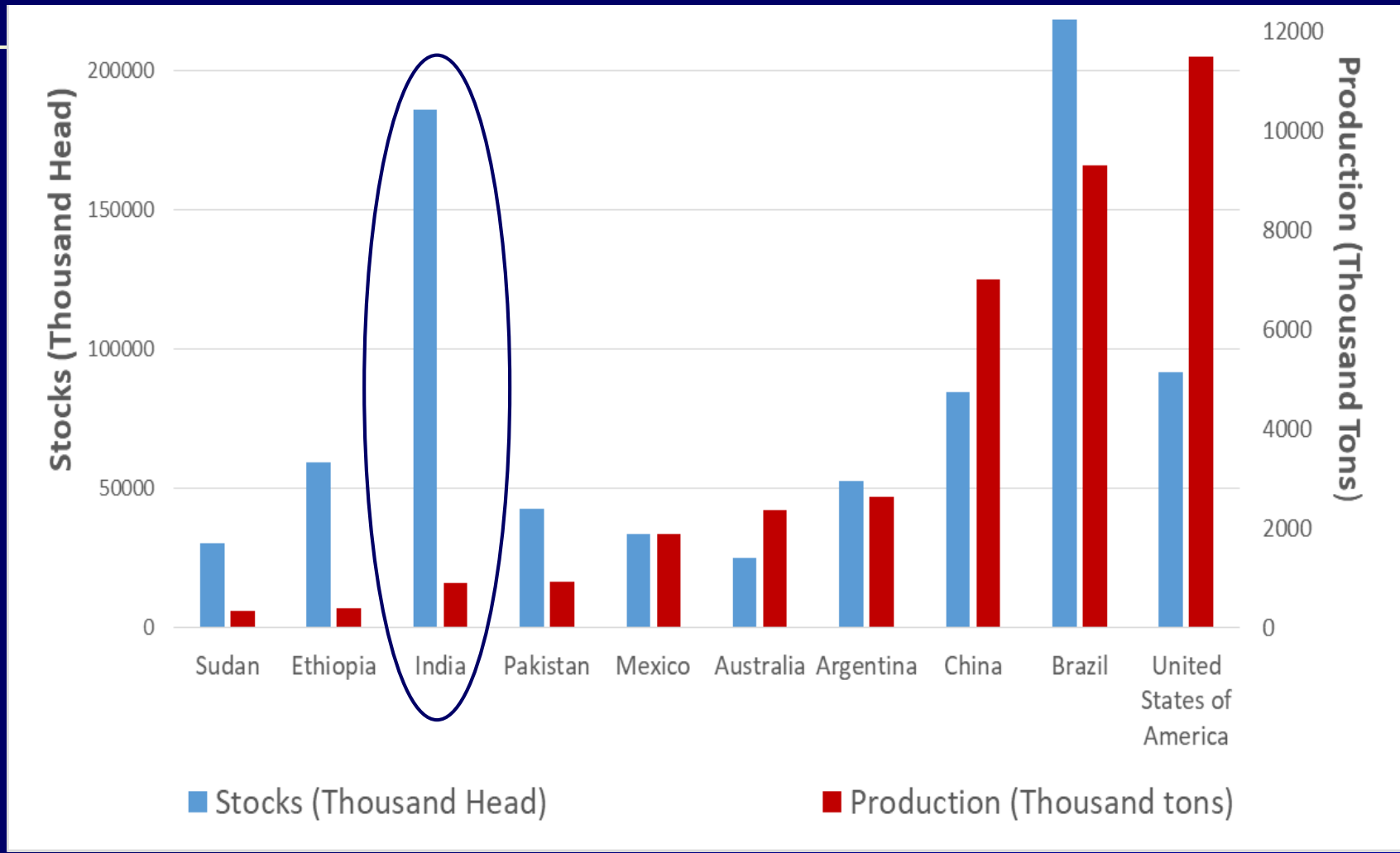











2016 Global Beef Production Numbers

Cattle numbers (Thousand Head; blue, left)

vs. Beef production (Thousand Tonnes; red, right)



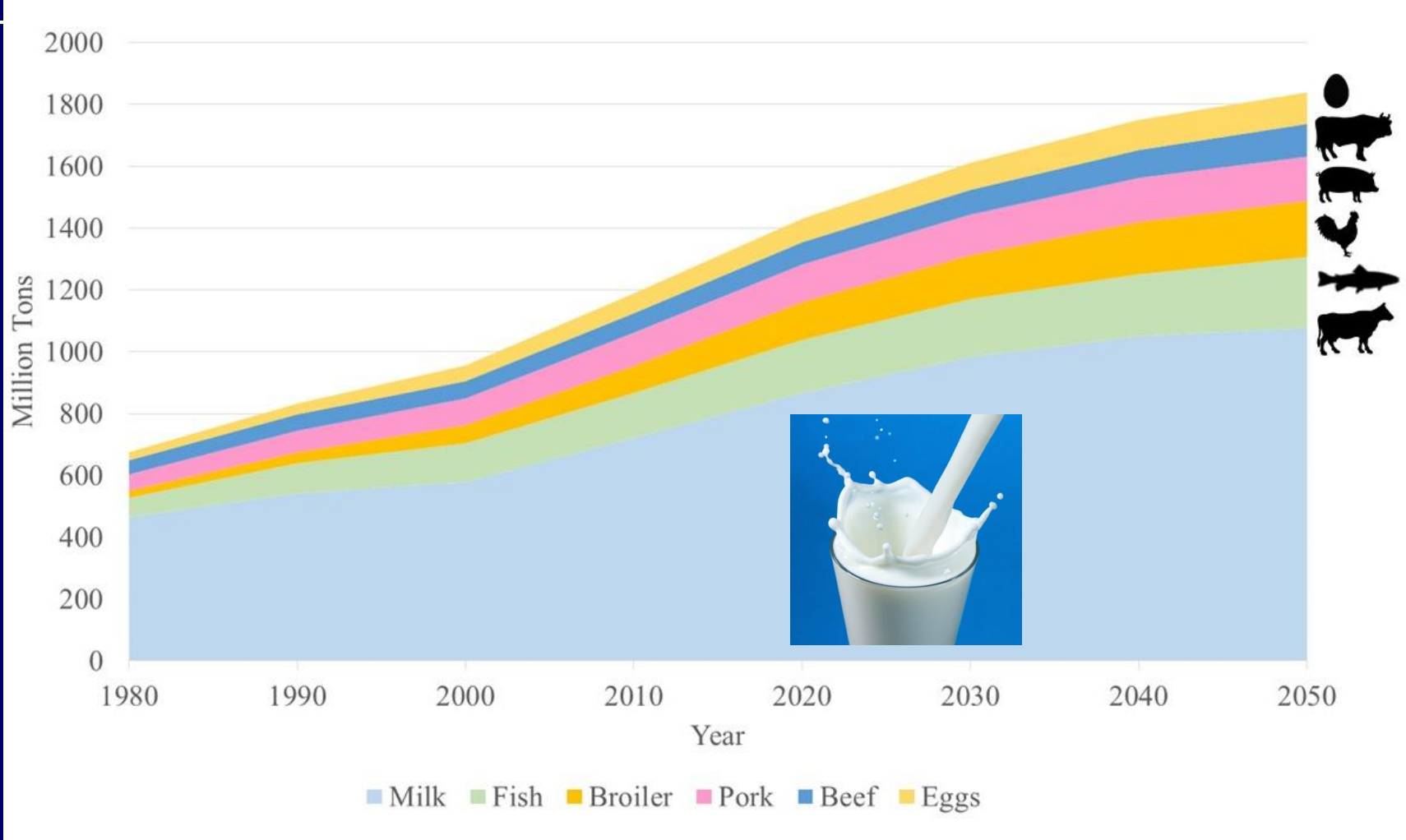
Crop/species	2017 total production	2017	Amount needed at 1950s rate	Additional needed
<p>Soybeans</p> 	<p>4,391,553,000 BU (263,493,180,000 lb) (119,769,627,000 kg)</p>	<p>82,591,000 Acres (33,423,392 ha)</p>	<p>202,375,714 Acres (81,898.546 ha)</p>	<p>~ 120 million Acres</p>  <p>(~48 million ha)</p>
<p>Corn</p> 	<p>14,604,067,000 BU (817,827,752,000 lb) (371,739,887,000 kg)</p>	<p>83,136,000 Acres (33,643,946 ha)</p>	<p>382,305,419 Acres (155,522,885 ha)</p>	 <p>(~120 million ha)</p>
<p>Dairy cattle</p> 	<p>215,466,000,000 lbs milk (97,939,090,900 kg)</p>	<p>9,392,180 head</p>	<p>40,546,857 head</p>	<p>~ 31 million head</p> 
<p>Broilers</p> 	<p>41,039,000,000 lbs meat (18,654,090,900 kg)</p>	<p>8,913,000,000 head</p>	<p>13,324,350,649 head</p>	<p>~ 4.4 billion head & additional 66.5 billion lbs feed as less efficient FCR</p>

A man in a white lab coat and purple bow tie stands with his right arm raised. The background is dark with various elements: a glowing blue ring-like object at the top, a yellow line graph on the left, a glowing yellow horizontal line on the right, and a brown circular object on a table in the bottom left. The word "SCIENCE" is written in large, bold, white letters with a black outline across the center.

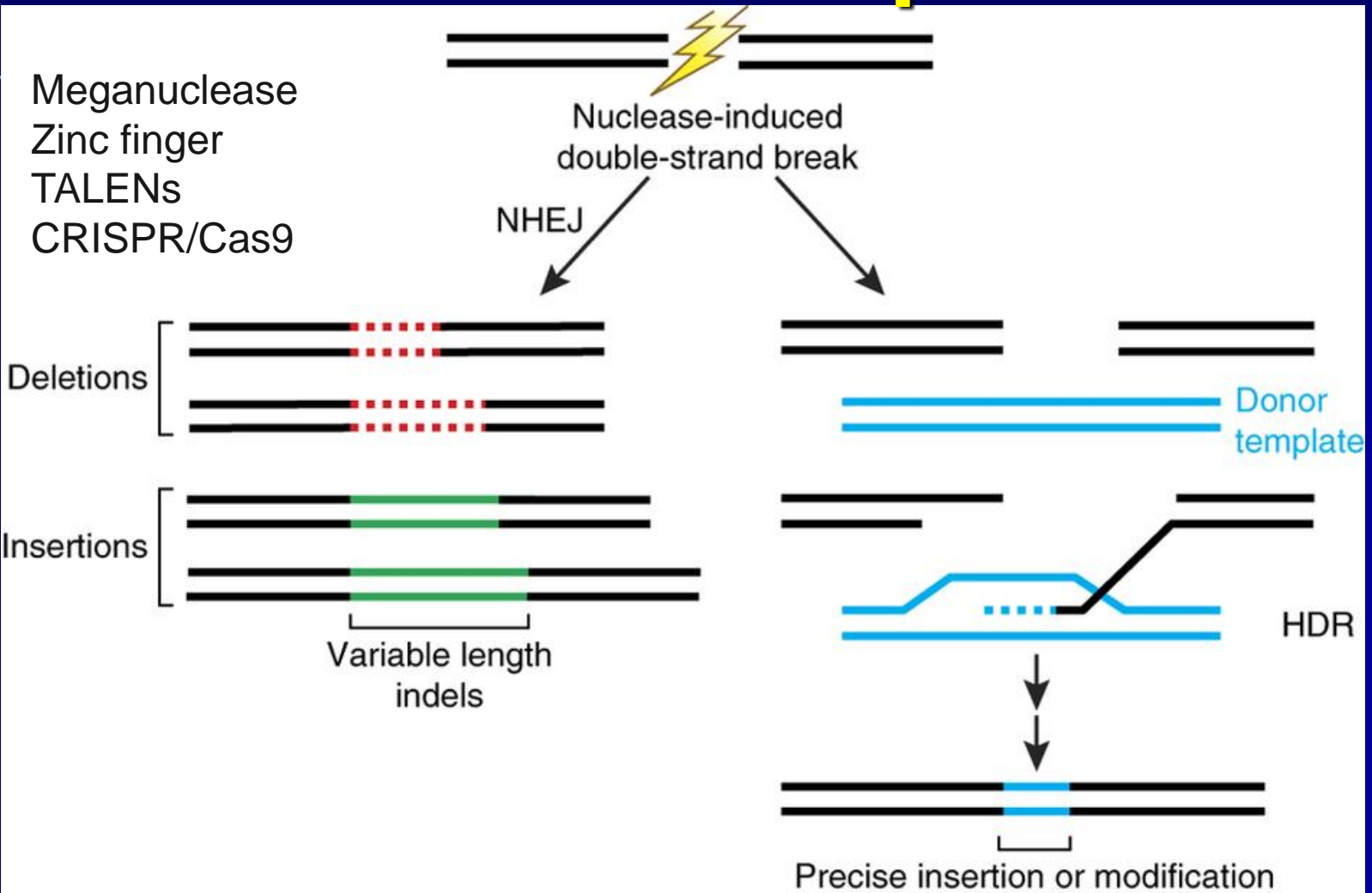
SCIENCE



Egg, beef, pork, chicken, fish and milk production since 1980 and projected to 2050 (FAO 2018; Alexandratos and Bruinsma, 2012).



Will Gene Editing enable the next inflection point?



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	Targeted Trait/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.



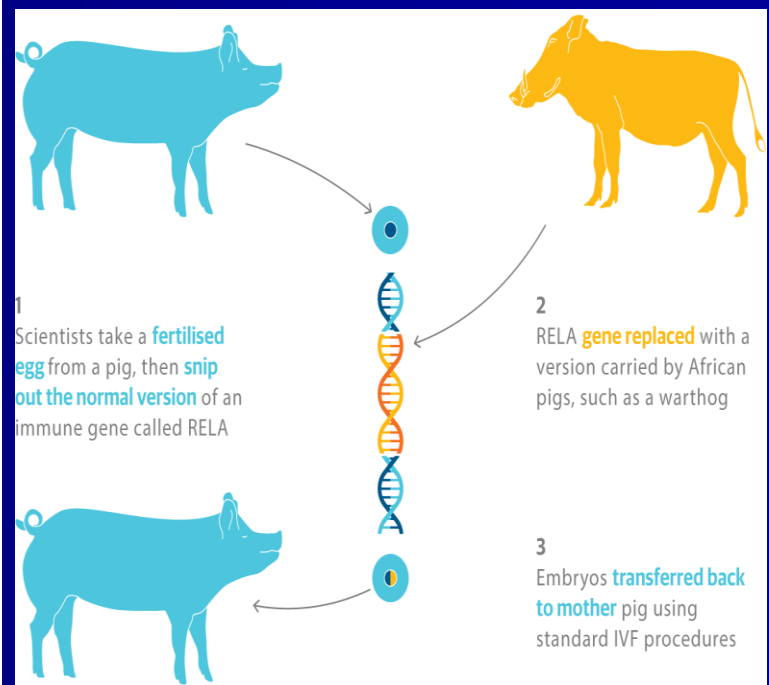
Gene editing to produce African Swine Fever resistant pigs



Pigs resting in a pen at a pig farm in Yiyang county, in China's central Henan province. On Aug.10, 2018. (GREG BAKER/AFP/Getty Images)

China's African Swine Fever Outbreak Likely Caused by Imports From Russia

BY FRANK FANG, EPOCH TIMES
Updated: August 27, 2018



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



What is the problem we are trying to solve?

Editing for Porcine Reproductive and Respiratory Syndrome (PRRS) Virus



The Telegraph

Home Video News World Sport **Finance** Comment Culture Travel Life Women Fa
Companies Comment Personal Finance ISAs Economy Markets Property Enterprise F



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

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Genus breeds first pigs resistant to major infection

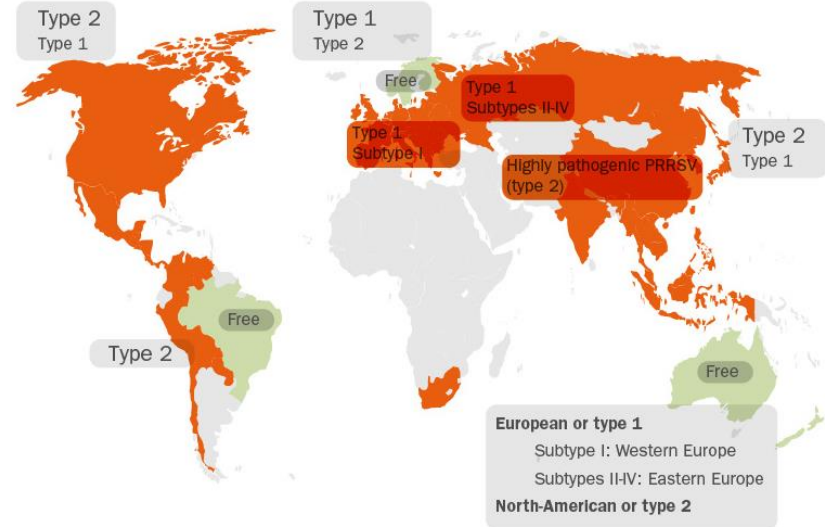
The genetically-enhanced porkers are a "potential game-changer" for the industry

27 0 14 41 Email



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

PRRS virus global distribution (2014)



Gene silencing creates PRRS resistance

Whitworth et al. 2016. **Gene-edited pigs are protected from porcine reproductive and respiratory syndrome virus (PRRSV).**

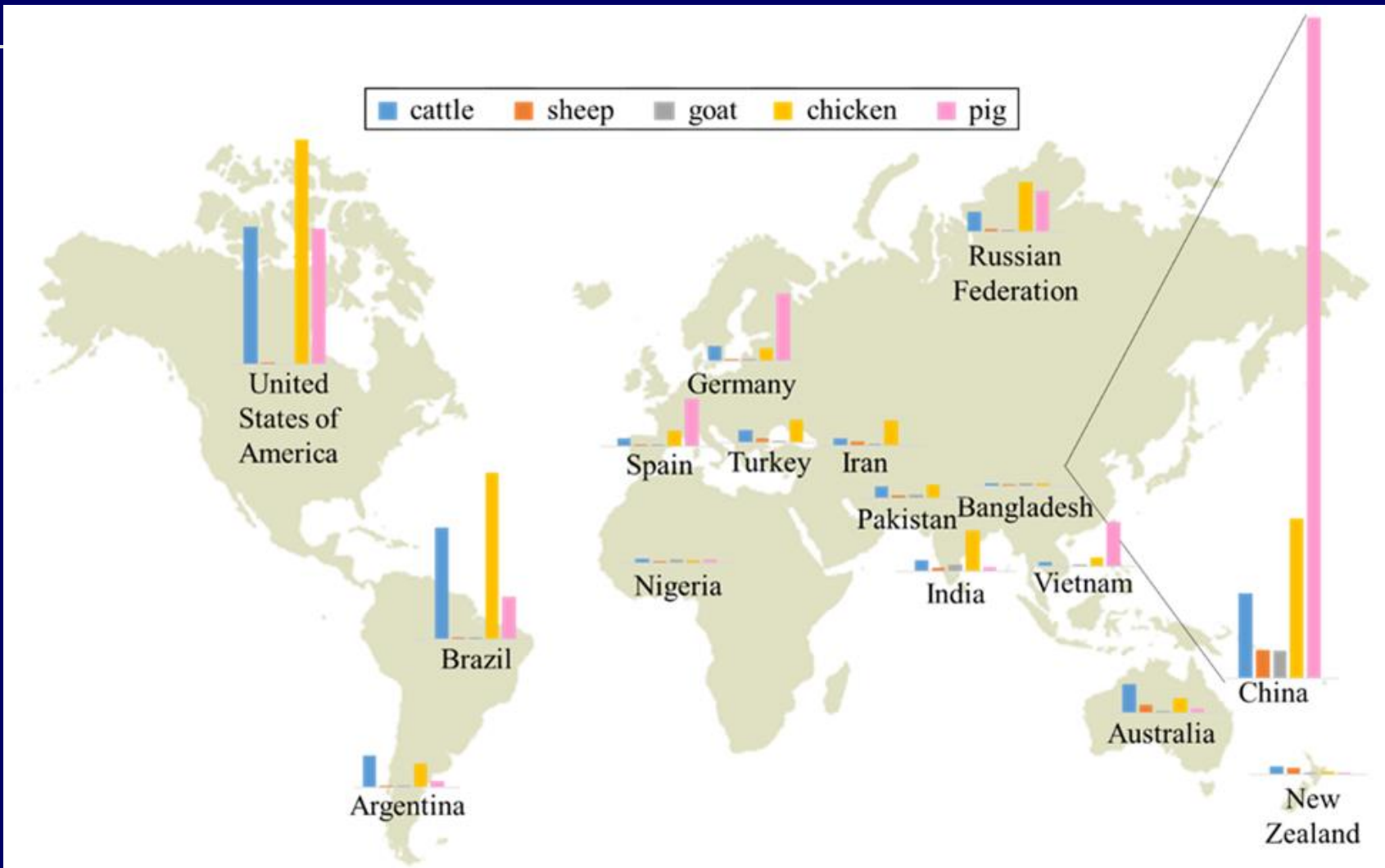
Nature Biotechnology 34:20-22.

University of Missouri, USA



Meat production by country in 2016

Countries listed include the top 5 producing countries for beef, chicken, pork, sheep and goat meat (FAO, 2018).





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



Gene Edited Polled Calves

Intraspecies allele substitution at polled locus



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

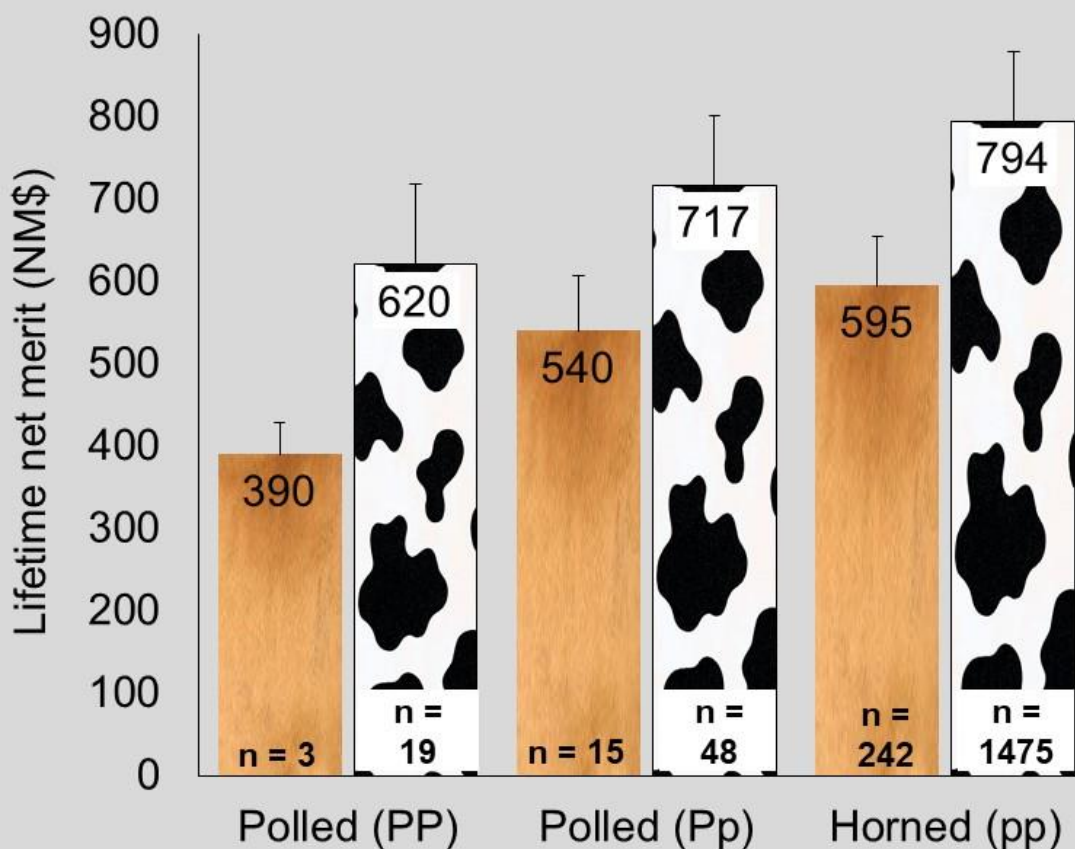


Current polled dairy sires have inferior genetic merit



Maci Mueller

Average NM\$ of the top 50% of polled and horned Holstein and Jersey bulls registered with the NAAB in March 2018

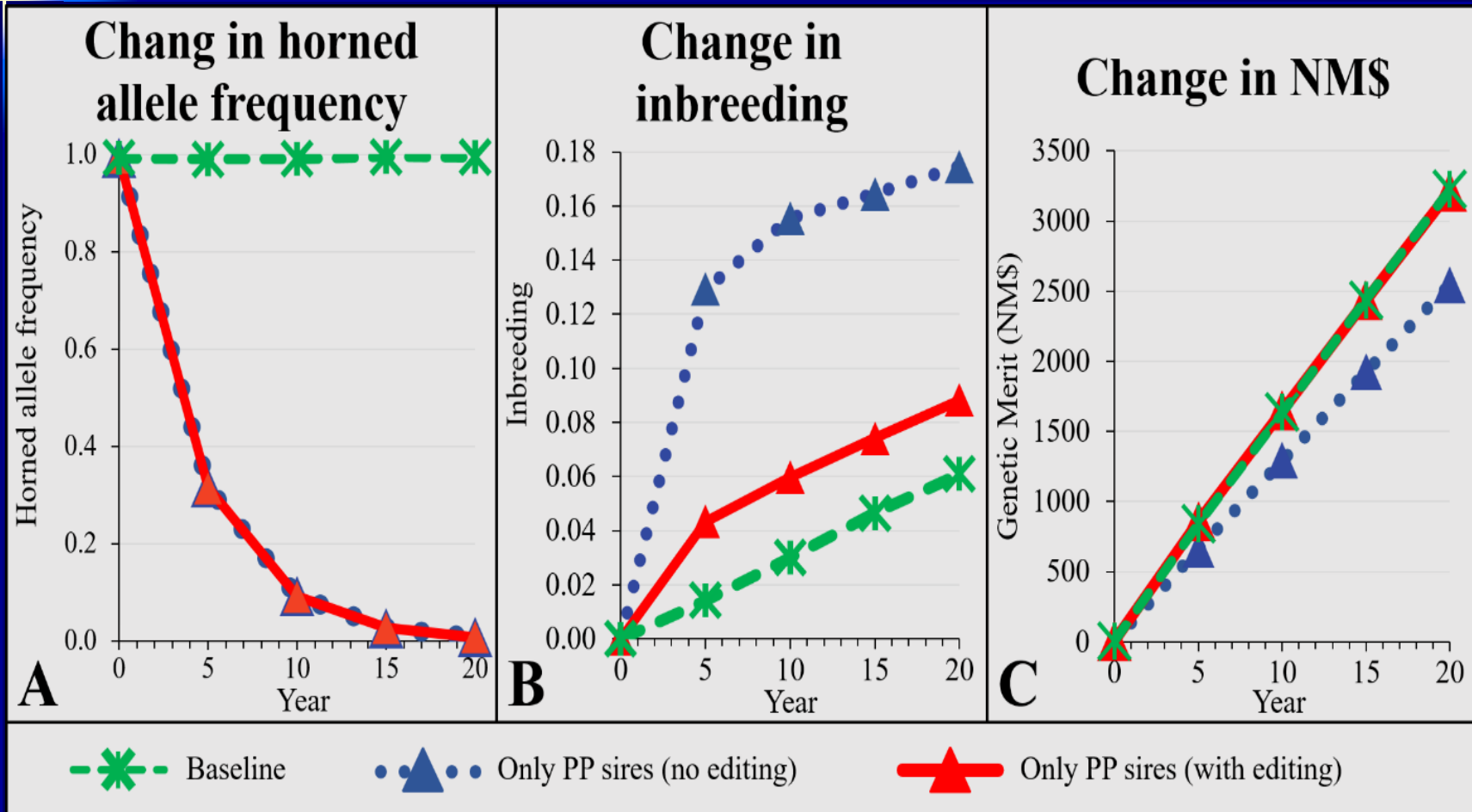


- ❖ Daughters of polled Holstein sires will earn less over their lifetimes [Spurlock et al., 2014]
- ❖ Polled allele frequency is 0.0071 [Null, 2015]
- ❖ Adding polled to selection indices is not effective [Cole, 2015]
- ❖ If used exclusively polled sires would increase inbreeding & decrease genetic gain [Mueller et al., 2018]

[Maci Mueller et al., 2019, *in press*]



Simulation of introgression of the POLLED allele via conventional breeding versus gene editing



[Maci Mueller et al., 2019, Journal of Dairy Science, *In Press*]



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



March 28th, 2018 USDA statement

No additional regulatory requirements if plants could otherwise have been developed through traditional breeding



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Secretary Perdue Issues USDA Statement on Plant Breeding Innovation

(Washington, D.C., March 28, 2018) – U.S. Secretary of Agriculture Sonny Perdue today issued a statement providing clarification on the U.S. Department of Agriculture’s (USDA) oversight of plants produced through innovative new breeding techniques which include techniques called genome editing.

Press Release

Release No. 0070.18

Contact: USDA Press

Email: press@oc.usda.gov

Under its biotechnology regulations, USDA does not regulate or have any plans to regulate plants that could otherwise have been developed through traditional breeding techniques as long as they are not plant pests or developed using plant pests. This includes a set of new techniques that are increasingly being used by plant breeders to produce new plant varieties that are indistinguishable from those developed through traditional breeding methods. The newest of these methods, such as genome editing, expand traditional plant breeding tools because they can introduce new plant traits more quickly and precisely, potentially saving years or even decades in bringing needed new varieties to farmers.



January 18th, 2017 FDA draft guidance 187 considers all gene edited animals whose genomes have been “altered intentionally” to be drugs



I am not a drug
I am a cow



National Pork Producers Council

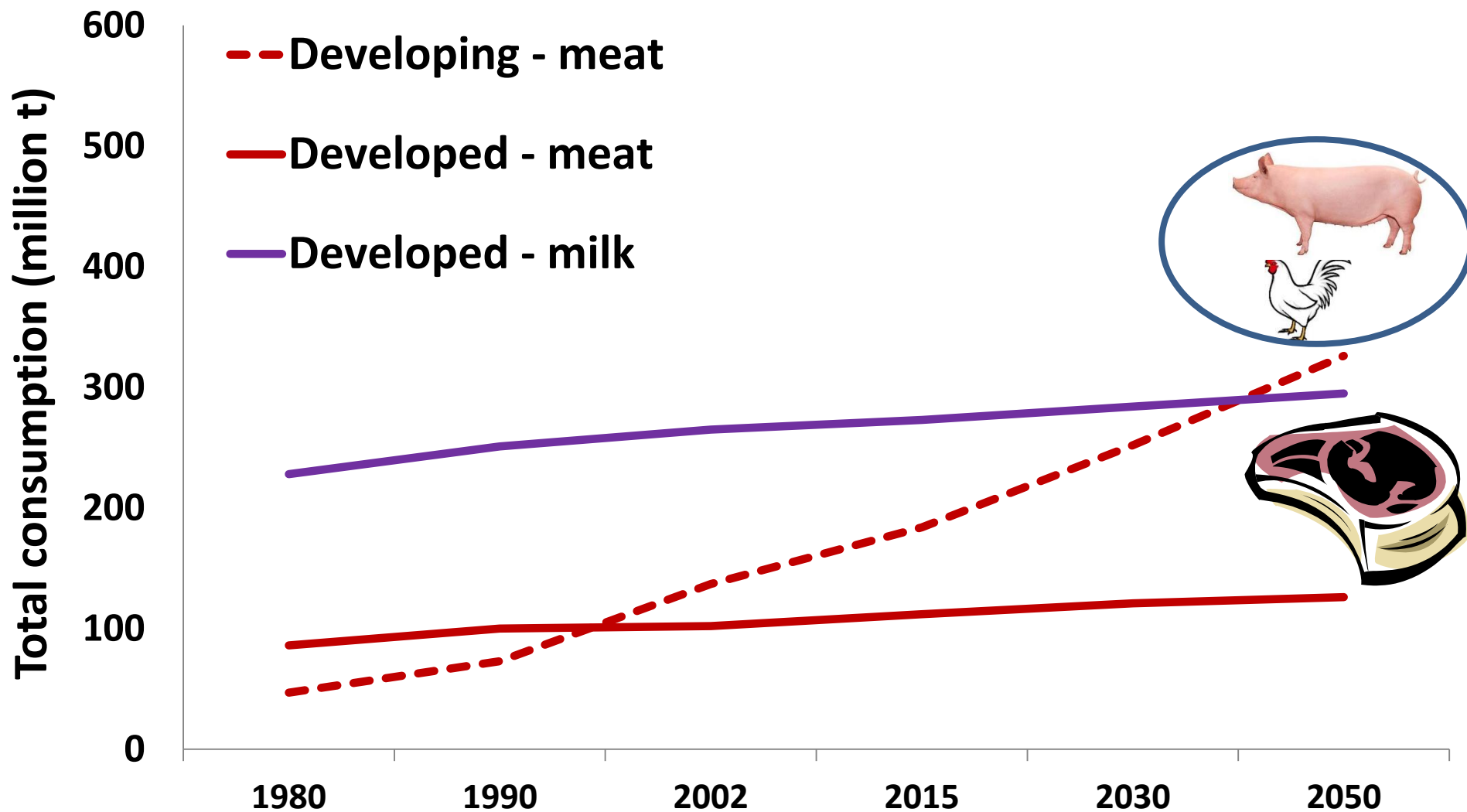
Position paper on "Regulation of Gene Edited Animals"

"This [FDA] regulatory path will result in a lengthy and expensive approval process, and functionally make any gene edited animal a living animal drug—and every farm raising them a drug manufacturing facility. It does not allow for a risk-based approach that takes into consideration the familiarity or complexity of the genetic changes, and the fact that they could be achieved through conventional breeding techniques (though at the expense of time and genetic improvement from decades of animal breeding). The FDA approach is also out of step with the regulatory pathways under development in the rest of the world"



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).



Whole Foods Market has announced they are going to stock slow growing chickens



ESSAYS FOOD & CONSEQUENCES UNCATEGORIZED

Why Slow-Growing Chickens Are the Next Big Thing

The change coming to chicken.

By CHRIS NUTTALL-SMITH Art by MOLLY MATALON





Entering the Whole Foods "alternative fact" zone

Whole Foods, have committed *"to replace fast-growing chicken breeds with slower-growing breeds"*

Nothing else about how the chickens are being raised is changing, they are just around for 14 more days before slaughter....

Why? According to Theo Weening, the global meat buyer for Whole Foods Market, the slow-growing bird *"is a much better, healthier chicken, & at the same time it's a much [more] flavorful chicken as well"*.

Where is the objective, evidence-base to support this assertion?

Why is growing less than 50 grams/day for 58 days better for welfare than growing at 61 grams/day for 44 days?

And why would this be a much more flavorful chicken if nothing else changed?

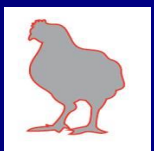
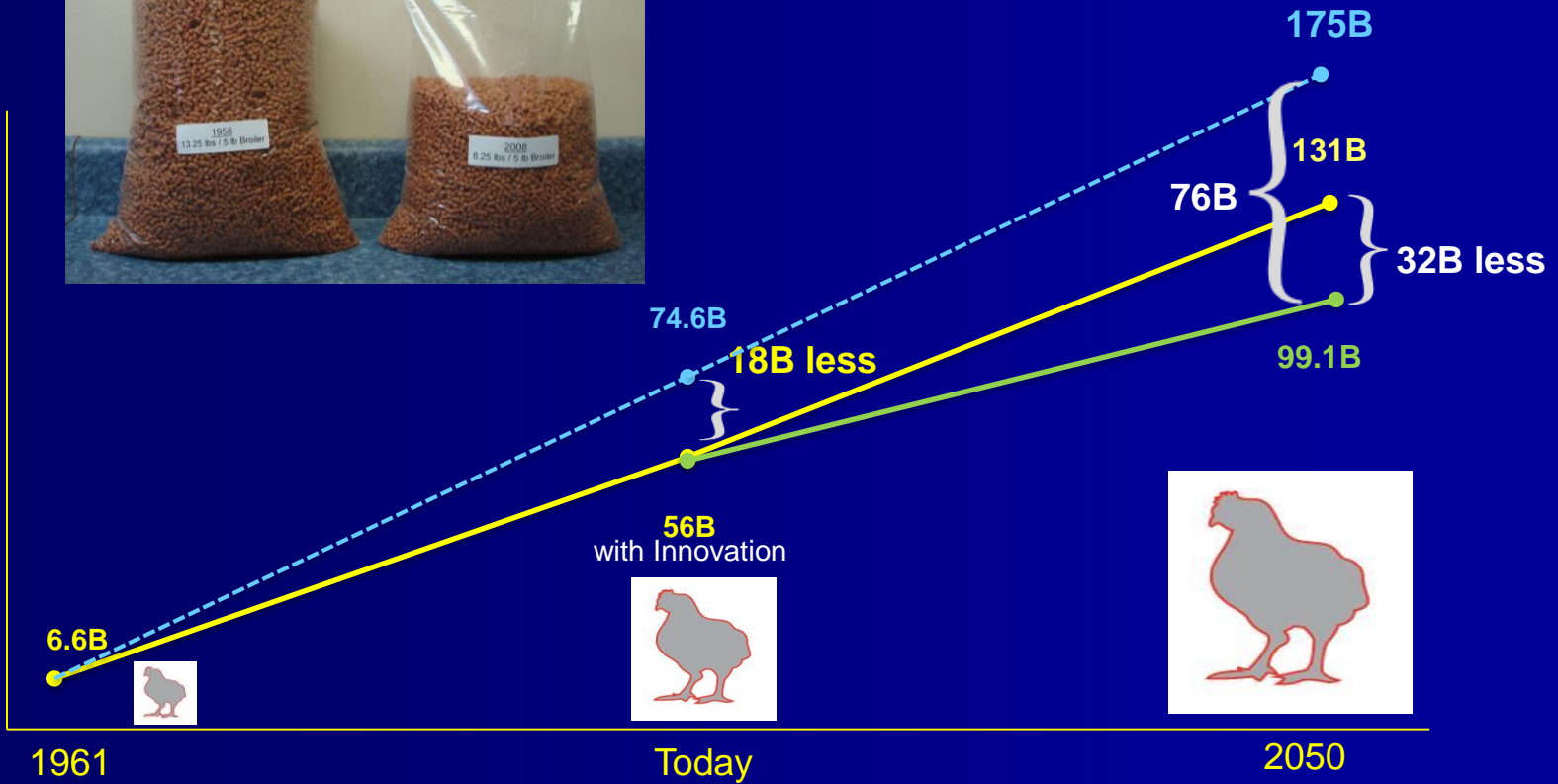




The impact of innovation on animal breeding programs



Number of Animals (In billions)



- - - - ● Without innovation = no productivity increase
- - - - ● Current rate of genetic improvement
- - - - ● With new breeding methods allowed

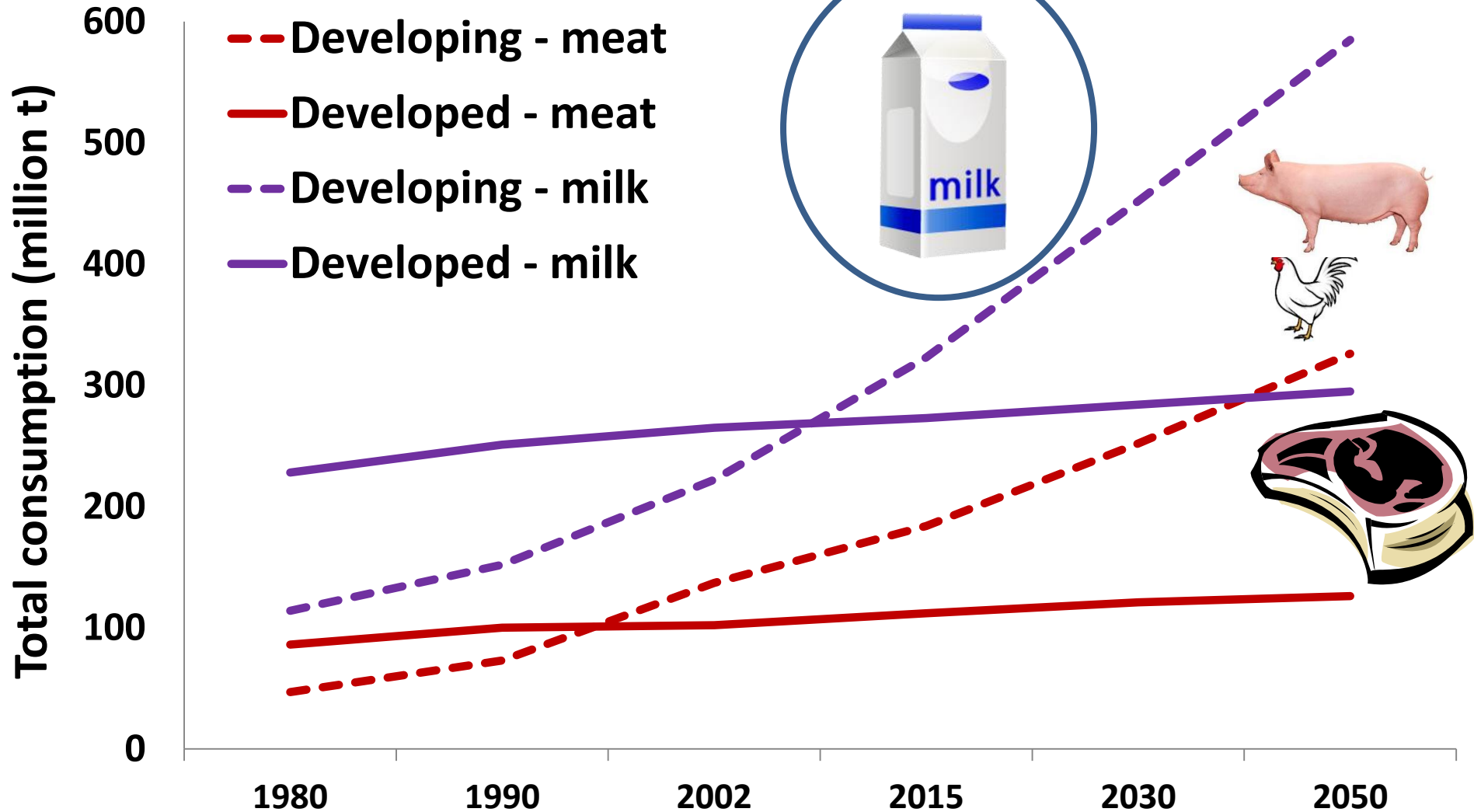


Cognitive dissonance: mental discomfort experienced by a person who simultaneously holds two or more contradictory beliefs, ideas, or values

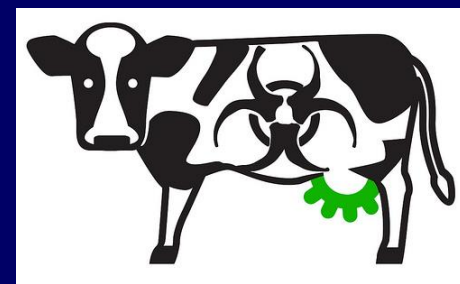


Past and projected trends in consumption of meat and milk in developing and developed countries

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



Lost rBST to the fearmongering (\$\$)



got hormones?
we don't.



Western Family milk is all natural from cows not treated with the growth hormone rBST.

got responsibility?
we don't either!



Our milk results in 7% more methane emissions per glass because we cater to fearmongering about safe technology to **increase our sales \$\$\$**

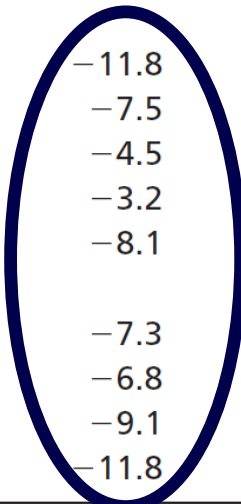


Increased methane /unit milk by 7.3%



Table 1. Effects of rbST use on resource input and waste output (per unit of milk) over the lactation cycle of an average cow

	Resource input or waste output per kilogram of milk*	Change per unit of milk with rbST use [†] , %
Resource inputs		
Net energy for maintenance, MJ	1.73	-11.8
Metabolizable protein for maintenance, g	30.4	-7.5
Total net energy requirement [‡] , MJ	4.79	-4.5
Total metabolizable protein requirement [‡] , g	77.6	-3.2
Feedstuffs per kg dry matter	0.82	-8.1
Waste outputs		
Methane, g	26.2	-7.3
Manure, kilogram freshweight	1.92	-6.8
N excretion, g	5.67	-9.1
P excretion, g	2.98	-11.8



Capper JL, Castañeda-Gutiérrez E, Cady RA, Bauman DE. 2008 The environmental impact of recombinant bovine somatotropin (rbST) use in dairy production. Proc Natl Acad Sci U S A 105:9668-73



**Chobani uses milk from cows fed GMOs.
How “natural” is THAT?**



Monsanto Latte?

**Tell Starbucks to serve
only organic, non-GMO milk.**

GMOiNSiDE
Coalition Powered by Green America



Opinion differences between the public and scientists

Percentage agreeing with statement

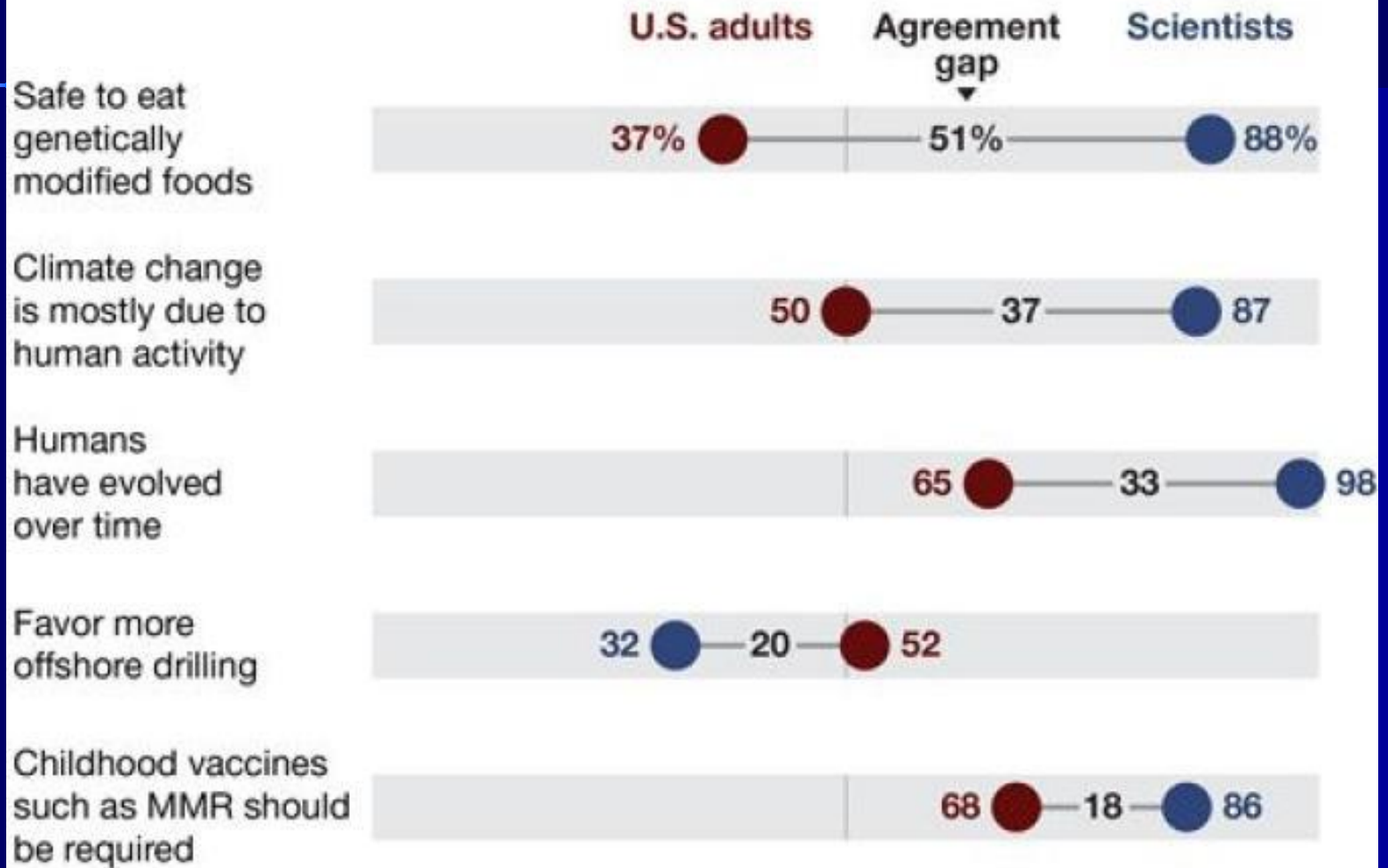


Image from <http://news.nationalgeographic.com/news/2014/06/150129-public-opinion-aaas-health-education-science/>
http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/pi_2015-01-29_science-and-society-00-01/

GMOs

5 DANGERS + THE AUTISM/ALLERGY CONNECTION



400% increase
in allergies since GMOs were introduced.



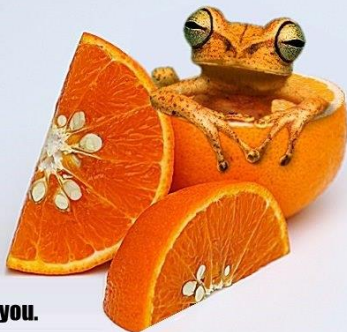
Will **Roundup** rob him of someday having babies of his own?
Gerber uses RoundUp Ready GMOs in its Good Starts for American babies. But a new study published in the journal *Free Radical Medicine & Biology* implicates Roundup in male infertility at concentration levels well within the EPA's "safe levels"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



Orange Juice
May Soon
Contain
Pig Genes



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!

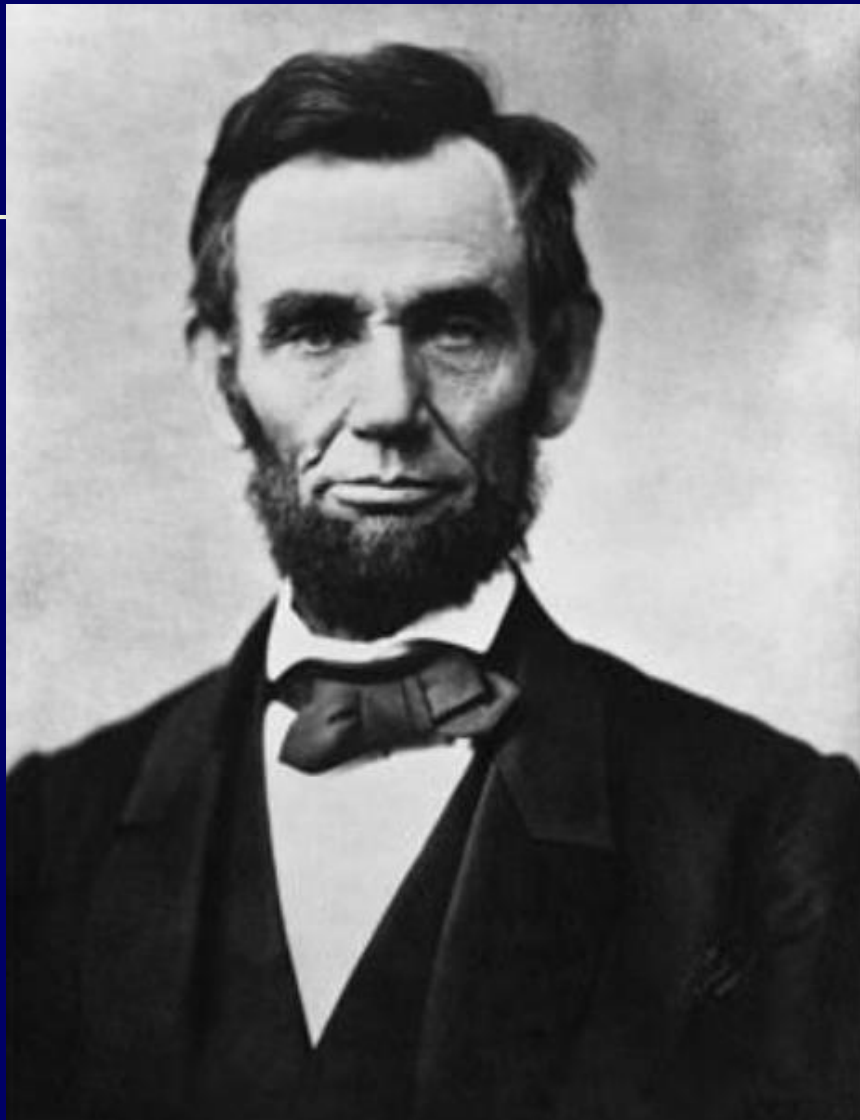
GMO FOOD IS DANGEROUS!



United Nations Photo



homecuresthatwork.com



“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>

What does non-GMO milk mean?

Farmers have to source more expensive non-GMO feed, despite the fact there is no detectible difference in the resulting milk





Why should consumers care?



Because GM has facilitated reductions in pesticide use & environmental footprint of agricultural production

- *50% decrease in global insecticide use on cotton as a result of Bt cotton (~20 million kg active ingredient)*
- *GM crops 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%.*
- *Important cuts in fuel use and no till, resulting in a significant reduction in the release of GHG emissions ~ removing 11.9 million cars from the roads.*

Brookes, G. and Barfoot, P., 2017. Environmental impacts of genetically modified (GM) crop use 1996–2015: impacts on pesticide use and carbon emissions. *GM crops & food*, 8(2), pp.117-147.

DOI: 10.1080/21645698.2017.1309490



“We monetarize precluding farmer access to safe technology which has proven to reduce GHG emissions & global insecticide use. WE HARM biodiversity & beneficial insects”



**GOODBYE
BUTTERFLY
Project**

VERIFIED



There is a need to defend objective truth – especially around food & agriculture – because “alternative ag facts” harm sustainability



“Preying on a parent’s instinctive desire to protect the health of their children by using lies to scare them into paying more money for absence-labeled foods, or worse to avoid fresh produce altogether due to misguided fears of GMOs or pesticides, is the most unethical and disingenuous way to increase market share imaginable.”

- Alison Van Eenennaam





I can make money by asking an increased price for products brandishing absence labels for something that does not exist!!

#marketinggenius



**NON
UNICORN
Project**

VERIFIED

A. Van Eenennaam
Laboratory

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





Thanks for inviting me!

UC DAVIS 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.



United States
Department of
Agriculture

National Institute
of Food and
Agriculture

