"Cost-benefit considerations of livestock genomics: who pays, who benefits"

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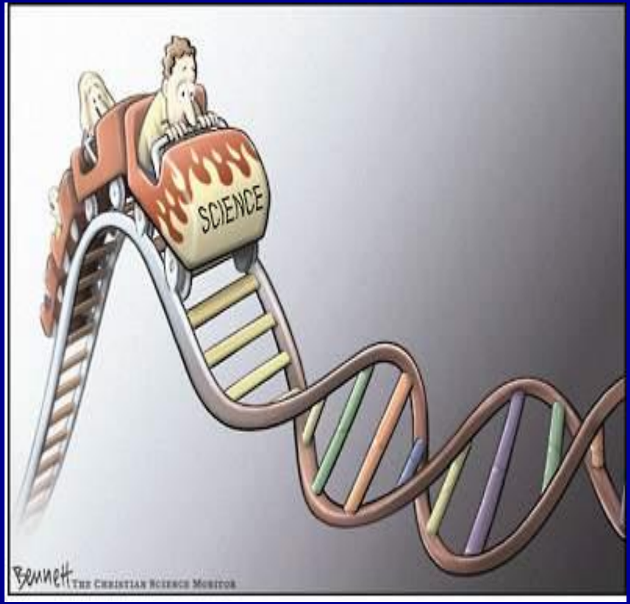
UCDAVIS ANIMAL SCIENCE



Biotechnology is used a lot in animal agriculture – need to be very specific about which one you are talking about as they are associated with different cost and benefits

PRODUCTION

- Bovine somatotropin
- Beta-agonists
- Implants
- Ionophores
- Genetically engineered feed (i.e. GM corn, soy)
- Antibiotics
- Cages/feedlots
- Vaccines
- Castration/dehorning

GENETIC

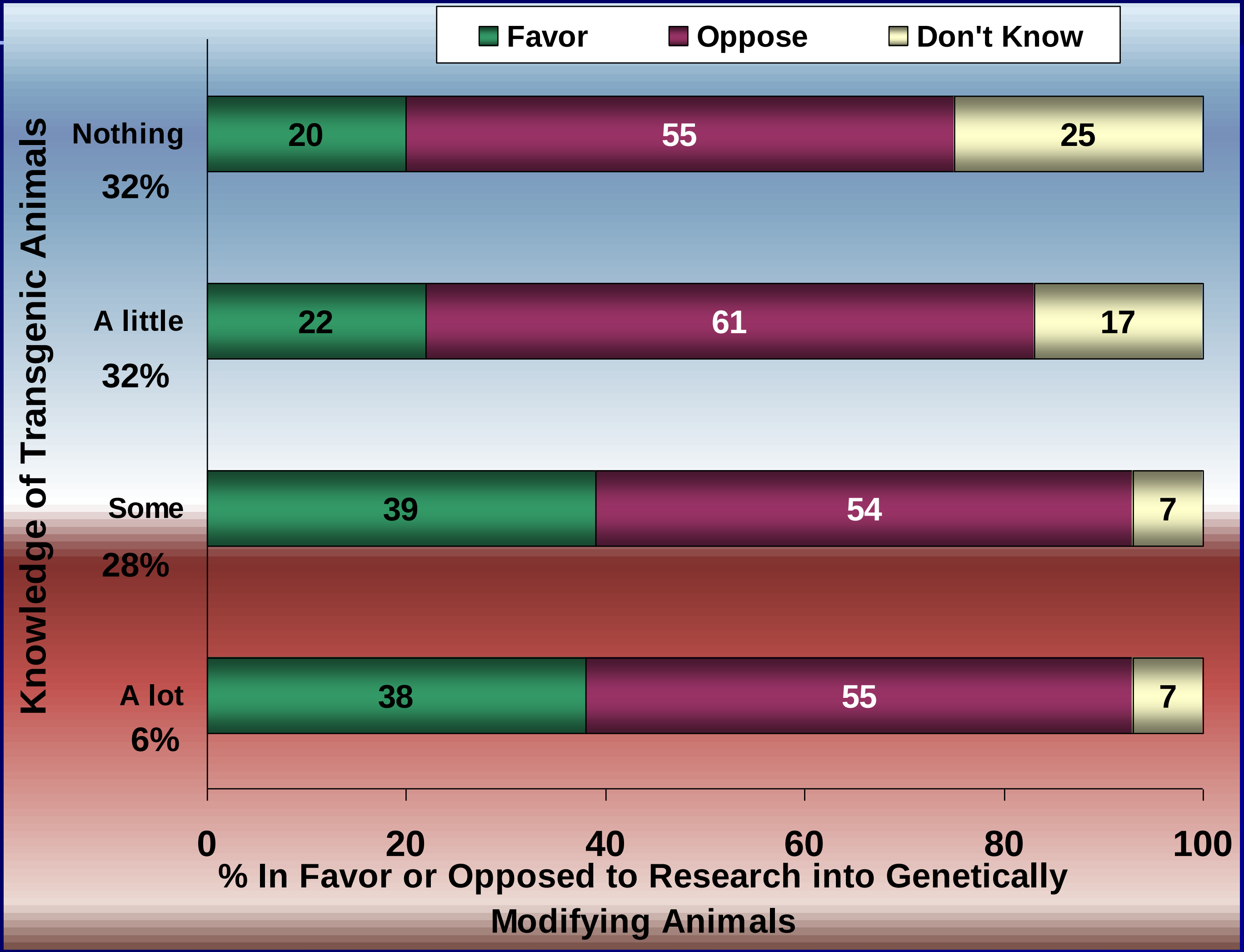
- Cloning
- Genetic engineering
- Gene editing of target genes e.g. myostatin, prion protein
- Genomic selection
- Embryo transfer
- Artificial insemination
- Estrus synchronization
- Crossbreeding
- Selective breeding programs

Our charge

"There are many economic issues associated with developments in livestock genomics. Some of the issues that will be discussed by this panel – what issues are ripe for research in the economic area?

The aim of this workshop is to assist Alberta researchers identify the most pressing GE3LS issues that would be suitable for economic research

The majority of Americans oppose scientific research into genetic modifications of animals - irrespective of self-assessed knowledge level



10/2005

http://pewagbiotech.org/research/2005update/2005summary.pdf

“The public opposes research into genetic modifications of animals ”

- The majority (55%) of Americans believe that the “genetic modification” of animals is morally objectionable.

Schilling, B. J., Hallman, W. K., Adelaja, A. O., and Marxen, L. J.2002. *Consumer Knowledge of Food Biotechnology: A Descriptive Study of U. S. Residents*. Food Policy Institute, Cook College, Rutgers - The State University of New Jersey. 25p.

- It should be noted that in this same study, consumer acceptance of traditional animal crossbreeding techniques was only 31 %, with 50% of respondents finding such practices morally wrong !

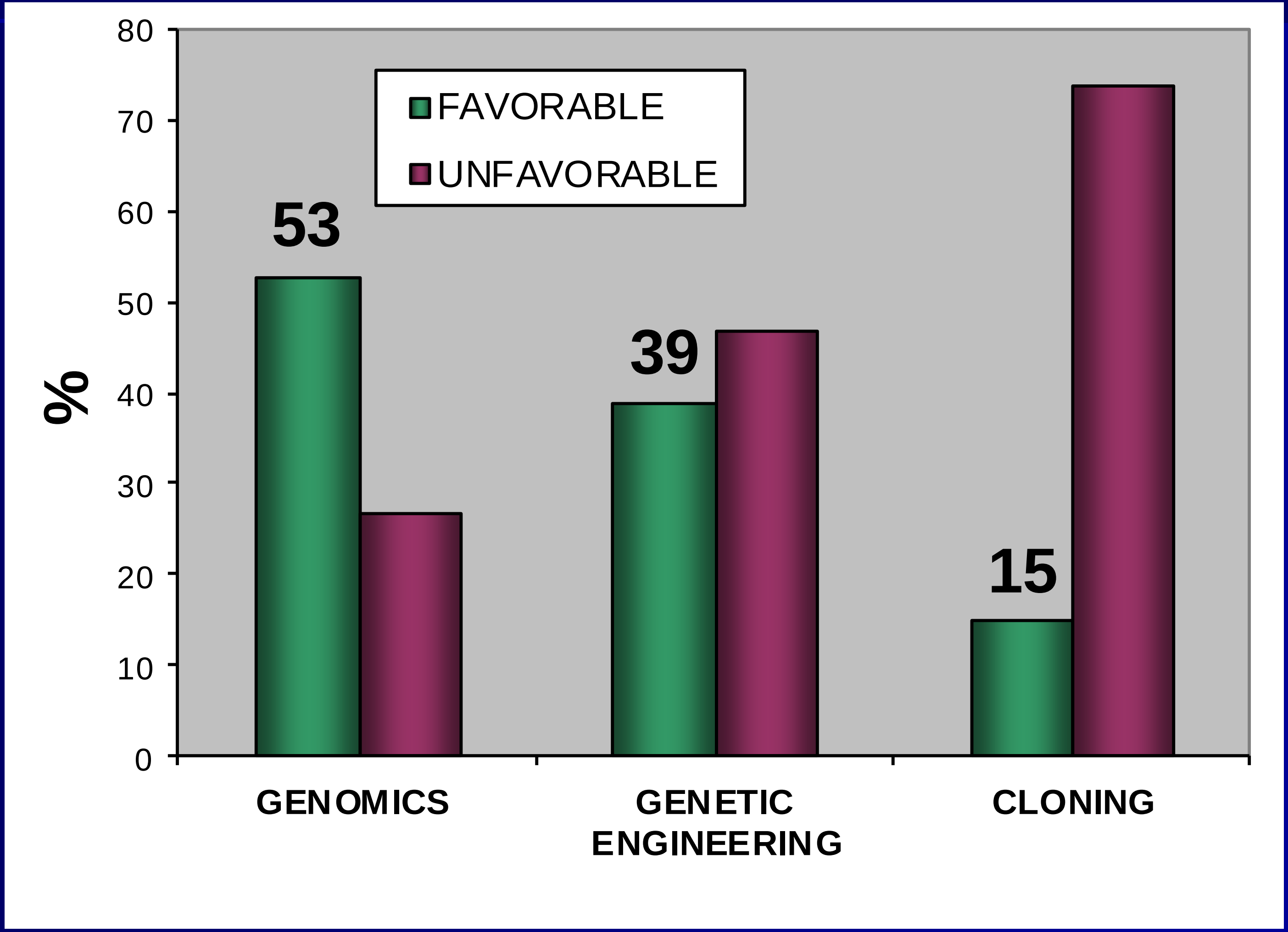
There is little organized activist opposition to conventional animal breeding which has DRAMATICALLY modified domestic livestock

Animal breeders have been genetically modifying animals for faster growth and improved feed conversion for many years using selective breeding

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

US Public Attitudes Towards Specific "Modern Animal Biotechnologies"

(International Food Information Council Survey of US, 2005)



http://ific.org/research/upload/2005BiotechSurvey.pdf

And in some cases using the process of recombinant DNA (rDNA)

Founder female produced in 1989

GROWTH ENHANCEMENT IN TRANSGENIC ATLANTIC SALMON BY THE USE OF AN "ALL FISH" CHIMERIC GROWTH HORMONE GENE CONSTRUCT

Shao Jun Du, Zhiyuan Gong, Garth L. Fletcher[1], Margaret A. Shears[1], Madonna J. King[1], David R. Idler[1] and Choy L. Hew*

Research Institute, The Hospital for Sick Children and Departments of Clinical Biochemistry and Biochemistry, University of Toronto, Toronto, Canada M5G 1L5. [1]Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, Newfoundland, Canada A1C 5S7. *Corresponding author.

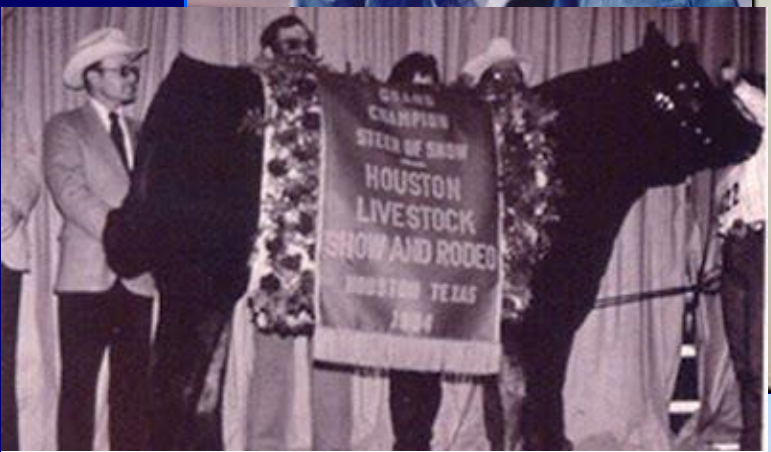
We have developed an "all fish" growth hormone (GH) chimeric gene construct by using an antifreeze protein gene (AFP) promoter from ocean pout linked to a chinook salmon GH cDNA clone. After microinjection into fertilized, nonactivated Atlantic salmon eggs via the micropyle, transgenic Atlantic salmon were generated. The presence of the transgene was

transgenic Atlantic salmon by using an "all fish" transgene consisting of a promoter derived from an ocean pout antifreeze protein (opAFP) gene[9], and the GH cDNA clone from chinook salmon[10].

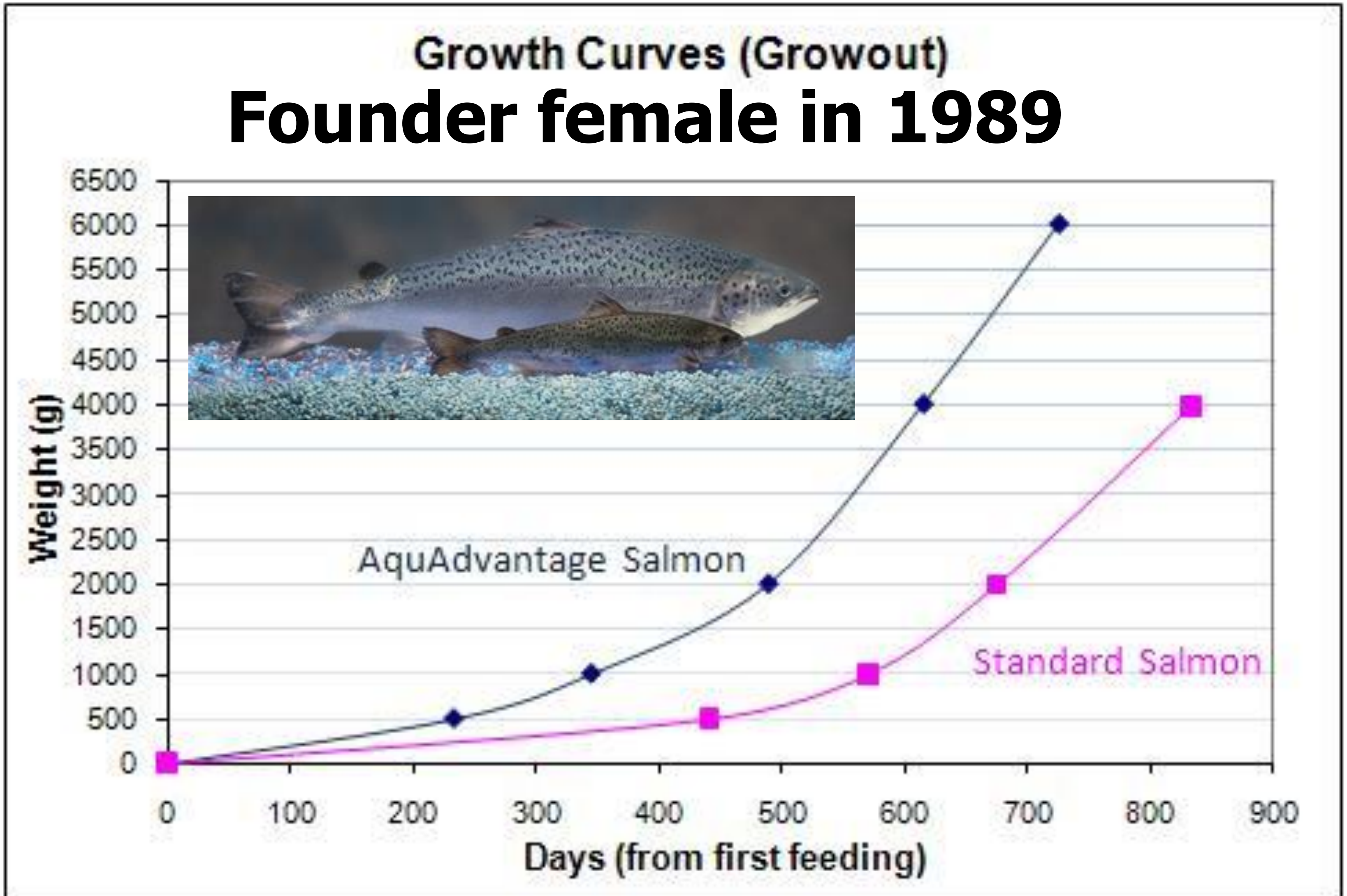
University of Toronto/Memorial University of Newfoundland, Canada

Nature Biotechnology. 1992. 10:176 – 181.

ANR
UNIVERSITY of CALIFORNIA



Fish reach adult size in 16 to 18 months instead of 30 months



Date	Event
September 1995	AquaBounty submits Investigational New Animal Drug (INAD) application with FDA for fast-growing salmon with intent to commercialize
September 2010	Public Veterinary Medicine Advisory Committee (VMAC) meeting to consider data on safety and efficacy of AquAdvantage salmon Held in Washington DC

The public VMAC meeting held in Washington, DC was intended to increase transparency, clarity, and public confidence in the GE animal regulatory process

10. Frankenfish Aren't Animals, They're "Animal Drugs" 1 of 11

Obama's FDA is regulating genetically engineered salmon, a genetically modified organism (GMO) that is the first of its kind, not as an animal, but as an animal drug.

"There is little benefit to society if attempts to increase public participation in the regulatory process are used as an opportunity to vilify technology."
Van Eenennaam, A.L. and W.M. Muir. 2011 Nature Biotechnology. 29: 706–710

Timeline of AquAdvantage regulatory process

25+ years from discovery to application?

Year	Event
1989	• Founder AquAdvantage fish produced in Canada
1995	• FDA review of AquAdvantage salmon begins (INAD)
2001	• First regulatory study submitted by Aqua Bounty Technologies to U.S. FDA for a New Animal Drug Applications (NADA)
2009	• FDA guidance on how GE animals will be regulated • FDA approval of first GE animal pharmaceutical • Final AquAdvantage regulatory study submitted to FDA
2010	• **FDA VMAC meeting on AquAdvantage salmon (9/20/10)**
2011	• Political efforts to defund FDA, ban fish, delay approval
2012	• FDA released "FONSI" finding of environmental assessment
2014	• **AquaBounty Total R&D investment > $60 million to develop and bring the AquAdvantage salmon through the regulatory approval process *thus far*** (D. Frank, CFO, AquaBounty, pers. comm.) • Still waiting for regulatory decision on AquAdvantage salmon • Development of GE animal technology moving to other countries with more predictable policy environments

What the implications of having to spend $60+ million to bring a fast-growing GE fish to market, when conventional fish (and other animal) breeders routinely develop all manner of fast-growing animals that are associated with the same set of risks?

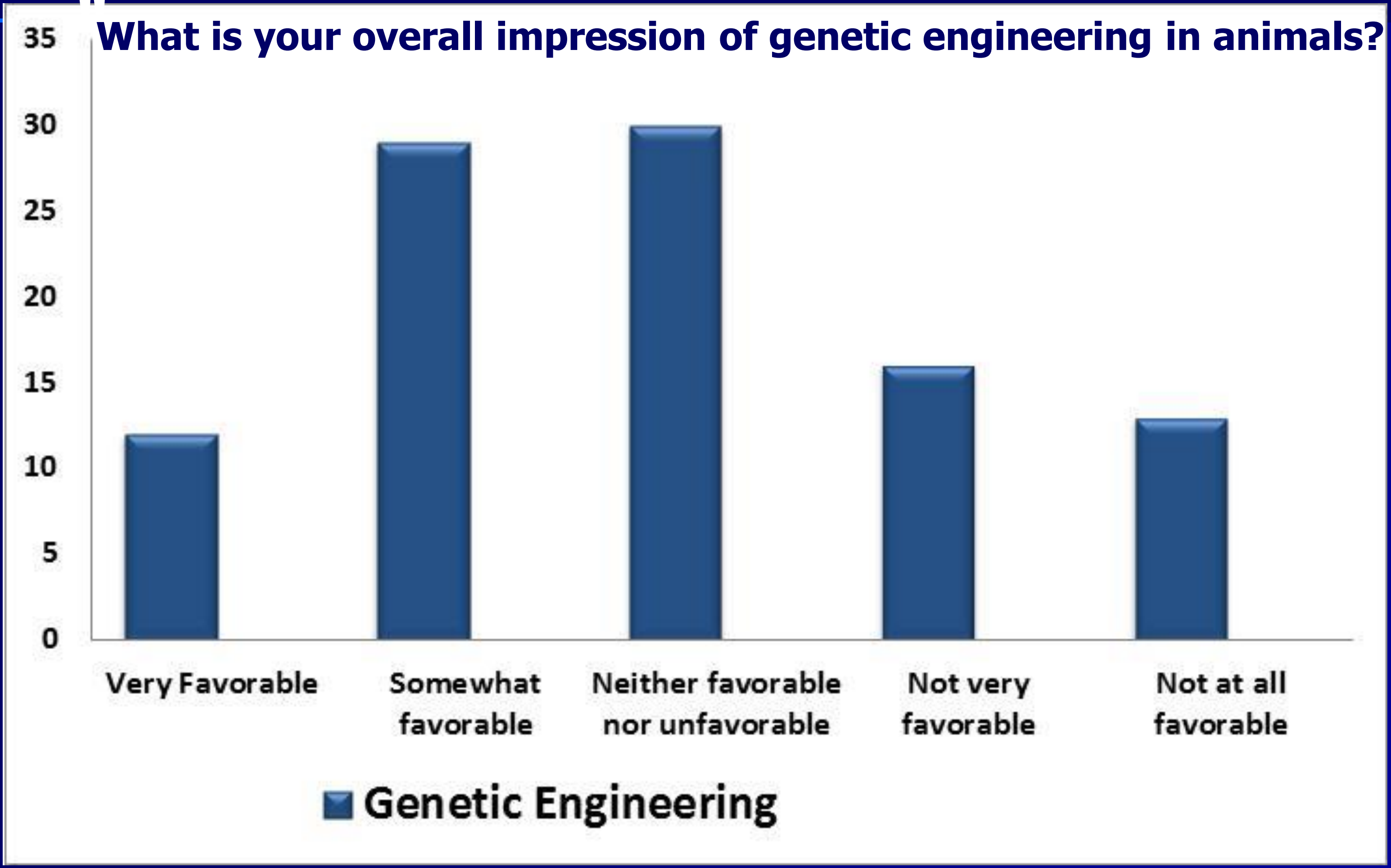
$0

$60,000,000!!

It is often stated that AquAdvantage is precedent setting – but many people already think they eat genetically modified animals – and they do – it is just that modifications were not done with rDNA

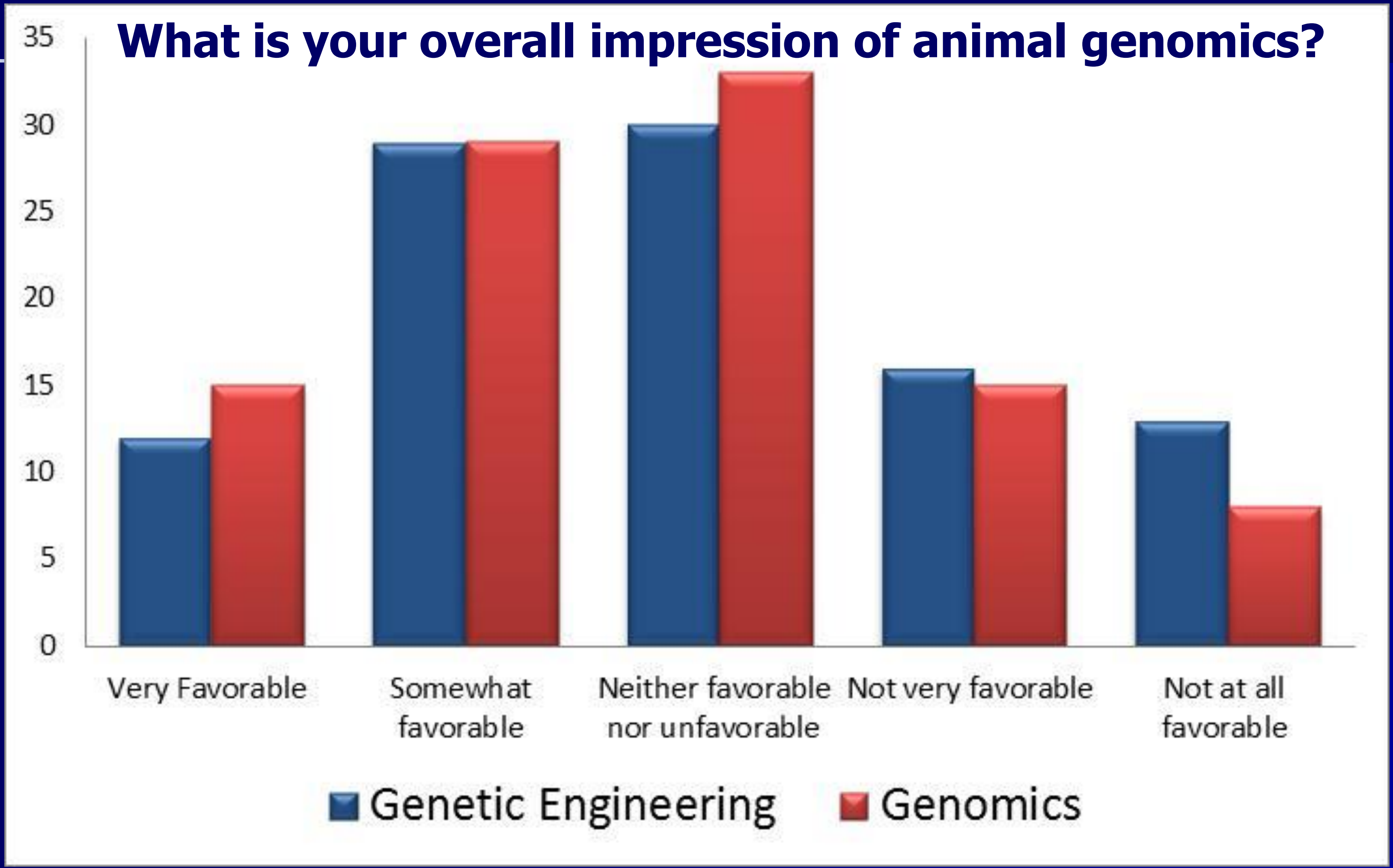
https://fbcdn-sphotos-f-a.akamaihd.net/hphotos-ak-ash3/p480x480/936235_497070347014003_426756402_n.jpg

Genetic engineering is a form of animal biotechnology that allows for the transfer of beneficial traits from one animal to another in a precise way that allows for improved nutritional content or less environmental impact. **(IFIC, 2012)**



http://www.foodinsight.org/Resources/Detail.aspx?topic=2012ConsumerPerceptionsofTechnologySurvey

Genomics is a way of evaluating the genetic makeup of farm animals to help make breeding decisions that will result in producing better offspring for improved meat, milk, and egg quality. **(IFIC, 2012)**



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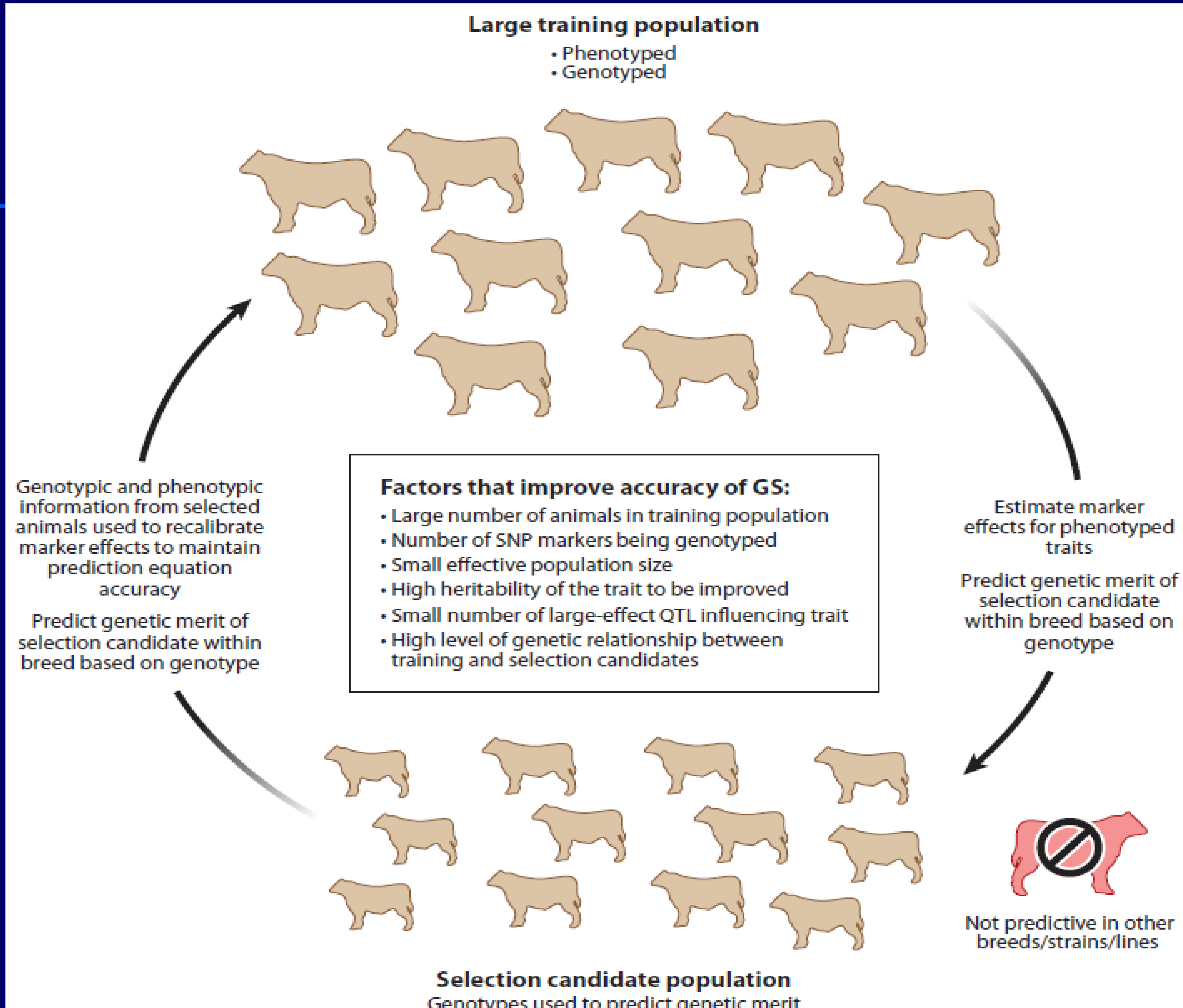
Genomic Selection (GS)



Van Eenennaam *et al*. 2014. Ann. Rev. Anim. Biosci. 2:105-139.

Genomic Selection (GS)

GS may offer selection criteria for traits that are not currently considered in breeding objectives due to an absence of objective, quantifiable measures upon which to base selection decisions.

The GS approach is clearly attractive for difficult to measure traits such as reproductive success and longevity in varied environments, efficiency of nutrient utilization, animal temperament, stress susceptibility, innate resistance or susceptibility to disease, adaptability, and reduced GHG emissions.

In theory, GS offers the opportunity to provide DNA-based selection criteria for multiple hard-to-measure traits simultaneously.

Van Eenennaam, A.L. 2014. **Genetics and sustainable animal agriculture**. Chapter 5 *pages* 53 – 66. in "*Sustainable Animal Agriculture*" E. Kebreab (ed.) CABI Publishing.

Genomic Selection (GS)

- Considerable investment in both genotyping and phenotyping will be required to develop the large phenotyped and genotyped reference populations that will be required to realize the full potential of GS.
- For disease surveillance, it might be possible to integrate GS approaches using the phenotypes that are collected as part of routine government-funded disease surveillance (e.g. collection of case-control samples)
- These approaches may ultimately reveal a sub-set of markers of sufficiently large effect that they can be cost-effectively combined into a reduced SNP DNA
- This strengthens the case for government and industry investment in GS initiatives

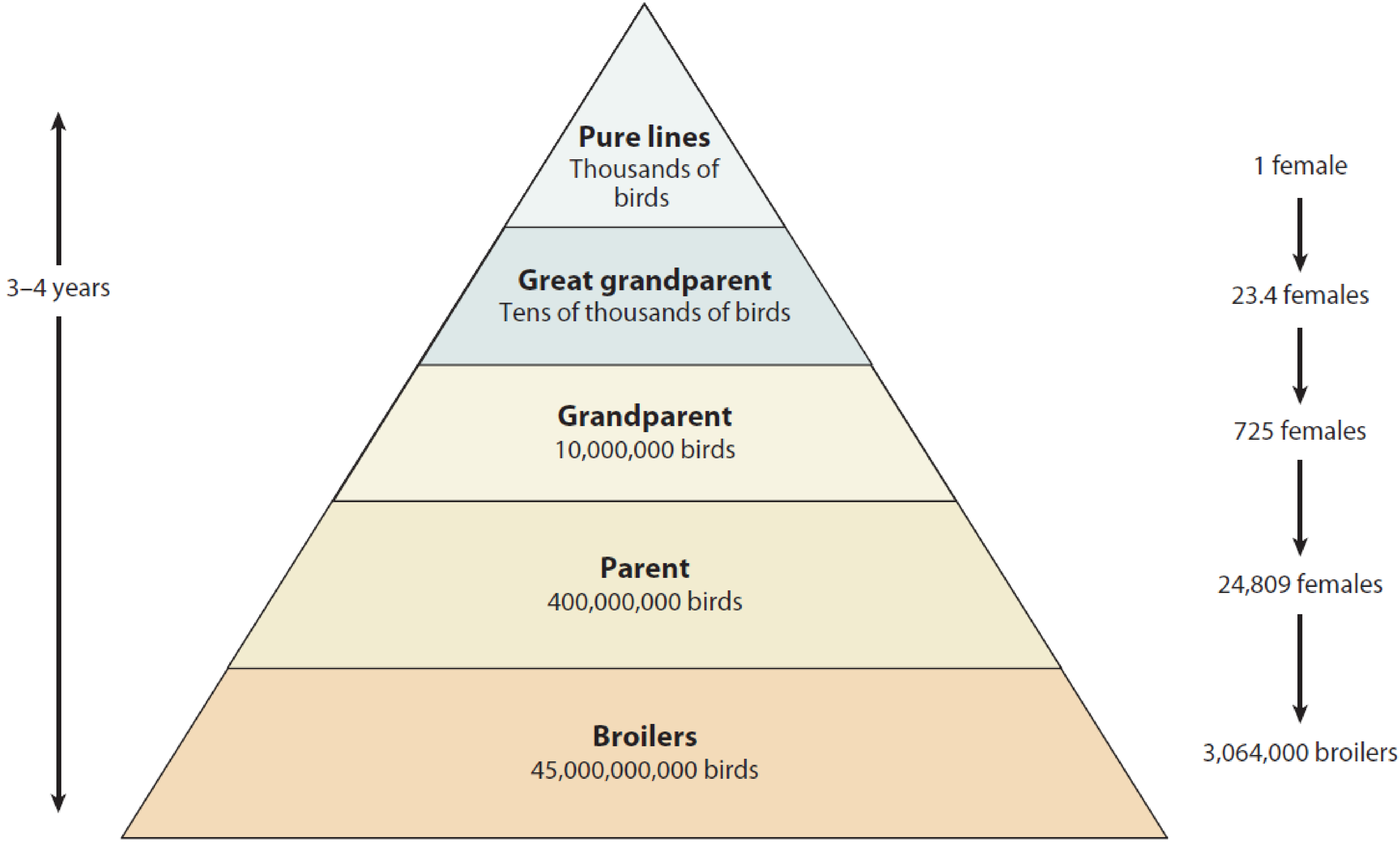
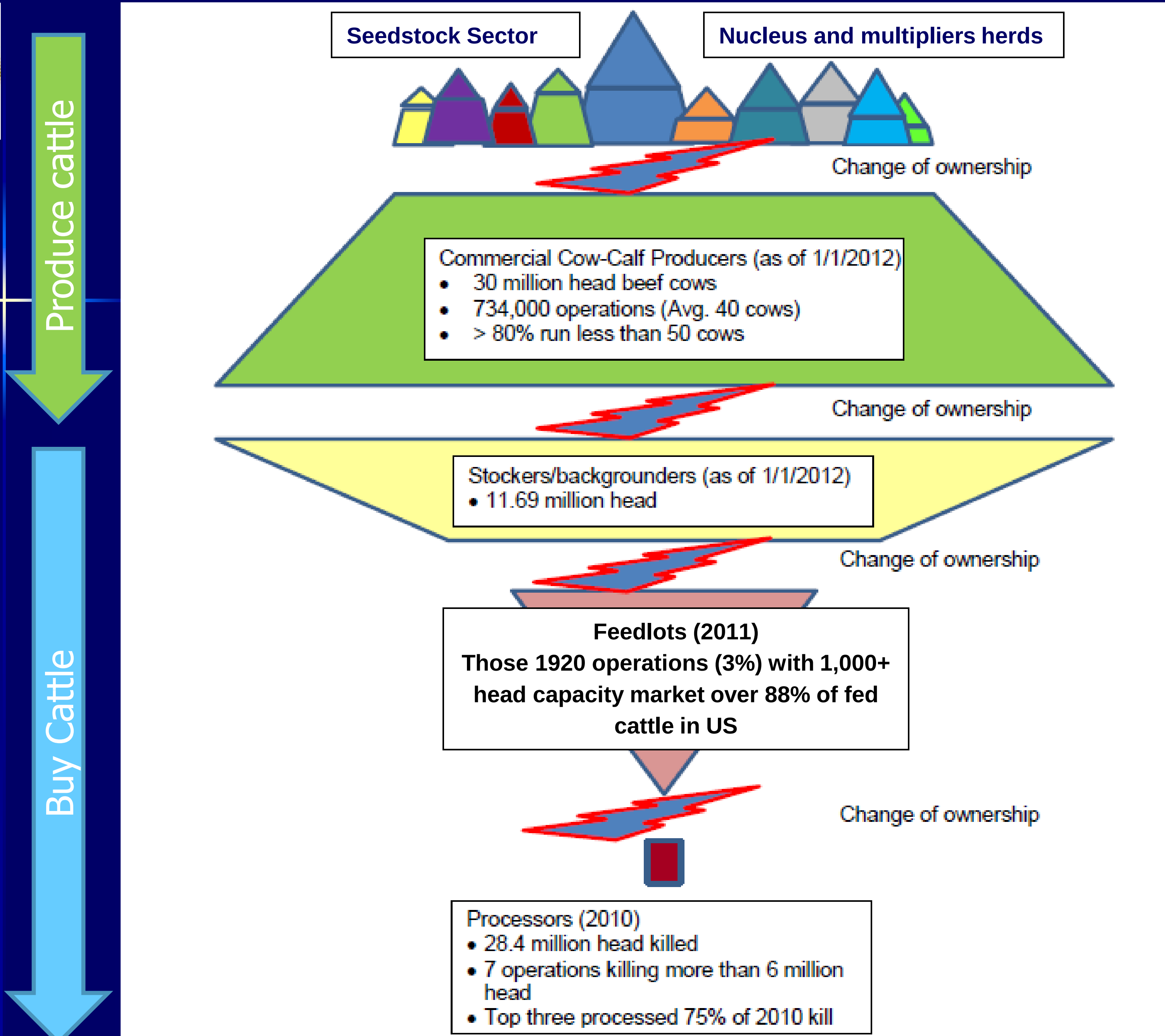


Figure 8

Broiler industry structure and global estimate of bird numbers (modified from Reference 100) alongside estimates of timeline and genetic expressions derived from a single pedigree female broiler chicken (Dr. Rachel Hawkin, Cobb-Vantress, personal communication).

Van Eenennaam *et al*. 2014. Ann. Rev. Animal Biosciences. 2:105-139.



Van Eenennaam *et al*. 2014. Ann. Rev. Anim. Biosci. 2:105-139.

Genomic Selection (GS)

- In the absence of vertical integration, breeding goals will be developed based on the individual producer's financial interests. The producer is the one investing in breeding stock and in a competitive market their decision will be based on the ways they perceive their animals contribute to farm profit.

- If there is market failure (e.g. there is no price incentive associated with the inclusion of improved animal welfare in breeding objectives), then alternative approaches will need to be implemented to incentivize their inclusion such as subsidized breeding, regulations, fines for poor welfare or increased prices for products labelled according to specific welfare grades.

Van Eenennaam 2014. Genetics and sustainable animal agriculture.

Genomic Selection (GS)

- Although on the surface GS may arouse less public opposition because it utilizes naturally occurring genetic variation, some associated applications to reduce generation interval that are enabled by GS may be seen as contrary to animal welfare.
- These include the use of germ line approaches to shorten the generation interval, such as the harvest of oocytes from calves that are still in utero, or an approach where breeding is essentially done in the laboratory using GS to predict the Estimated Breeding Value (EPD) of cells derived from *in vitro* meiosis events
- The rate of genetic change in the dairy industry has increased several FOLD since the implementation of GS

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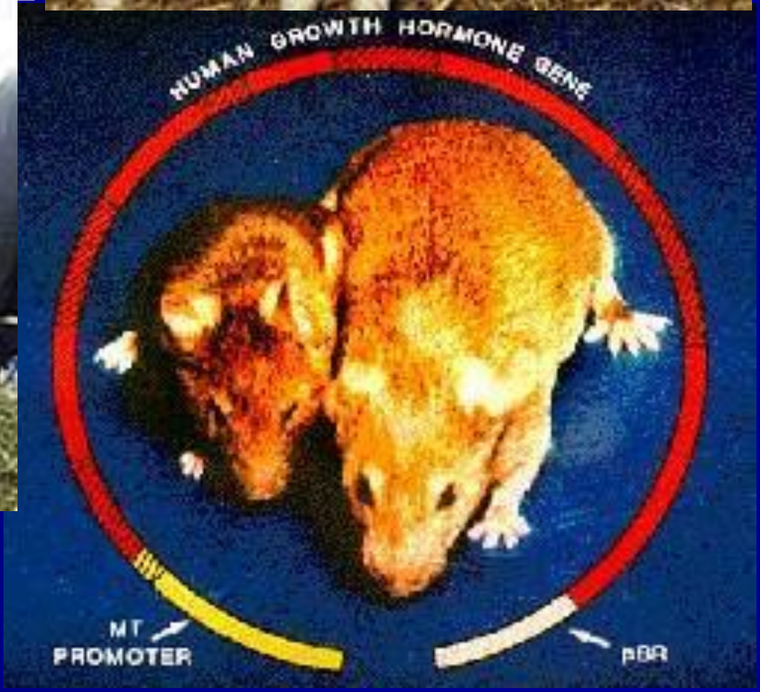
LIVESTOCK GENOMICS TOPICS RIPE FOR ECONOMIC RESEARCH

- Cost:benefit analysis (including opportunity costs forgone) of regulations – how should benefits be included in evaluations?
- Economic implications of asynchronous approvals and trade disruption effects in the absence of international harmonization
- Economics of the protest industry – public costs and benefits
- Economic implications of regulating gene editing technologies
- Who pays for genetic improvement of traits that are a public good but subject to market failure?
- What are the implications of genomic selection to optimum breeding program design?
- Will genomic technologies hasten the vertical integration of animal breeding/industries in beef?

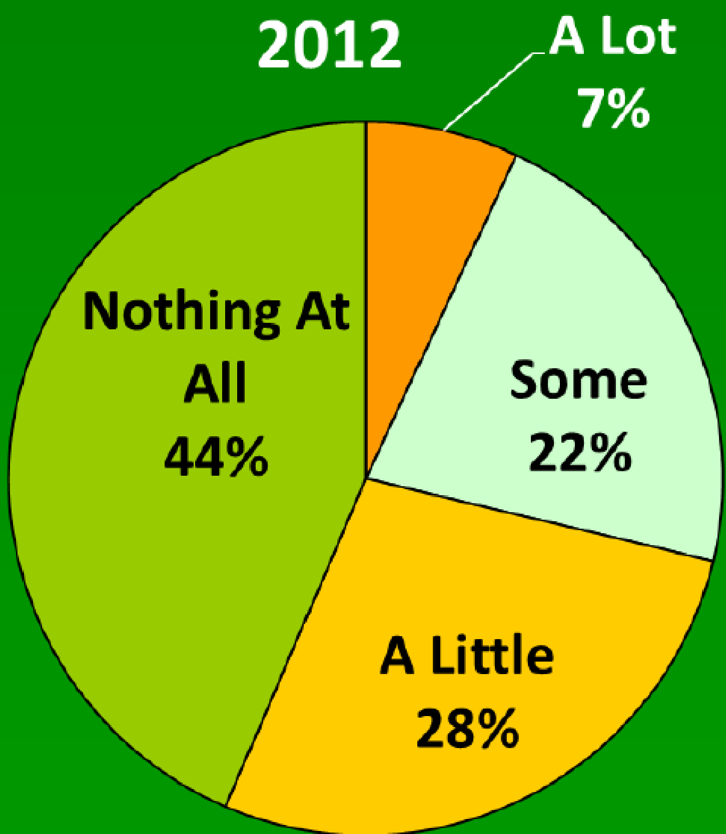


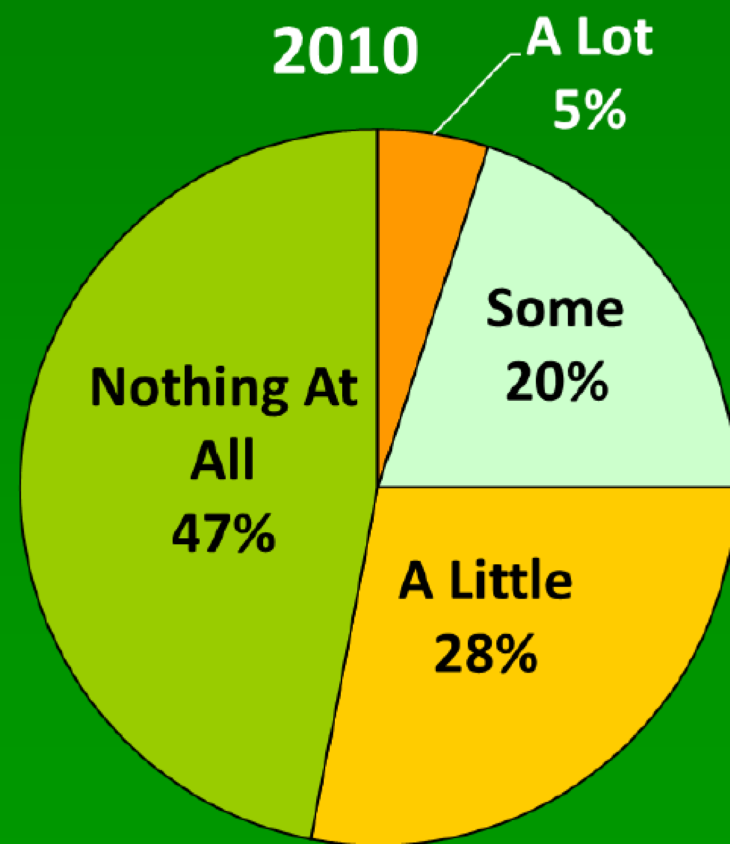
Van Eenennaam 4/23/2014

Animal Biotechnology and Genomics Education

Awareness of Animal Biotechnology

Consumers' awareness of animal biotechnology is consistent, with just over half reporting some awareness.



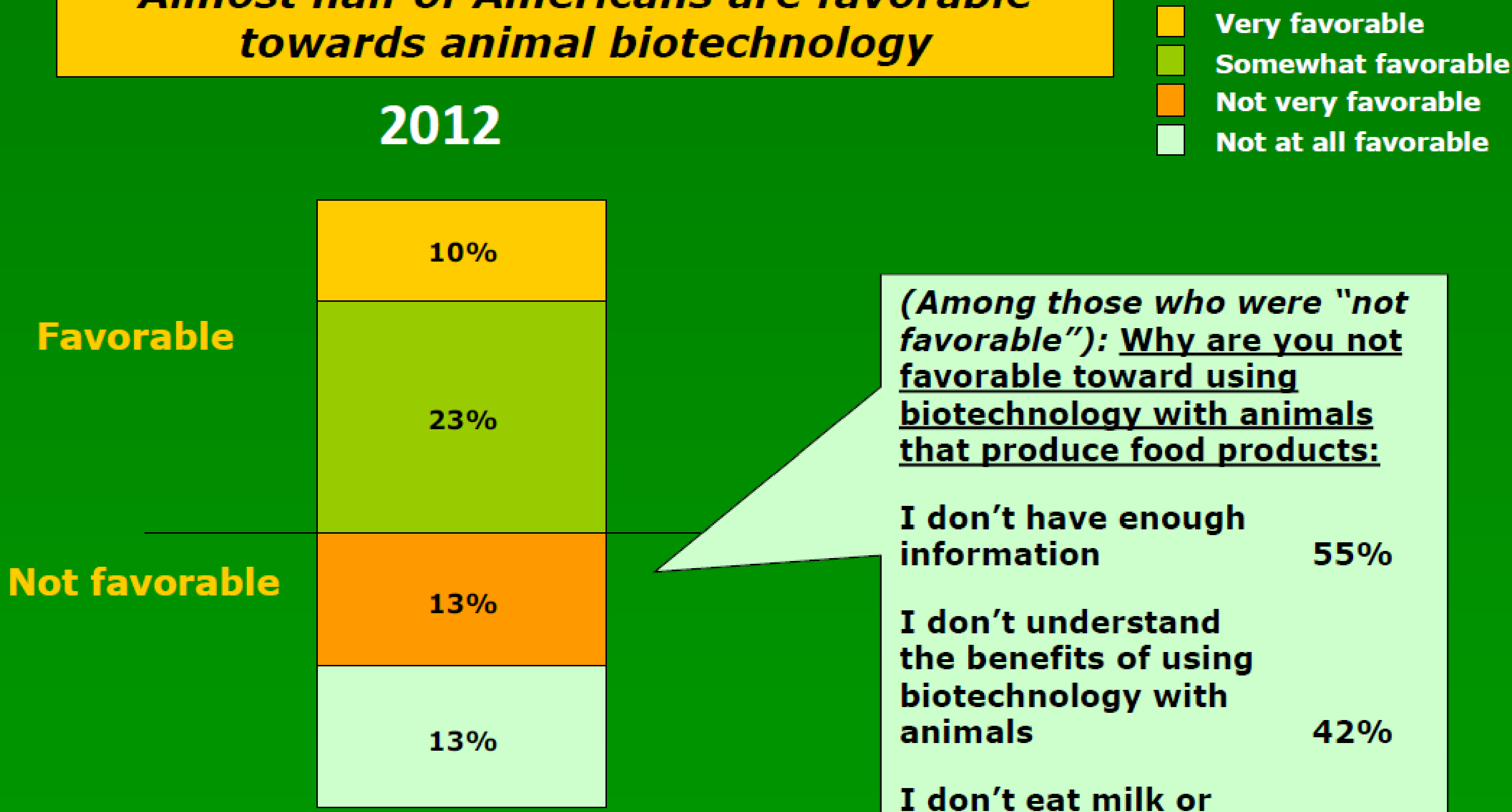


Q28. First of all, how much have you read or heard about applying the science of biotechnology to animals? Would you say you have heard…?

Impressions of Animal Biotech

Almost half of Americans are favorable towards animal biotechnology

2012



Neutral **25%**

Don't know enough to form an opinion **16%**

n=381

(Among those who were "not favorable"): ***<u>Why are you not favorable toward using biotechnology with animals that produce food products:</u>***

I don't have enough information	55%
I don't understand the benefits of using biotechnology with animals	42%
I don't eat milk or dairy products	5%
Other	16%

Q29. What is your overall impression of using animal biotechnology with animals that produce food products such as meat, milk, and eggs? Would you say you are...?

Q29A. Why are you not favorable toward using biotechnology with animals that produce food products? *Check all that apply.*

IFIC International Food Information Council

Impressions of Animal Genomics

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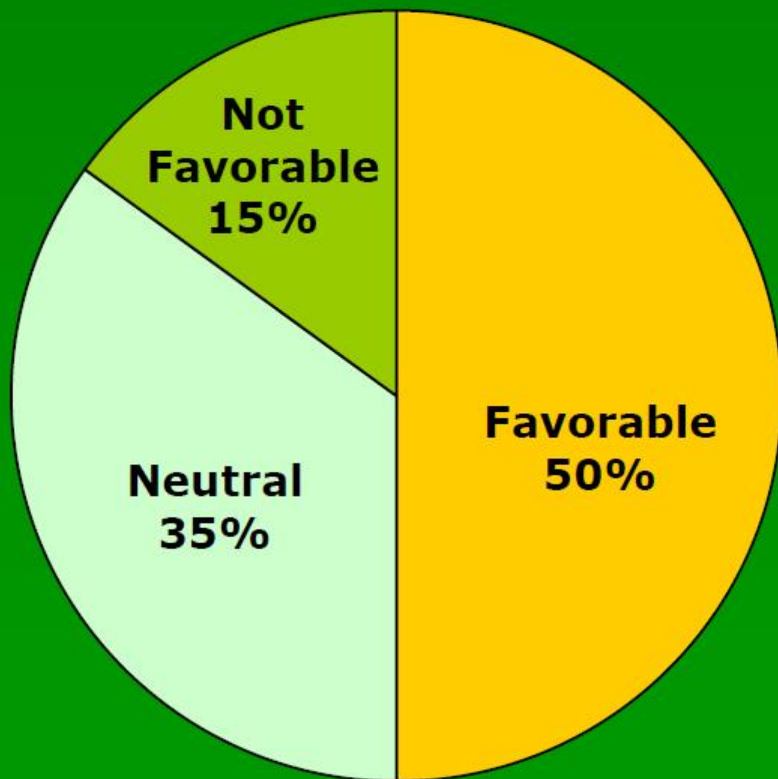
2012



Q33A. Genomics is a way of evaluating the genetic makeup of farm animals to help make breeding decisions that will result in producing better offspring for improved meat, milk, and egg quality. What is your overall impression of animal genomics?

Impressions of Genetic Engineering

Almost half of Americans are favorable towards genetic engineering

Q34A. *Genetic engineering.* Genetic engineering is a form of animal biotechnology that allows for the transfer of beneficial traits from one animal to another in a precise way that allows for improved nutritional content or less environmental impact. What is your overall impression of genetic engineering in animals?

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