"Animal biotechnologies and agricultural sustainability"

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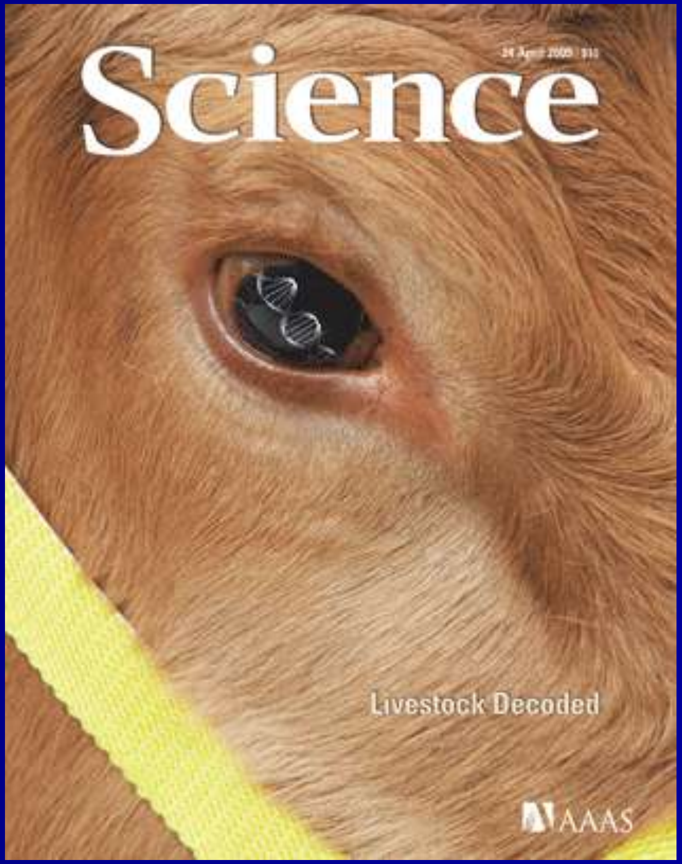

IFT Sustainability Workshop 06/08/09


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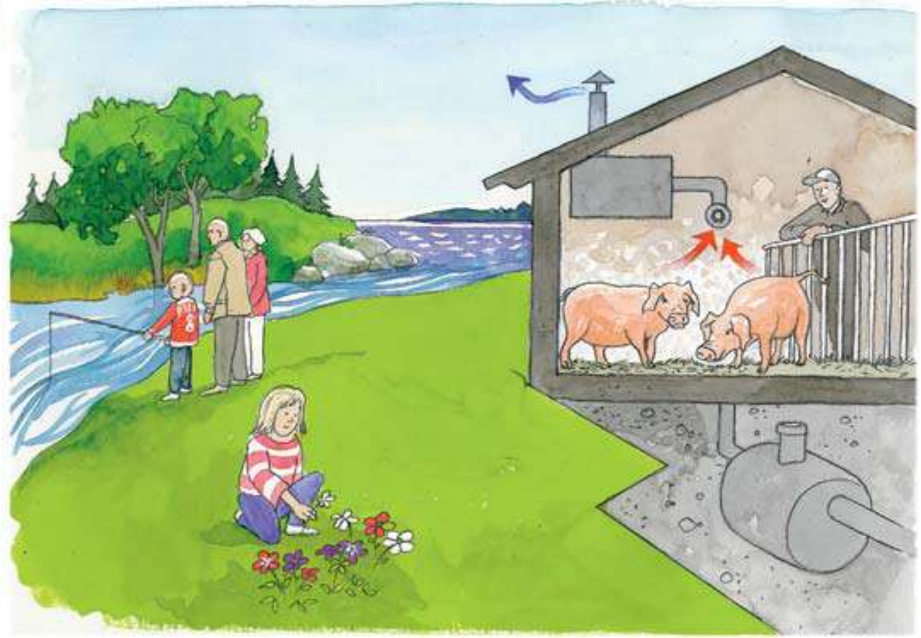
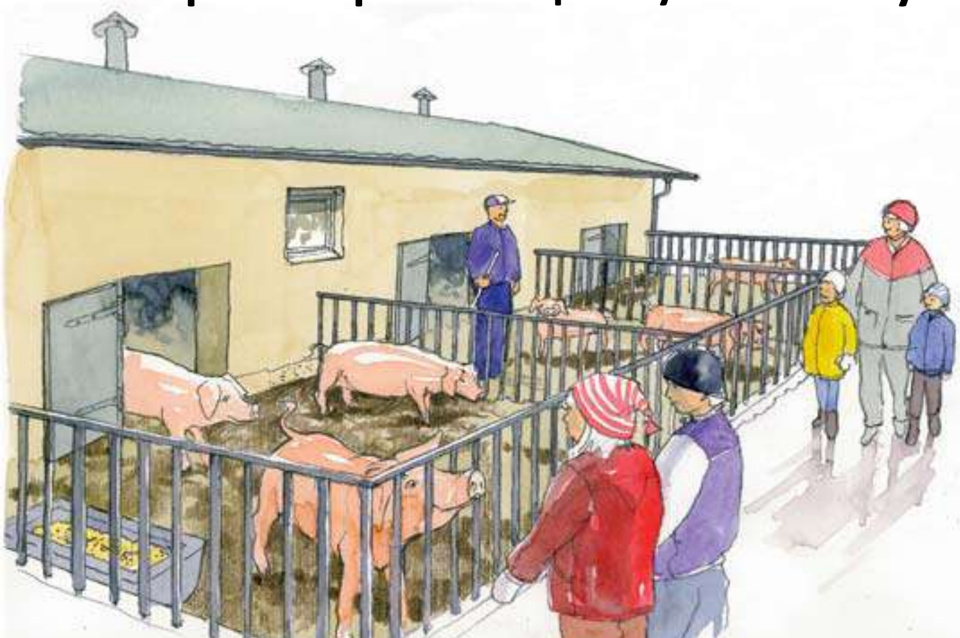
WHICH ANIMAL AGRICULTURE SYSTEM IS SUSTAINABLE?

1. Improved product quality and safety.



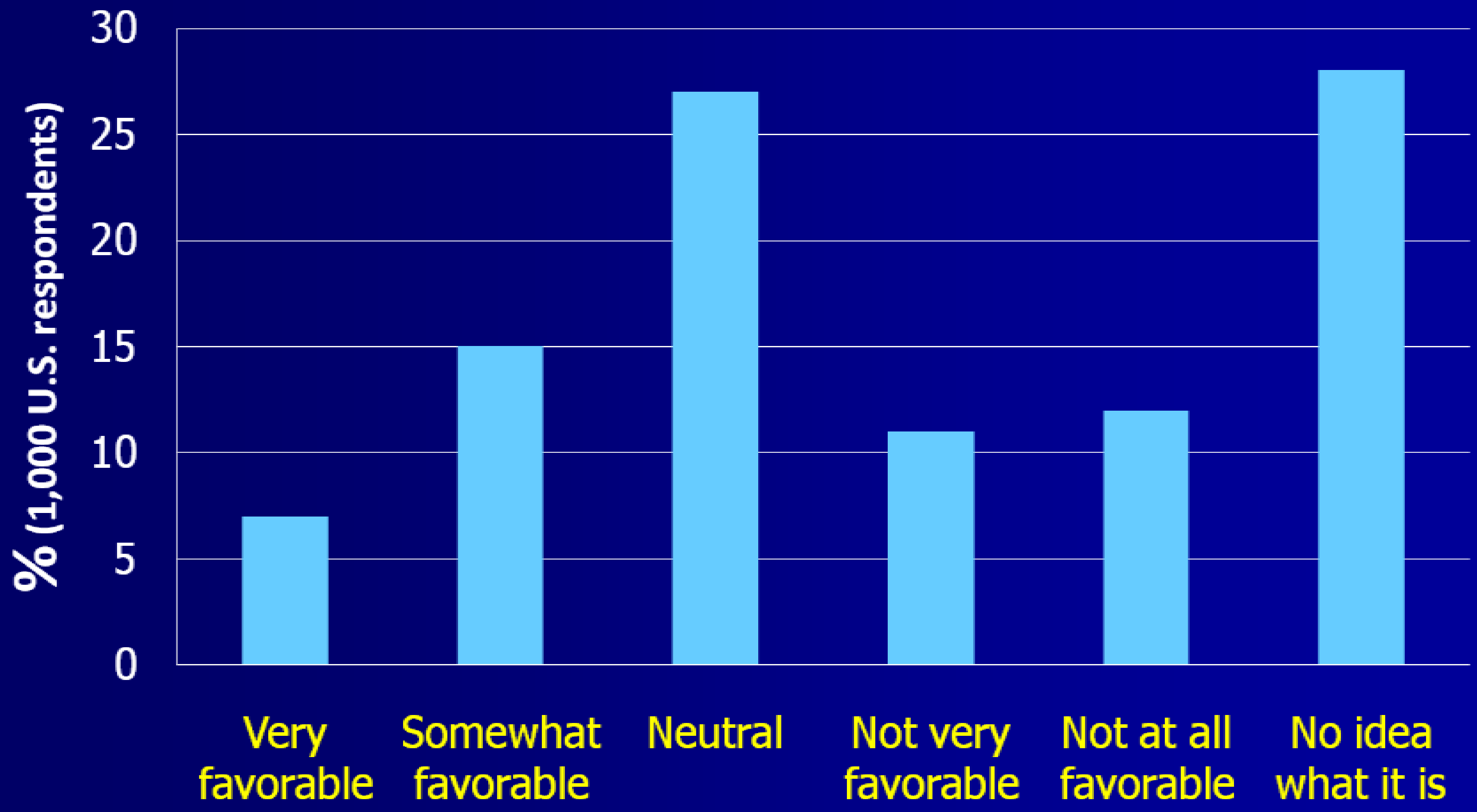
3. Decreased impact on the environment and efficient use of natural resources.



2. Improved animal welfare and natural behavior.

Illustrations from Stern,S., Sonesson,U., Gunnarsson,S., Oborn,I., Kumm,K.I., & Nybrant,T. Sustainable development of food production: A case study on scenarios for pig production. *Ambio* 34, 402-407 (2005).

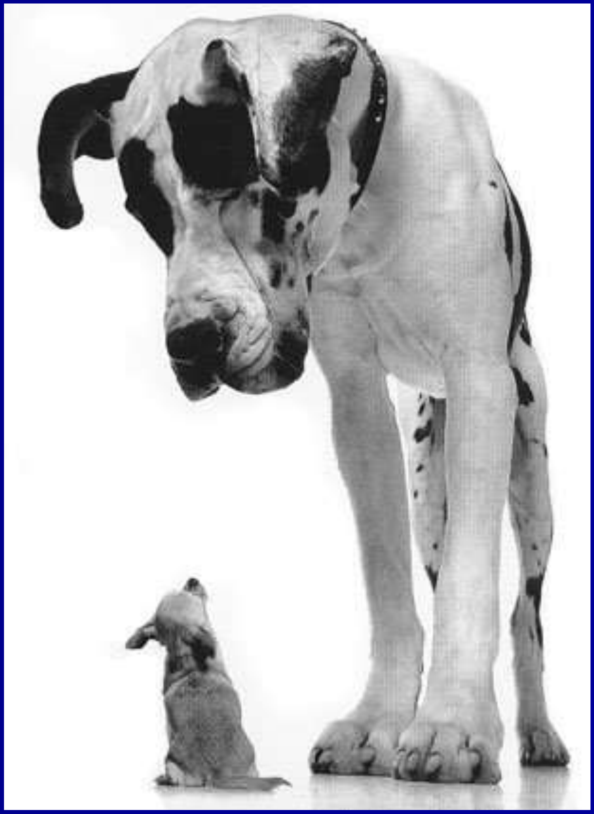
What is your overall impression of using biotechnology with animals that produce food products such as meat, milk, and eggs?



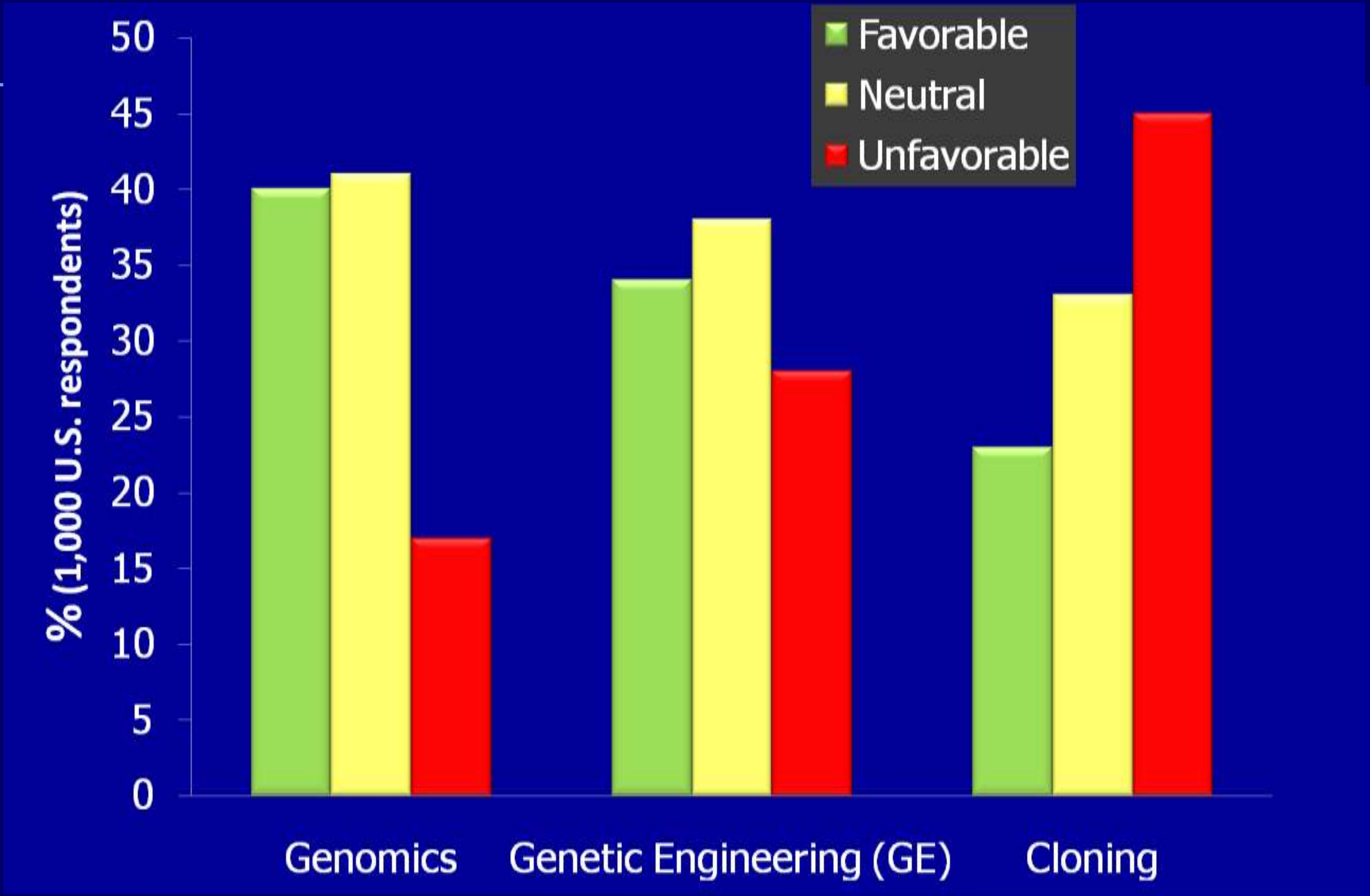
IFIC (2008) http://www.ific.org/research/biotechres.cfm

Animal biotechnology: The application of science and engineering to animals.

- "Conventional" selection (breeding programs)
- Artificial Insemination
- Embryo transfer
- DNA-informed selection



Public Attitudes Towards Specific "Animal Biotechnologies" (IFIC, 2008)



http://www.ific.org/research/biotechres.cfm

Animal biotechnology: The application of science and engineering to animals.

- Conventional selection (breeding programs)
- Artificial Insemination
- Embryo transfer
- DNA-informed selection (genomics)
- Genetic engineering
- Cloning

DOT and DITTO,
cloned Holstein calves at UC Davis

Genetic progress can is driven by the four components of the "breeders" equation:

ΔG =

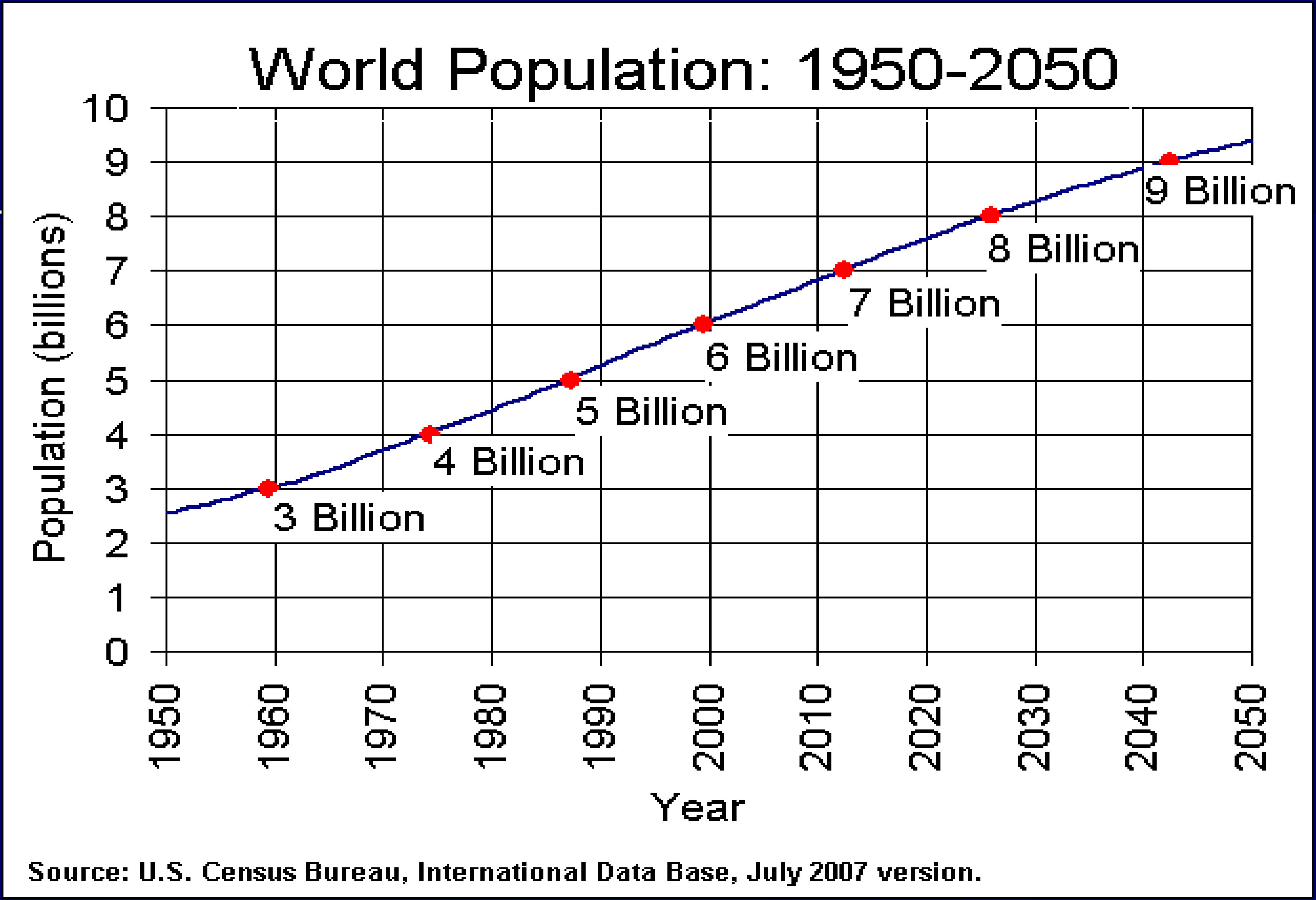
↑ ***intensity of selection***

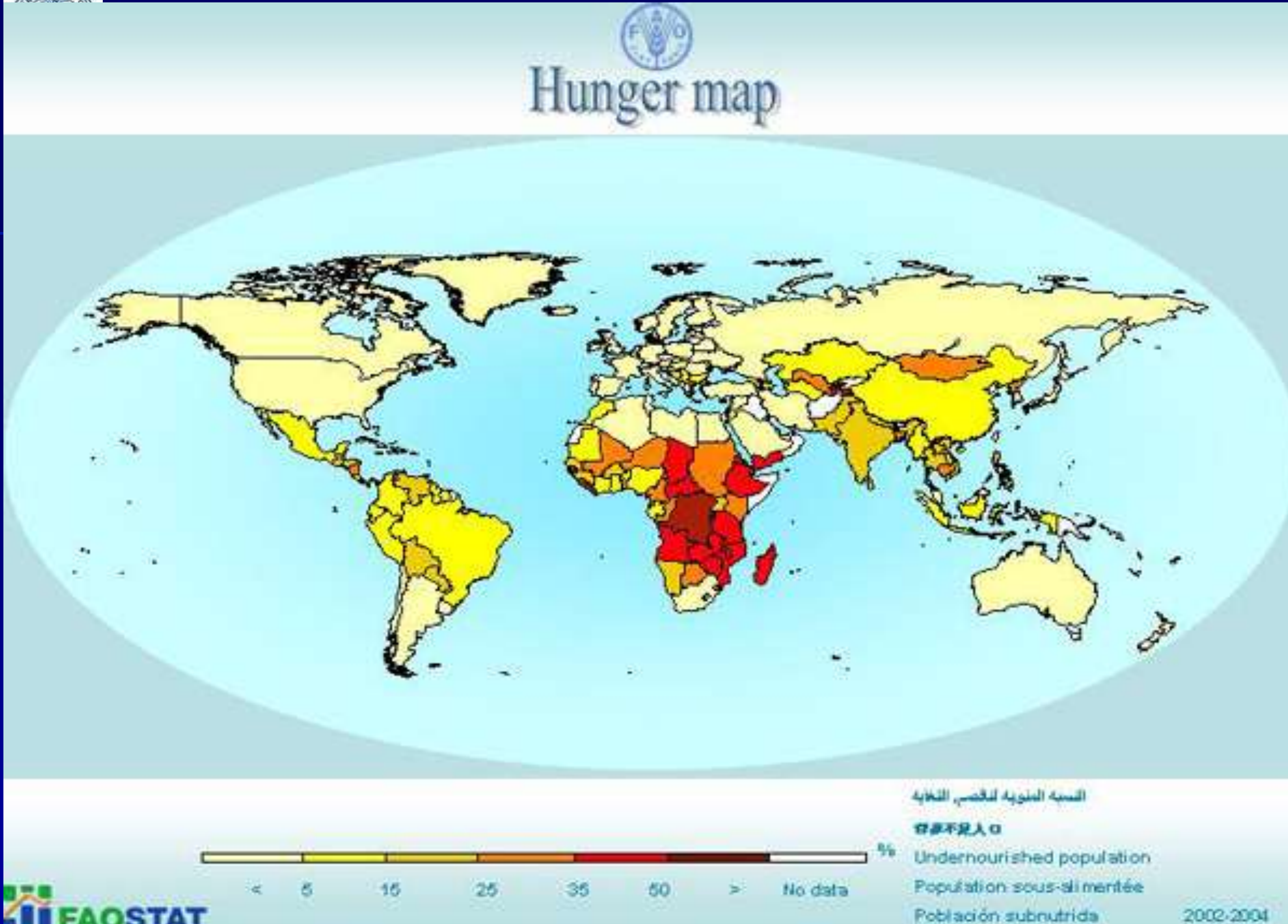
↑ ***accuracy of selection***

↑ ***genetic variation***

↓ ***generation interval***




World Population: 1950-2050
Population (billions)
10
9
8
7
6
5
4
3
2
1
0
3 Billion
4 Billion
5 Billion
6 Billion
7 Billion
8 Billion
9 Billion
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Year
Source: U.S. Census Bureau, International Data Base, July 2007 version.


Hunger map
< 5 15 25 35 50 > No data
%
Undernourished population
Population sous-alimentée
Población subnutrida
2002-2004
FAOSTAT

Proportional increase in world head of livestock 1961-2004; data from FAO (2005)

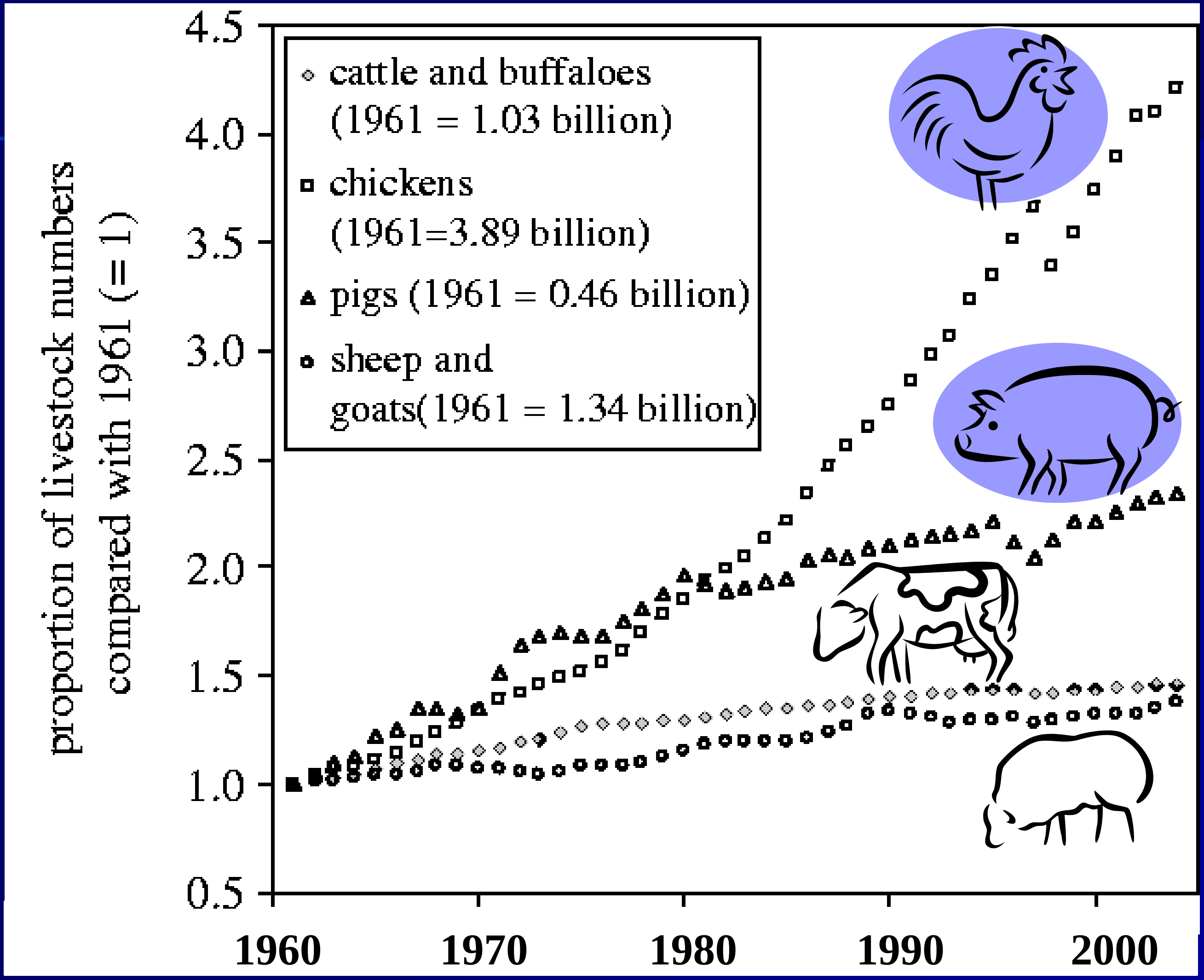


Figure based on Pretty, J. (2008) Agricultural sustainability: concepts, principles and evidence. Philosophical Transactions of the Royal Society B-Biological Sciences 363:447-465.

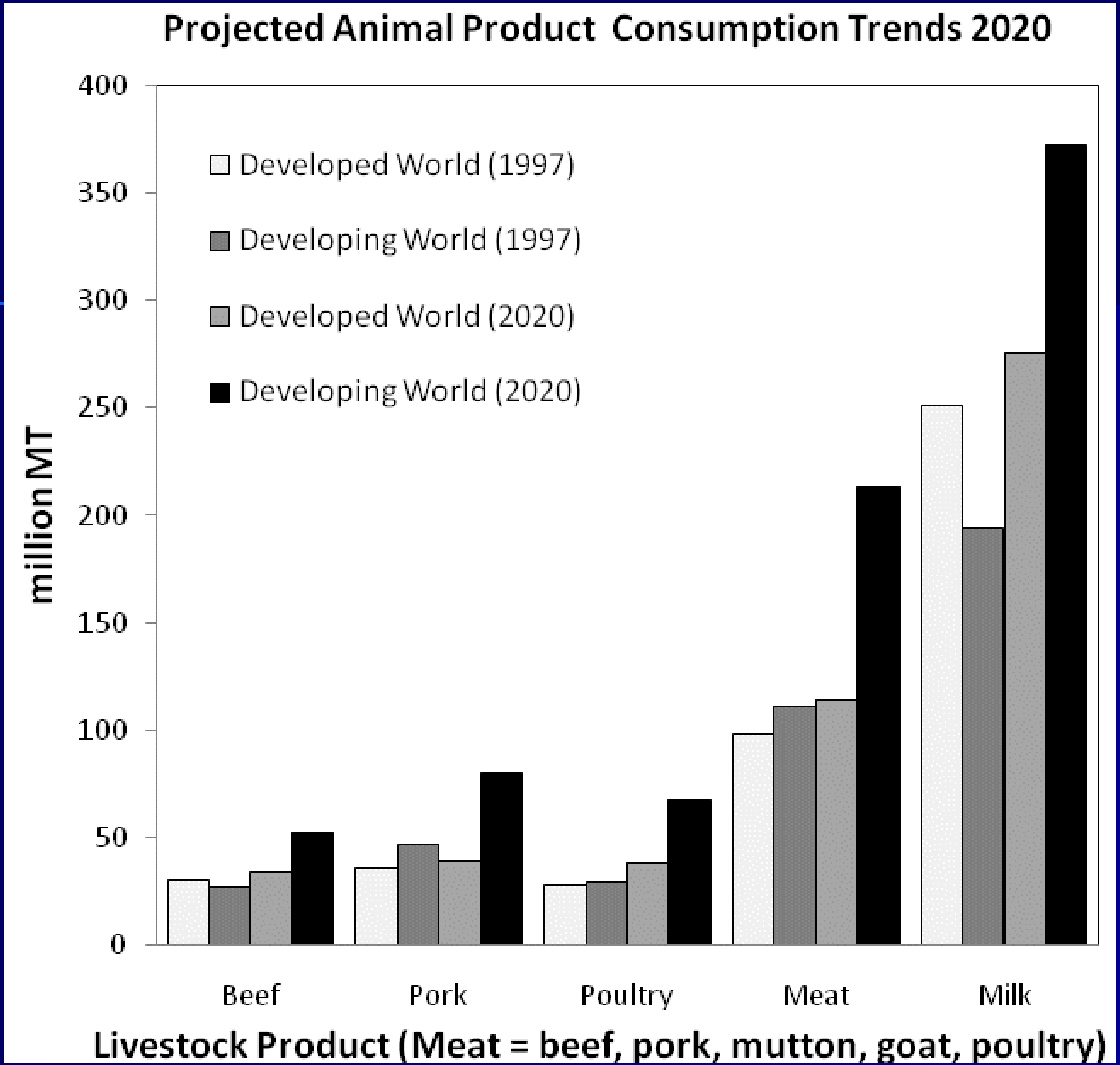


Figure from Delgado, C. L. 2003. Rising consumption of meat and milk in developing countries has created a new food revolution. Journal of Nutrition 133:3907S-3910S.

Extant GE livestock applications

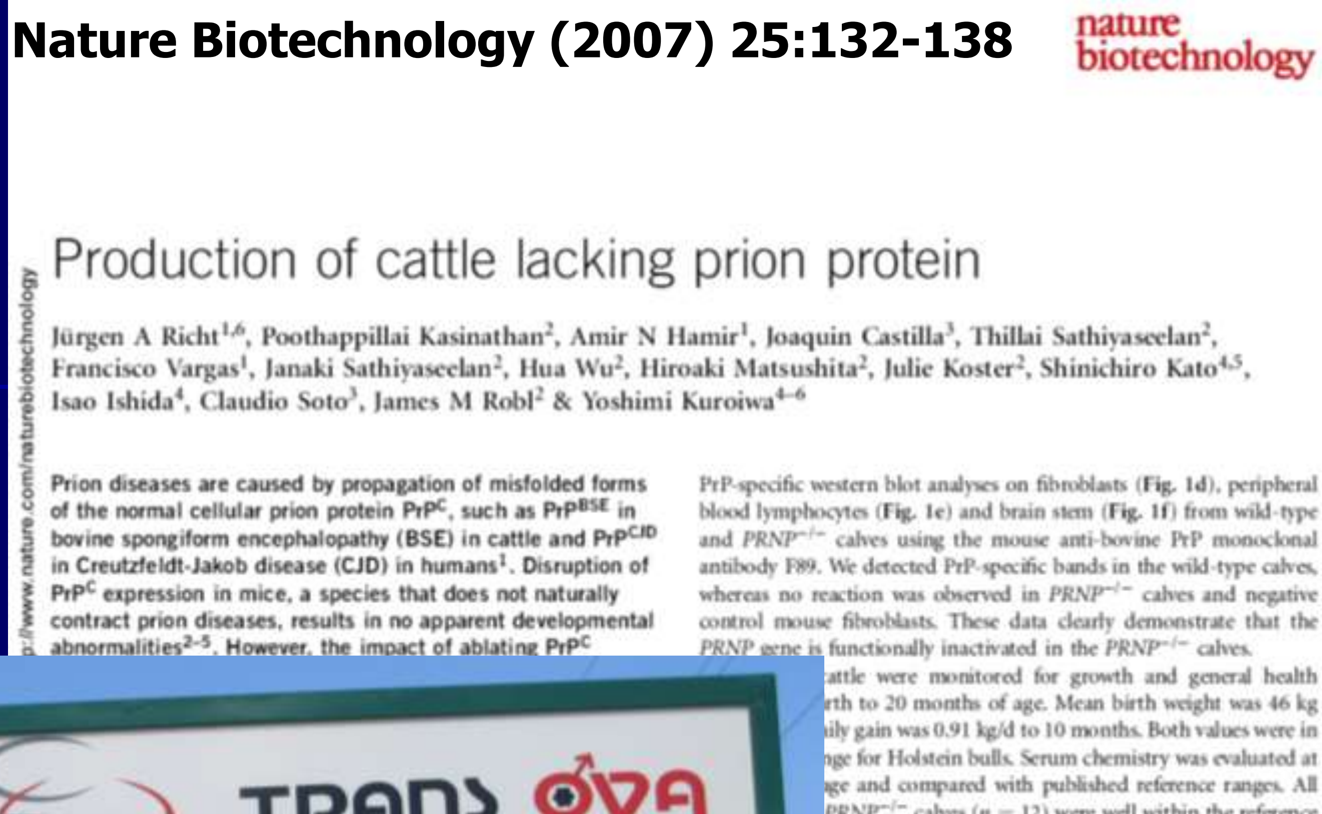
	Species	Gene	Approach
ENVIRONMENTAL			
Decreased P in manure	**Swine**	**Phytase**	**Transgene overexpression**
PRODUCT QUALITY			
Increased ω-3 fatty acids in meat	Swine	n-3 fatty acid desaturase	Clone/Transgene overexpression
Increase cheese yield from milk	Cattle	β-casein, κ-casein	Clone/Transgene overexpression
DISEASE RESISTANCE			
BSE resistance	**Cattle**	**Prion**	**Knockout**
Mastitis resistance	Cattle	Lysostaphin, Lactoferrin	Transgene overexpression
BSE resistance	Goat	Prion	RNAi transgene
Visna virus resistance	Sheep	Visna virus envelope gene	Transgene overexpression
Mastitis resistance	Goats	Lysozyme	Transgene overexpression
GCH virus resistance	Grass Carp	Lactoferrin	Transgene overexpression
Bacterial resistance	Channel Catfish	Cecropin B gene	Transgene overexpression
PRODUCTIVITY			
Enhanced growth rate	Many fish species	Growth Hormone	Transgene overexpression
Enhanced milk production	Swine	α-lactalbumin	Transgene overexpression
Enhanced growth rate	Swine	Growth hormone	Transgene overexpression
Enhanced growth rate	Swine	Insulin-like-growth factor	Transgene overexpression

Enviropig™ (Low-phosphorus manure)
http://www.uoguelph.ca/enviropig/

“reduces fecal phosphorus output by up to 75%”

Golovan, S. P., et al. 2001. Pigs expressing salivary phytase produce low-phosphorus manure. Nature Biotechnology 19:741-745.

Nature Biotechnology (2007) 25:132-138


nature biotechnology

Production of cattle lacking prion protein

Jürgen A Richt[1,6], Poothappillai Kasinathan[2], Amir N Hamir[1], Joaquin Castilla[3], Thillai Sathiyaseelan[2], Francisco Vargas[1], Janaki Sathiyaseelan[2], Hua Wu[2], Hiroaki Matsushita[2], Julie Koster[2], Shinichiro Kato[4,5], Isao Ishida[4], Claudio Soto[3], James M Robl[2] & Yoshimi Kuroiwa[4–6]

http://www.nature.com/naturebiotechnology

Prion diseases are caused by propagation of misfolded forms of the normal cellular prion protein PrP^C, such as PrP^{BSE} in bovine spongiform encephalopathy (BSE) in cattle and PrP^{CJD} in Creutzfeldt-Jakob disease (CJD) in humans[1]. Disruption of PrP^C expression in mice, a species that does not naturally contract prion diseases, results in no apparent developmental abnormalities[2–5]. However, the impact of ablating PrP^C

PrP-specific western blot analyses on fibroblasts (Fig. 1d), peripheral blood lymphocytes (Fig. 1e) and brain stem (Fig. 1f) from wild-type and $PRNP^{-/-}$ calves using the mouse anti-bovine PrP monoclonal antibody F89. We detected PrP-specific bands in the wild-type calves, whereas no reaction was observed in $PRNP^{-/-}$ calves and negative control mouse fibroblasts. These data clearly demonstrate that the *PRNP* gene is functionally inactivated in the $PRNP^{-/-}$ calves.

...attle were monitored for growth and general health ...rth to 20 months of age. Mean birth weight was 46 kg ...ily gain was 0.91 kg/d to 10 months. Both values were in ...nge for Holstein bulls. Serum chemistry was evaluated at ...ge and compared with published reference ranges. All

http://www.hematech.com

Envisioned GE livestock applications

ENVISIONED APPICATIONS	Species	Proposed Approach
Suppressing infectious pathogens (e.g. foot-and-mouth disease resistance)	Various	RNAi
Avian flu resistance	Poultry	RNAi
Coronavirus-resistance	Swine	RNAi /Knockout
Low lactose milk	Cattle	Transgene overexpression
Low lactose milk	Cattle	RNAi /Knockout
Increased ovulation rate	Sheep	RNAi /Knockout
High omega-3 fatty acid milk	Cattle	Transgene overexpression
Resistance to Brucellosis	Cattle	Transgene overexpression
Decreased P in manure	Poultry	Transgene overexpression
Increased lean-muscle growth	Cattle	RNAi /Knockout
Increased post-natal growth	Various	RNAi /Knockout
Enhanced mammary gland development	Various	RNAi /Knockout

2001 foot-and-mouth outbreak in UK

- $ 3.5 to $ 6 billion lost, Numerous producer suicides
- Millions of animals slaughtered from 10,000 farms

Is it possible that "**playing it safe**" by abandoning research and development in transgenic animals might deny us a technique or products which could prevent an environmental or public health disaster in fifty years time, or could prove invaluable in the treatment of some disease?

Would there be general acceptance of transgenic technology if it could be applied to engineering resistance to influenza in poultry and therefore lessen the risk of an influenza epidemic, such as the one in 1918 that killed more than 20 million people?

Clark,J. & Whitelaw,B. 2003. A future for transgenic livestock. *Nature Reviews Genetics* **4**, 825-833

As a result of selective breeding and increasing crop yields, in 2005 the amount of crop land required to produce one ton of meat and poultry was 1/3 that required in the 1960s

U.S. Feed Grain/Soybean Acres Used Per Ton of Meat and Poultry Production

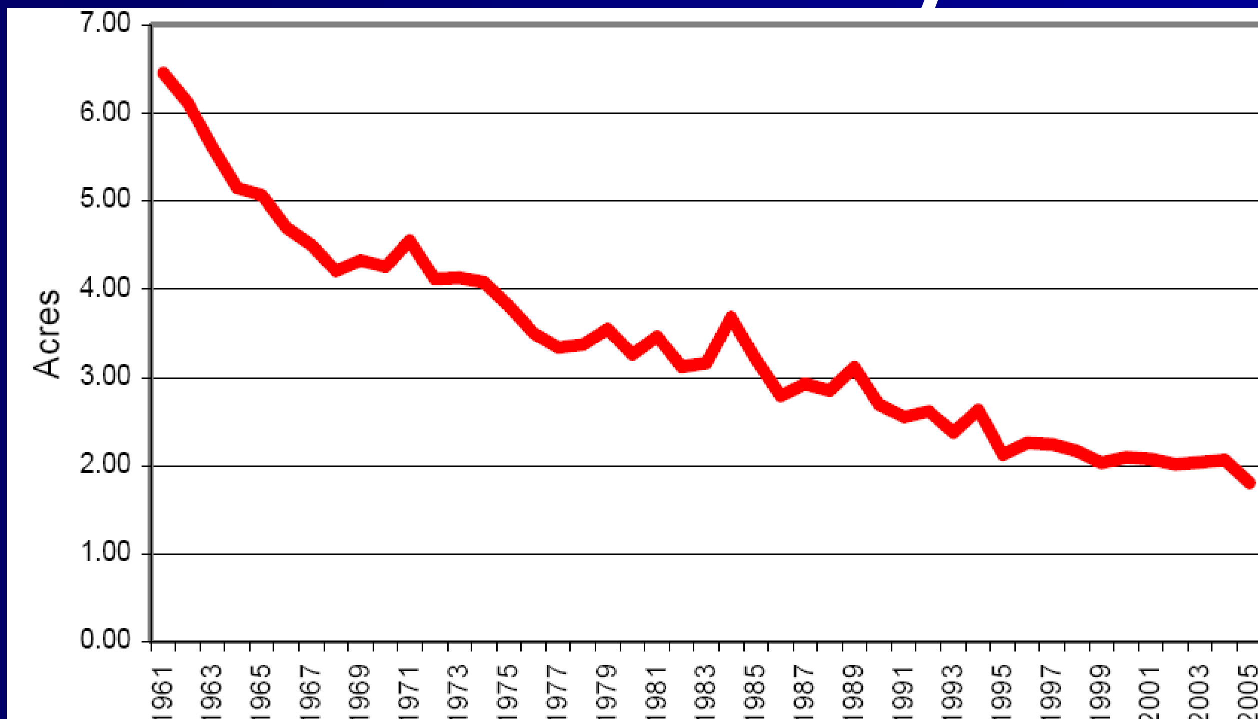


Figure from Elam, T. 2007. Is Organic Beef and Dairy Production a Responsible Use of Our Resources? Pages 66-75, 22nd Annual Southwest Nutrition and Management Conference. The University of Arizona, Tempe, AZ.

Capper, J. L., E. Castaneda-Gutierrez, R. A. Cady, and D. E. Bauman.

The environmental impact of recombinant bovine somatotropin (rbST) use in dairy production.

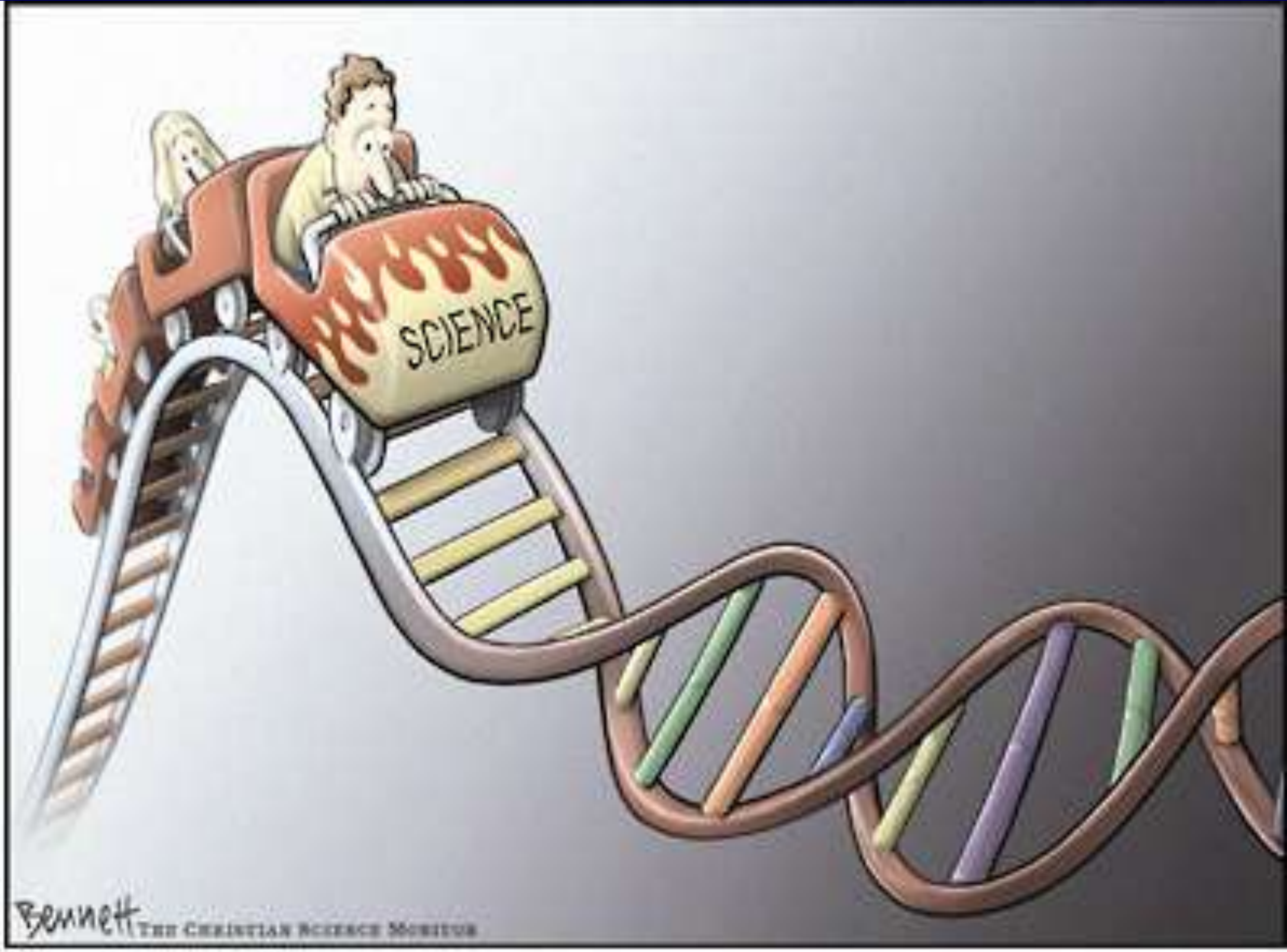
Proc Natl. Acad. Sci. USA (2008) 105:9668-9673.

The use of rBST:

- markedly improved the efficiency of milk production, AND ALSO
- decreased eutrophication, acidification, greenhouse gas emissions, and fossil fuel use per gallon of milk produced

This example emphasizes the need to weigh decisions to restrict producer access to a high yield technology or genetic resource that improves productive efficiency against the potential negative impact such decisions may have on achieving environmental sustainability goals.

Given the projected demand for animal products in the future, serious consideration must be given to all technologies that can move animal agriculture towards production systems that integrate a sustainable balance of environmental, animal well-being, social, and economic goals.


SCIENCE
Bennett
THE CHRISTIAN SCIENCE MONITOR