Alternative Food Production Systems: The Science and Implications

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Food Forum Workshop August 7, 2019

Outline

- Invitro cell culture
- Comparison to meat industry
- Improvements in protein production over time
- Climate and Natural Resource Use
- Cultural considerations
- Nutritional Concerns

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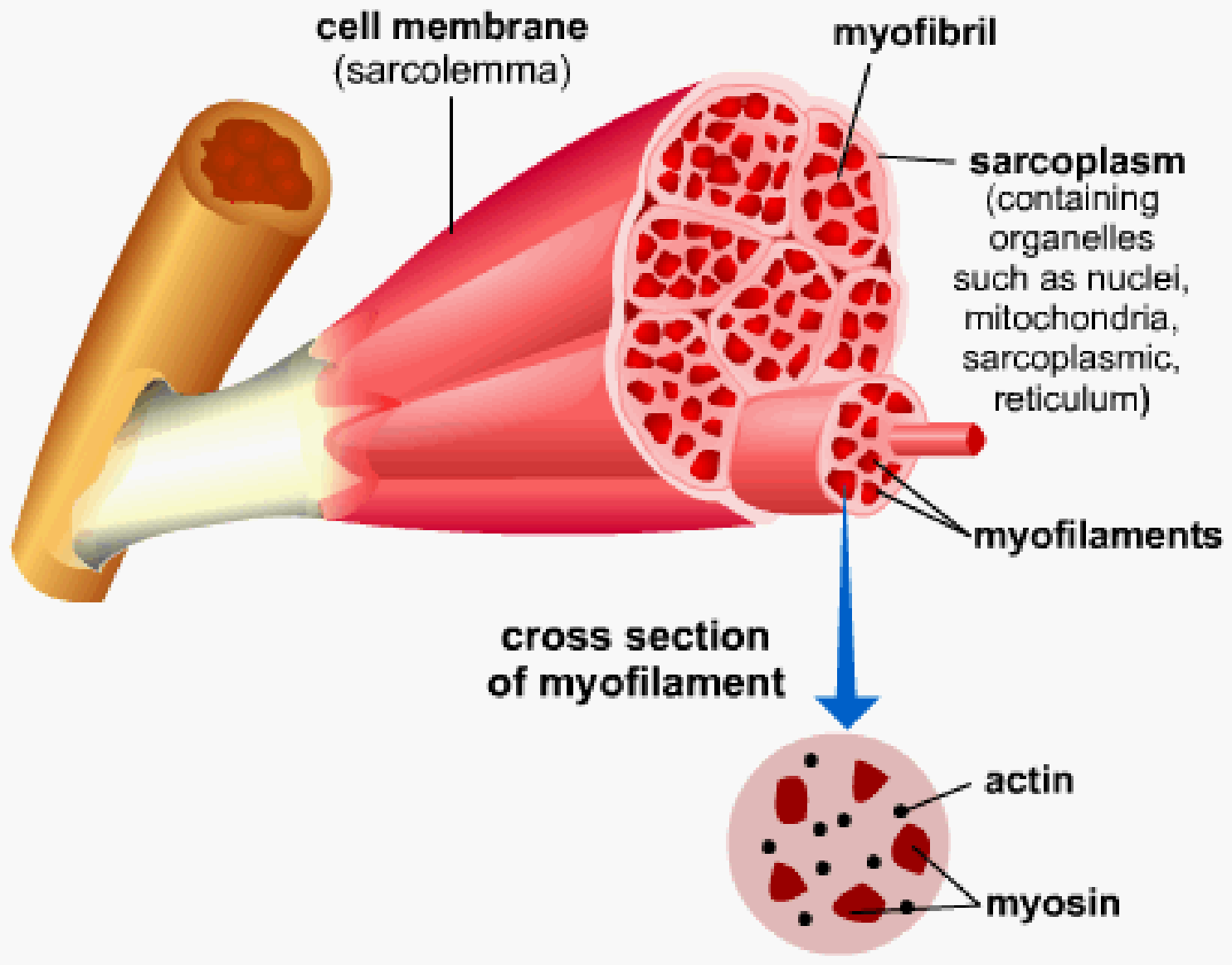
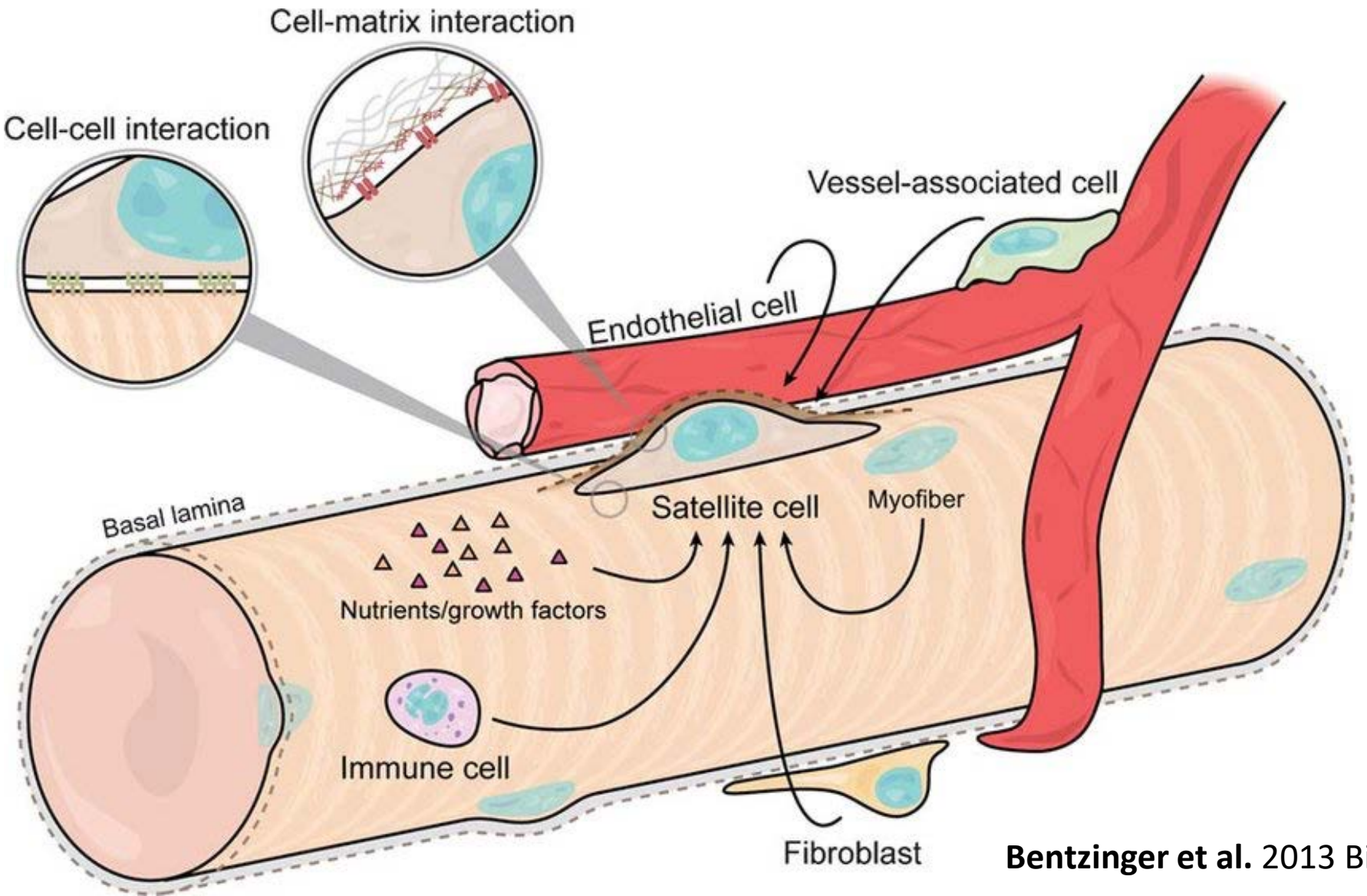
Muscle Structure

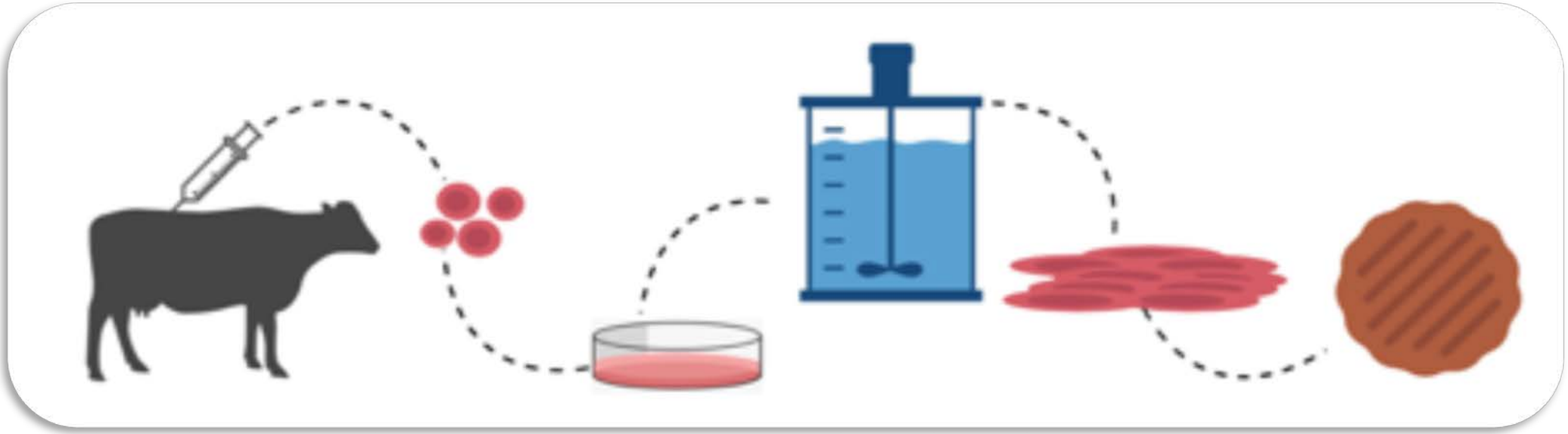


Satellite Cells



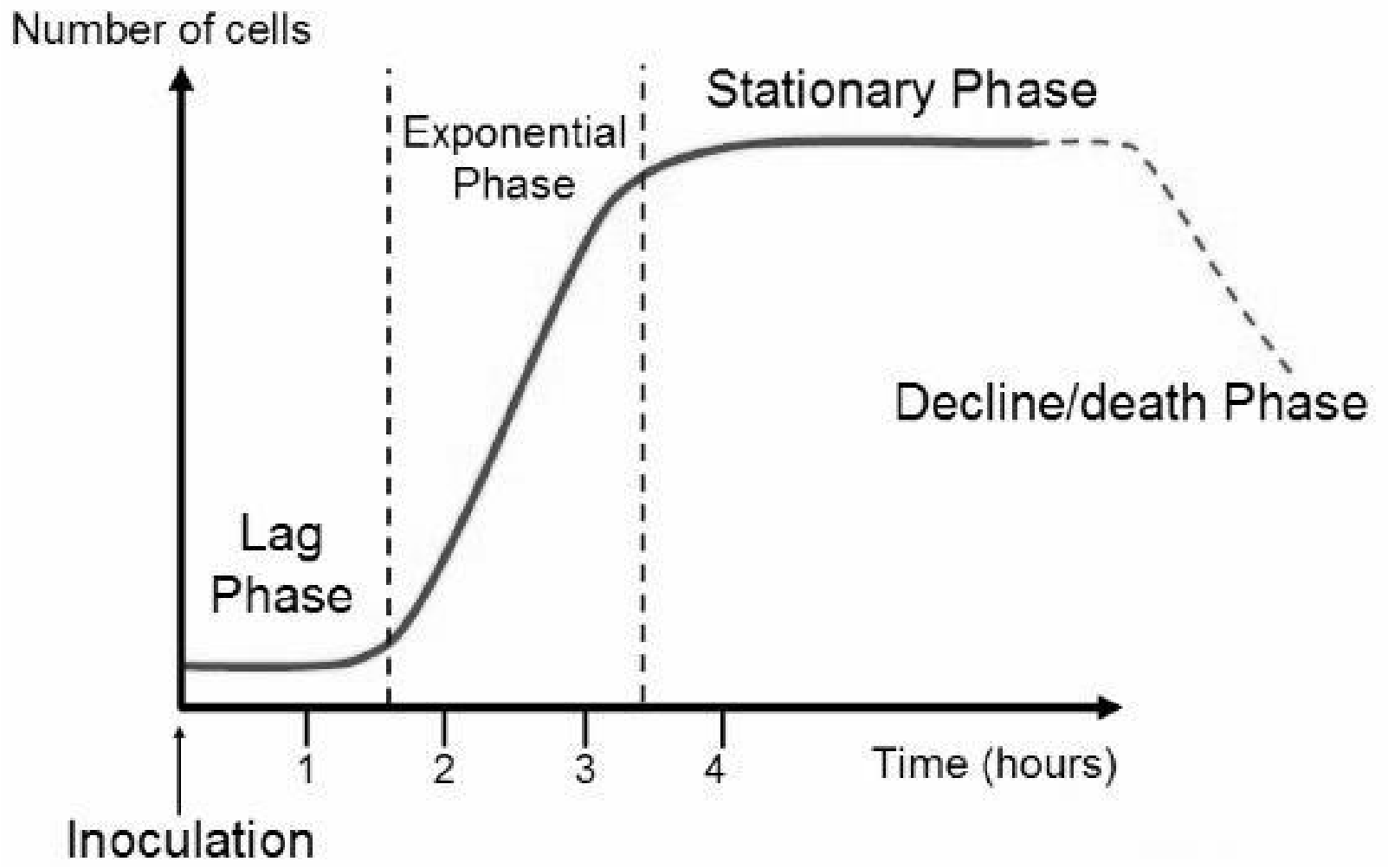
Bentzinger et al. 2013 BioEssays 35:231-41

Process of Invitro Meat

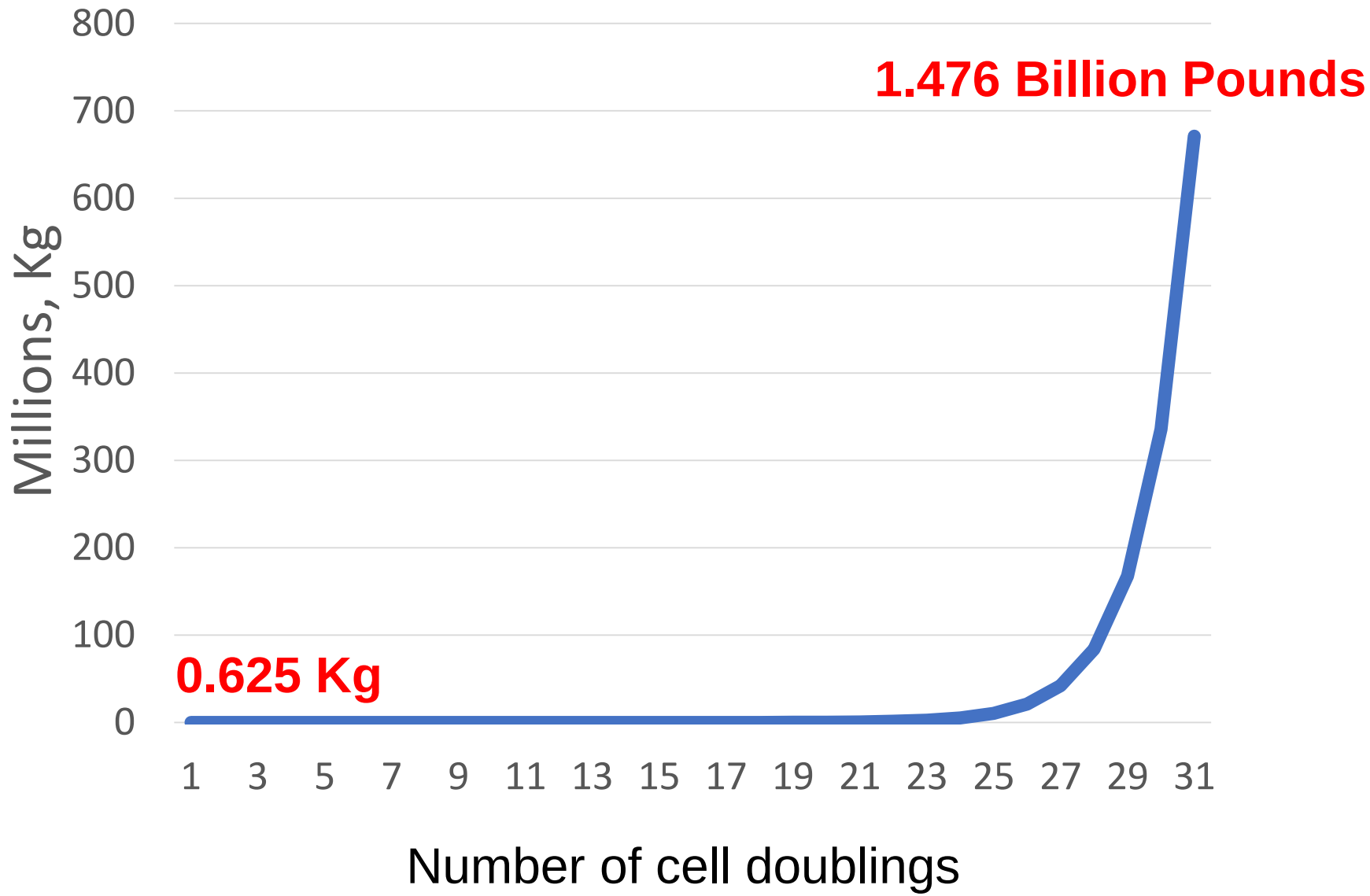


Langelaan, M.L.P. *et al.,* 2010. *Trends in Food Science & Technology* 21 (2):59-66.
Sharma, S. *et al.,* 2015. *Journal of Food Science and Technology-Mysore* 52 (12):7599-7607.
Specht, E.A. *et al.,* 2018. *Biochemical Engineering Journal* 132:161-168.

Growth Cycle of cells in culture



Increase in cell number over time



How much protein does this equate too?

- 39 Million head of cattle
  - 1250 pounds live weight
  - 750 pound carcass
  - 525 pounds meat
- 20.475 Billion pounds of beef/year

- If cells double 30 times = 1.476 Billion pounds
- ~ 14 head a cattle per year


HR. HANSEN

Numerous Start-Ups

MEMPHIS MEATS
San Francisco, CA

JUST
San Francisco, CA

mosa meat
Maastricht, Netherlands

SuperMeat
Israel

FM TECHNOLOGIES
Jerusalem, Israel

ALEPH FARMS
CLEAN MEAT GROWERS
Rehovot, Israel

Finless Foods
Emeryville, CA

WILD TYPE
San Francisco, CA

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- Invitro cell culture
- Inputs vs Outputs – Traditional vs in vitro
- Improvements in protein production over time
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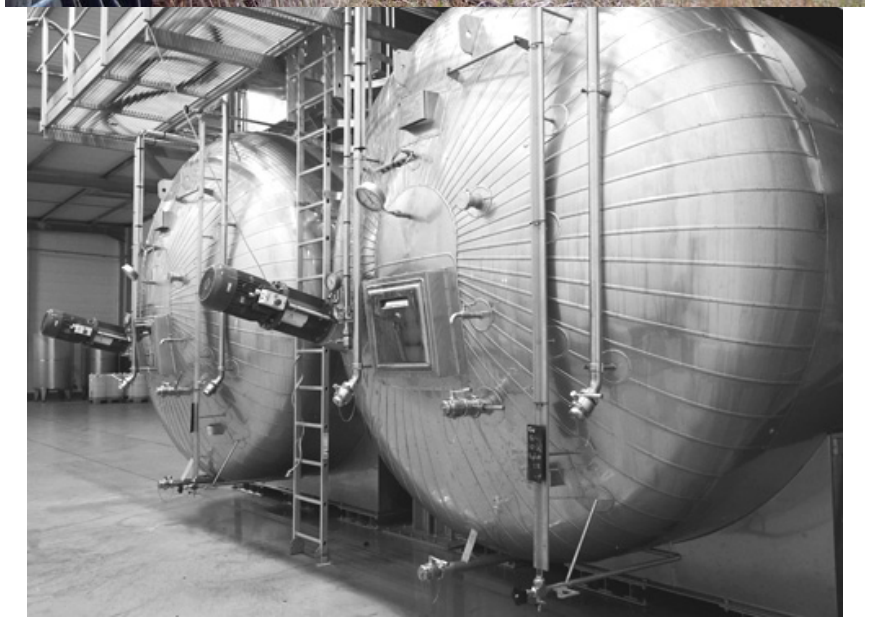
Input and output of conventional vs. Invitro Meat

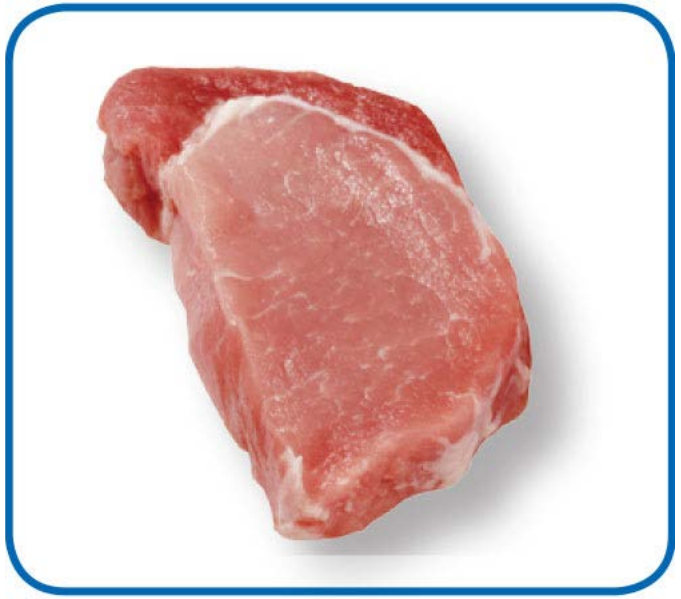
Roughage
Concentrate
Vitamins/Minerals
Water
Animals

Amino Acids
Vitamins/Minerals
Water
Animal cells

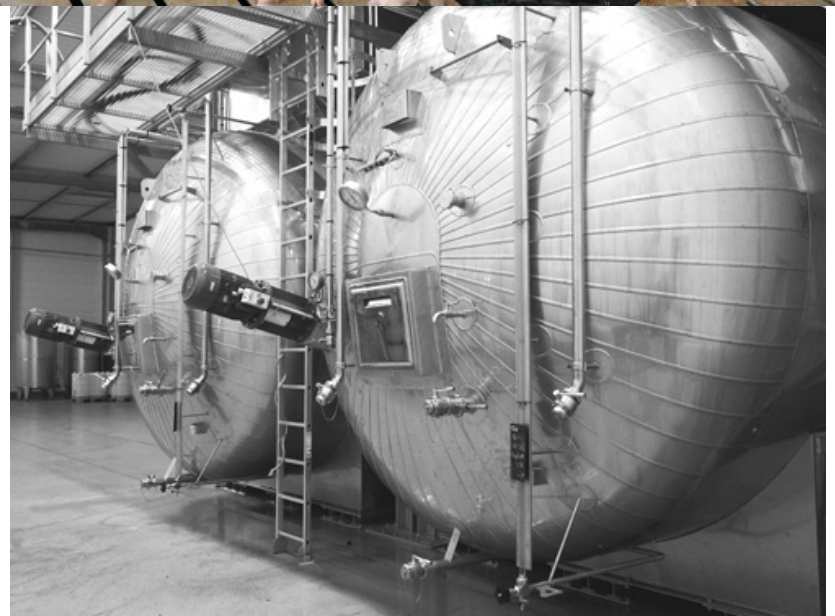


Input and output of conventional vs. Invitro Meat

Carbohydrate
Concentrate
Vitamins/Minerals
Water
Animals



Amino Acids
Vitamins/Minerals
Water
Animal cells



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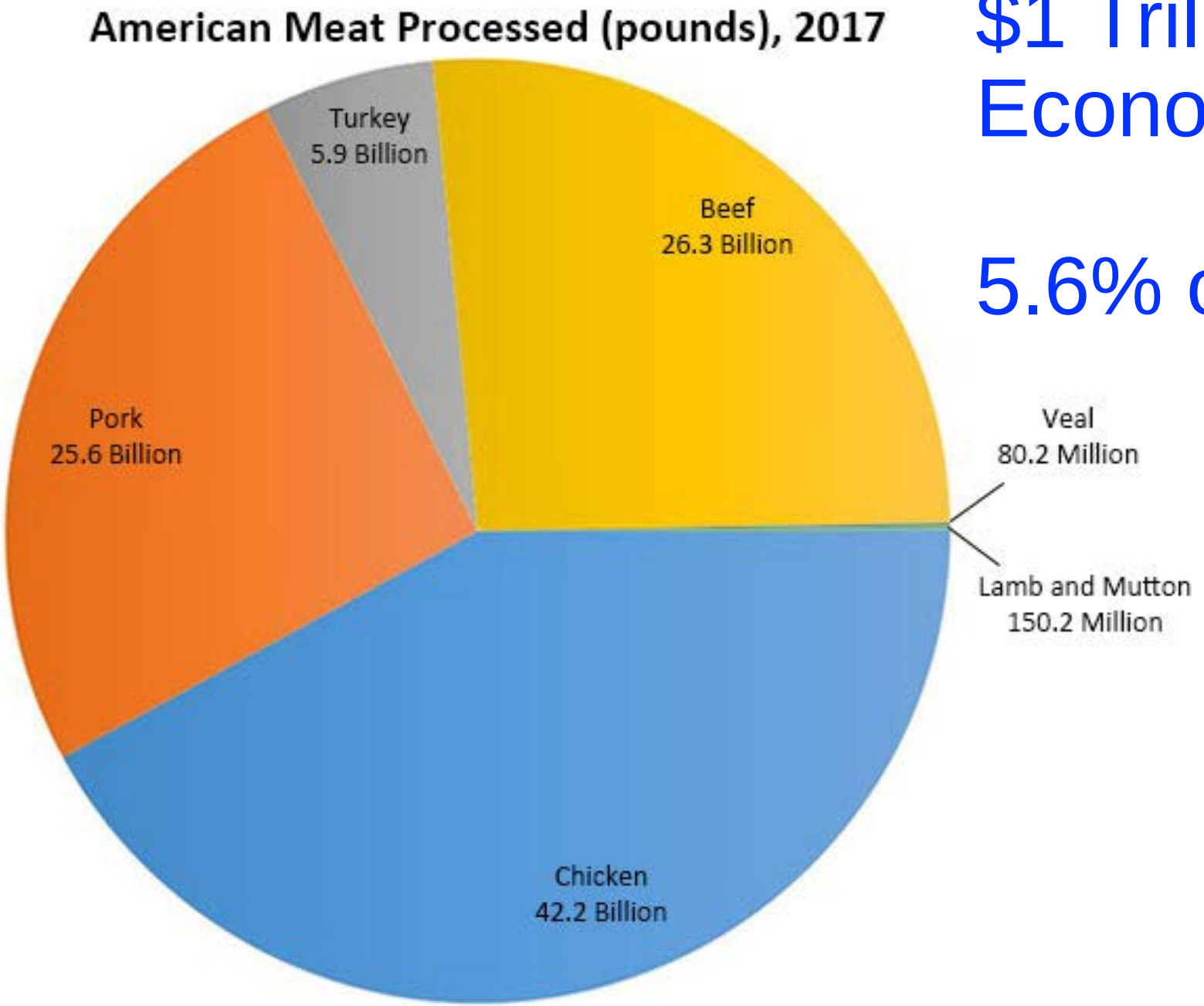
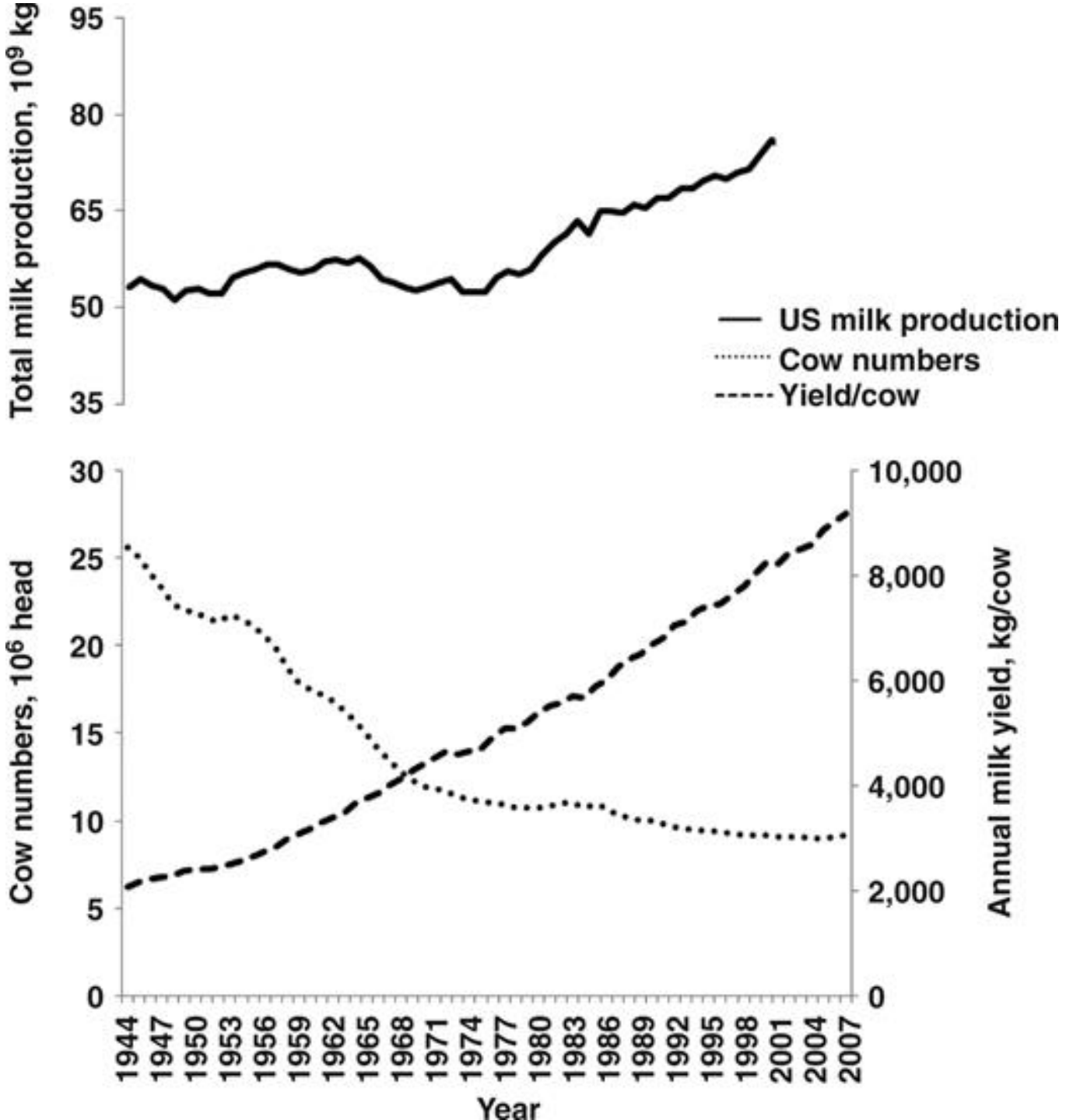


$1 Trillion Economic Impact

5.6% of U.S. GDP

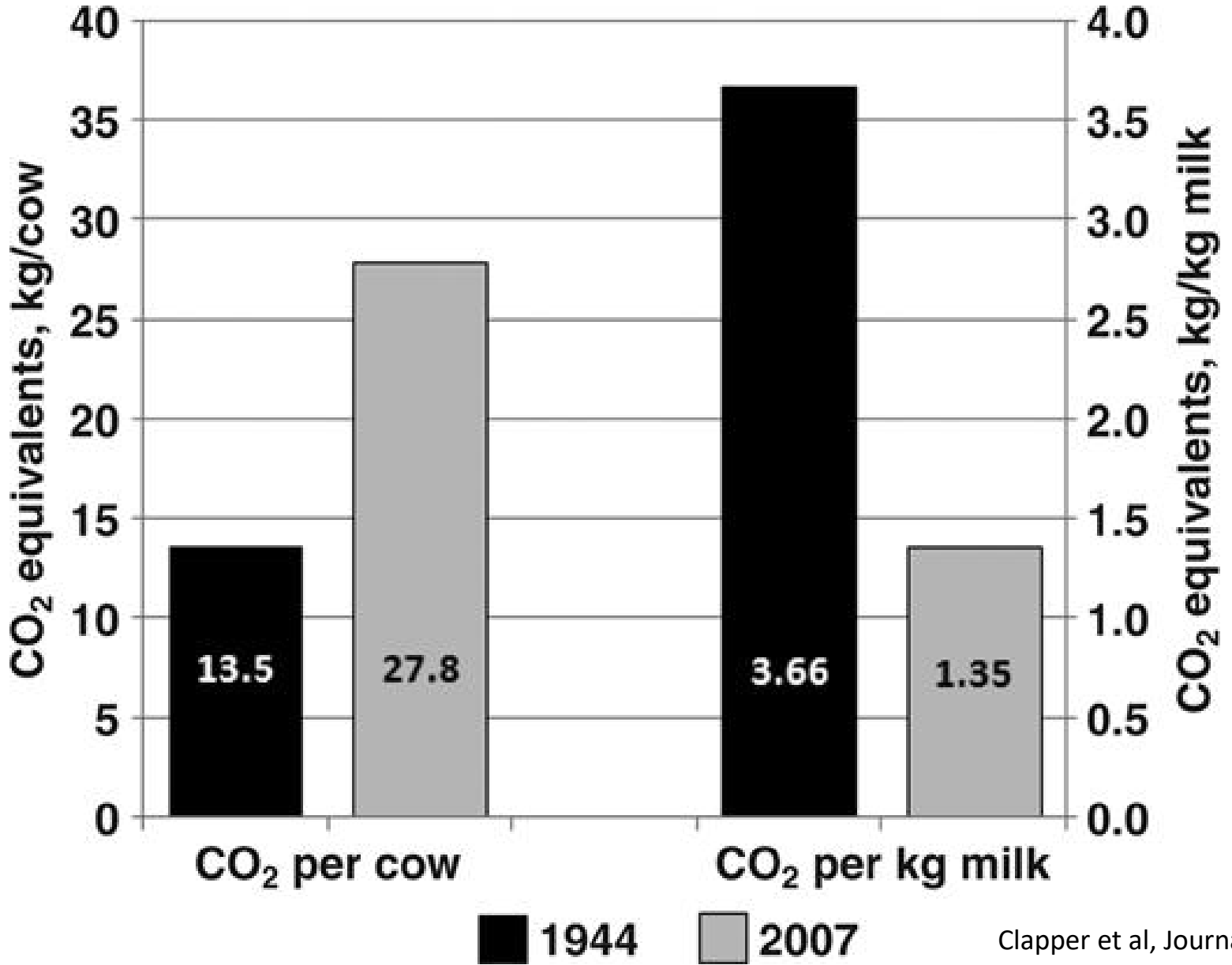
NORTH AMERICAN MEAT INSTITUTE

Change in U.S. Dairy Industry Over Time



Clapper et al, Journal of Animal Sciences 78:2160-67

CO2 Emissions from Dairy Cows



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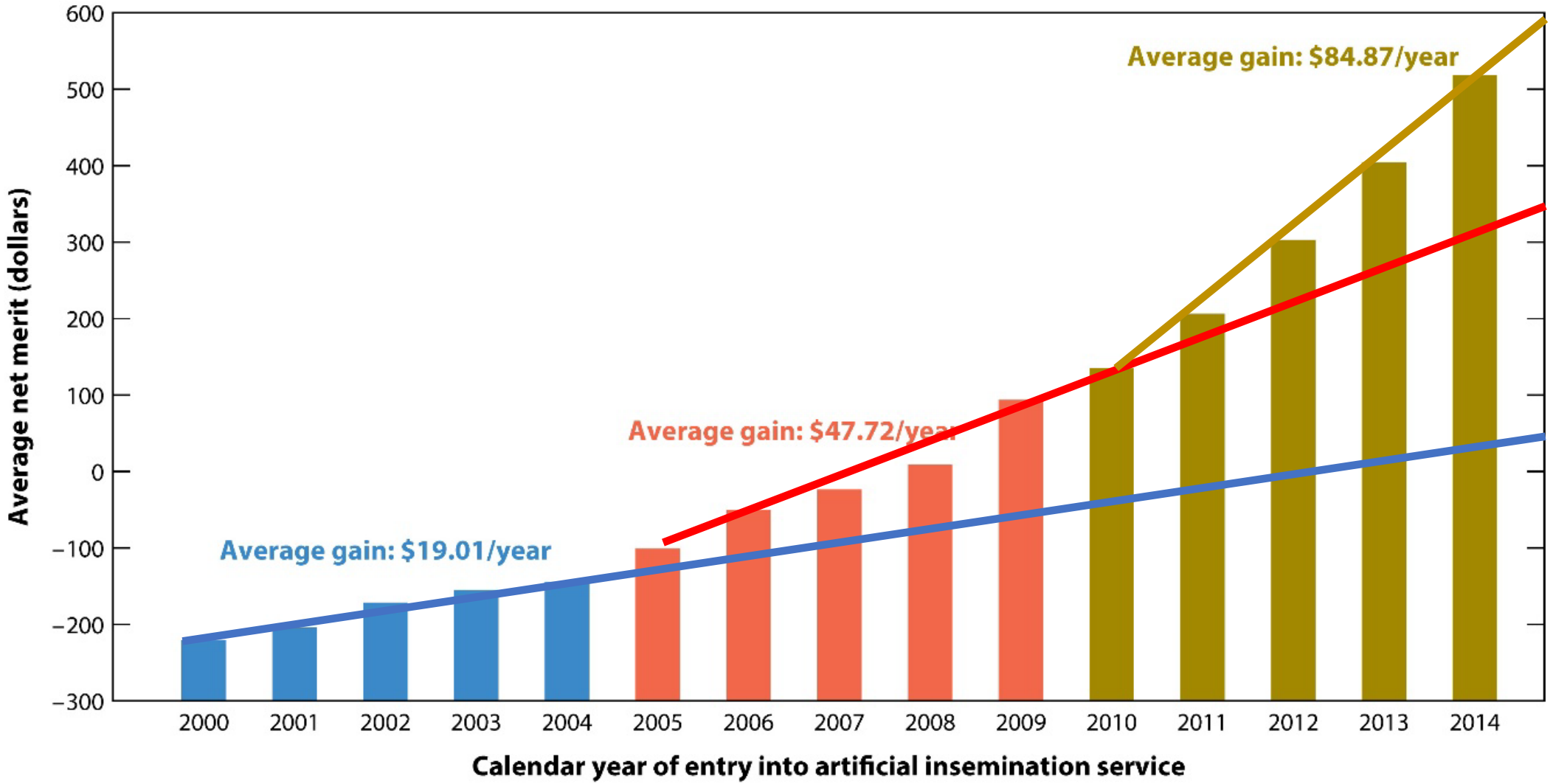
The average genetic value for net merit of artificial insemination bulls by year of entry into artificial insemination



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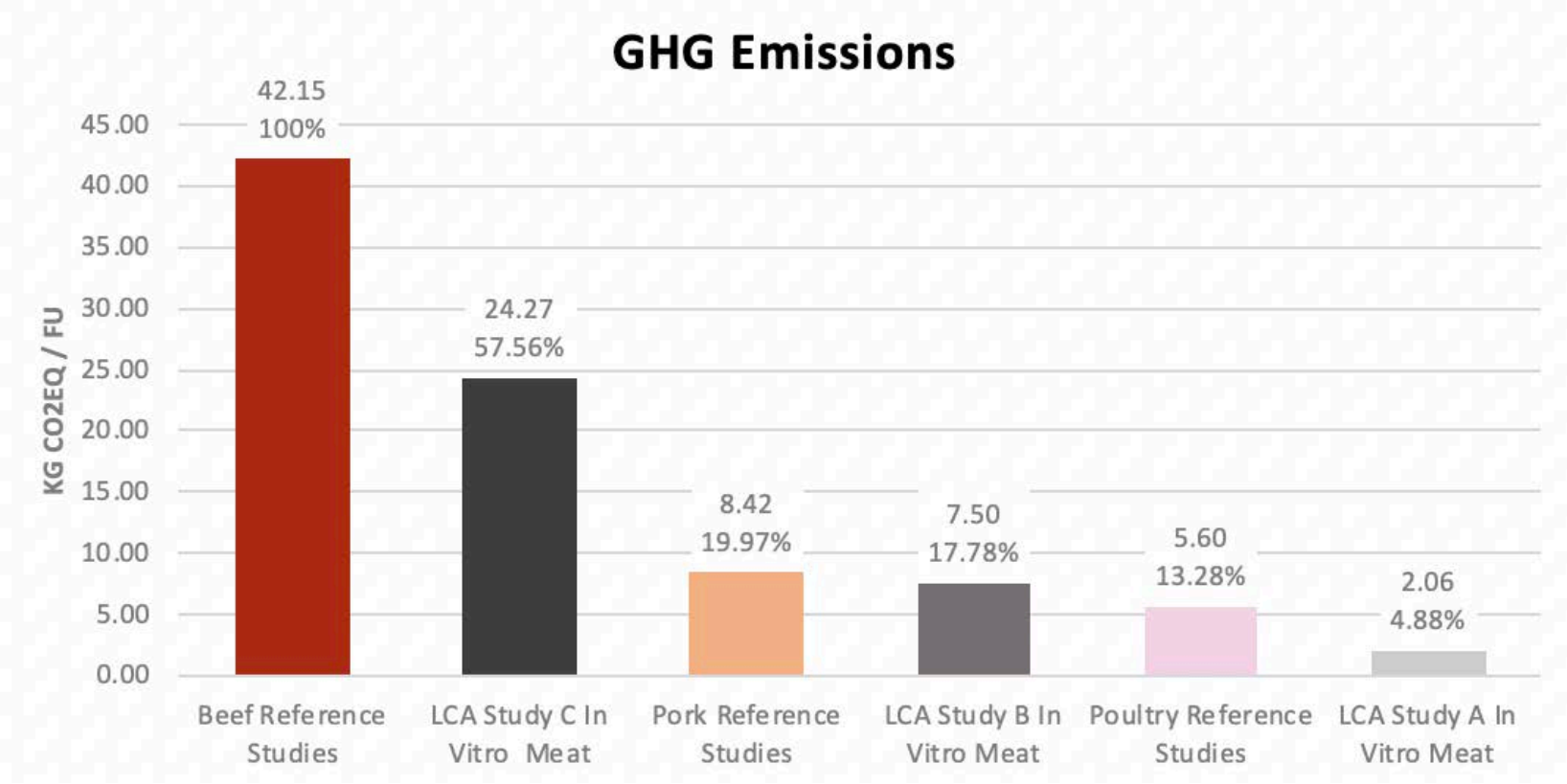
Greenhouse Gas (GHG) Emissions

- Most dominant GHGs
  - Methane (CH_4)
  - Carbon Dioxide (CO_2)
  - Nitrous Oxide (N_2O)
- Methods of *In Vitro* Meat LCAs rely on those of the reference studies
  - Allocation methods
  - System boundaries

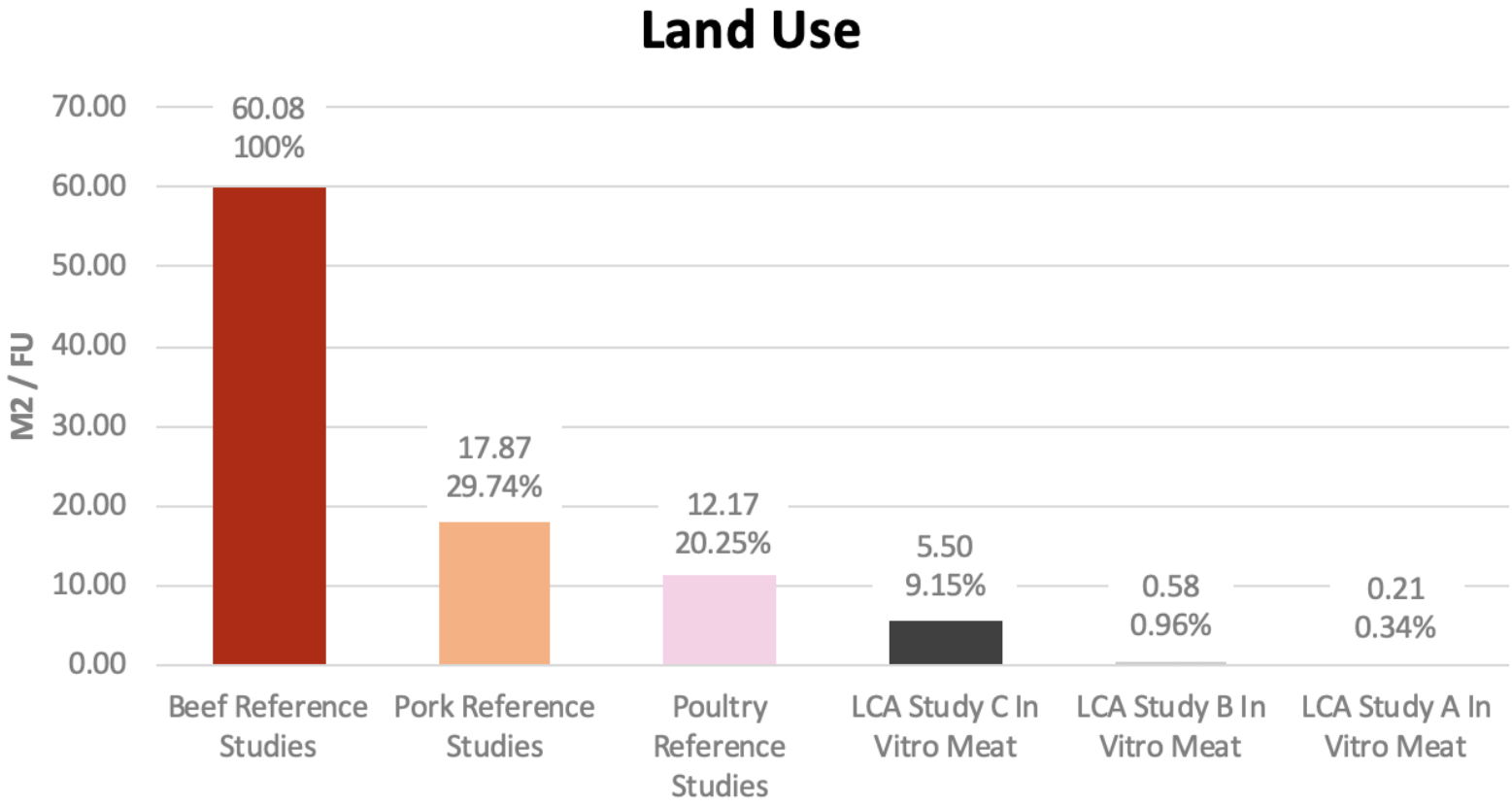


Mitigation potential represented by percent of the highest impact meat.

Mattick, C.S. et al., 2015. *Journal of Integrative Agriculture.* 14 (2):249-254.
Mattick, C.S. et al., 2015. *Environ. Sci. Technol.* 49 (19):11941-11949
Smetana, S. et al., 2015. *Intl. Journal of Life Cycle Assessment.*
Tuomisto, H.L. & de Mattos, M.J.T. 2011. *Environ. Sci. Technol.* 45 (14):6117-6123.

Land Use

- Construction or conversion to carneries
- Advantage: could be located on non-agricultural land
- Virtual land use not included
  - Energy production
  - Feed production
- Non-animal-derived growth media vs. animal-derived growth media
- Intensification



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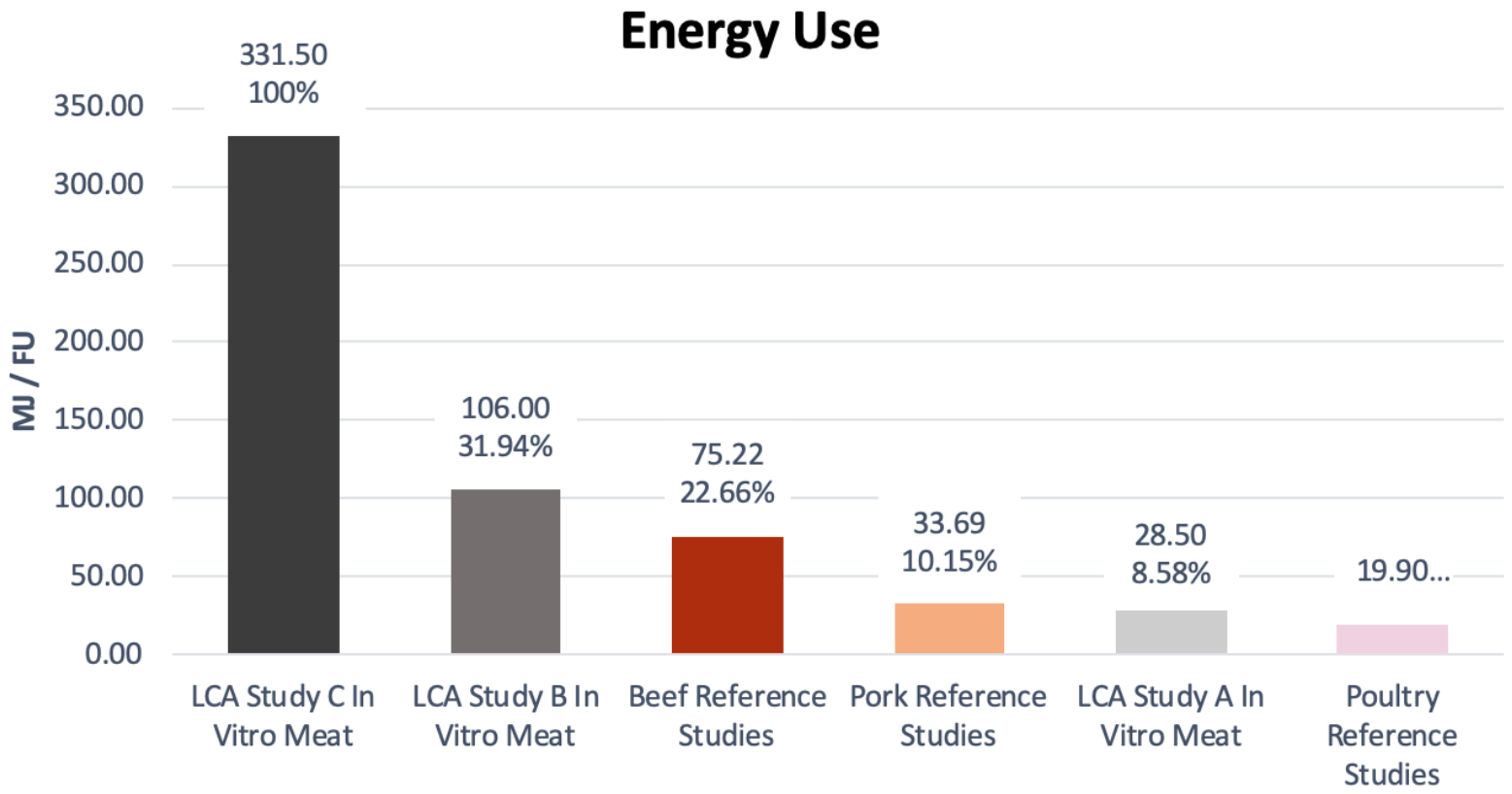
Energy Use

- Industrial energy use in carneries
- Tradeoffs of renewable substitutes
- Values represent the lowest reports in the U.S. and Europe



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Eutrophication Potential

- Only assessed in 1 existing LCA
- Untreated *in vitro* meat waste flows vs. managed livestock waste flows
- Exclusion of spent media

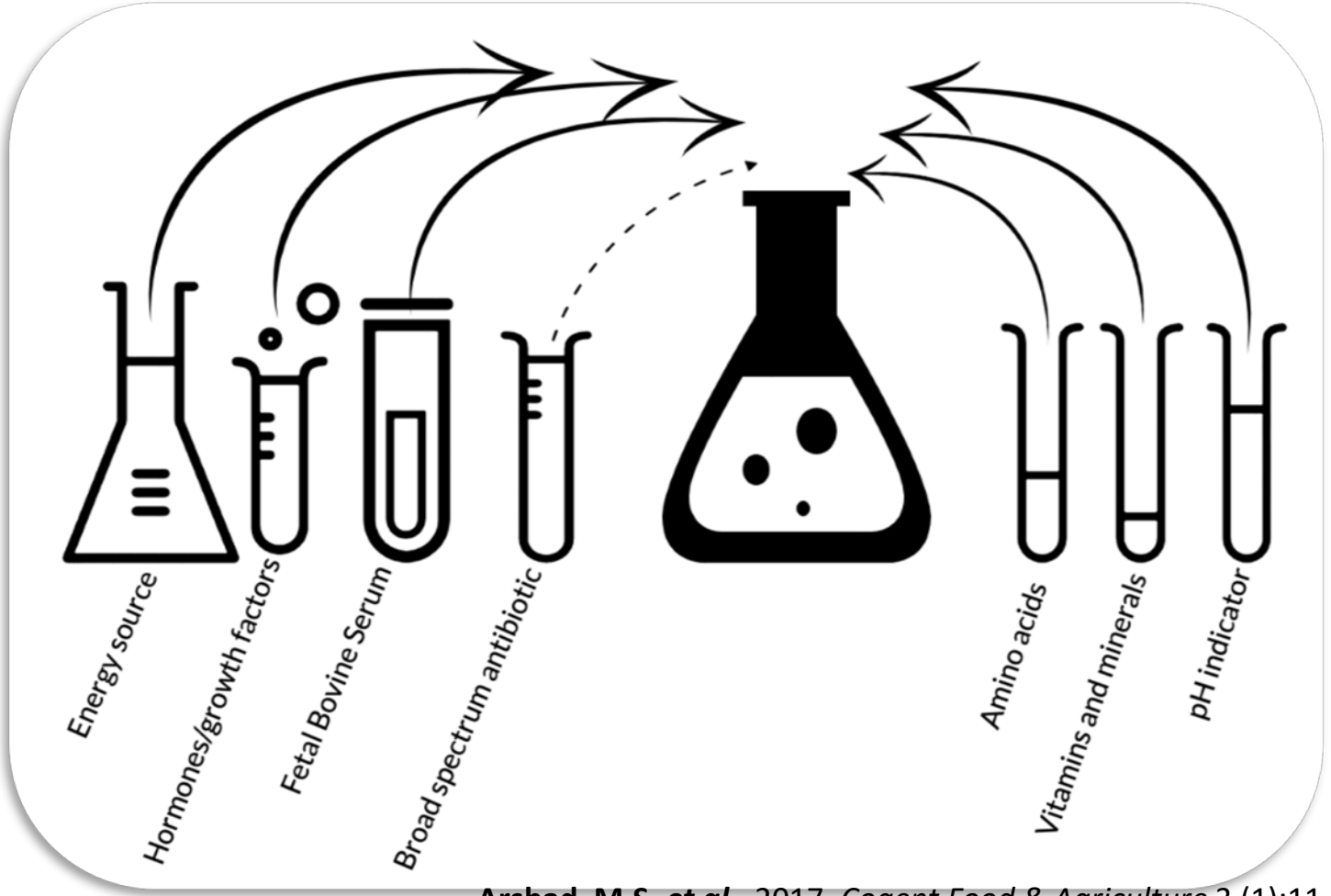
WATER USE (RANKED FROM LOWEST TO HIGHEST)	g PO_4eq / 1 kg *IN VITRO* MEAT
Poultry Reference Studies	*0.07*
LCA Study B In Vitro Meat	*0.05-0.15*
Pork Reference Studies	*0.25*
Beef Reference Studies	*0.21*
LCA Study A In Vitro Meat	*Not assessed*
LCA Study C In Vitro Meat	*Not assessed*

Mattick, C.S. *et al.*, 2015. *Environ. Sci. Technol.*49 (19): 11941-11949

Effects of Additives in the Growth Medium

Concerning Additives

- Steroids
  - Dexamethasone
  - IBMX
- Hormones
  - Androgens and Estrogen
  - IGF
- Antimicrobials



Arshad, M.S. *et al.,* 2017. *Cogent Food & Agriculture* 3 (1):11.
Kamanga-Sollo, E. *et al.,* 2010. *Domestic Animal Endocrinology* 39 (1):54-62.
Post & Hocquette. 2017. *New Aspects of Meat Quality*, 425-439.
Post, M.J. 2014. In *Frontiers in Agricultural Sustainability: Studying the Protein Supply Chain to Improve Dietary Quality*, 29-33.
Velloso, C.P. 2008. *British Journal of Pharmacology* 154 (3):557-568.

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Cultural Considerations of Diets

- Kosher
  - "(t)he taking of the cell from a living animal is a violation of one of the seven laws of Noah – thou shalt not tear the limb of a living animal"
  - Animals must be slaughtered in accordance to kosher rules for *in vitro* meat to be kosher
- Halal
  - Some schools of thought- embryonic acceptable if mother slaughtered halal
  - Cells from adults must be slaughtered in halal fashion
  - No blood or serum can remain in the product
    - Non-animal-derived growth medium would be best

Hamdan, M.N. *et al.,* 2018. *Journal of Religion & Health* 57 (6):2193-2206.
Regenstein, J.M. 2019. *Cell based meat production.*
Regenstein, J.M. *et al.,* 2003. *Comprehensive Reviews in Food Science and Food Safety* 2:111-127.

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Nutritional Concerns, Possible Health Advantages, and Biomimicry

Nutrition concerns

- Lack of heme iron
- Lack of vitamin B12
- Lack of conjugated linoleic acid

Nutrition opportunities

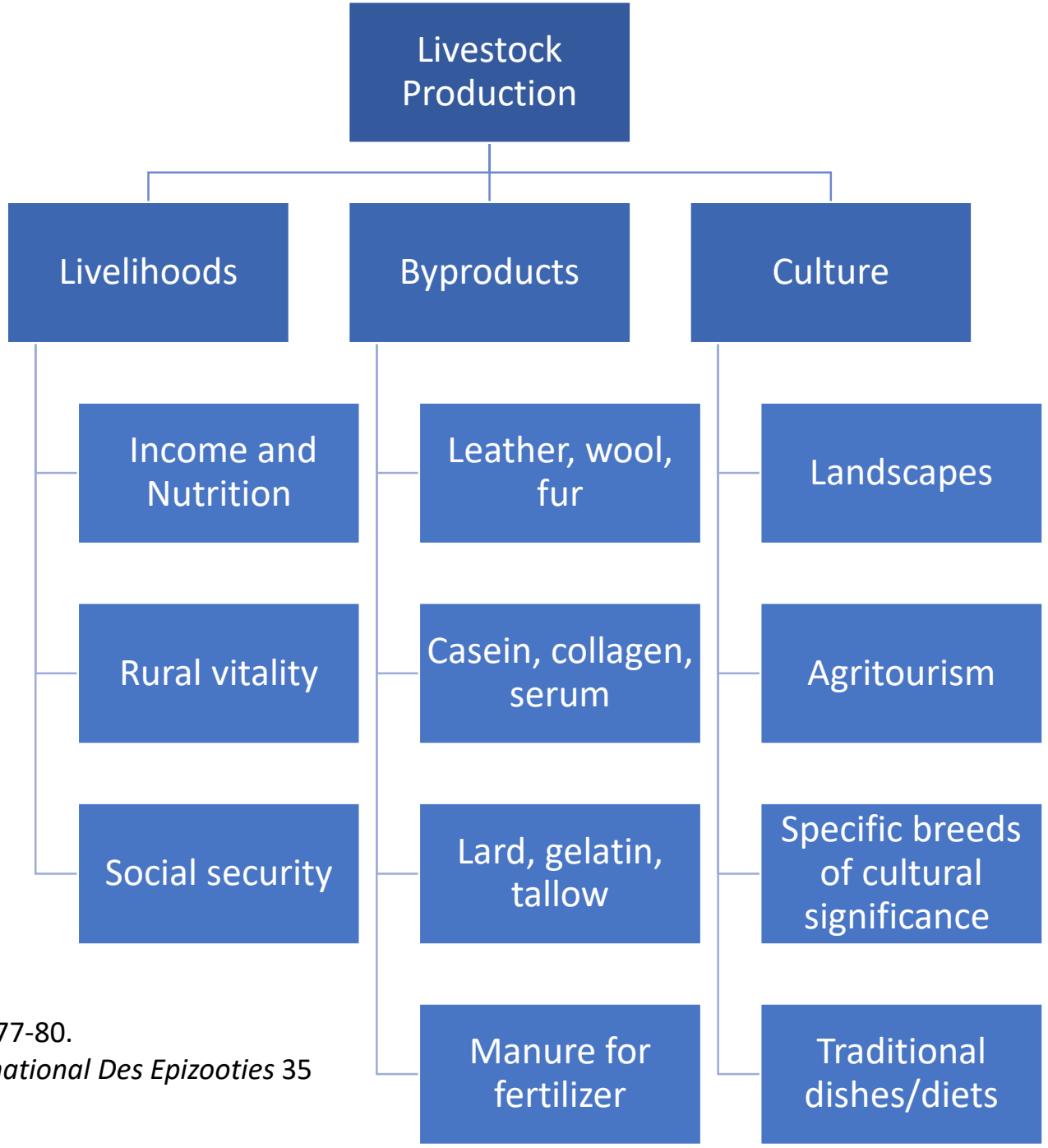
- Removing linkage between meat and cardiovascular disease
  - Myristic acid and palmitic acid
- Addition of Omega 3 fatty acid

Does it taste and feel the same?

- Lack of adipose (fat) tissue
- Addition of other cell types (vascular and neural)
- Post-harvest events
- Color (yellow)

Bhat, Z.F. *et al*., 2017. *Critical Reviews in Food Science and Nutrition* 57 (4):782-789.
Post & Hocquette. 2017. *New Aspects of Meat Quality*, 425-439.

Importance of Livestock



Kemi, A.O. 2016. *IOSR Journal of Agriculture and Veterinary Science* 9:77-80.
Kohler-Rollefson, I. 2016. *Revue Scientifique Et Technique-Office International Des Epizooties* 35 (2):611-618.
Ryschawy, J. *et al.*, 2017. *Animal* 11 (10):1861-1872.

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