UF | IFAS
UNIVERSITY of FLORIDA

UPCOMING WEBINAR

SEPTEMBER 18 2019, 1-2PM

Chad Carr

Jason Sheffler

Wendy Dahl

PRODUCTION, WHOLESOMENESS, and SUSTAINABILITY of ANIMAL-SOURCED FOODS

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PRODUCTION, WHOLESOMENESS, and SUSTAINABILITY of ANIMAL-SOURCED FOODS

Chad Carr

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Wendy Dahl

- Production Systems & Technologies in US Animal Agriculture
- Animal-Sourced Foods in the Diet in the Developed & Developing World
- Sustainability of US Animal Agriculture
- US Animal Welfare
- Antibiotic Resistance
- In-vitro Animal Protein

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

UF IFAS AMU NIFA

Antimicrobial Resistance Research

The Average American

- At least three generations removed from production agriculture
- Distrust of science- but don't know who to believe
- Eat mostly away from home- convenience & they can't cook
- But a growing interest in "knowing where their food comes from"

We are too fat, our diets aren't good & the weather is bad- Who is to blame?

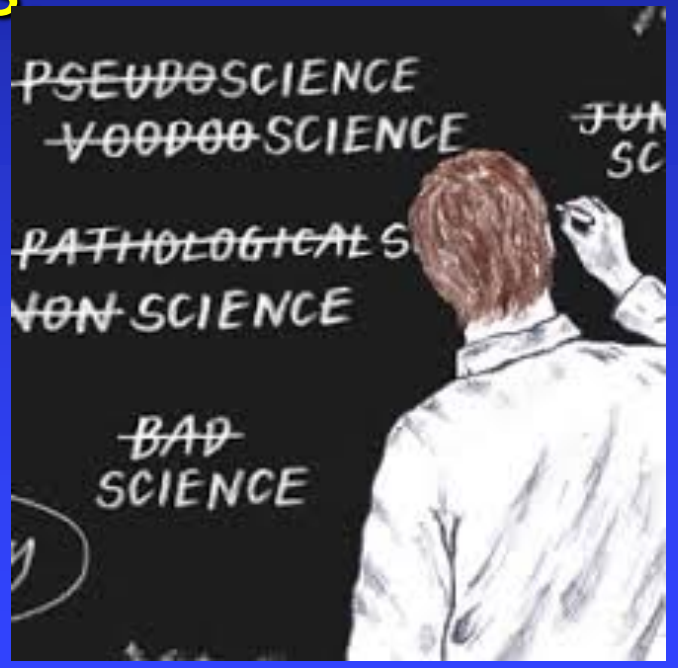
- Leads to perception that American food system is broken
- Fear mongering

Why people quit/reduce meat consumption?

- “Animals are treated poorly prior to slaughter”
- “It has bad stuff added or fed to it”
- “It is not sustainable/bad for the environment”
- “It is bad for me”

What are consumers being told?

- Healthier- leaner, more desirable nutritional profile which results in less obesity, diabetes, heart disease, cancer
- Safer- less chemicals, antibiotics, hormones pesticides, herbicides
- No genetic modification
- Taste better/fresher
- Better animal welfare
- Lower environmental impact
- Pseudo-science/truthiness- “It just has to be right”

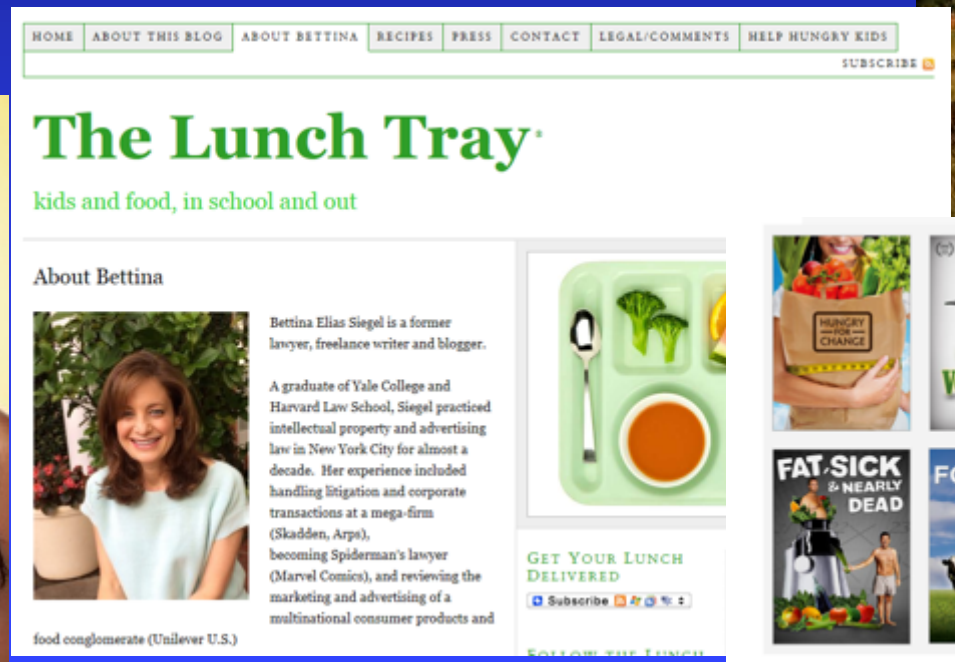


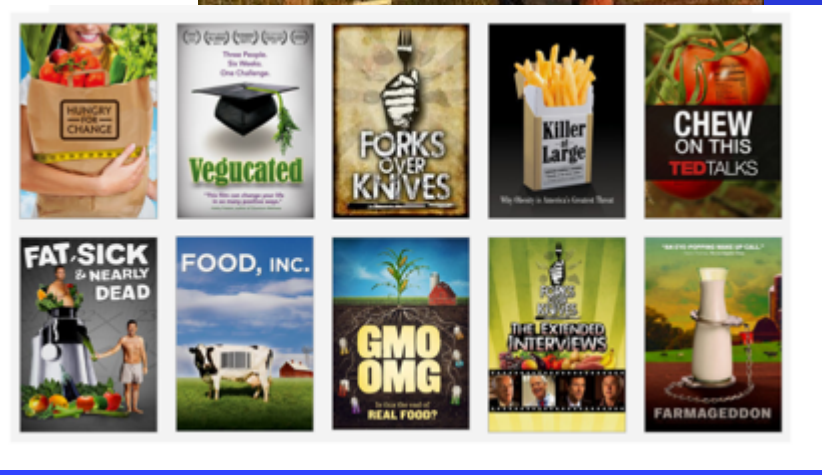
People are passionate about food
Choice is good

- Good to make your own opinion- but not your own facts

Why are these products growing in popularity?

- Everyone now has a voice
- The loudest most convincing
- Food elitism
- Anthropomorphism





Artisan is fine- but a multifaceted challenge

- A MUCH greater % will need to be farmers- pre-industrial revolution-type %
- Would impact **everything**
  - Environment
  - Land values
  - Urban sprawl
  - Transportation
  - Technology & manufacturing ↓

Resources/Social Media

- http://www.meatmythcrushers.com/
- https://www.coursera.org/course/meatweeat
- http://farmingamerica.org/agvocates-who-are-they/
- http://momatthemeatcounter.blogspot.com/
- http://sustainablebeef.org/

Animal Welfare

- To sell to major processors
  - All producers must be welfare & quality assurance trained

Growth Promotants/Implants

- No growth promoting hormones with pigs or chickens- only cattle & sheep
- Why use implants?
  - Increase weight gain
    - $$$$$
  - Increase feed efficiency
    - feed less to get a lb. of gain
  - Lower production costs
  - Lower carcass fat percentage
    - anabolic agent ↓ fat ↑ protein

Human Estradiol Production

	Estradiol Produced /day
Boys	41,000 nanograms
Girls	43,000 – 54,000 nanograms
Adult Male	168,000 nanograms
Non-Pregnant Female	20,000,000 nanograms
Pregnant Female	4,000,000 – 64,300,000 nanograms

One Birth Control Pill contains the same amount of estrogen as 125,000 lbs of beef from implanted steers.

Estrogen Content

	Estrogen/100 grams
Untreated Steer	1.1 nanograms
Implanted Steer	1.4 nanograms
Untreated Heifer	1.3 nanograms
Pregnant Heifer	21.9 – 55.6 nanograms
Cabbage	2,400 nanograms
Peas	400 nanograms
Wheatgerm**	1,013 nanograms
Soybean oil**	189,133 nanograms
Milk**	13.6 nanograms

Nanogram = 1 billionth of a gram


4 oz. serving raw Cabbage
2,700 nanograms Estrogen
4 oz. serving raw Peas
454 nanograms Estrogen
4 oz. serving Potato
300 nanograms Estrogen
4 oz. serving Beef
1.6 nanograms Estrogen

Beta Agonists

- Organic molecules similar to norepinephirine and epinephrine that bind to a Beta-adrenergic receptor to produce a biological effect
- Improves feed efficiency and % meat yield
- Ractopamine (RAC) & Zilpaterol hydrochloride (ZIL)
  - RAC- Beef and pigs- use reduced non-tariff barrier China
  - ZIL- not currently used in US beef industry

Antibiotics

- **Why use antibiotics?**
  - **To treat disease**
  - **To prevent disease**
  - **Increase rate and efficiency of growth**

Antibiotics

- How are antibiotics administered?
  - Therapeutic antibiotics are injectable and given only if animal has clinical signs of illness
  - Sub-thereputic antibiotics are included within the feed or water source
    - Only generally offered at times of extensive stress (weaning and/or transportation between production stages)
  - Growth promoting antibiotics
    - Coccdiostats- poultry
    - Ionophores- cattle- Antibiotics not used in humans
    - Tylosin- Feedlot cattle- prevent liver abscesses
  - All have **mandated withdrawal times** prior to slaughter

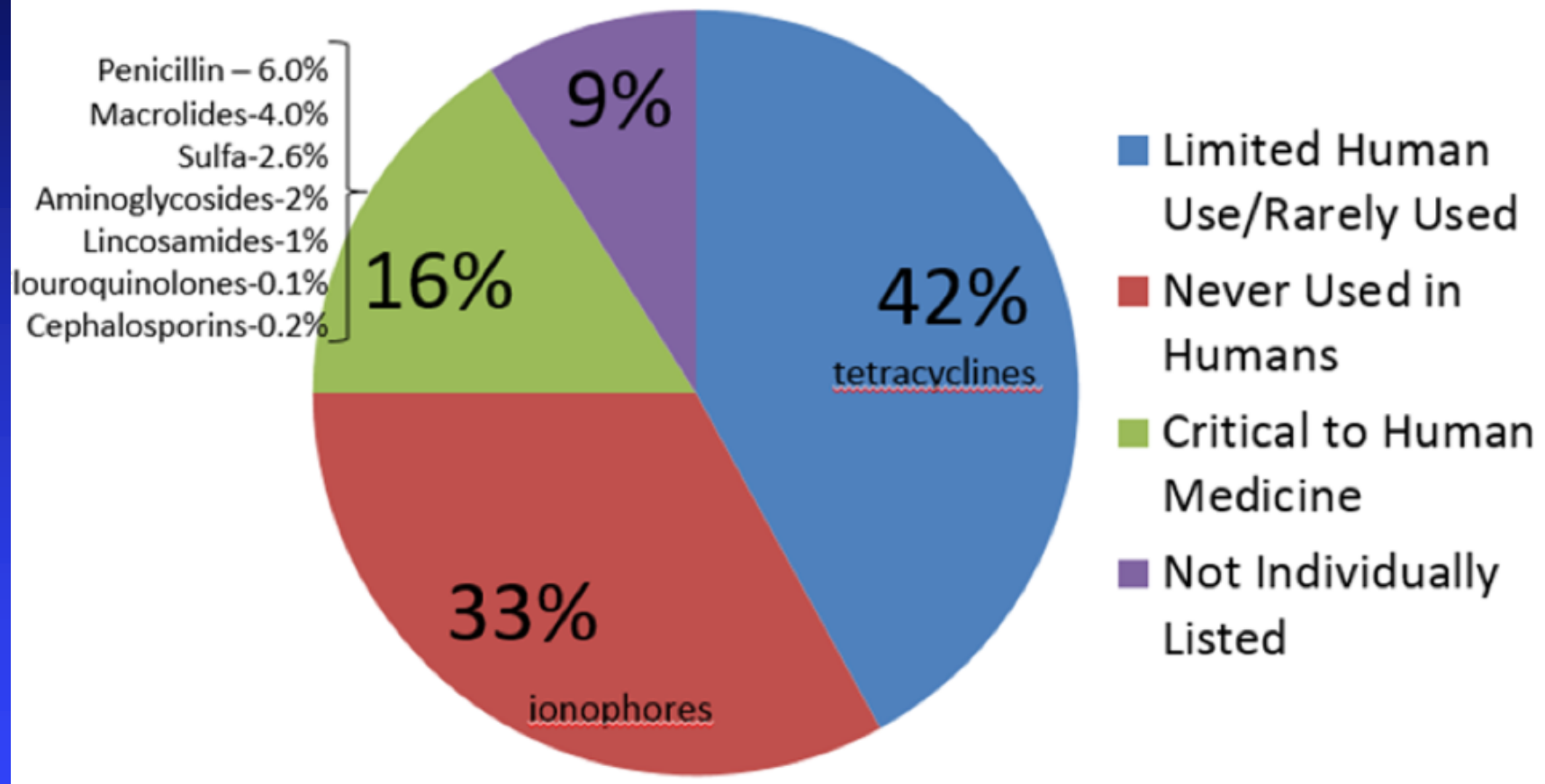
Antibiotics

- Withdrawal time
  - Amount of time required for medication to be metabolized, broken down or excreted so residue levels are below safe levels set for human consumption
  - Adherence not problem
  - Set through research and government regulations
  - Included in medication records

Antibiotics

- Antimicrobial resistance- complicated
- Only 16% of livestock antibiotics used in human medicine
- Livestock industry should continue judicious therapeutic use of penicillin and tetracycline - because of human use

Antibiotics Sold for Animals – Key Categories



Source-
https://www.fda.gov/downloads/forindustry/userfees/animaldruguserfeeactadufa/ucm588085.pdf

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US FDA- VFD

- Veterinary Feed Directive- Jan 2017
  - No impact on injectable antibiotics, rather only those included in feed or water.
  - Disallows the use of antibiotics for growth promotion and encourages the judicious use of medically important feed-grade antibiotics.

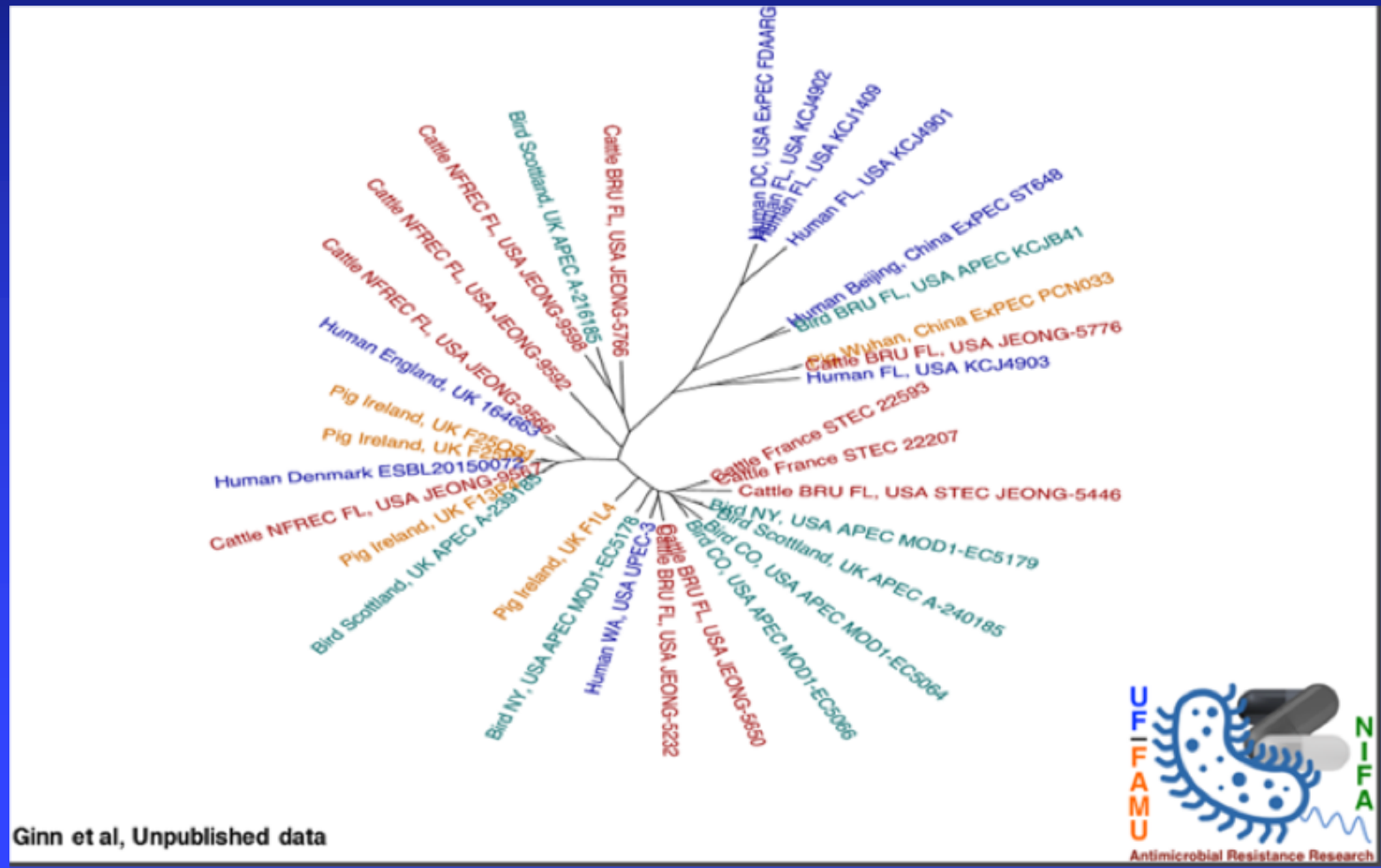
Subtherapeutic Antibiotic Ban

- Denmark: 1999-Banned growth-promoting antibiotics in pork and poultry production
  - Disease and death in animals rose
  - Required more therapeutic antibiotics
  - Did not decrease antibiotic resistance in humans or improve human health
- Netherlands: 2006- Banned growth-promoting antibiotics in pork and poultry production
  - Initially same as Denmark-, but now decreasing
  - The Salmonella typhimurium isolated from cattle, hogs, and people have become less resistant to antibiotics since 2006.

UF AMR Work

- Over 92% of the calves tested positive for expressing ESBLs at least once during the first year of life, despite never being exposed to any antibiotic. (Mir et al., 2018).
- It is possible that the pathogens could have developed ESBLs through natural evolution of the microbiota in the soil on this farm as described in permafrost (D'Costa, et al., 2011). It is also possible ARMs could have been introduced into the soil via vectors such as contaminated bird droppings or municipal wastewater effluents.

- Similar to pathogenic E.Coli identified from a pig in China, a human with foodborne illness in Florida, cattle at the University of Florida beef farm, and a bird at the same farm (Ginn et al., unpublished).

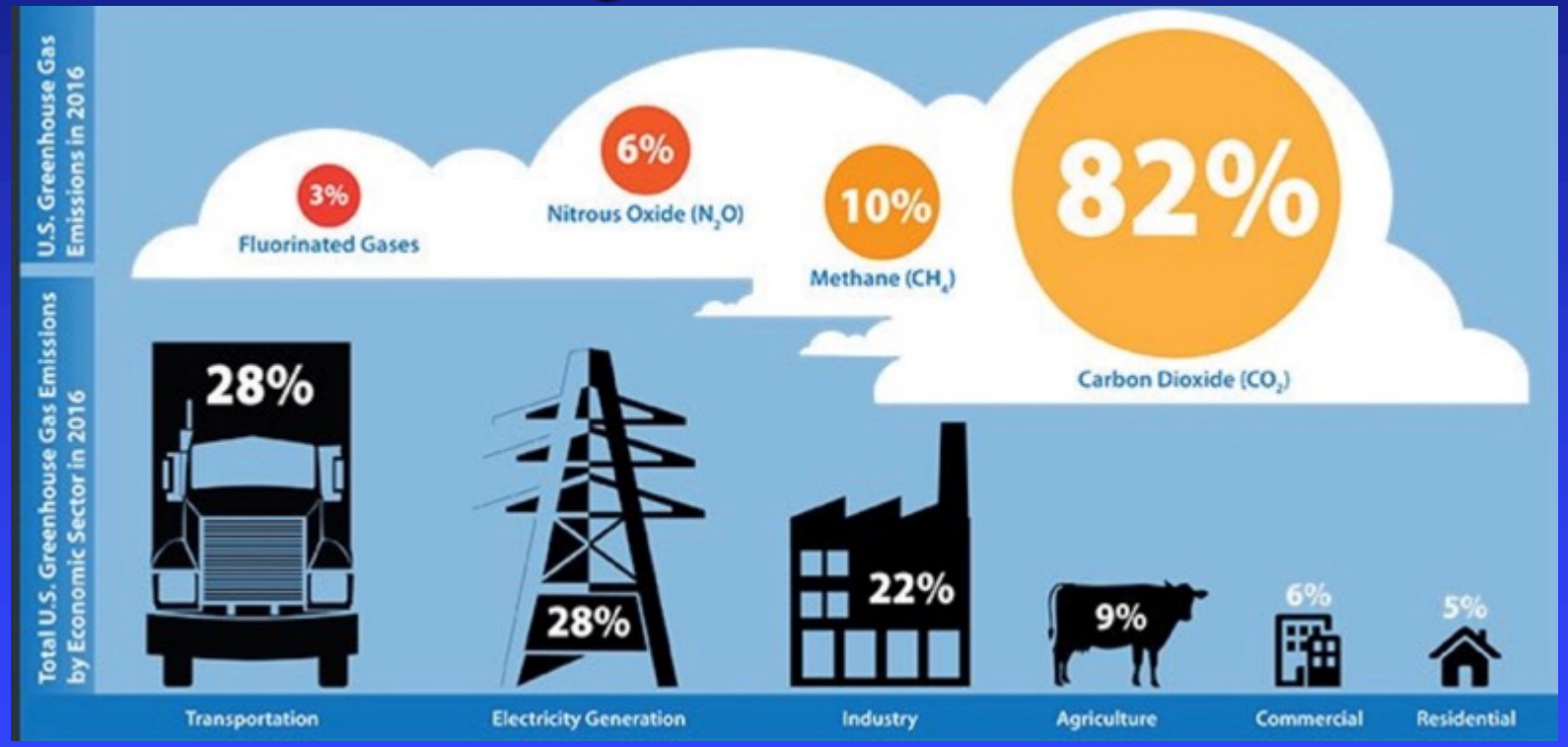


Sustainability

- Wikipedia definition- The capacity to endure
- Pew Commission Definition, 2008- Management to be maintained indefinitely
- Now, sometimes perceived within organic/natural/locavore movement
  - natural, green, organic, locally grown, small farm, humanely treated, climate saving, environmentally friendly, small carbon footprint, energy-saving, free range, fair trade, fair worker treatment, socially responsible and corporate responsibility
- Carbon footprint of animal greater than plant

EPA

- US Animal Agriculture- 3.9%



Carbon Footprint per lb of Beef

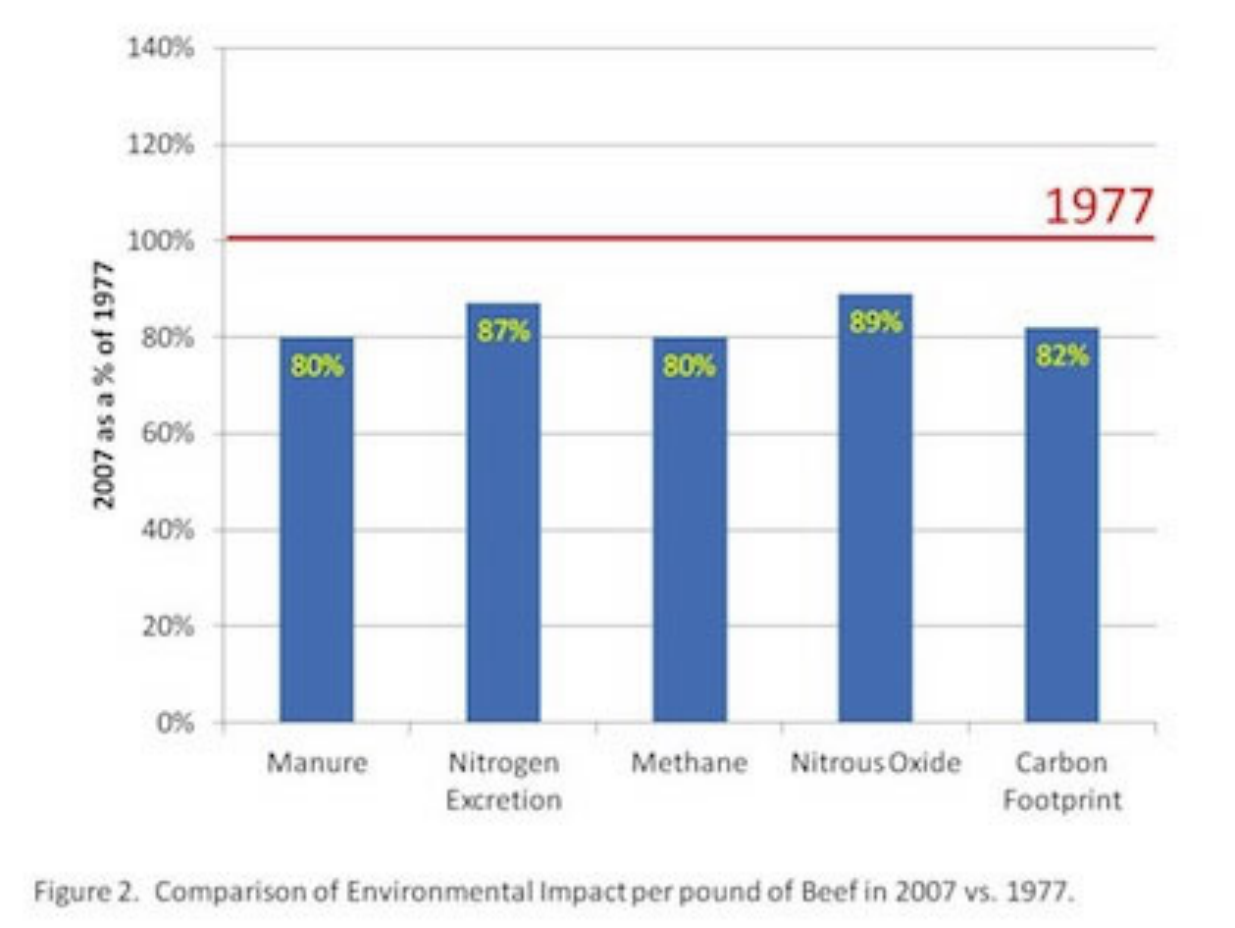
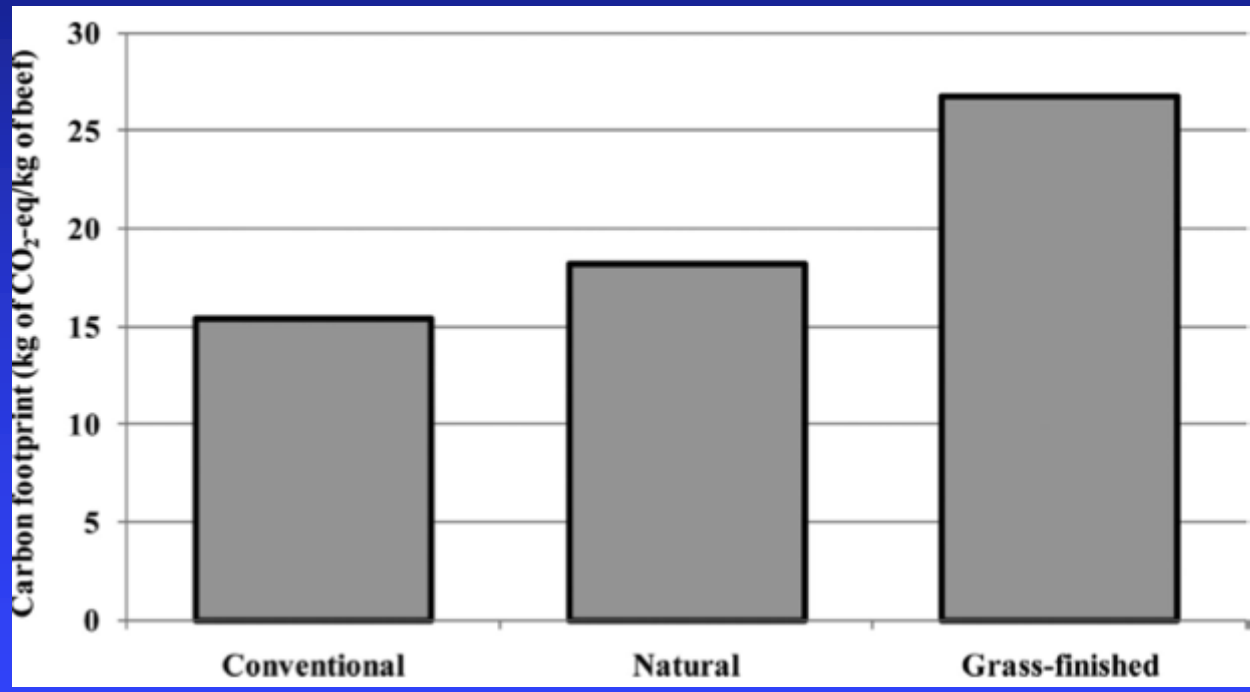


Figure 2. Comparison of Environmental Impact per pound of Beef in 2007 vs. 1977.



Capper et al. 2010

Each pound of beef produced in 2007 used

- 10 percent less feed energy
- 20 percent less feedstuffs
- 30 percent less land
- 14 percent less water
- 9 percent less fossil fuel energy
- 18 percent decrease in total carbon emissions (methane, nitrous oxide and carbon dioxide)

Than the beef produced in 1977

Animal-sourced Food for Thought

Dr. Wendy Dahl
Associate Professor and Nutrition Extension Specialist
UF/IFAS Food Science & Human Nutrition
wdahl@ufl.edu

Dietary patterns and risk of chronic disease…it's complicated

"Most [published nutrition research] assumes disease risk is modulated by the most abundant substances; for example, carbohydrates or fats…

….food preparation methods (*e.g.*, red meat cooking) may be influential.

Risk may vary by an individual's genetic background, metabolic profile, age, or environmental exposures."

Ioannidis JPA. **The Challenge of Reforming Nutritional Epidemiologic Research.** JAMA. 2018;320:969-970.

Is it all about meat?

- Do meat-eaters have different health outcomes compared to non-meat-eaters due to differences in dietary intakes beyond meat? Is it diet quality?
- EPIC-Oxford study of 30,239 participants categorized: regular meat eaters *vs*. low and non-meat-eaters

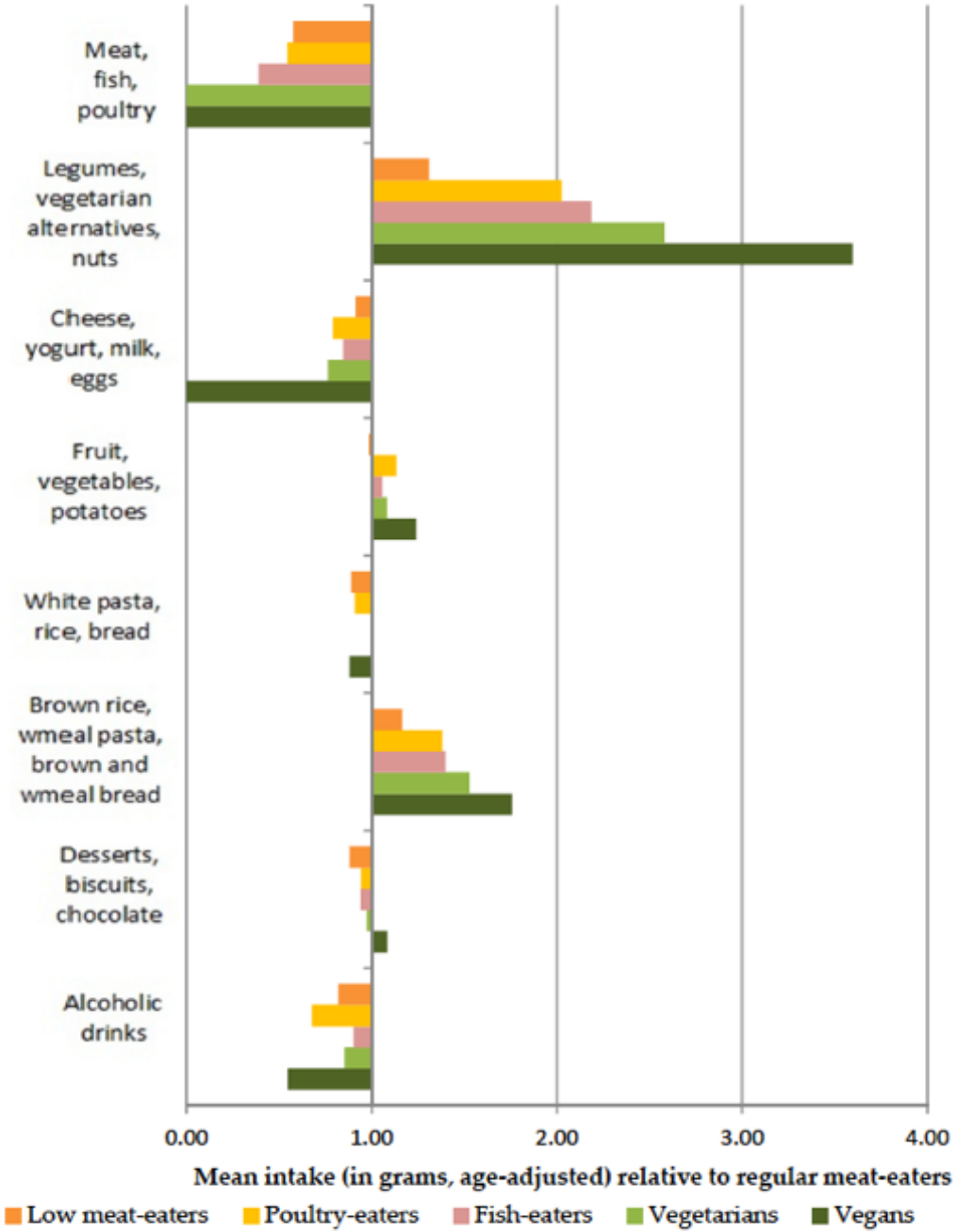


Figure 1. Relative age-adjusted mean (g) consumption of foods in low meat-eaters, poultry-eaters fish-eaters, vegetarians and vegans compared to regular meat-eaters among men.

Papier et al. Nutrients. 2019 Apr 11;11(4). pii: E824.

Health benefits of plant-based dietary patterns

- Mediterranean-type, Dietary Approach to Stop Hypertension (DASH) and the Mediterranean-DASH diet Intervention for Neurodegenerative Delay (MIND) diets and Anti-inflammatory diets associated with slower cognitive decline.
- What benefits the brain, benefits the heart and the kidneys…
- Plant-based dietary patterns that have lower consumption of processed foods.
- Plant-based dietary pattern *vs.* vegetarian *vs.* vegan

Chen et al. J Alzheimers Dis. 2019;67(2):583-619; Rees et al. Cochrane Database Syst Rev. 2019 Mar 13;3:CD009825; Kim et al. Clin J Am Soc Nephrol. 2019 May 7;14(5):682-691

DASH diet

- Low fat, low sodium – higher calcium, magnesium, potassium and fiber.
- "Retains effectiveness to reduce blood pressure when lean pork is substituted for chicken and fish as the predominant source of protein"

Sedentary, Woman, Age 32	Calorie Needs: 1,800
Grains	6 servings
Vegetables	4-5 servings
Fruits	4-5 servings
Fat-Free or Low-Fat Dairy	2-3 servings
Lean Meats, Poultry or Fish	6 or less
Nuts, Seeds, Legumes	4 per week
Fats & Oils	2-3
Sweets/Added Sugars	5 or less per week

Sayer et al. Am J Clin Nutr. 2015 Aug;102(2):302-8.

Diet Quality

A measure of adherence to the Dietary Guidelines of Americans

Recommended Eating Patterns:

- **Healthy US Style**: 26 oz animal-sourced (meat, poultry and eggs) + 8 oz seafood
- **Healthy Mediterranean Style**: 26 oz (animal sources) + 15 oz seafood
- **Healthy Vegetarian**: includes eggs and higher dairy

HEI-2015[1] Components and Scoring Standards

Component	Maximum points	Standard for maximum score	Standard for minimum score of zero
Adequacy:			
Total Fruits[2]	5	≥0.8 cup equivalent per 1,000 kcal	No Fruit
Whole Fruits[3]	5	≥0.4 cup equivalent per 1,000 kcal	No Whole Fruit
Total Vegetables[4]	5	≥1.1 cup equivalent per 1,000 kcal	No Vegetables
Greens and Beans[4]	5	≥0.2 cup equivalent per 1,000 kcal	No Dark-Green Vegetables or Legumes
Whole Grains	10	≥1.5 ounce equivalent per 1,000 kcal	No Whole Grains
Dairy[5]	10	≥1.3 cup equivalent per 1,000 kcal	No Dairy
Total Protein Foods[4]	5	≥2.5 ounce equivalent per 1,000 kcal	No Protein Foods
Seafood and Plant Proteins[4,6]	5	≥0.8 ounce equivalent per 1,000 kcal	No Seafood or Plant Proteins
Fatty Acids[7]	10	(PUFAs + MUFAs) / SFAs ≥2.5	(PUFAs + MUFAs)/SFAs ≤1.2
Moderation:			
Refined Grains	10	≤1.8 ounce equivalent per 1,000 kcal	≥4.3 ounce equivalent per 1,000 kcal
Sodium	10	≤1.1 grams per 1,000 kcal	≥2.0 grams per 1,000 kcal
Added Sugars	10	≤6.5% of energy	≥26% of energy
Saturated Fats	10	≤8% of energy	≥16% of energy

[1] Intakes between the minimum and maximum standards are scored proportionately.

[2] Includes 100% fruit juice.

[3] Includes all forms except juice.

[4] Includes legumes (beans and peas).

[5] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.

[6] Includes seafood; nuts, seeds, soy products (other than beverages), and legumes (beans and peas).

[7] Ratio of poly- and mono-unsaturated fatty acids (PUFAs and MUFAs) to saturated fatty acids (SFAs).

Malnutrition: A global perspective

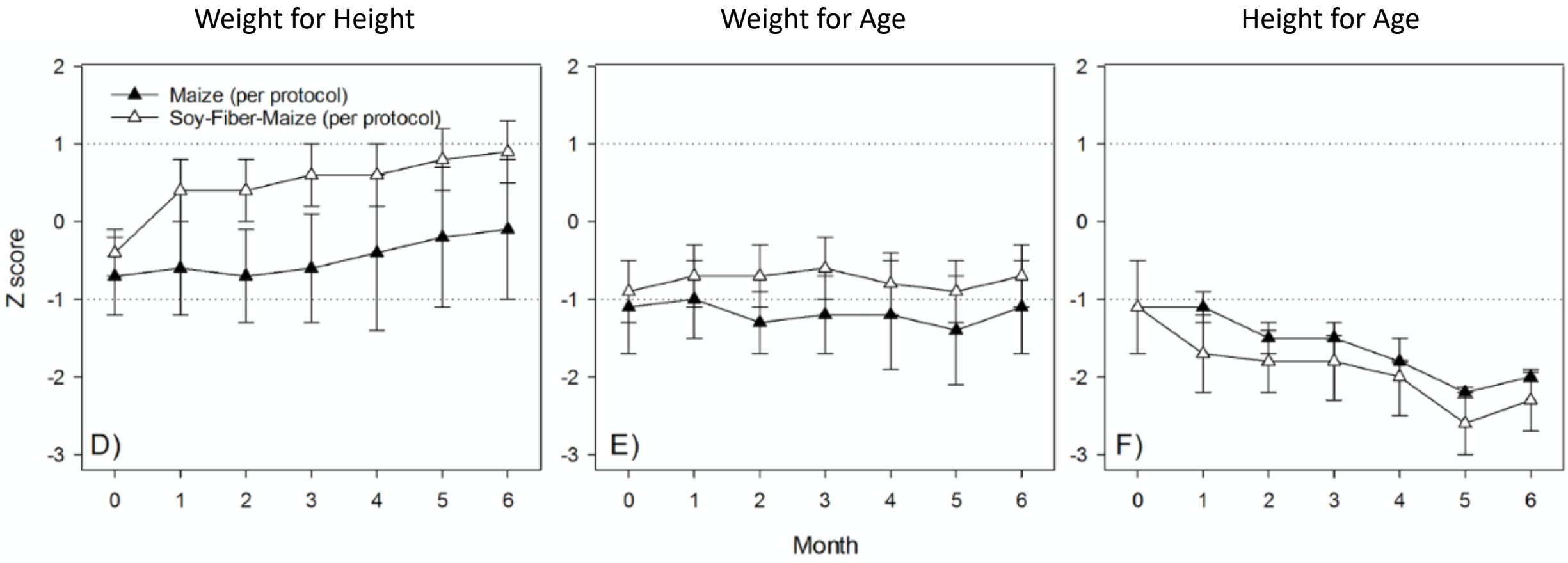
- 52 million children < 5 y are wasted (low weight-for-height)
- 17 million are severely wasted
- 155 million are stunted (low height for age)
- 41 million are overweight or obese
- 45% of deaths among children < 5 y related to undernutrition.

https://www.who.int/news-room/fact-sheets/detail/malnutrition

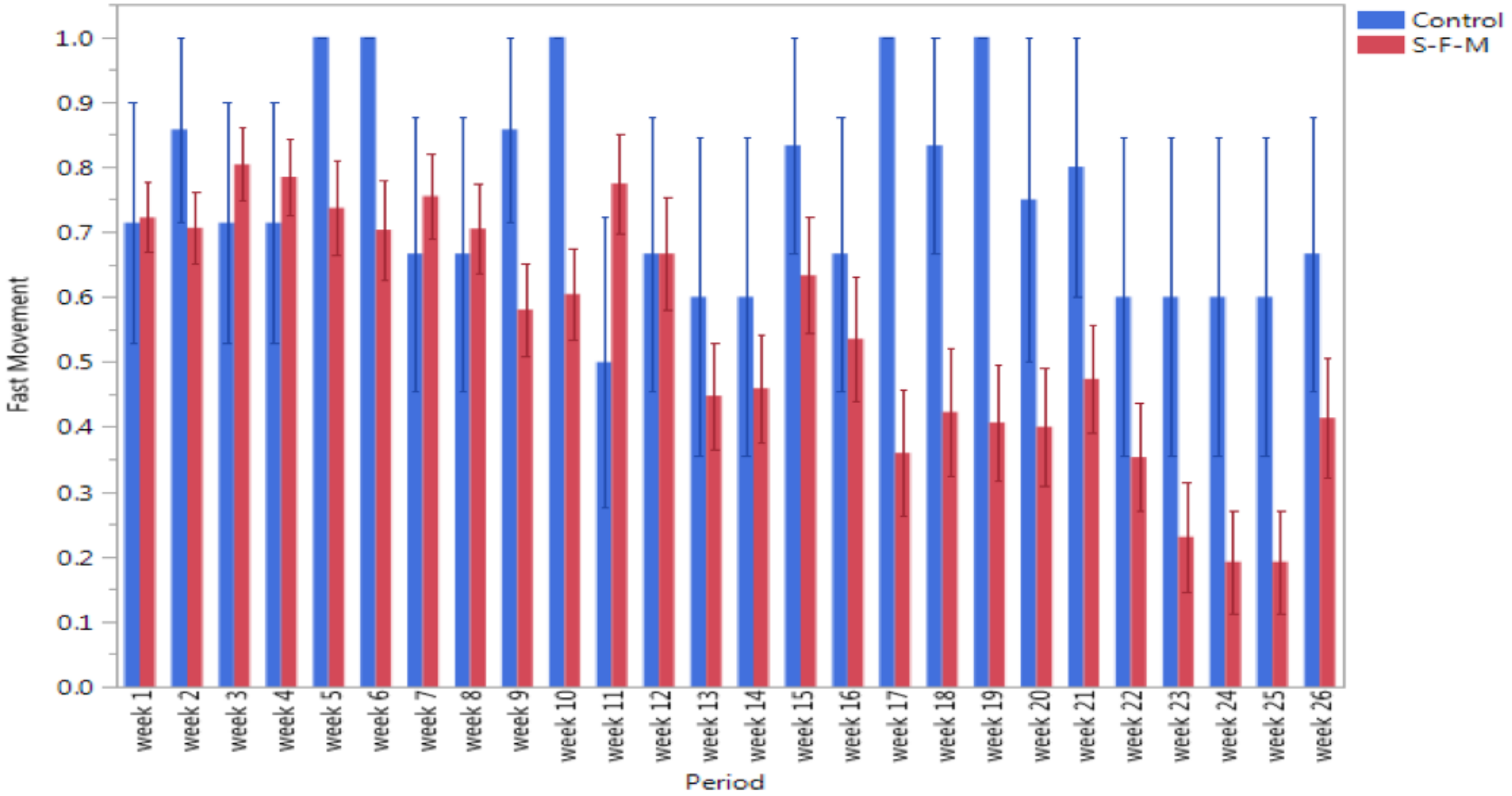
Diet of Rural Malawian Infants and Children

- Complementary foods included maize porridge and some fish broth, bean broth and insects (rainy season).
- No meat, poultry or fish, no nuts, no vegetables – little fruit. (Note: dairy is not consumed by adults or children)
- We studied infants/children 6 mo - 3 y of age - intervention to increase protein and fiber (soy+maize)

Too little to late…



Diarrhea: Is diet diversity or quality important?

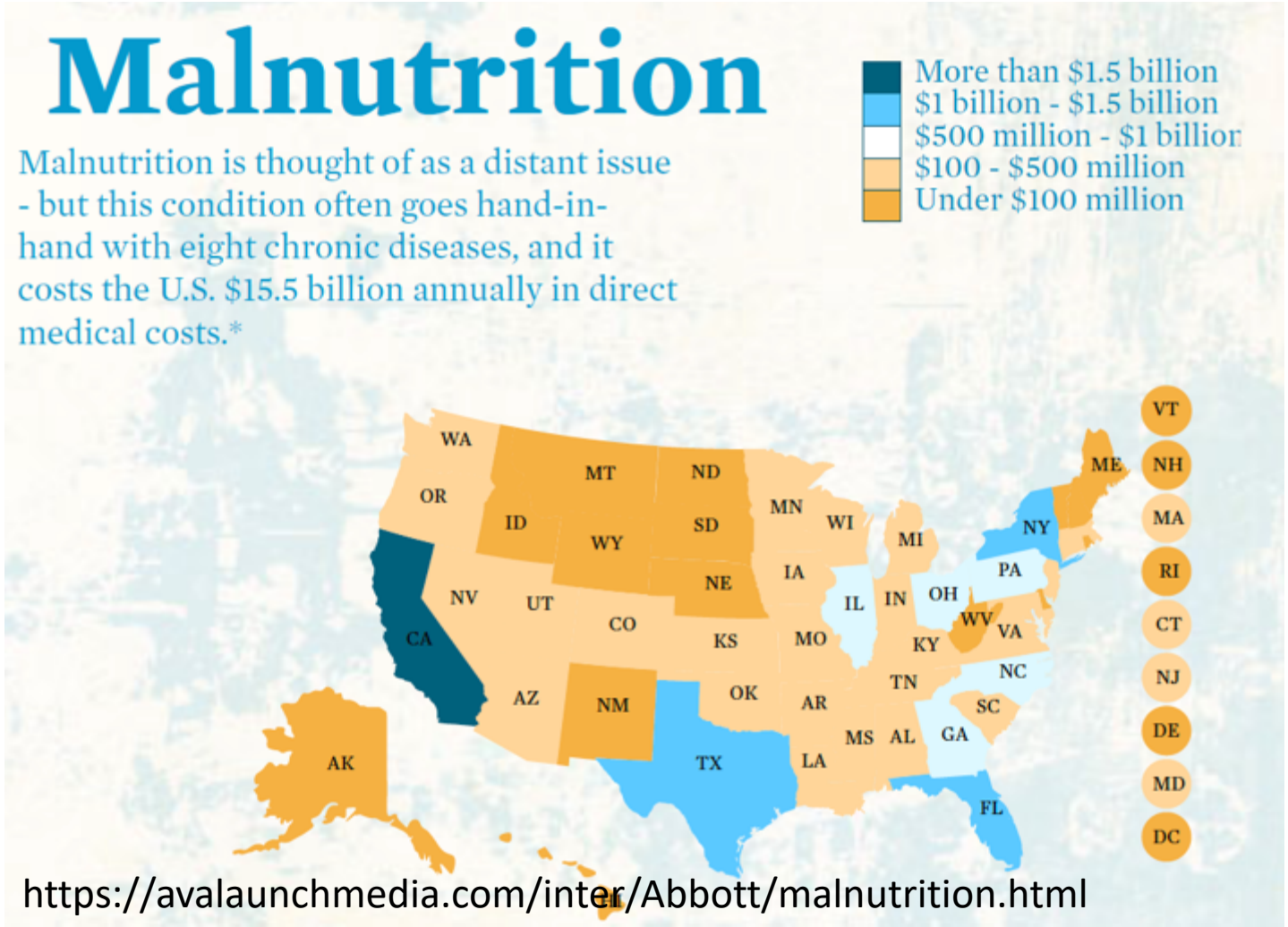


Animal-sourced Foods

Challenges to consider…

- Affordability when many live on < $1 USD/day
- Changing dietary habits/taboos
- Unexpected consequences *e.g.* increased diarrhea rates in children with chicken ownership

A Florida Perspective



https://avalaunchmedia.com/inter/Abbott/malnutrition.html

COAST

1. Have you lost weight recently without trying?
   Yes
   No
2. Have you been eating less food because of a decreased appetite?
   Yes
   No
3. Do you have an illness or condition that has made you change the kind and/or amount of food you eat?
   Yes
   No
4. In general, how healthy is your overall diet?
   Poor
   Good
   Very good
5. Do you consume…
   - Dairy products (milk, cheese, yogurt) or soy milk at least once a day? Yes No
   - Meat, poultry (e.g. chicken), fish/seafood, or eggs every day? Yes No
   - Legumes (e.g. beans), soy products, nuts, or seeds at least twice a week? Yes No

Are older adults getting enough protein?

- Recommended Dietary Allowance (RDA) for protein considered suboptimal for older adults due to age-related changes.
- Higher protein intake is associated with a reduced risk for sarcopenia and increased strength.
- About 25% of community-dwelling older adults, particularly women, have inadequate protein intake.

Landi et al 2016; Isanejad et al 2016; Mishra et al 2018; Bauer et al 2013; ter Borg et al 2013

What is the impact of a high protein diet on general wellness in older women?

A high protein diet, in keeping with the acceptable macronutrient distribution ranges (AMDR) and provided intermittently over 18 weeks to older women.

- Improved muscle mass
- Indicators of wellness were unchanged
- Microbiota profile relatively stability

Ford et al. pending publication

Conclusions

- Dietary patterns currently recommended in the US include animal-sourced foods.
- Plant-based diets, with moderate intakes of animal-sourced foods and an emphasis on high diet quality, promote health and wellness.
- Specific needs of differing populations (developing vs developed world) and sub-groups (older adults, disease states, infants etc.) within the larger population need to be considered when making recommendations.

Cell cultured meat: current status and future implications

Jason Scheffler, PhD
University of Florida
Department of Animal Sciences

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https://www.drovers.com/article/cattlemens-groups-voice-concerns-lab-grown-meat-usda-fda

MEMPHIS MEATS

MISSION BARNS

NEW HARVEST

Finless Foods

NEW AGE MEATS

WILD TYPE

TECH & SCIENCE

SYNTHETIC HAMBURGER READY FOR SALE WITHIN FIVE YEARS

BY **NICK WINCHESTER** ON 10/16/15 AT 2:45 PM EDT

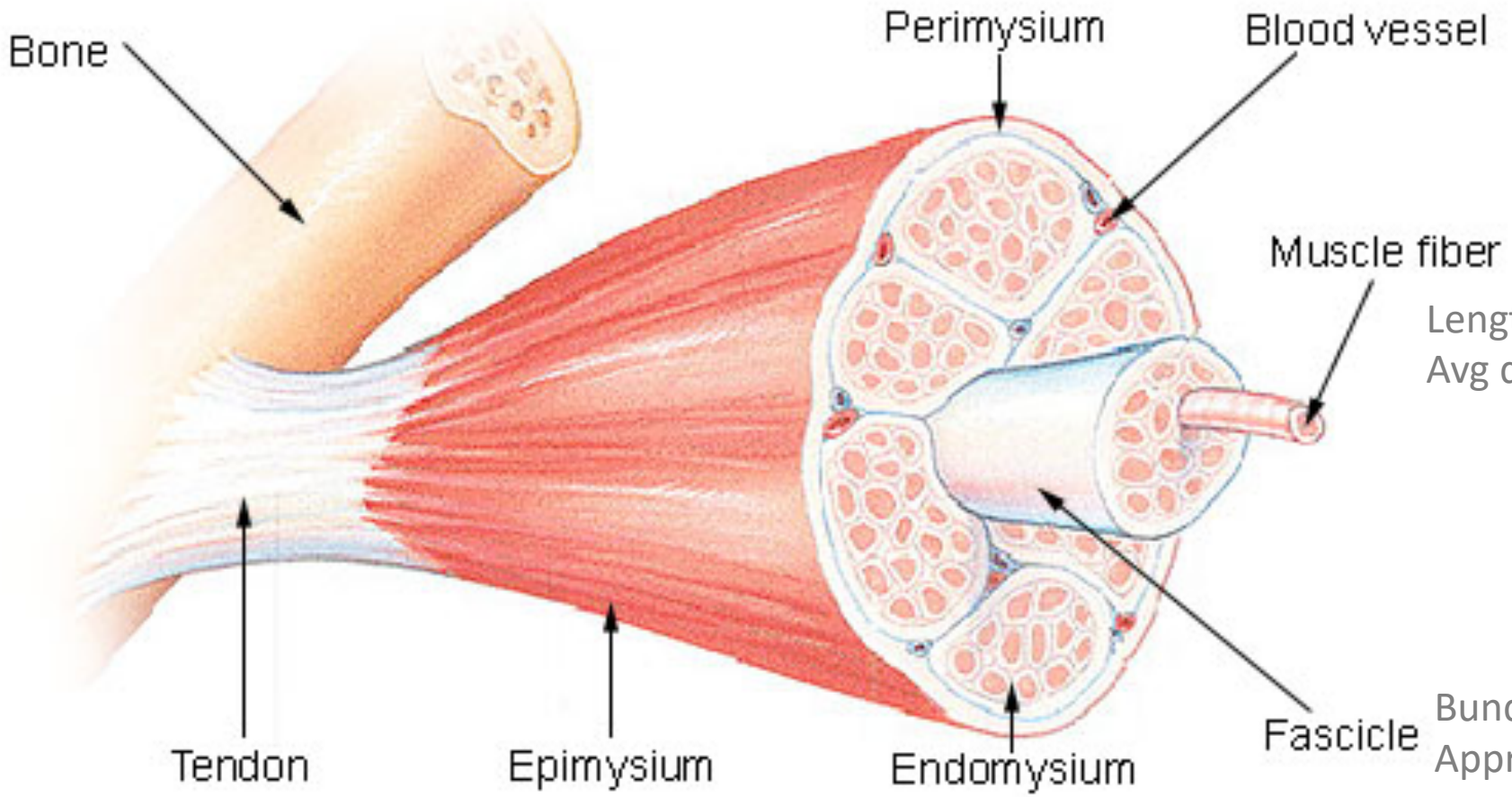
Mark Post holding the world's first lab-grown hamburger during a launch event in London, August 5, 2013. The burger's manufacturers said this week that they hope their product will be readily available within five years.

DAVID PARRY/REUTERS

Skeletal muscle is a heterogeneous tissue

Structure of skeletal muscle

Connective tissue sheath surrounding entire muscle
Marbling (intramuscular fat) located within perimysium, between and around bundles



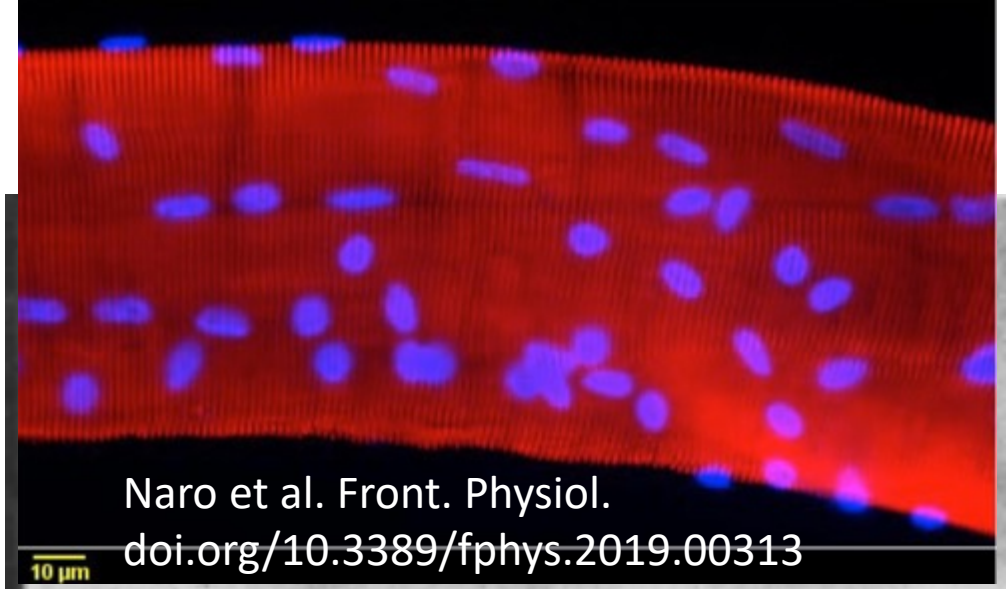
a.k.a. myofiber, muscle cell, myocyte

Length varies few mm to many cm
Avg diameter 10-100 µm

Bundle of muscle cells,
Approx. 50-300 fibers/bundle

Connective tissue sheath surrounding entire muscle

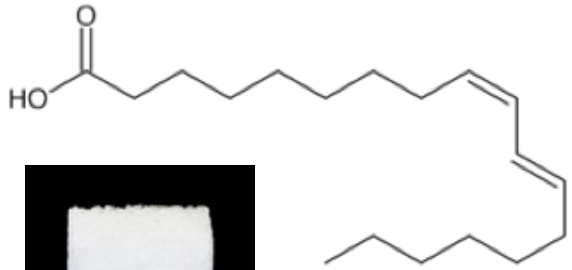
Connective tissue sheath surrounding individual muscle

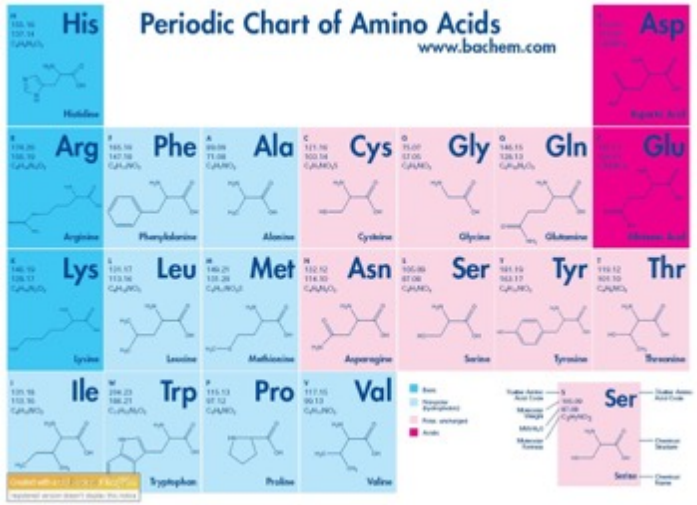


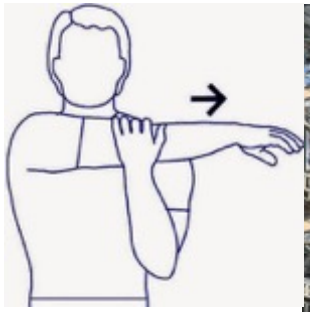
Naro et al. Front. Physiol.
doi.org/10.3389/fphys.2019.00313

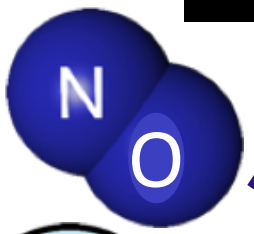
(Bischoff, 1986)

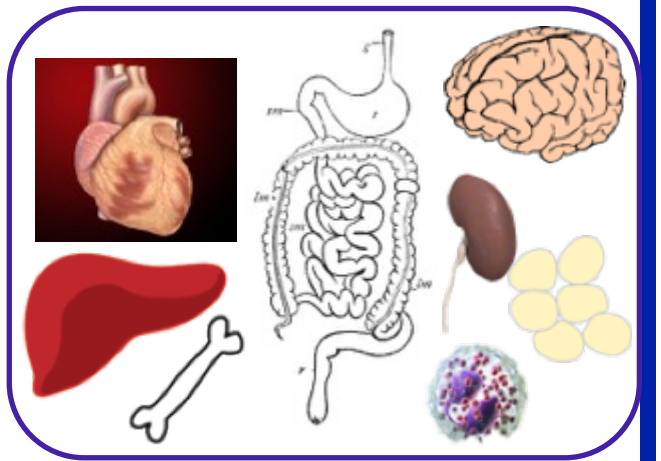
FIG. 2. Interference contrast micrograph of presumptive satellite cell in cultured muscle fiber. The satellite cell is on the lower right edge of the muscle fiber. The arrow refers to the former end plate which was located by iontophoretic application of ACh; ×1,000.











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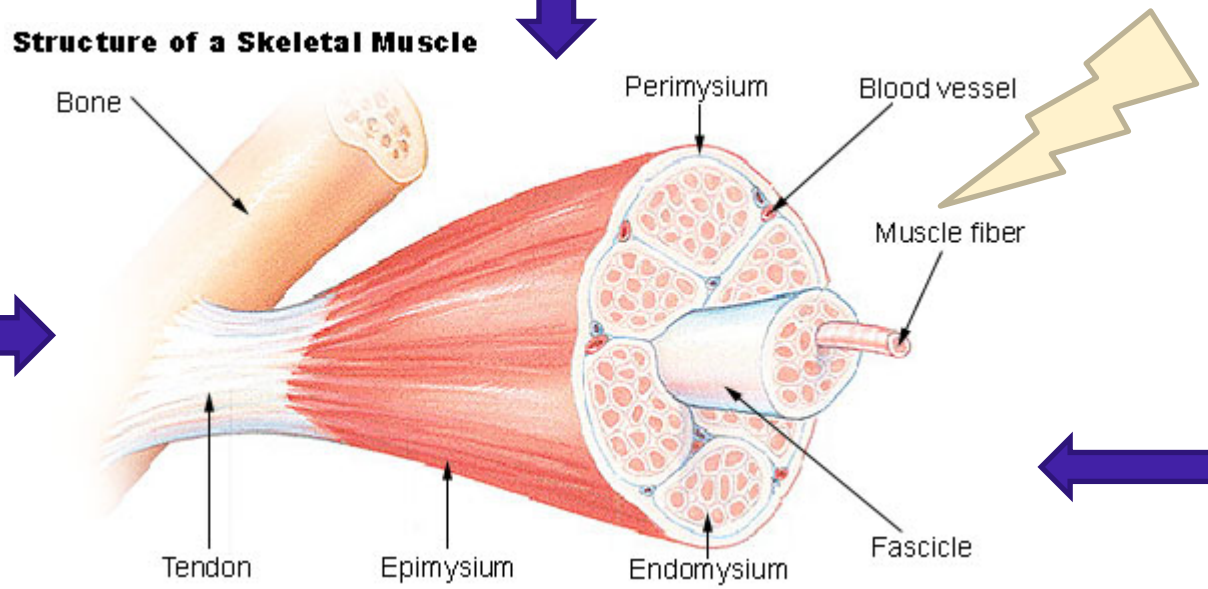
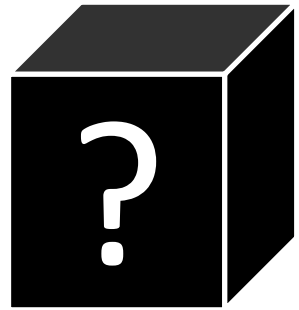


Hormones

Growth factors



https://www.web-books.com/eLibrary/Medicine/Physiology/Muscular/MuscleStructure.htm

Patrick J. Lynch, medical illustrator [CC BY 2.5 (https://creativecommons.org/licenses/by/2.5)]

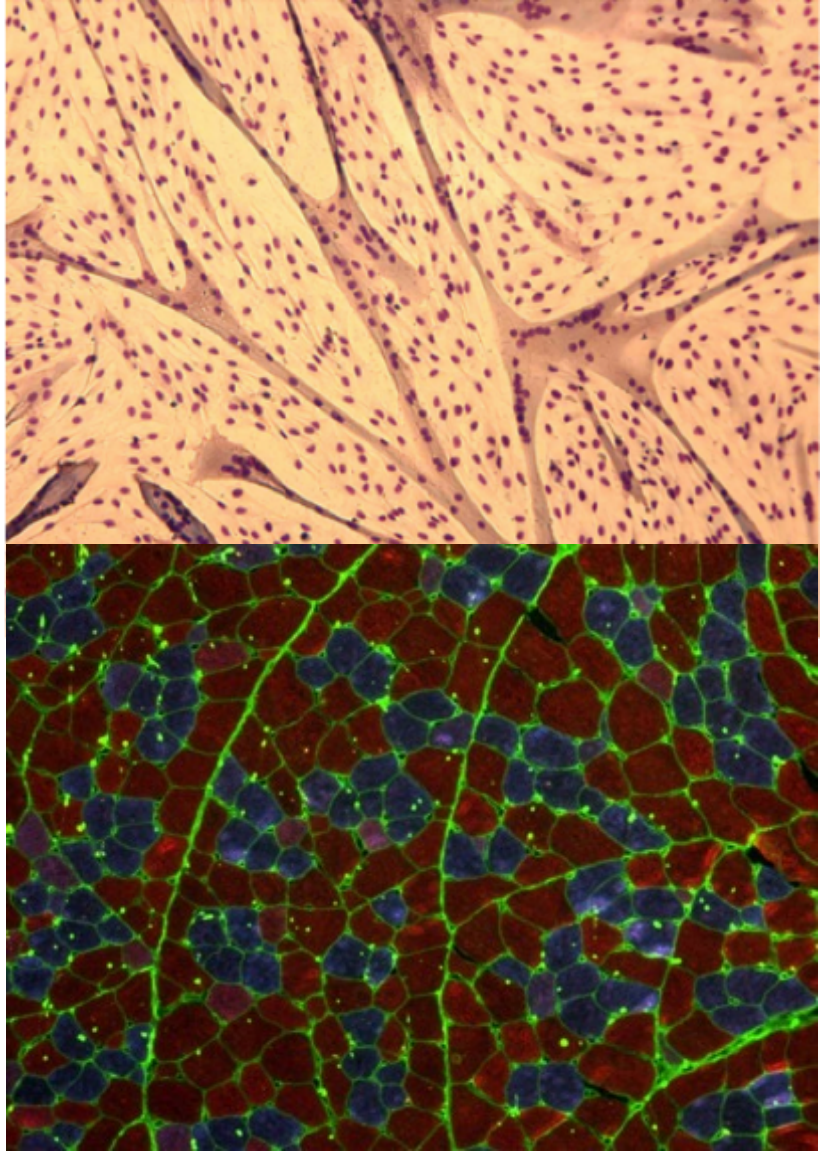
Major hurdles for cell culture

Technical
- Cell source
- Scaffolding
- Media

Financial
- Funding
- Efficiency

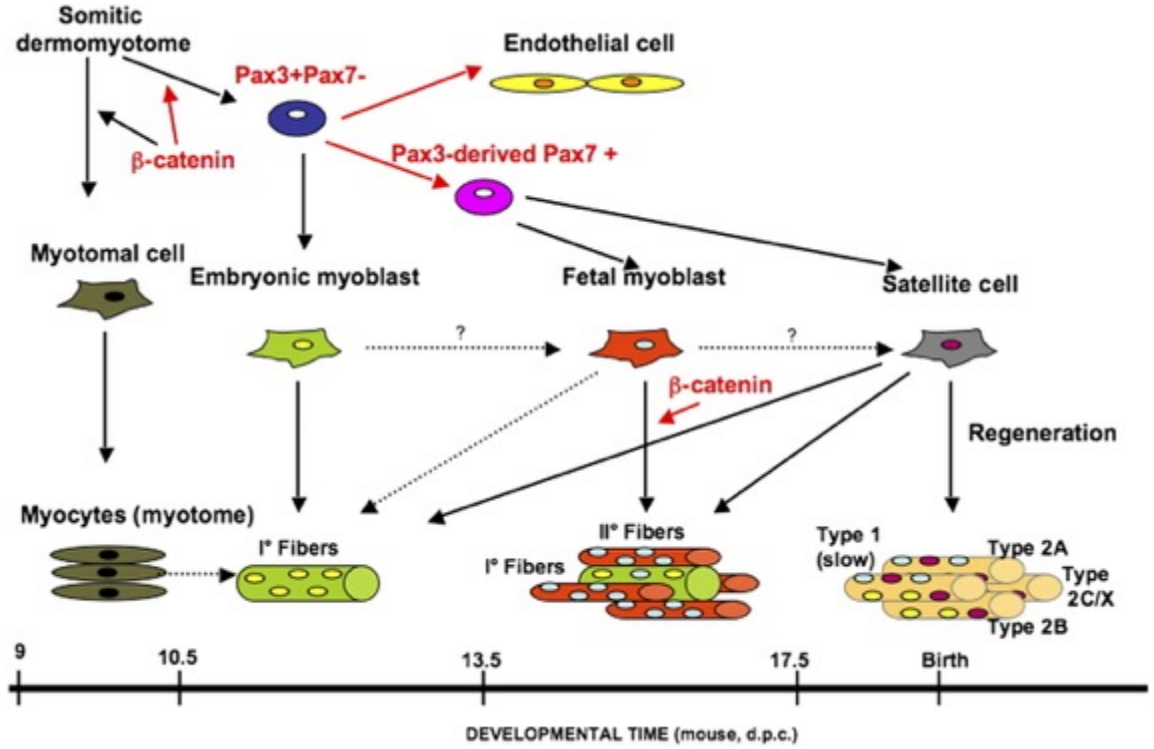
Regulatory

Environmental



Where do the starting cells come from?

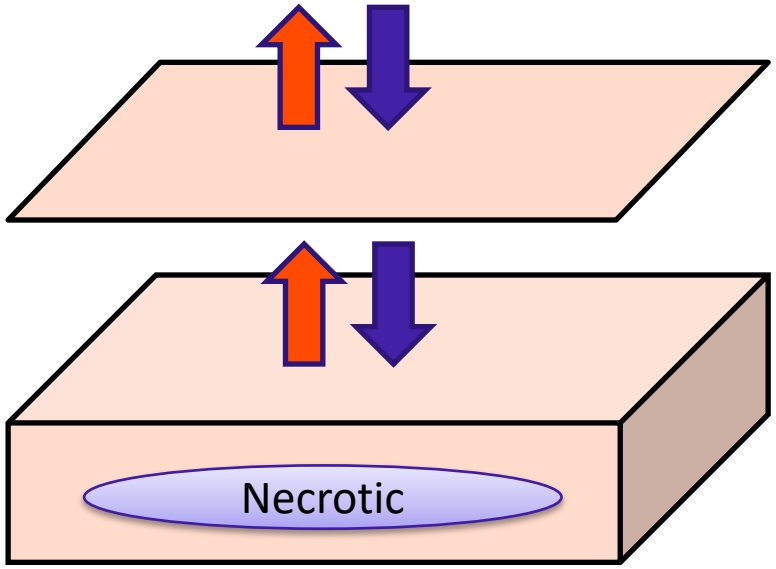
- Satellite cells
  - Derived from living animal
  - Limited proliferative capacity
- Embryonic stem cells
  - Pluripotent Immortal
- Molecular modification
  - Gene editing (CRISPR, Micro-RNA, siRNA)
  - Immortalize, direct lineage, functional characteristics

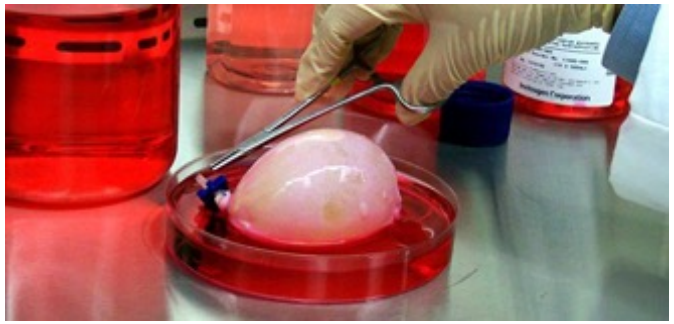


Graziella Messina, and Giulio Cossu Genes Dev. 2009;23:902-905

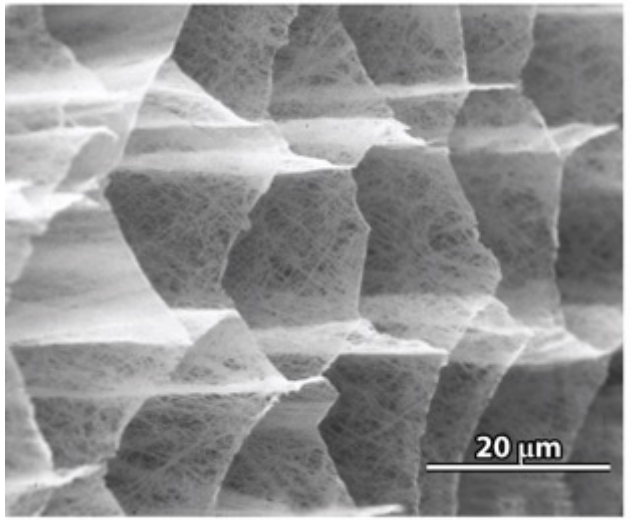
Scaffolding

- Muscle is a dense tissue
  - Fibroblasts produce connective tissue harness
  - How to facilitate nutrient and exchange?
  - Concede structure?

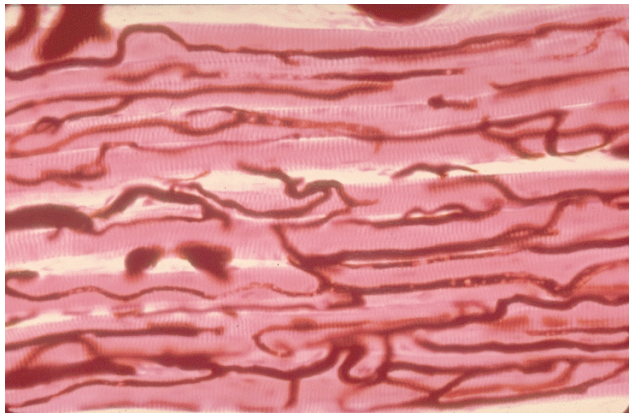




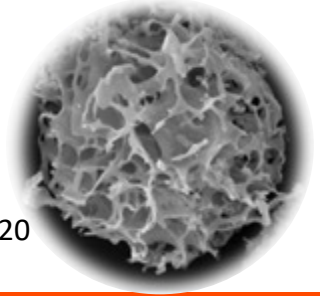
https://www.newsweek.com/future-medicine-growing-new-organs-69037



Purslow 2014. Annu Rev Food Sci Technol. 5:133-153



http://udspace.udel.edu/handle/19716/2040

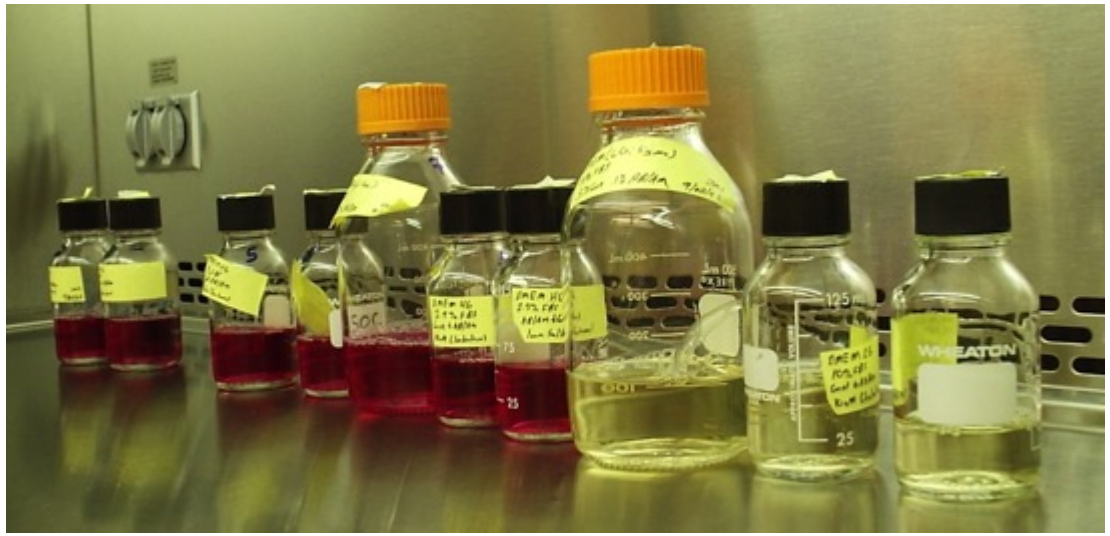


Huang et al. 2018. Carbohydrate Polymers. 202:611-620
https://doi.org/10.1016/j.carbpol.2018.09.021

Classic Media

- Basal media
- Fetal Bovine Serum
- Antibiotics

List cost- $656/l



Dulbecco's Modified Eagle's Medium (DMEM)

Inorganic Salts	**Vitamins**
Calcium Chloride	Choline Chloride
Ferric Nitrate • $9H_2O$	Folic Acid
Magnesium Sulfate (anhydrous)	*myo*-Inositol
Potassium Chloride	Niacinamide
Sodium Bicarbonate	D-Pantothenic Acid (hemicalcium)
Sodium Chloride	Pyridoxal • HCl
Sodium Phosphate Monobasic (anhydrous)	Pyridoxine • HCl
Amino Acids	Riboflavin
L-Arginine • HCl	Thiamine • HCl
L-Cystine • 2HCl	**Other**
Glycine	D-Glucose
L-Histidine • HCl • H_2O	Phenol Red • Na
L-Isoleucine	Pyruvic Acid • Na
L-Leucine	**Add**
L-Lysine • HCl	L-Glutamine
L-Methionine	
L-Phenylalanine	
L-Serine	
L-Threonine	
L-Tryptophan	
L-Tyrosine • 2Na •$2H_2O$	
L-Valine	

Cell cultured meat is biologically feasible

The challenge is to attain economic feasibility

New Age Meats
https://www.businessinsider.com/taste-test-lab-grown-meat-sausage-cost-2018-11

Scale up

- Equipment
- Culture media needs to reduce cost
  - Serum-based media may be ~$25/l
  - Serum-free media is $100+/l
    - A liter of media ≠ a kilogram (2.2 lbs) of meat

  - 80/20 ground beef- $3.22/lb
  - Boneless ribeye steak- $9.22/lb
  - Boneless/skinless chicken breast- $2.51/lb
  - Center cut pork chops $2.39/lb
  - Ground pork $3.21

https://www.ams.usda.gov/market-news/retail

Who should regulate lab cultured meat?

- Animal cell cultured food technology:
  - "Controlled growth of animal cells from livestock, poultry, fish, or other animals, their subsequent differentiation into various cell types, and their collection and processing into food"

https://blogs.scientificamerican.com/observations/lab-grown-meat-is-on-the-way/

Who should regulate lab cultured meat?

- Currently, there is a memorandum of understanding between USDA and FDA
  - FDA
    - Pre-market/preproduction consultations
    - Oversees cell collection from animals, banking, and growth
    - Hands off legal authority to USDA at harvest
  - USDA-FSIS
    - Harvesting and processing
    - Mark of inspection
    - Labeling

https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm626117.htm

Who should regulate lab cultured meat?

- Both FDA and USDA have indicated they have received very little information from companies developing cultured meats
  - Will delay regulatory review and approval
- Research needed
  - Risks
  - Composition
  - Nutrition
  - Shelf-life
  - Functionality

Does FDA regulate culturing of meat from a pharmaceutical or food perspective?

Environmental Science & Technology

Environ. Sci. Technol. 2011, 45, 6117–6123
Dx .doi.org/10.1021/es200130u

ARTICLE

pubs.acs.org/est

Environmental Impacts of Cultured Meat Production

Hanna L. Tuomisto[†,*] and M. Joost Teixeira de Mattos[‡]

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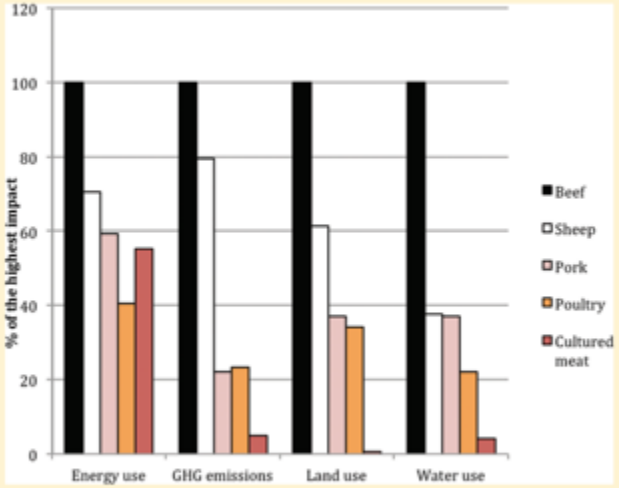
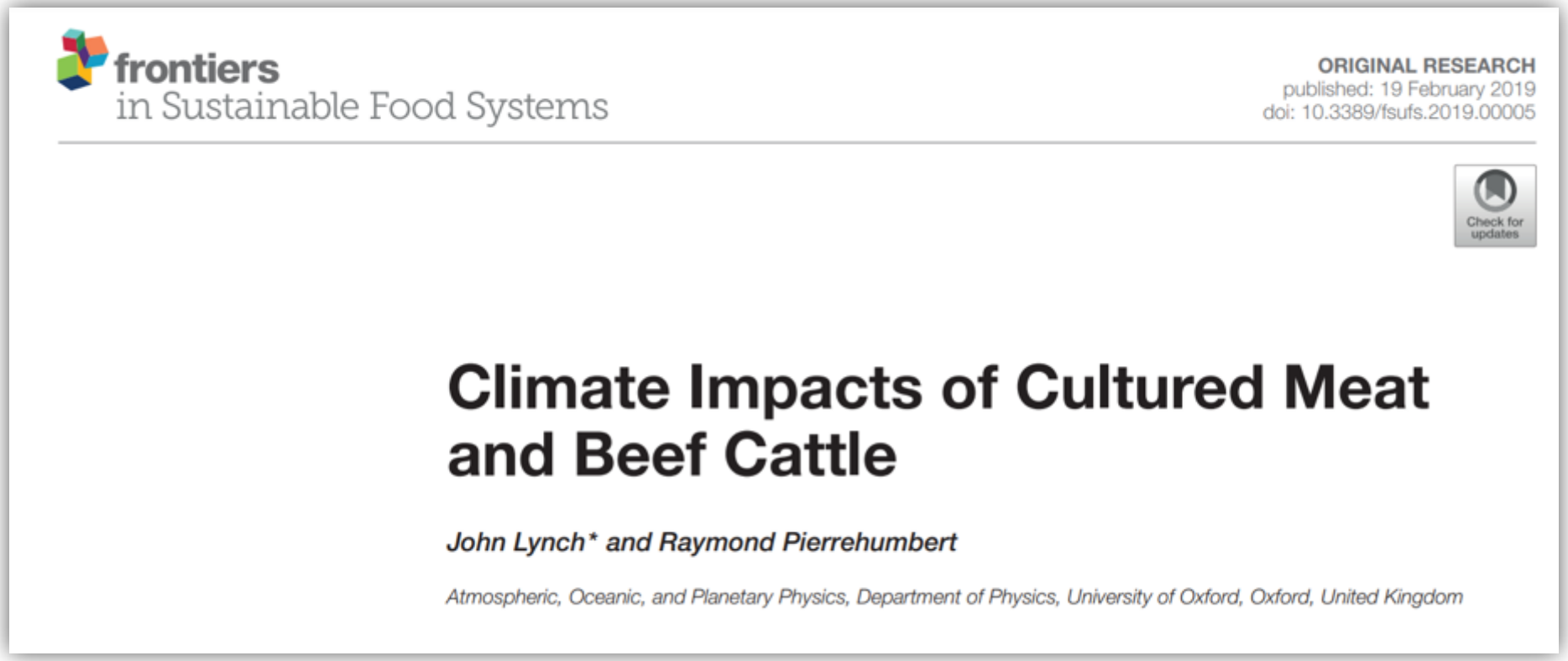
Supporting Information

ABSTRACT: Cultured meat (i.e., meat produced in vitro using tissue engineering techniques) is being developed as a potentially healthier and more efficient alternative to conventional meat. Life cycle assessment (LCA) research method was used for assessing environmental impacts of large-scale cultured meat production. Cyanobacteria hydrolysate was assumed to be used as the nutrient and energy source for muscle cell growth. The results showed that production of 1000 kg cultured meat requires 26−33 GJ energy, 367−521 m^3 water, 190−230 m^2 land, and emits 1900−2240 kg CO_2-eq GHG emissions. In comparison to conventionally produced European meat, cultured meat involves approximately 7−45% lower energy use (only poultry has lower energy use), 78−96% lower GHG emissions, 99% lower land use, and 82−96% lower water use depending on the product compared. Despite high uncertainty, it is concluded that the overall environmental impacts of cultured meat production are substantially lower than those of conventionally produced meat.



Cultured meat has:
7-45% lower energy use
78-96% lower GHG emissions,
99% lower land use
82-96% lower water use

Compared to conventionally produced European meat



frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 19 February 2019
doi: 10.3389/fsufs.2019.00005

Check for updates

Climate Impacts of Cultured Meat and Beef Cattle

John Lynch and Raymond Pierrehumbert*

Atmospheric, Oceanic, and Planetary Physics, Department of Physics, University of Oxford, Oxford, United Kingdom

"We conclude that cultured meat is not prima facie climatically superior to cattle; its relative impact instead depends on the availability of decarbonized energy generation and the specific production systems that are realized."

Front. Sustain. Food Syst., 19 February 2019
https://doi.org/10.3389/fsufs.2019.00005

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Science & Environment

Cultured lab meat may make climate change worse

By Matt McGrath
Environment correspondent

19 February 2019 Share

Climate change

Growing meat in the laboratory may do more damage to the climate in the long run than meat from cattle, say scientists.

WIRED The Confounding Climate Science of Lab-Grown Meat

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MATT SIMON SCIENCE 02.19.19 05:00 AM

THE CONFOUNDING CLIMATE SCIENCE OF LAB-GROWN MEAT

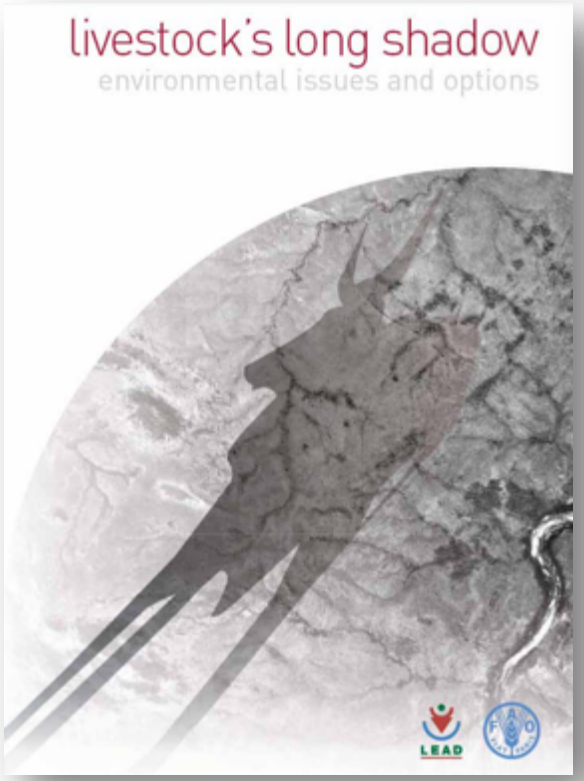
VICTOR DE SCHWANBERG/SCIENCE SOURCE

https://www.wired.com/story/the-confounding-climate-science-of-lab-grown-meat/

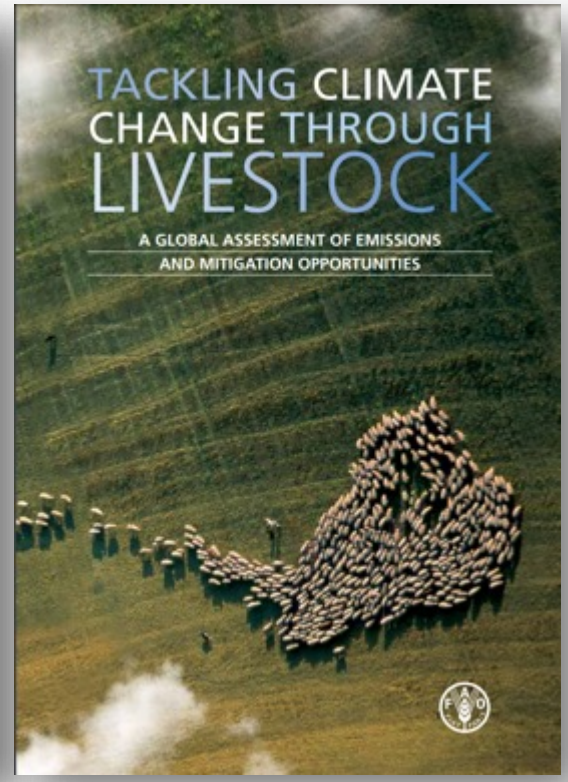
What changed?

- Livestock numbers were refined

- More complete life cycle analysis on cell-based meat



2006



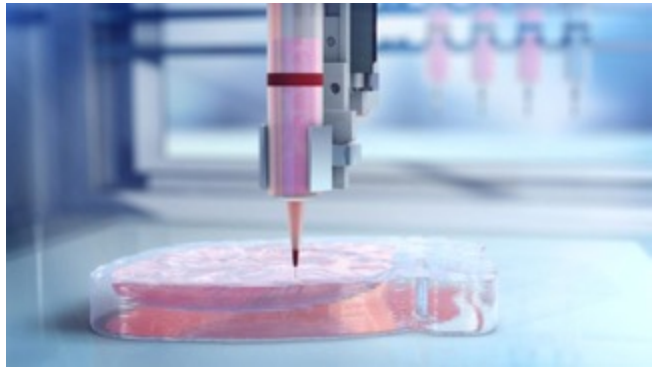
2013

Who will eat it?

- Affordability?
- Accepting of technology? → GMO, gene editing, lab culture
- Vegan/Vegetarian??
- Flexitarian?

- Will that population be big enough to make a dent in the conventionally produced meat market?

Predictions for the future



https://www.globalbiotechinsights.com/articles/14683/towards-a-3d-printed-human-heart

- Scalability?
- Price competitiveness will be a challenge
  - Will investors be patient?
    - Memphis meats- $20 Million
- Evolution of regulations
- Marketing against the all-natural/unprocessed trend→ niche
- Timeline?

- The end product will not look like what we currently imagine
- Potential for innovations to make big leaps or spin off into other applications

Questions?

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