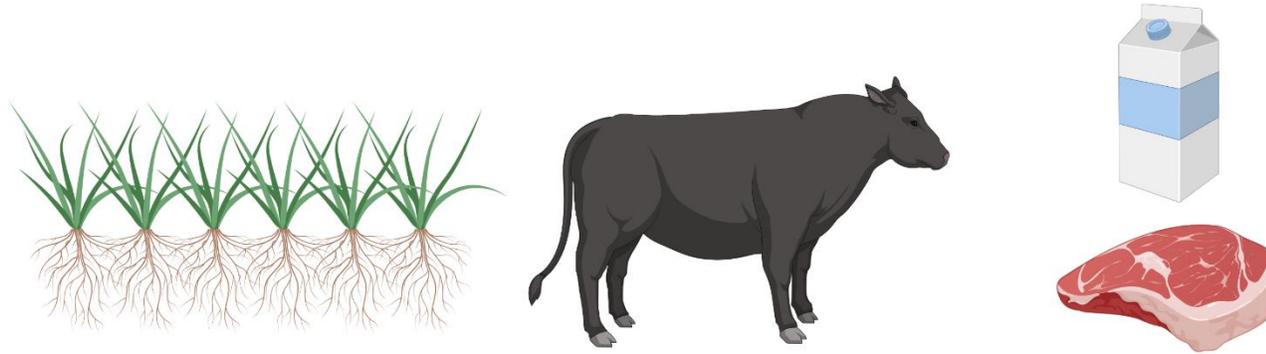


Red Meat, Health, and Sustainability: Consumption Trends in the USA and Globally



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@vanvlietphd



Stephan van Vliet

August 17th, 2022



UtahStateUniversity



My background

So Very Dutch

Dutch directness

The Dutch are renowned for speaking thier minds: from complete strangers reprimanding you for chatting in the train's quiet zone, to a friend not telling you a white lie about your bad haircut. Outsiders often see this as being rude or tactless, but for the Dutch it is actually a virtue of sincerity and honesty. They don't mince their words or beat around the bush, and are often not afraid to discuss hot topics such as religion, politics, immigration or money. In fact, it is even seen as a cultural faux pas to not have an opinion. Some Studies



trace this directness back to the country's history of Calvinism: Calvinist are concerned with the essence of things and what is really important. The good thing about this 'callous' openness? At least you know exactly where you stand with The Dutch

(c) by <A> - ARNOLD OVERHAART - 2015



Maastricht University



ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN



Washington
University in St. Louis
SCHOOL OF MEDICINE



Duke University
School of Medicine



Center for Human Nutrition UtahStateUniversity

Agenda

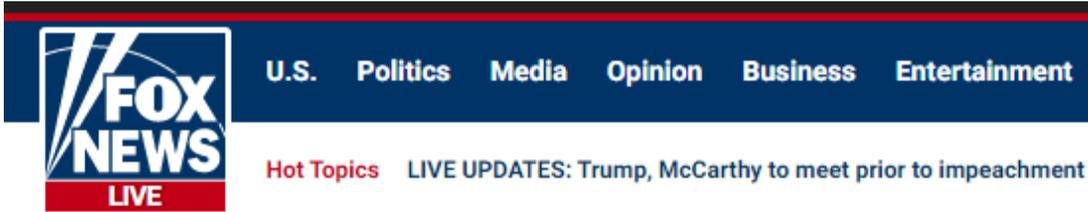
Red Meat and Human Health

- Part 1: Red Meat, Diet Quality, and Disease (10 min)
- Part 2: Contribution of Red Meat and Animal Foods to Nutrient Adequacy in US Diets and Globally

Red Meat and Sustainability

- Part 3: Agro-ecology: farming in harmony with Nature (5 min)
- Part 4: The effects of sustainable grazing on nutrient density of meat (10 min)

Part 1: Can I eat red meat and be healthy?



Red meat eaters may have a higher risk of dying from these 9 diseases

Annals of Internal Medicine®

Eat Less Red Meat, Scientists Said. Now Some Believe That Was Bad Advice.

The evidence is too weak to justify telling individuals to eat less beef and pork, according to new research. The findings “erode public trust,” critics said.



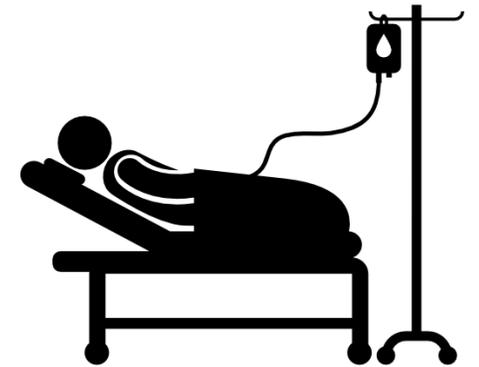
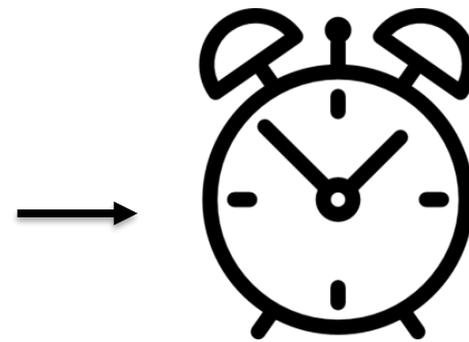
Study explains how red meat raises heart disease risk

Eating meat also altered kidney function, the researchers found.



Red and processed meat are not ok for health, study says, despite news to the contrary

by Sandee LaMotte. CNN



Epidemiological associations”

Red meat and disease risk: diet quality is key

“Healthy Dietary Patterns”

vs

“Standard Western Diet”



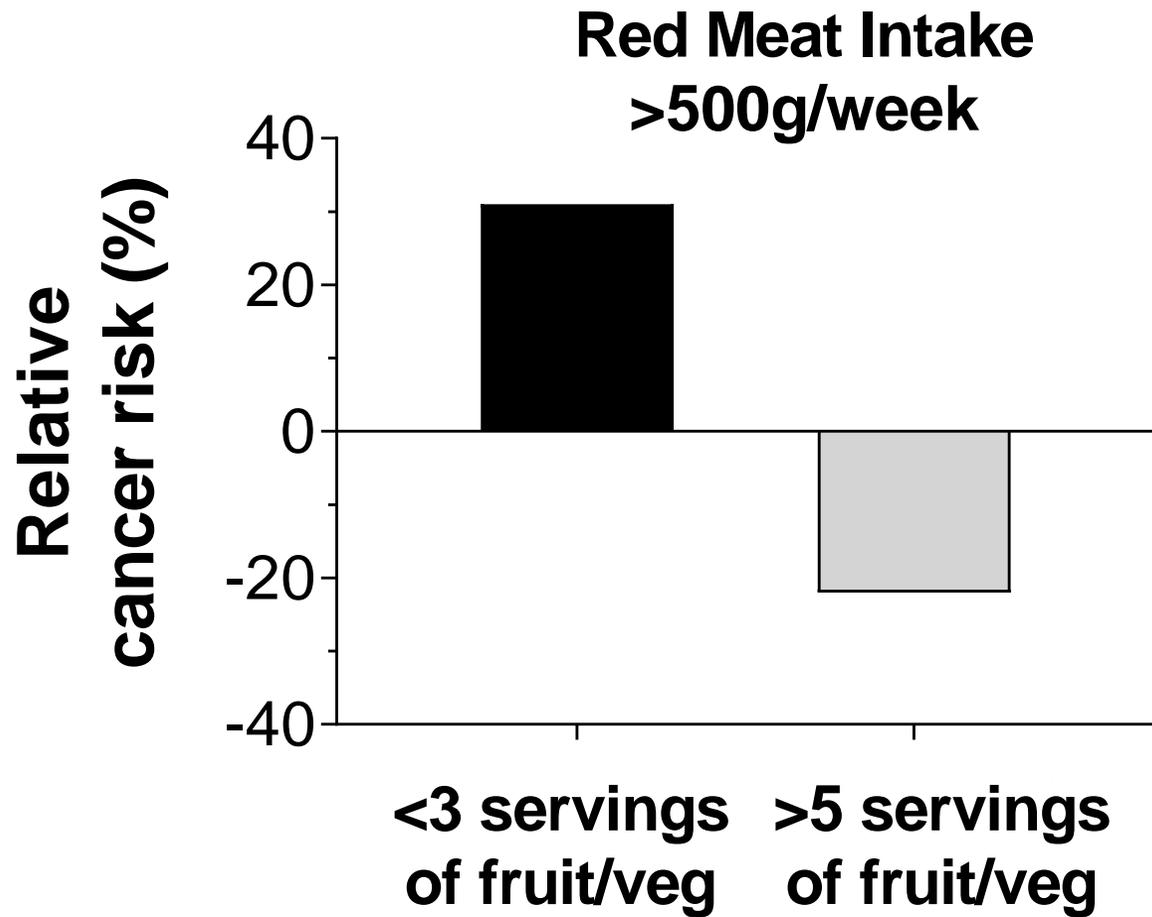
Neutral or protective



Increased risk of heart disease,
cancer, diabetes

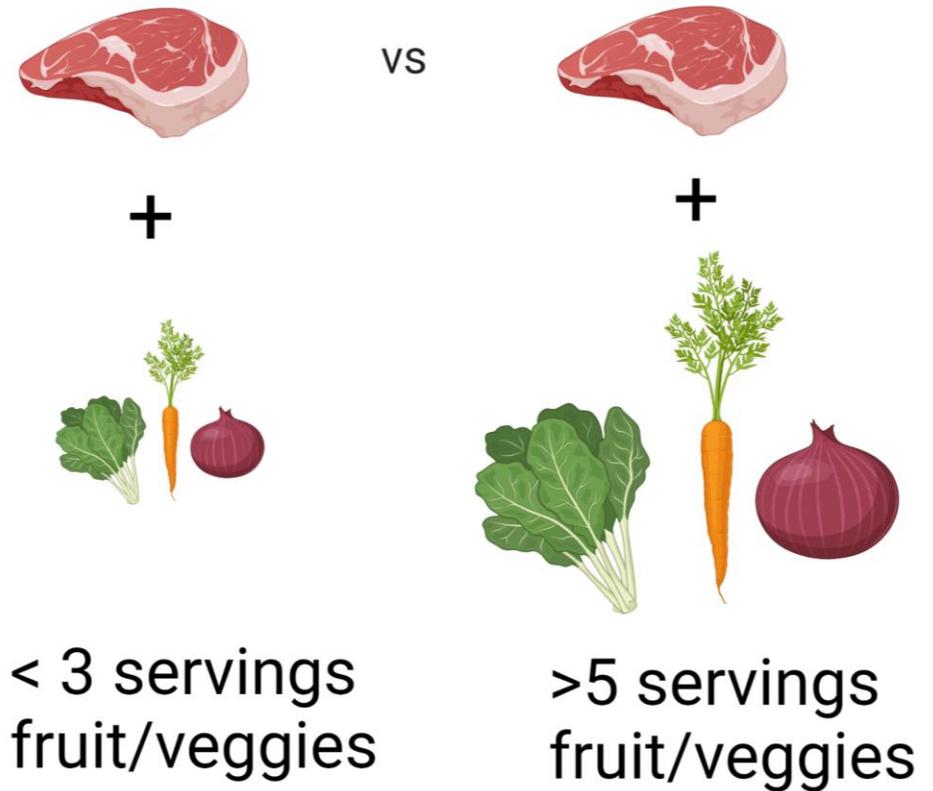
(how most people consume red meat
unfortunately)

Alberta's Tomorrow Project (10,000 Adults)



When consumed as part of high-quality diets, the associations of red meat with disease risk became “protective” (20% less cancer risk).

Equal amounts of red meat with low vs high fruit/veg intake



Maximova et al. Co-consumption of Vegetables and Fruit, Whole Grains, and Fiber Reduces the Cancer Risk of Red and Processed Meat in a Large Prospective Cohort of Adults from Alberta's Tomorrow. *Nutrients*. 2020. doi: <https://doi.org/10.3390/nu12082265>

Women's Health Initiative Study in the US (80,000 Women)

| Cancer site (<i>n</i> = participants with events) | No adjustment for BMI or dietary correlates | | | | With adjustment for BMI and dietary correlates | | | |
|--|---|----------------|----------------------------------|----------------|--|----------------|----------------------------------|----------------|
| | Red meat intake, g/d | <i>P</i> value | Red + processed meat intake, g/d | <i>P</i> value | Red meat intake, g/d | <i>P</i> value | Red + processed meat intake, g/d | <i>P</i> value |
| Breast (5139) | 1.10 (1.07, 1.13) | <0.001 | 1.09 (1.07, 1.12) | <0.001 | 1.03 (0.98, 1.09) | 0.24 | 1.01 (0.96, 1.06) | 0.68 |
| Colon (1060) | 1.12 (1.06, 1.18) | <0.001 | 1.11 (1.05, 1.16) | <0.001 | 1.12 (1.00, 1.26) | 0.06 | 1.11 (0.98, 1.24) | 0.08 |
| Rectum (158) | 1.01 (0.86, 1.17) | 0.94 | 1.02 (0.89, 1.17) | 0.78 | 0.98 (0.72, 1.33) | 0.89 | 1.04 (0.79, 1.37) | 0.79 |
| Endometrium (881) | 1.25 (1.18, 1.33) | <0.001 | 1.24 (1.18, 1.31) | <0.001 | 0.88 (0.77, 1.01) | 0.08 | 0.86 (0.75, 0.98) | 0.03 |
| Ovary (471) | 0.89 (0.81, 0.97) | 0.01 | 0.91 (0.84, 0.98) | 0.02 | 0.75 (0.61, 0.91) | 0.003 | 0.79 (0.67, 0.94) | 0.008 |
| Leukemia (439) | 1.01 (0.92, 1.11) | 0.82 | 1.03 (0.95, 1.11) | 0.50 | 0.89 (0.73, 1.08) | 0.24 | 0.99 (0.83, 1.18) | 0.89 |
| Lung (1426) | 0.98 (0.93, 1.03) | 0.34 | 0.98 (0.94, 1.02) | 0.36 | 0.95 (0.86, 1.05) | 0.33 | 0.96 (0.87, 1.06) | 0.40 |
| Lymphoma (804) | 1.05 (0.98, 1.12) | 0.20 | 1.04 (0.97, 1.10) | 0.27 | 1.08 (0.94, 1.24) | 0.28 | 1.07 (0.94, 1.21) | 0.34 |
| Bladder (166) | 0.93 (0.81, 1.06) | 0.28 | 0.93 (0.83, 1.05) | 0.24 | 0.78 (0.58, 1.06) | 0.12 | 0.71 (0.53, 0.96) | 0.02 |
| Kidney (309) | 1.15 (1.04, 1.27) | 0.006 | 1.19 (1.09, 1.30) | <0.001 | 0.74 (0.58, 0.93) | 0.01 | 0.85 (0.68, 1.06) | 0.15 |
| Pancreas (416) | 1.04 (0.95, 1.15) | 0.36 | 1.04 (0.96, 1.13) | 0.31 | 0.99 (0.82, 1.20) | 0.95 | 1.00 (0.83, 1.20) | 0.97 |
| Obesity related ² (7313) | 1.12 (1.09, 1.14) | <0.001 | 1.11 (1.09, 1.13) | <0.001 | 1.01 (0.96, 1.05) | 0.79 | 1.00 (0.95, 1.04) | 0.83 |
| Total invasive (12,804) | 1.07 (1.05, 1.09) | <0.001 | 1.07 (1.05, 1.08) | <0.001 | 0.98 (0.95, 1.01) | 0.23 | 0.98 (0.95, 1.02) | 0.33 |

“Associations of red meat appear to be almost entirely attributable to the high-fat, high-energy, and high-sodium intake associated with a high-meat dietary pattern, rather than to the meat per se”.

Consuming red meat daily for 4 weeks as part of a healthy diet improved health biomarkers

Healthy “Unprocessed” Diet



Beef Patty (beef, salt, pepper)

Oven Roasted Potatoes (potatoes, olive oil, salt)

Broccoli and Butter (broccoli, butter)

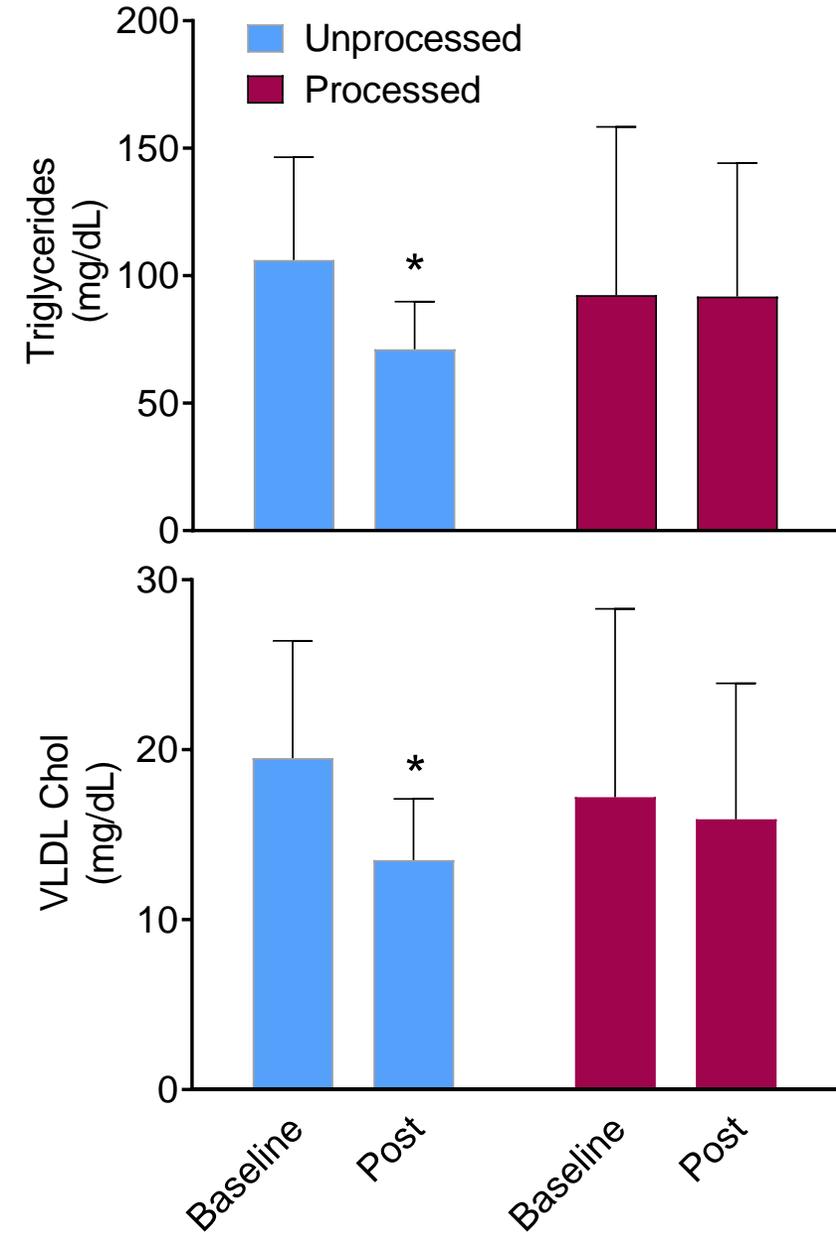
Standard Western “Processed” Diet



Beef Patty (beef, salt, pepper)

Great Value Fries (potatoes, vegetable oil [canola, soybean, cottonseed, sunflower, or corn]. Contains 2% or less of annatto extract [color], caramel color, salt, sodium acid pyrophosphate to maintain color.

Green Giant® Broccoli & Butter Sauce (Broccoli, Water, Butter [Cream, Natural Flavor], Sugar, Salt, Modified Corn Starch, Xanthan Gum, Natural Flavor, Annatto and Paprika Extract [Color].



Red meat important for aging and growth



cite as: *J Gerontol A Biol Sci Med Sci*, 2022, Vol. XX, No. XX, 1–7
<https://doi.org/10.1093/gerona/glab334>
Advance Access publication November 27, 2021

OXFORD

Research Report

Animal Protein Intake Is Inversely Associated With Mortality in Older Adults: The InCHIANTI Study

Tomás Meroño, PhD,^{1,2,•} Raúl Zamora-Ros, PhD,^{1,3,*} Nicole Hidalgo-Liberona, PhD,^{1,2,•} Montserrat Rabassa, PhD,¹ Stefania Bandinelli, MD,⁴ Luigi Ferrucci, MD,

REVIEW ARTICLE

Maternal & Child Nutrition WILEY

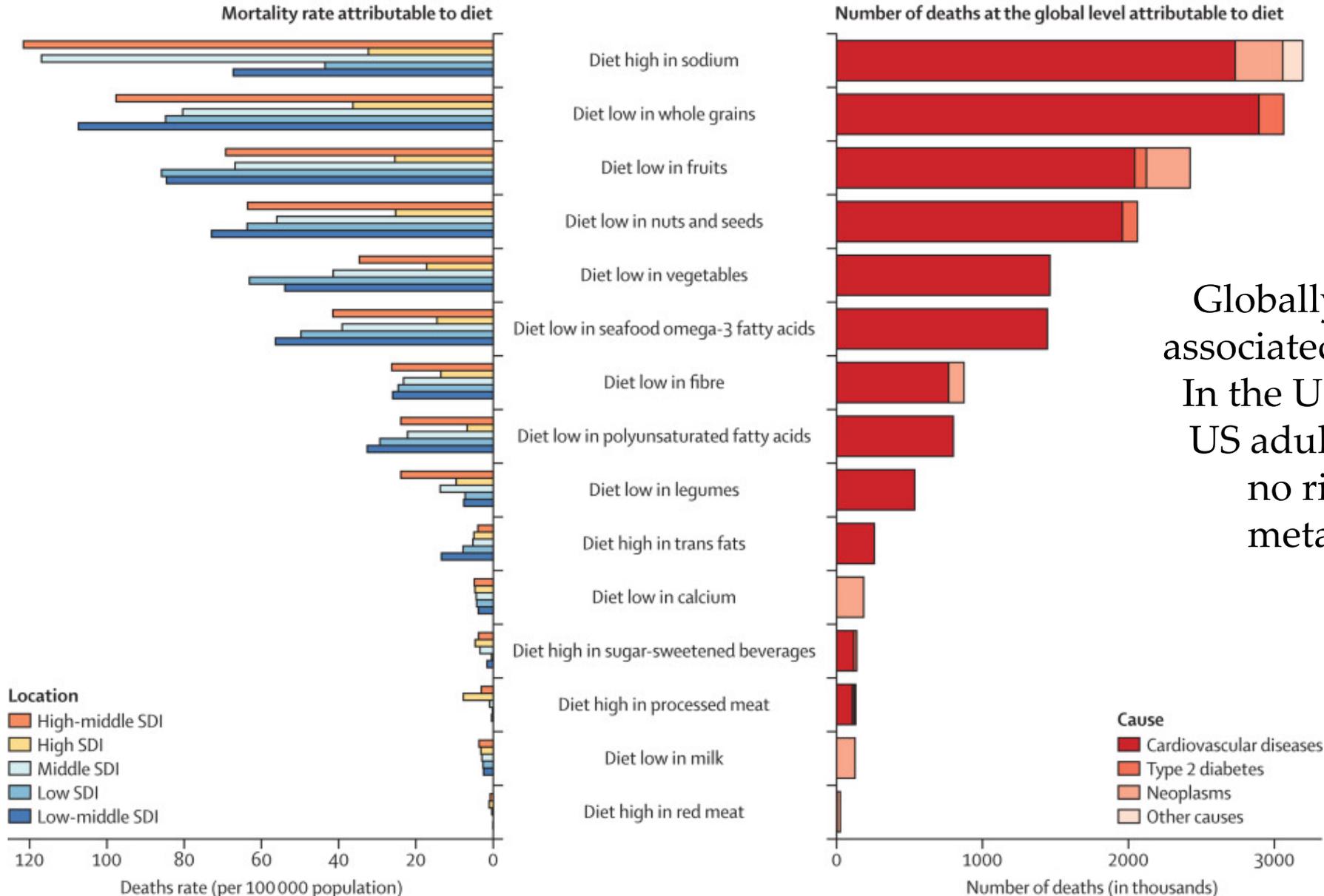
Animal source foods, rich in essential amino acids, are important for linear growth and development of young children in low- and middle-income countries

Key point: Consuming animal foods and red meat as part of traditional whole foods diets rather than highly processed Western Diets.

Part 2: Contribution of animal sourced foods to nutrient adequacy in US diets and globally (10 min)



Global burden of metabolic disease



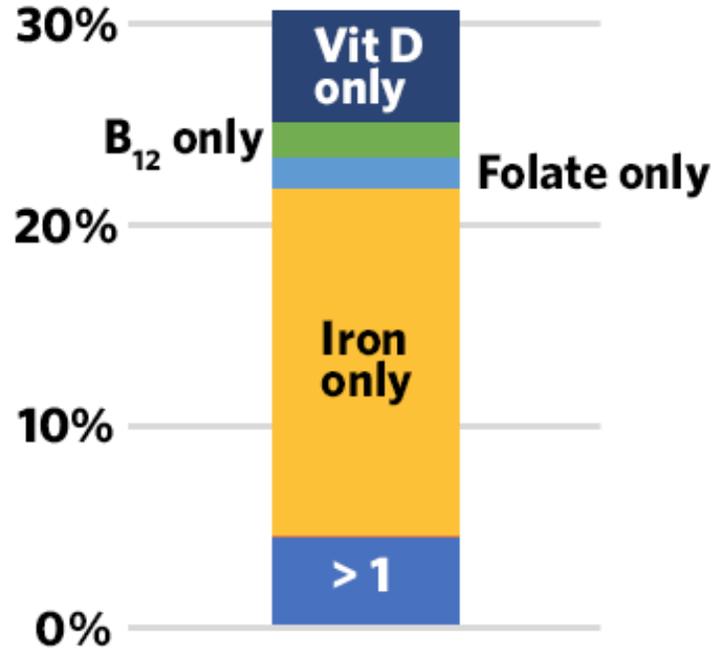
Globally 1 in 5 deaths is associated with poor diet...
In the US, only 10-30% of US adults are “healthy”:
no risk factors for metabolic disease

Global Burden of Disease (GBD) Study. *The Lancet*. 2018. doi:

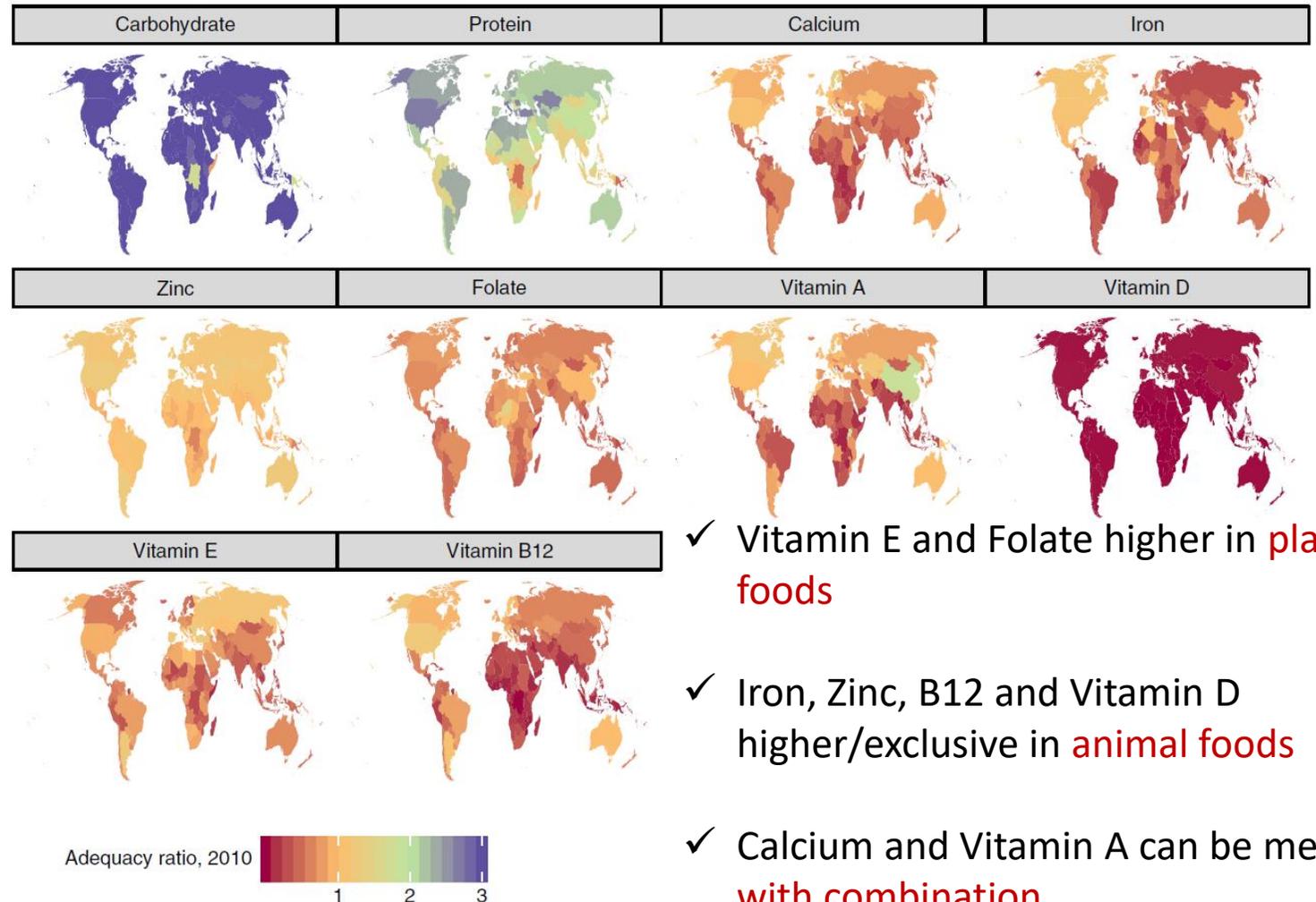
[https://doi.org/10.1016/S0140-6736\(18\)32225-6](https://doi.org/10.1016/S0140-6736(18)32225-6)

Not just a problem of low-to-middle income countries....

Micronutrient deficiency among US women aged 15-49y



> 30% of women in the US has at least one micronutrient deficiency, with iron deficiency being most common (21%).

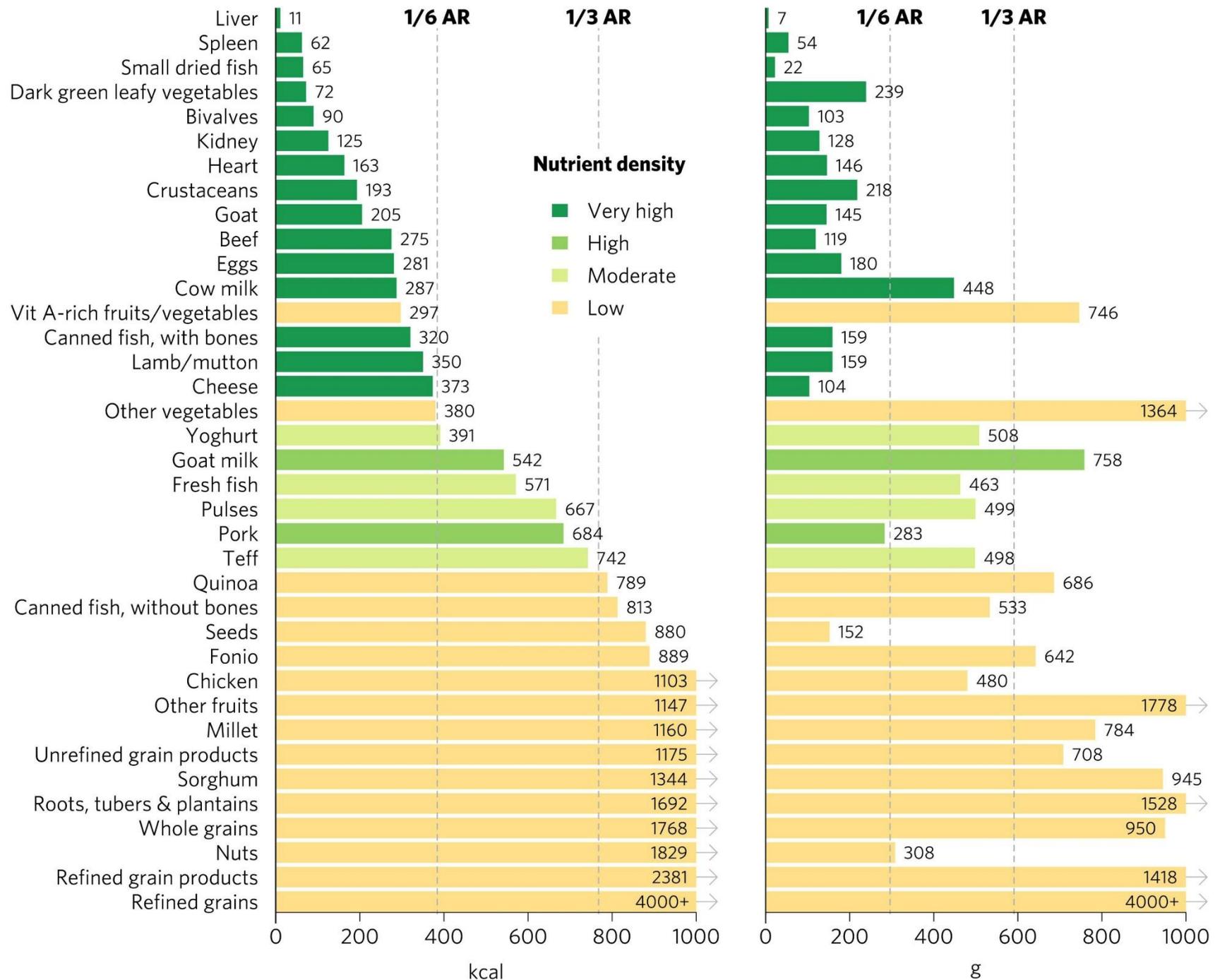


- ✓ Vitamin E and Folate higher in **plant foods**
- ✓ Iron, Zinc, B12 and Vitamin D higher/exclusive in **animal foods**
- ✓ Calcium and Vitamin A can be met **with combination**
- ✓ Synergy in animal and plant foods: **complementary contributions**

Top sources of commonly lacking nutrients in diets worldwide: Vitamin A, B12, calcium, iron, and zinc:

- ✓ Animal sourced foods
- ✓ Green leafy vegetables
- ✓ Vitamin-A rich fruits/vegetables

T. Beal and F. Ortenzi. Priority Micronutrient Density in Foods. *J. Animal Sci.* 2021. doi: <https://doi.org/10.1016/j.animal.2021.100285>



A metabolomics comparison of meat and plant based meats: beyond “protein”



Article | [Open Access](#) | [Published: 05 July 2021](#)

A metabolomics comparison of plant-based meat and grass-fed meat indicates large nutritional differences despite comparable Nutrition Facts panels

[Stephan van Vliet](#) , [James R. Bain](#), [Michael J. Muehlbauer](#), [Frederick D. Provenza](#), [Scott L. Kronberg](#), [Carl F. Pieper](#) & [Kim M. Huffman](#)

[Scientific Reports](#) **11**, Article number: 13828 (2021) | [Cite this article](#)

50k Accesses | **17** Citations | **1279** Altmetric | [Metrics](#)

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References

Nutrition Labels: Nutritionally Equivalent?

- “>50% of consumers view beef and plant-based meat alternatives as nutritionally interchangeable” (International Found Council, 2020).
- Novel plant-based meat alternatives are marketed as direct nutritional replacements for red meat.

“they’re designed to meet, if not exceed, the nutritional profile of their animal protein equivalents” (CEO of popular meat alternative company).



Similar Nutrition Labels = Nutritionally Equivalent?

Ground Beef

| Nutrition Facts | |
|------------------------------|------------|
| Serving size | (113g) |
| Amount Per Serving | |
| Calories | 220 |
| % Daily Value* | |
| Total Fat 14g | 18% |
| Saturated Fat 5g | 25% |
| <i>Trans</i> Fat 0g | |
| Cholesterol 60mg | 20% |
| Sodium 70mg | 3% |
| Total Carbohydrate 0g | 0% |
| Dietary Fiber 0g | 0% |
| Total Sugars 0g | |
| Includes 0g Added Sugars | 0% |
| Protein 23g | 46% |
| Vitamin D 0.1mcg | 0% |
| Calcium 12mg | 0% |
| Iron 2mg | 10% |
| Potassium 289mg | 6% |
| Thiamin 0.05mg | 4% |
| Riboflavin 0.2mg | 15% |
| Niacin 4.8mg | 30% |
| Vitamin B6 0.4mg | 25% |
| Folate 6mcg | 2% |
| Vitamin B12 2mcg | 80% |
| Phosphorus 175mg | 15% |
| Zinc 4.6mg | 40% |

*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

One is a beef burger
the other one is a plant-
based alternative

Which is which?

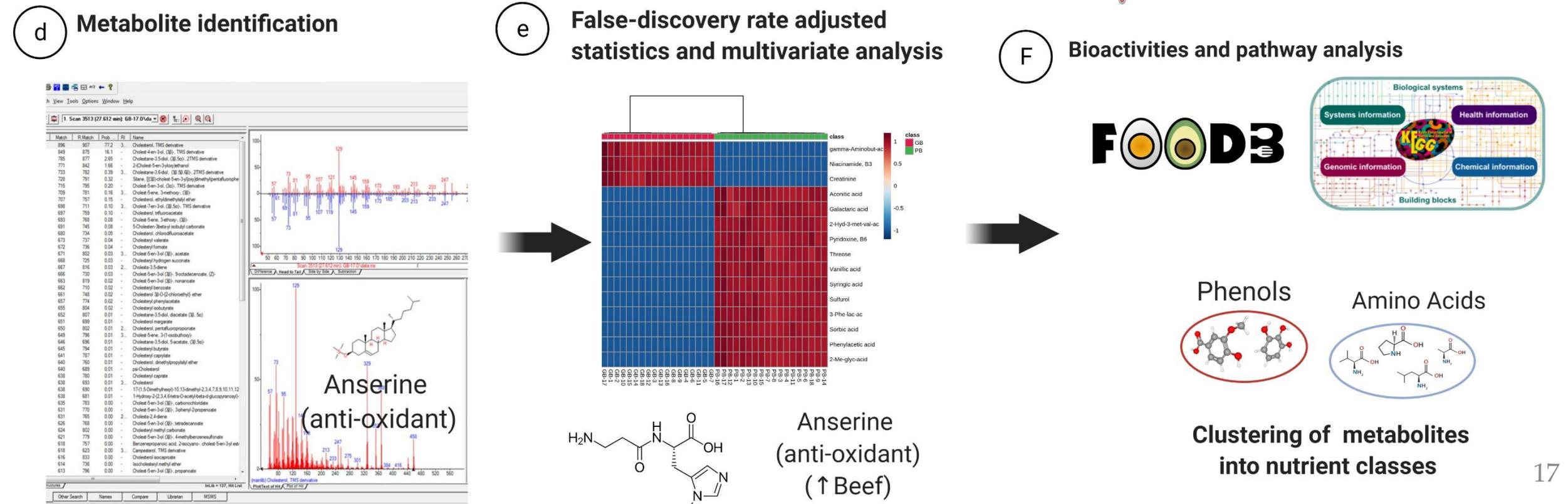
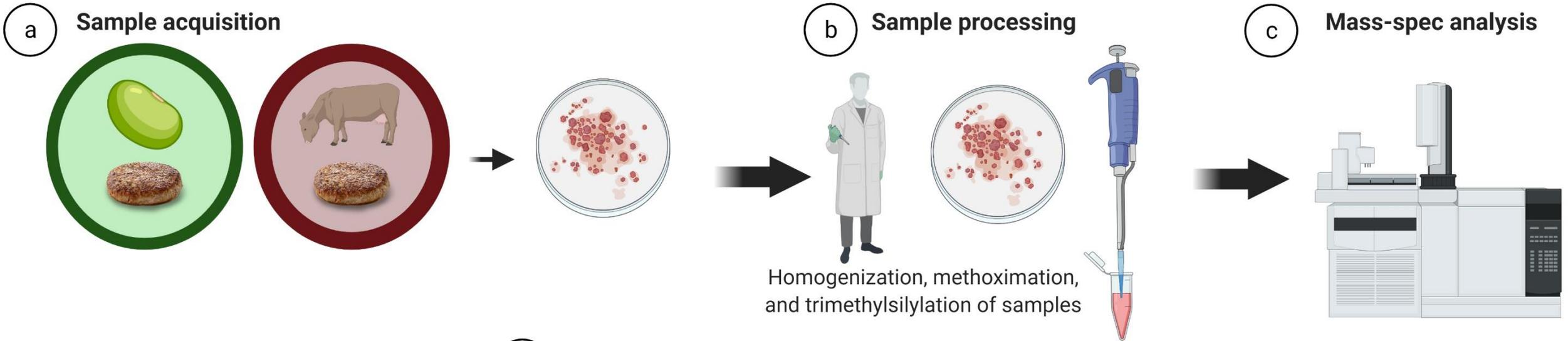


Plant Alternative

| Nutrition Facts | |
|------------------------------|------------|
| Serving size | (113g) |
| Amount Per Serving | |
| Calories | 250 |
| % Daily Value* | |
| Total Fat 14g | 18% |
| Saturated Fat 8g | 40% |
| <i>Trans</i> Fat 0g | |
| Cholesterol 0mg | 0% |
| Sodium 370mg | 16% |
| Total Carbohydrate 9g | 3% |
| Dietary Fiber 3g | 11% |
| Total Sugars 0g | |
| Includes 0g Added Sugars | 0% |
| Protein 19g | 38% |
| Vitamin D 0mcg | 0% |
| Calcium 180mg | 15% |
| Iron 4.2mg | 25% |
| Potassium 610mg | 15% |
| Thiamin 28.2mg | 2350% |
| Riboflavin 0.4mg | 30% |
| Niacin 4.8mg | 30% |
| Vitamin B6 0.4mg | 25% |
| Folate 115mcg | 30% |
| Vitamin B12 3mcg | 120% |
| Phosphorus 180mg | 15% |
| Zinc 5.5mg | 50% |

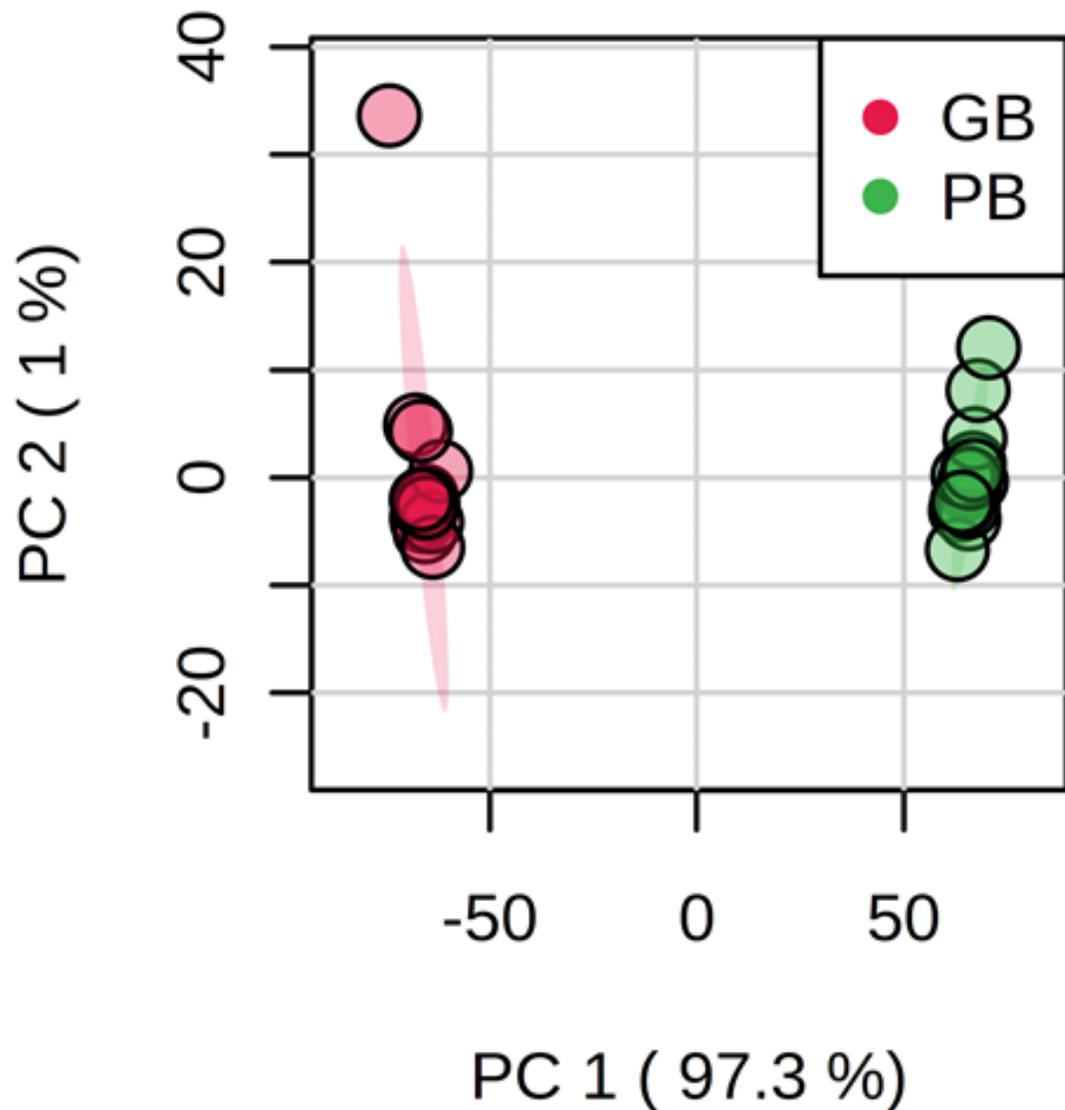
*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Study Workflow



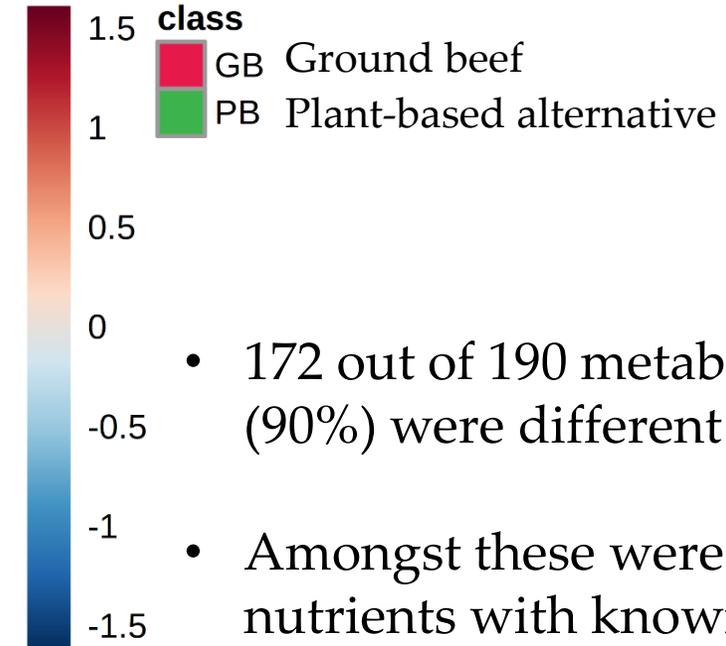
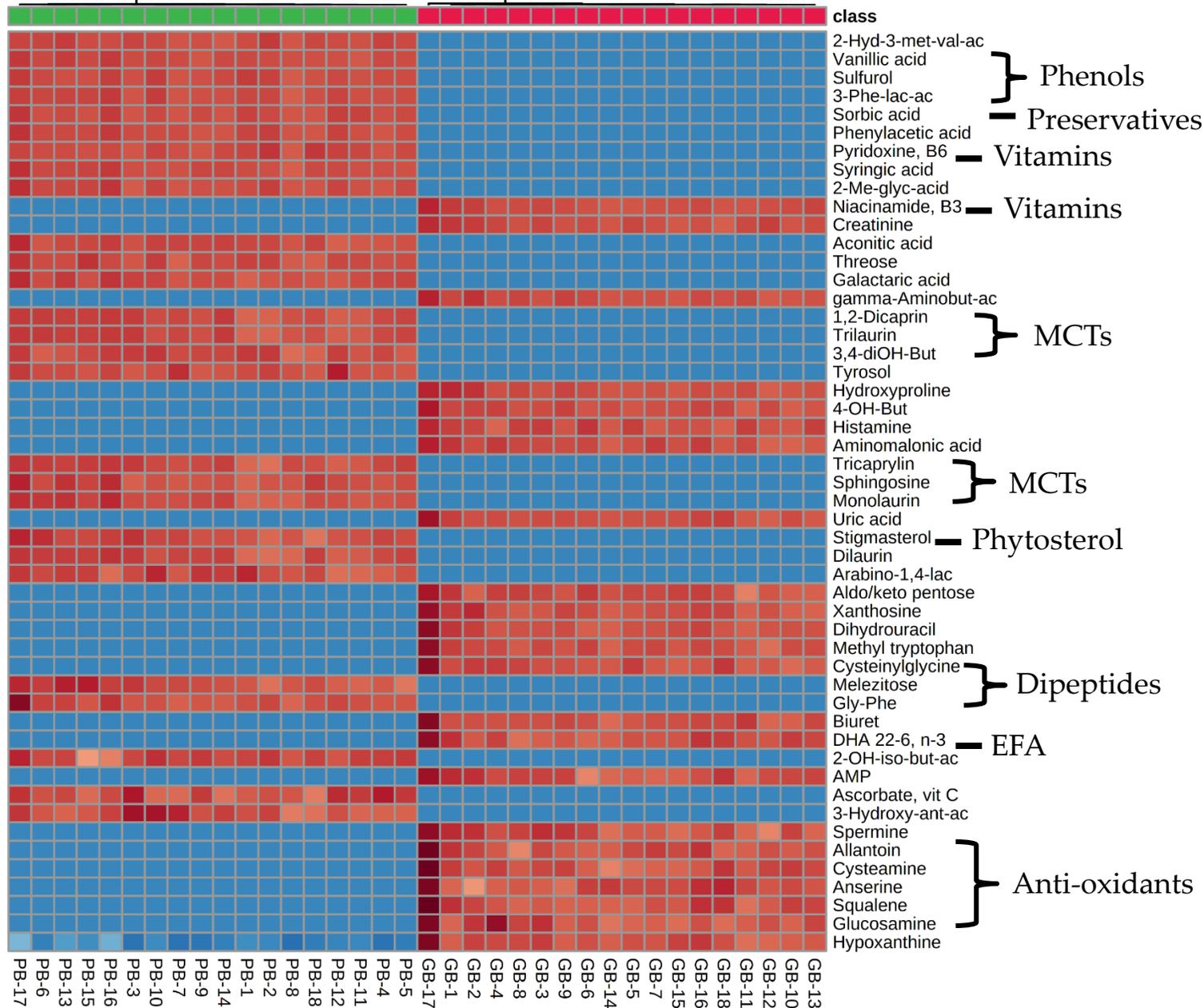
Principal Component Analysis

Scores Plot



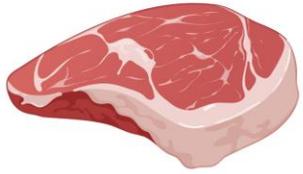
- GB= Ground Beef
PB = Plant-based meat
(n =18 for each group).
- Lack of overlap illustrates that substantial metabolite differences exist between beef and the plant-based meat.
- Not nutritionally interchangeable.

Heatmap



- 172 out of 190 metabolites (90%) were different ($P < 0.05$)
- Amongst these were various nutrients with known health effects (phenols, vitamins, antioxidants etc.)
- Blue=lower abundance
- Red=higher abundance

Beyond protein and vitamins

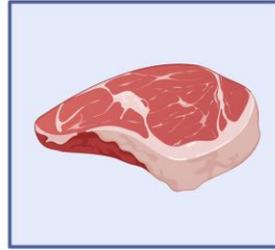


Protein, vitamins, minerals, saturated fat

| Nutrition Facts | |
|------------------------------|------------|
| Serving size | (112g) |
| Amount Per Serving | |
| Calories | 140 |
| % Daily Value* | |
| Total Fat 4.5g | 6% |
| Saturated Fat 2g | 10% |
| Trans Fat 0g | |
| Cholesterol 65mg | 22% |
| Sodium 20mg | 1% |
| Total Carbohydrate 0g | 0% |
| Dietary Fiber 0g | 0% |
| Total Sugars 0g | |
| Includes 0g Added Sugars | 0% |
| Protein 24g | 48% |
| Vitamin D 0.2mcg | 0% |
| Calcium 13mg | 0% |
| Iron 2.7mg | 15% |
| Potassium 329mg | 8% |
| Riboflavin | 10% |
| Vitamin B6 | 20% |
| Vitamin B12 | 40% |
| Zinc | 40% |

*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Beef Metabolome



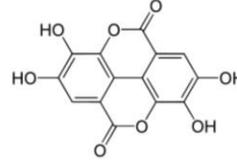
Food labels contain **<13 nutrients**; USDA Database tracks **150 components**.

These form the basis of our "nutritional understanding" and dietary guidelines/policies.



Food matrix contain **>10,000s metabolites** potentially capable of impacting human health (Their importance should not be ignored!)

Metabolites in meat/animal foods (estimated 40,000 compounds in beef)



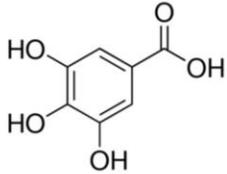
Anserine
Dipeptide, anti-oxidant, brain protective

Taurine
Amino acid, heart health, eye health, found in every cell in body

DHA, DPA, and EPA (Omega 3 fats)
Anti-inflammatory, anti-oxidant, neuro-protective, cardiovascular protective

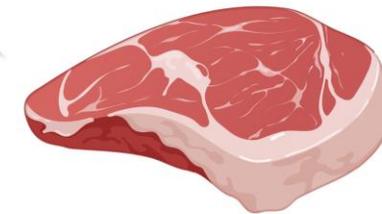
Creatine
Dipeptide, muscle health, brain health

Hydroxyproline
Important for connective tissue and collagen synthesis blood cells



Cysteamine
Anti-inflammatory, neuroprotective, and liver protective

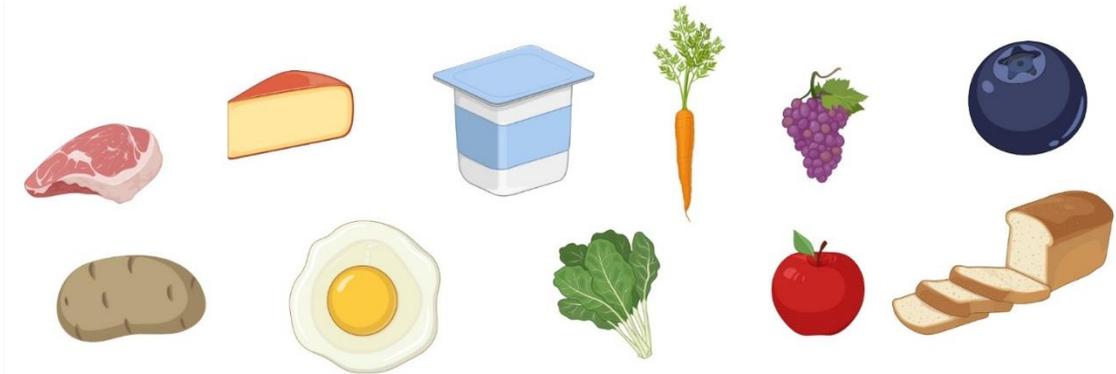
Phytochemicals
Unique medicinal plant compounds otherwise not consumed by humans



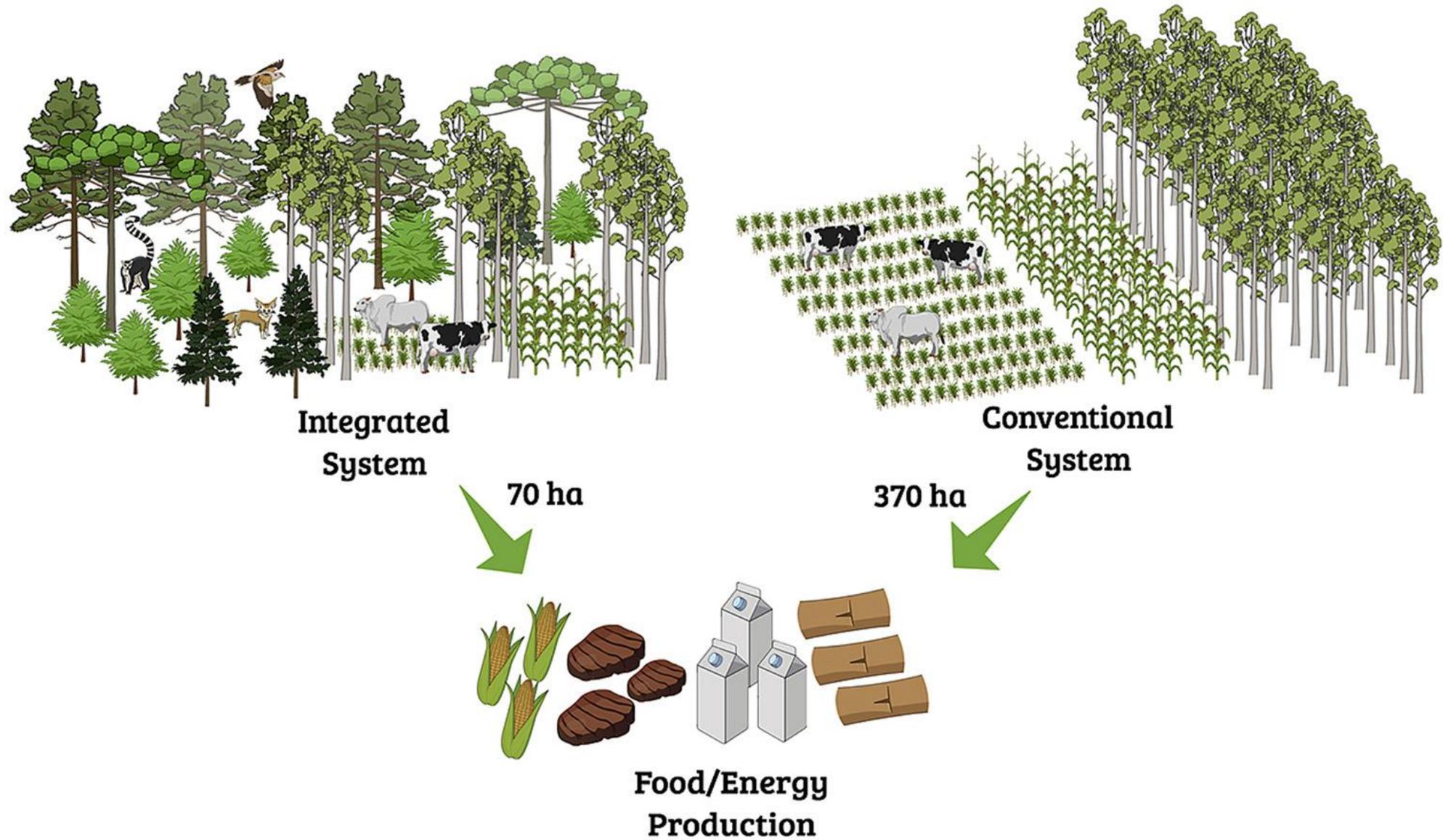
We do not eat nutrients, we eat foods. Food is more than the sum of nutrients.

Conclusions so far...

- Novel plant-based meat alternatives could perhaps be treated as meat alternatives in terms of sensory experience, but not as true meat replacements in terms of nutrition.
- Animal sourced foods are the only dietary source of retinol (Vitamin A), heme iron, Vitamin B12, and Vitamin D.
- Unique compounds with known health benefits in animal foods including DHA (omega-3), EPA (omega-3), anserine, creatine, cysteamine, taurine, CLA, and various bioactive peptides.
- Plant sources richer in Vitamin C, folate, manganese, thiamin, potassium, vitamin E, and phytochemicals.
- Together, plant and animal foods can synergistically contribute to nutrient adequacy as they contain complementary nutrients!



Part 3: Agro-ecology: farming in harmony with Nature (10 min)



Monoculture vs biodiversity: Creating landscapes that work for Nature

“Nature has introduced incredible biodiversity into ecosystems yet humans continue to simplify production to single species of crops or animals in separate production systems that require considerable external inputs and harm biodiversity”.

S.K Kronberg, S. van Vliet et al. Closing nutrient cycles for animal production – Current and future agroecological and socio-economic issues. *J. Animal Sci.* 2021. doi: <https://doi.org/10.1016/j.animal.2021.100285>



Monoculture: single crop or animal farming requiring considerable inputs (fertilizer, pesticides, mechanical disruption)



Biodiverse “regenerative farm” that produces multiple crops + livestock products

Productivity and sustainability

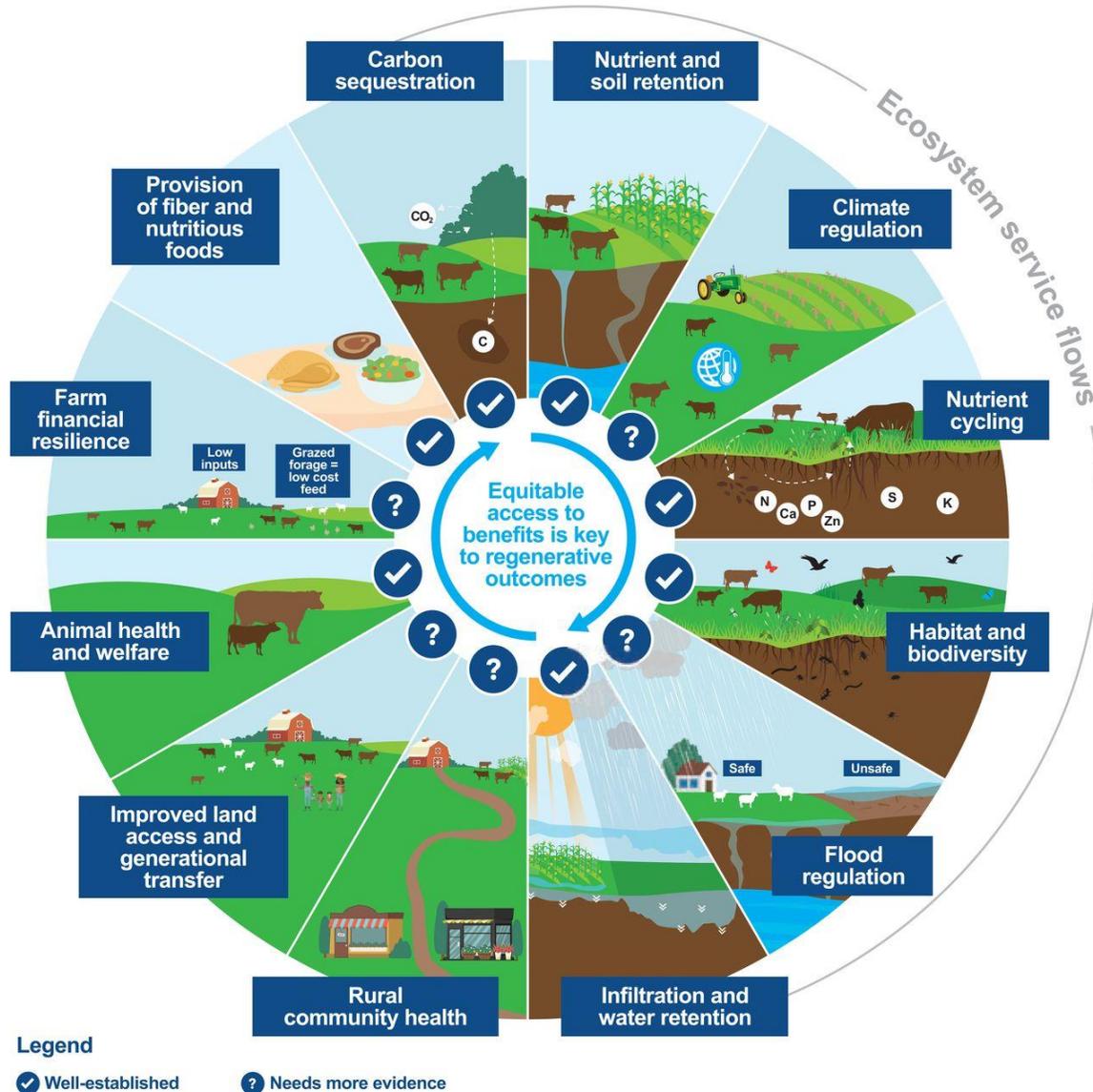
“Simplified systems may be productive in the short run, but they make it difficult for farming systems to recycle nutrients and be sustainable in the long-run”.

Five principles for sustainable food and agriculture (FAO, 2019):

- (1) Improving efficiency in the use of resources;
- (2) Conserving, protecting, and enhancing natural ecosystems;
- (3) Protecting and improving rural livelihoods, equity, and social well-being;
- (4) Enhancing the resilience of people, communities and ecosystems;
- (5) Promoting good governance of both natural and human systems



Agro-ecological systems: linking plant, animal, and human health



- ✓ Regularly move animals to mimic predation-migratory patterns
- ✓ DO NOT OVERGRAZE (leave 30-50% vegetation)
- ✓ Limit chemical, physical, and biological disturbance
- ✓ Add diversity of plants to provide wildlife habitat for birds, insects, and other mammals
- ✓ Keep the soil covered

Plant-Based Meats, Human Health, and Climate Change



Stephan van Vliet^{1*}



Scott L. Kronberg² and

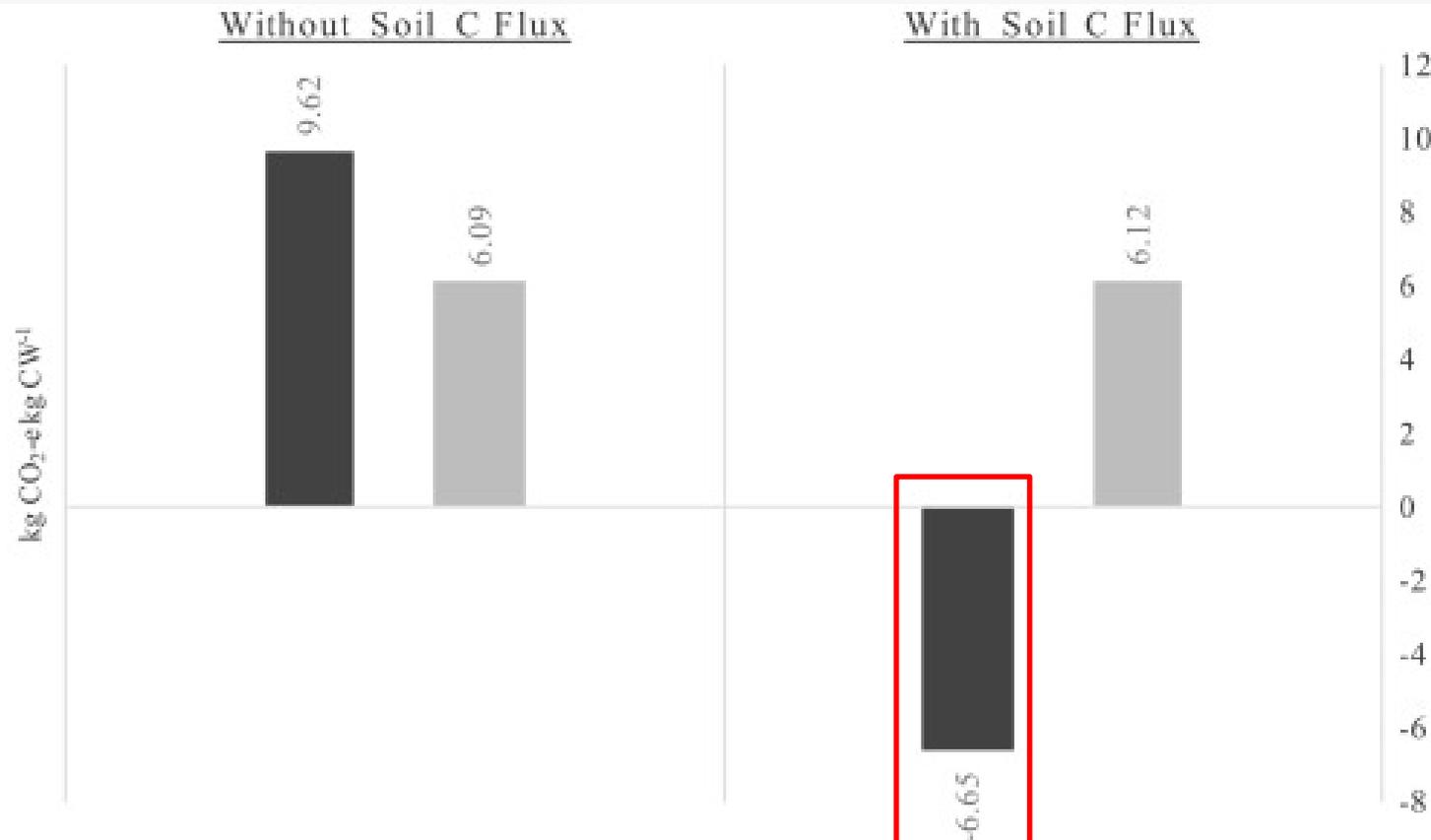


Frederick D. Provenza³

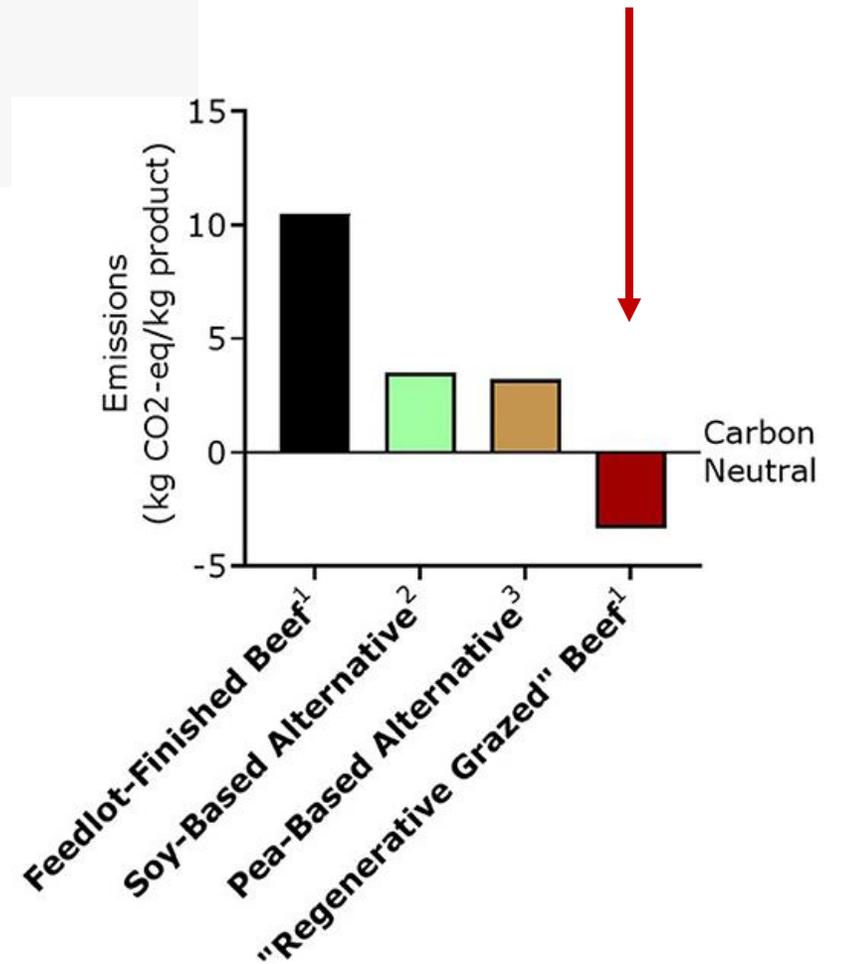
¹ Duke Molecular Physiology Institute, Duke University Medical Center, Durham, NC, United States

² Northern Great Plains Research Laboratory, USDA-Agricultural Research Service, Mandan, ND, United States

³ Department of Wildland Resources, Utah State University, Logan, UT, United States



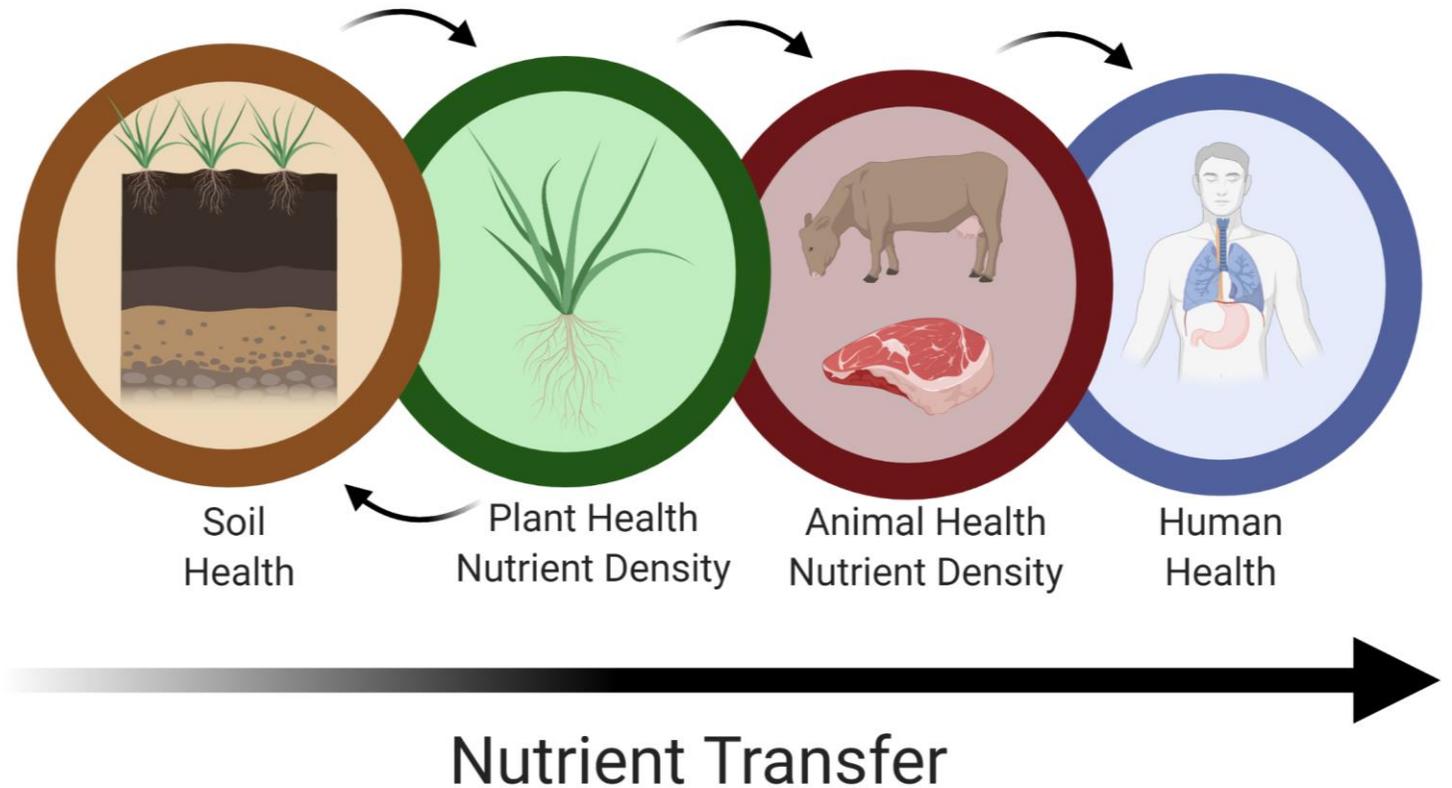
Considering carbon sequestration in soil



Part 4: The impact of grazing practices on nutrient density and animal health in North American ruminants

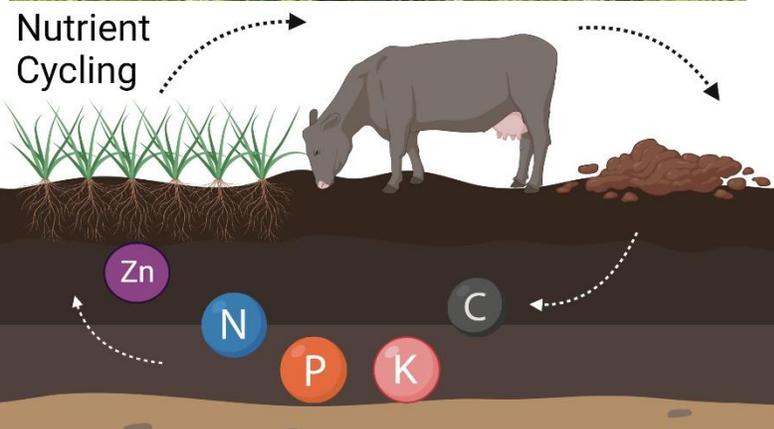


Linking livestock systems and human health: From farm to table to us!

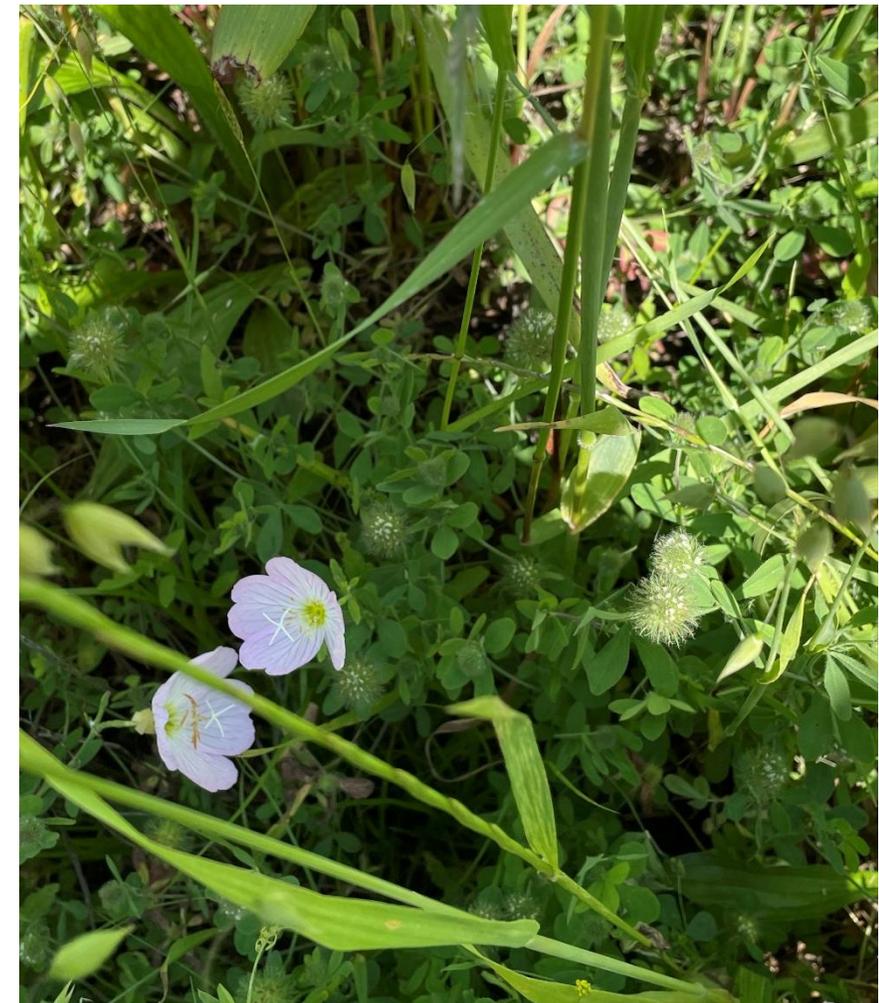


Healthy soils, healthy plants,
healthy animals, healthy humans?

Sample collection... Soil samples



Monoculture corn field
(used for livestock feed)



Biodiverse pasture

~ 1 mile apart

Sample collection.... Plant samples

Grain Sample
(Feedlot-finished)



Pasture Sample
(Grass-fed/finished)



Meat samples

Grain-Finished

Biodiverse Pasture-Finished

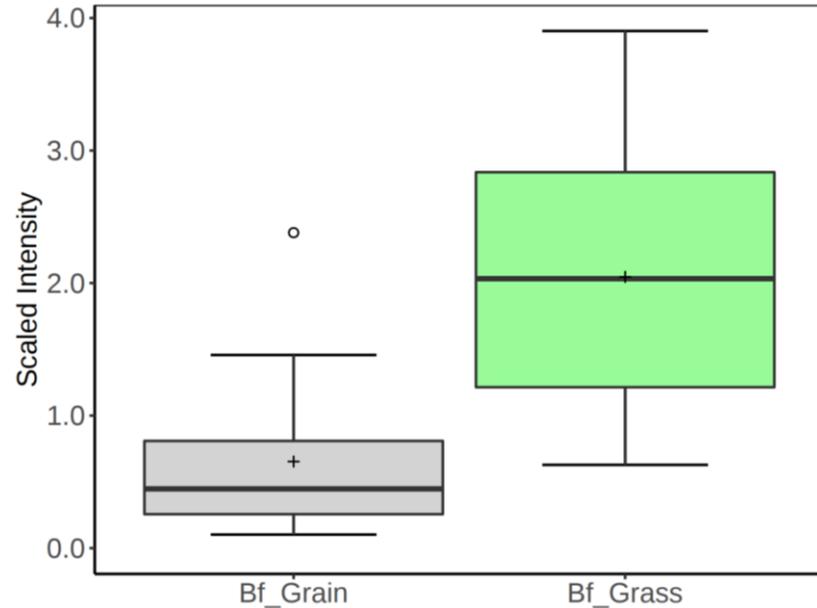
GRAZE
Grain-Briske.
4-10-21

GRAZE
Grass-Glenn
4-10-21

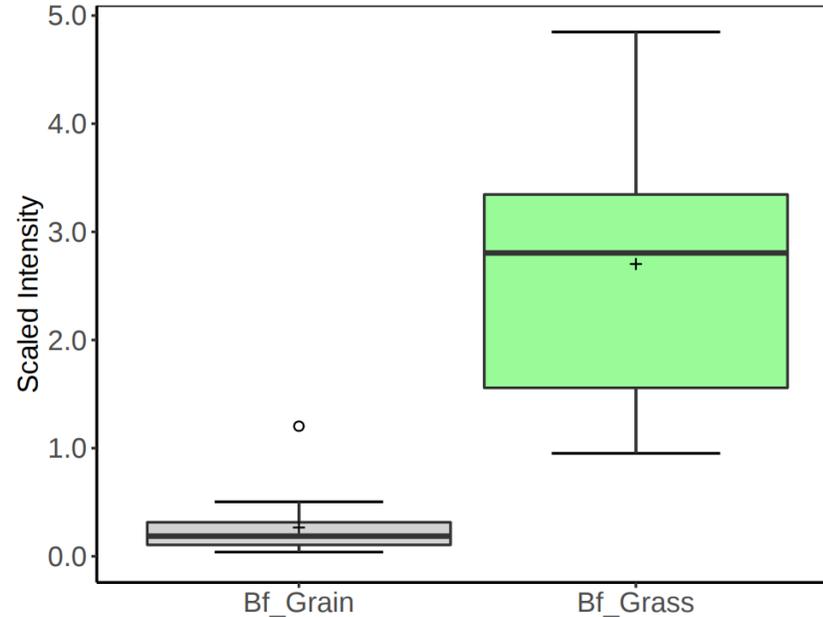


Omega-3s are enriched in biodiverse grass-fed beef

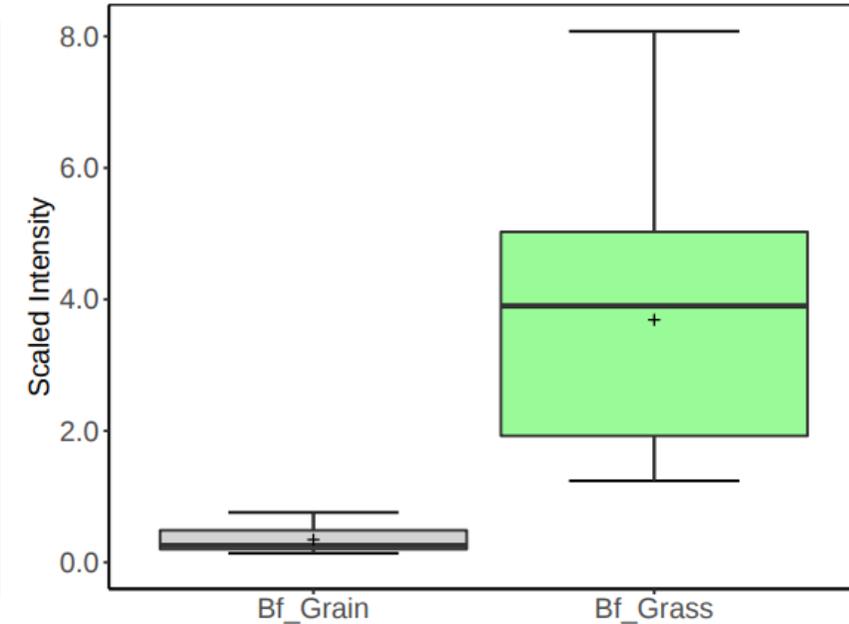
docosahexaenoate (DHA; 22:6n3)
Beef: HD4



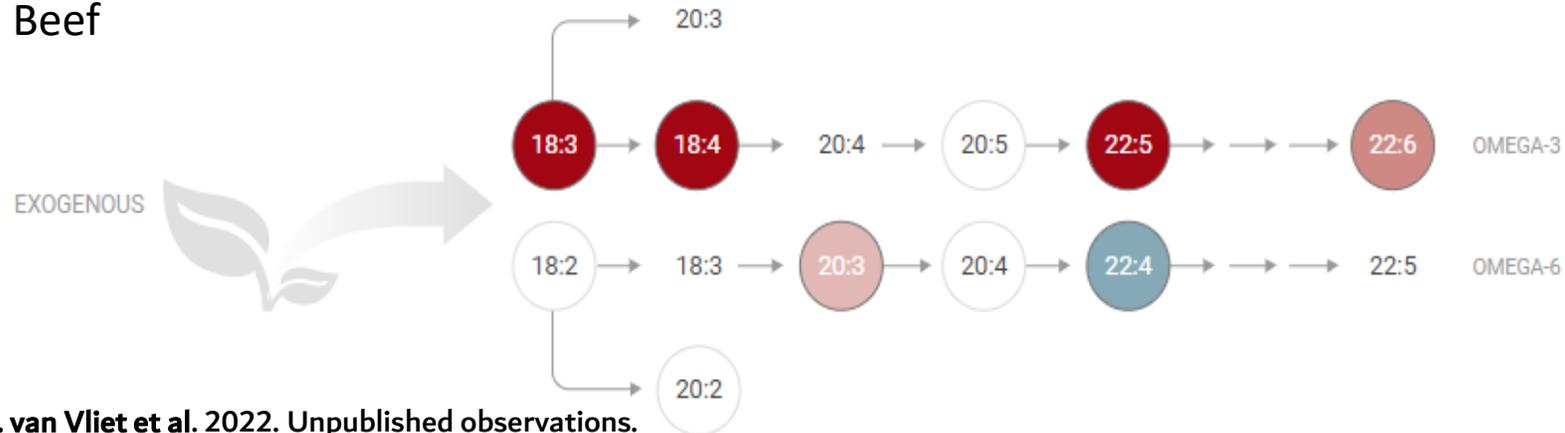
eicosapentaenoate (EPA; 20:5n3)
Beef: HD4



linolenate (18:3n3 or 3n6)
Beef: HD4



Beef

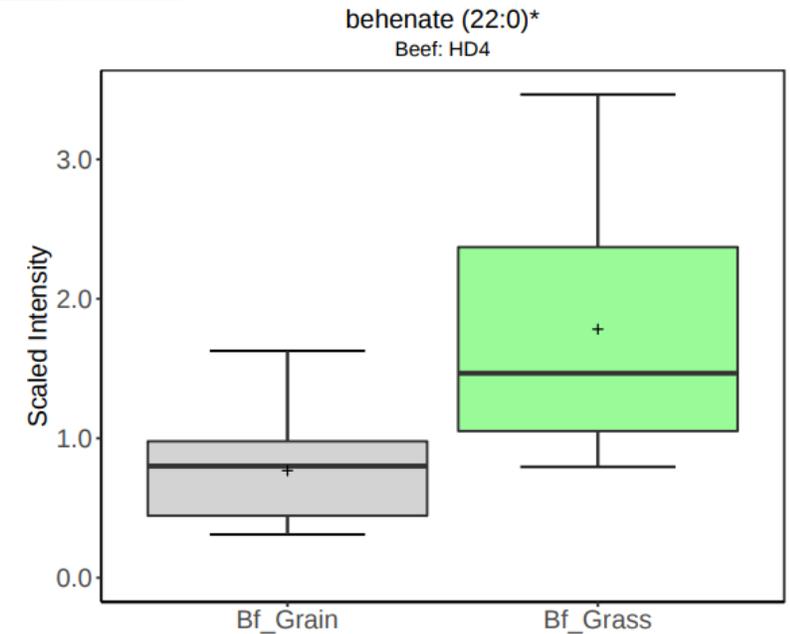
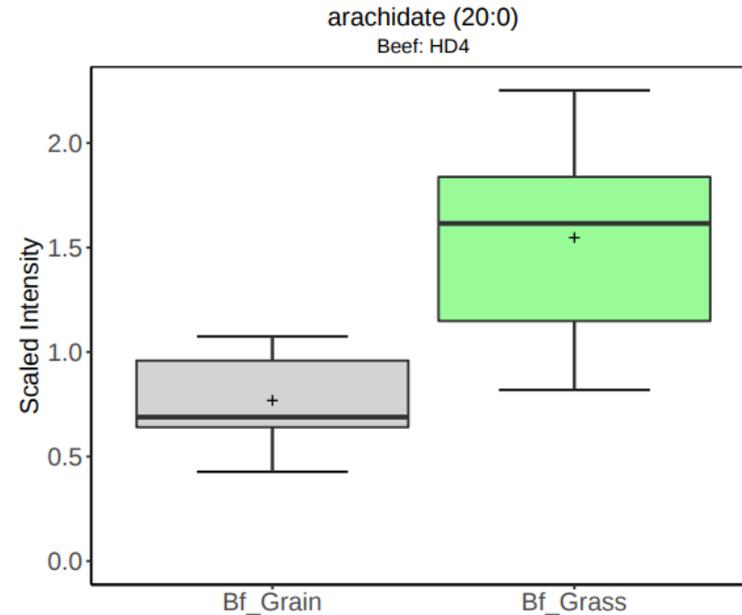
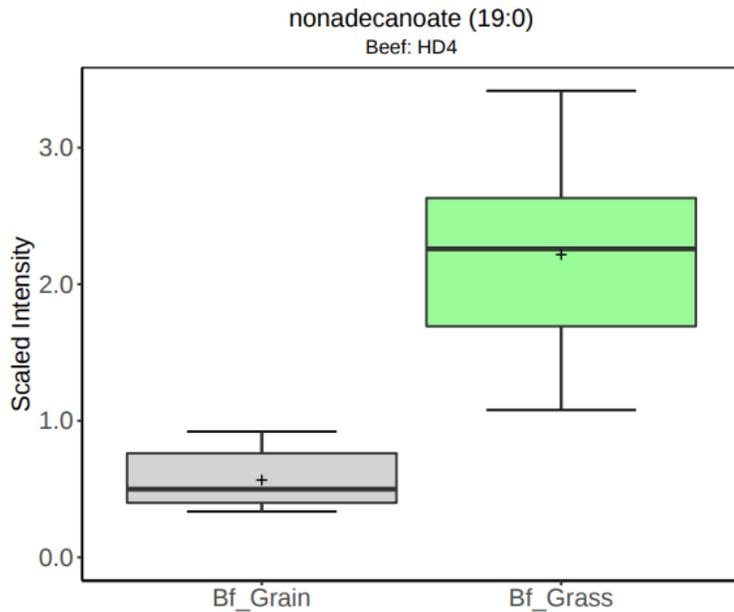


Docosahexanoic acid (DHA), Eicosapentaenoic acid (EPA) and Linolenic acid (ALA) are omega-3 fats.

They may help lower the risk of getting heart disease, cancer, and liver diseases and could help improve brain function.

DHA, EPA, and ALA were 3-, 10-, and 10-fold higher in grass-fed beef.

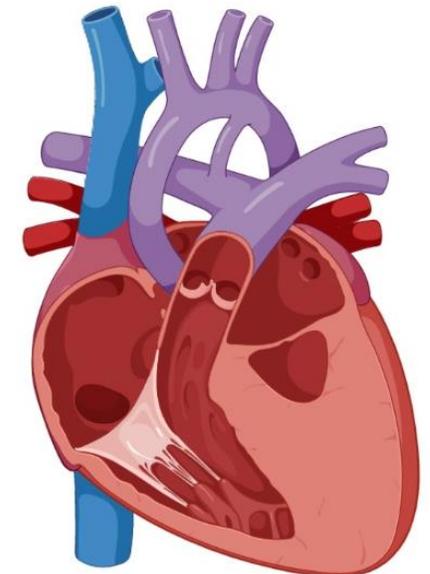
Healthier saturated fatty acids



Similar to the long-chain polyunsaturated (omega-3) fatty acids, very long-chain saturated fatty acids also became enriched in grass-fed beef.

These long-chain saturated fats are associated with a decreased risk of heart disease.

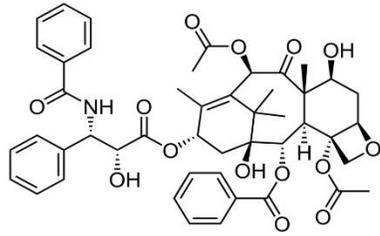
Beef isn't beef isn't beef; how you raise the animal matters!



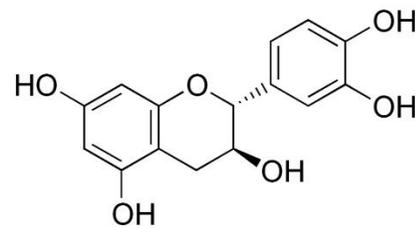
Phytochemicals (plant-produced metabolites) and health



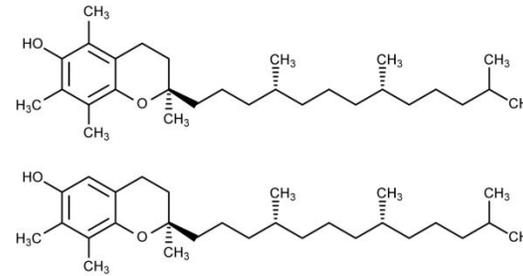
Plants respond biochemically to sunlight, moisture, nutrients, other plants, and herbivores by producing phytochemicals (10,000-100,000s)



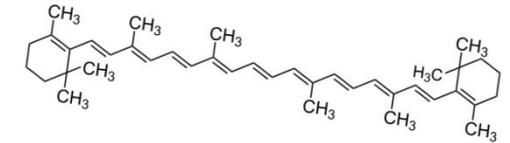
Terpenes



Phenols



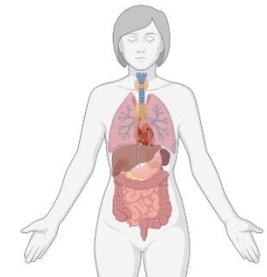
Tocopherols



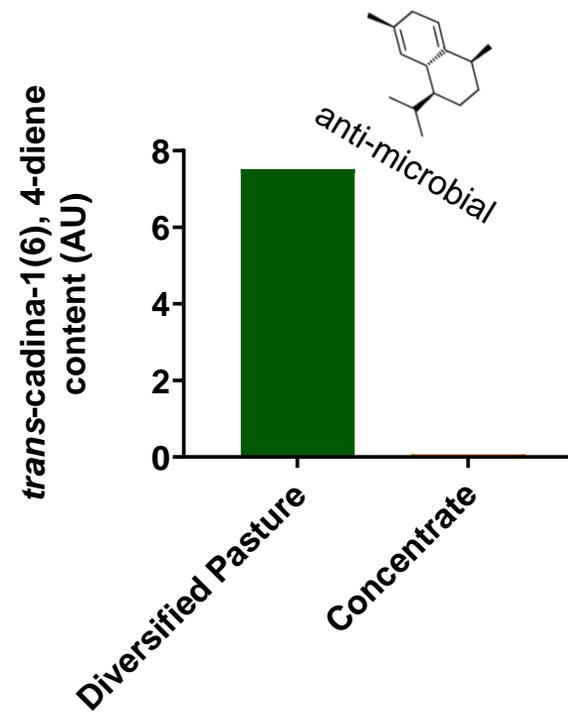
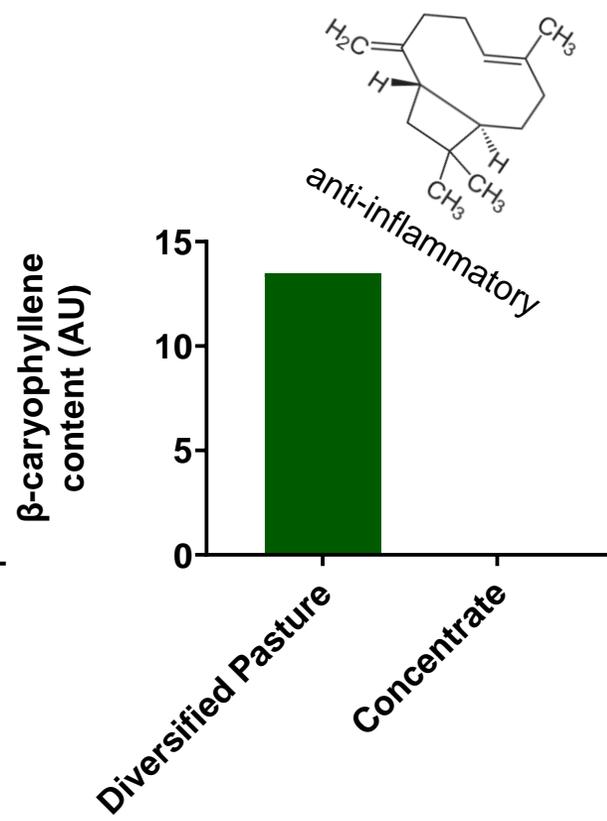
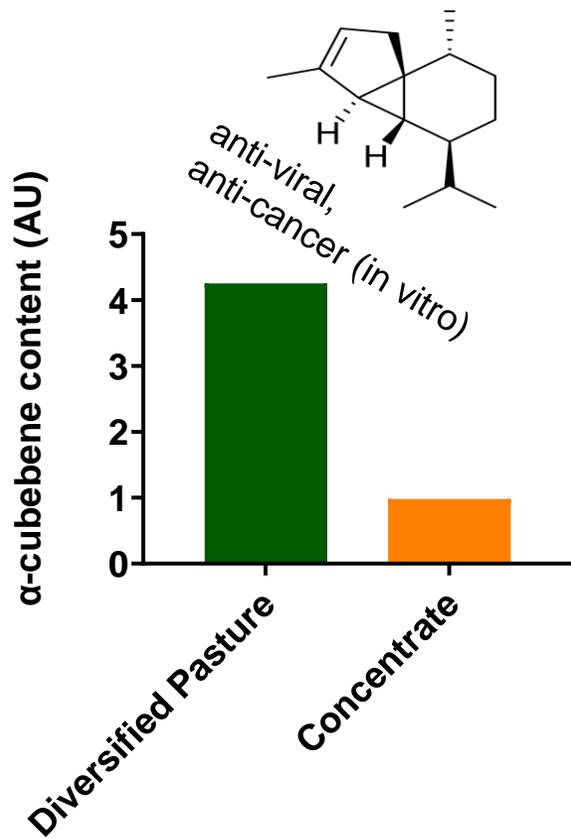
Carotenoids



Phytochemicals: potentially anti-inflammatory, anti-bacterial, anti-oxidant, brain-protective etc.

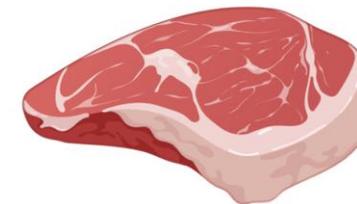


Pasture grazing accumulates phytochemicals in meat

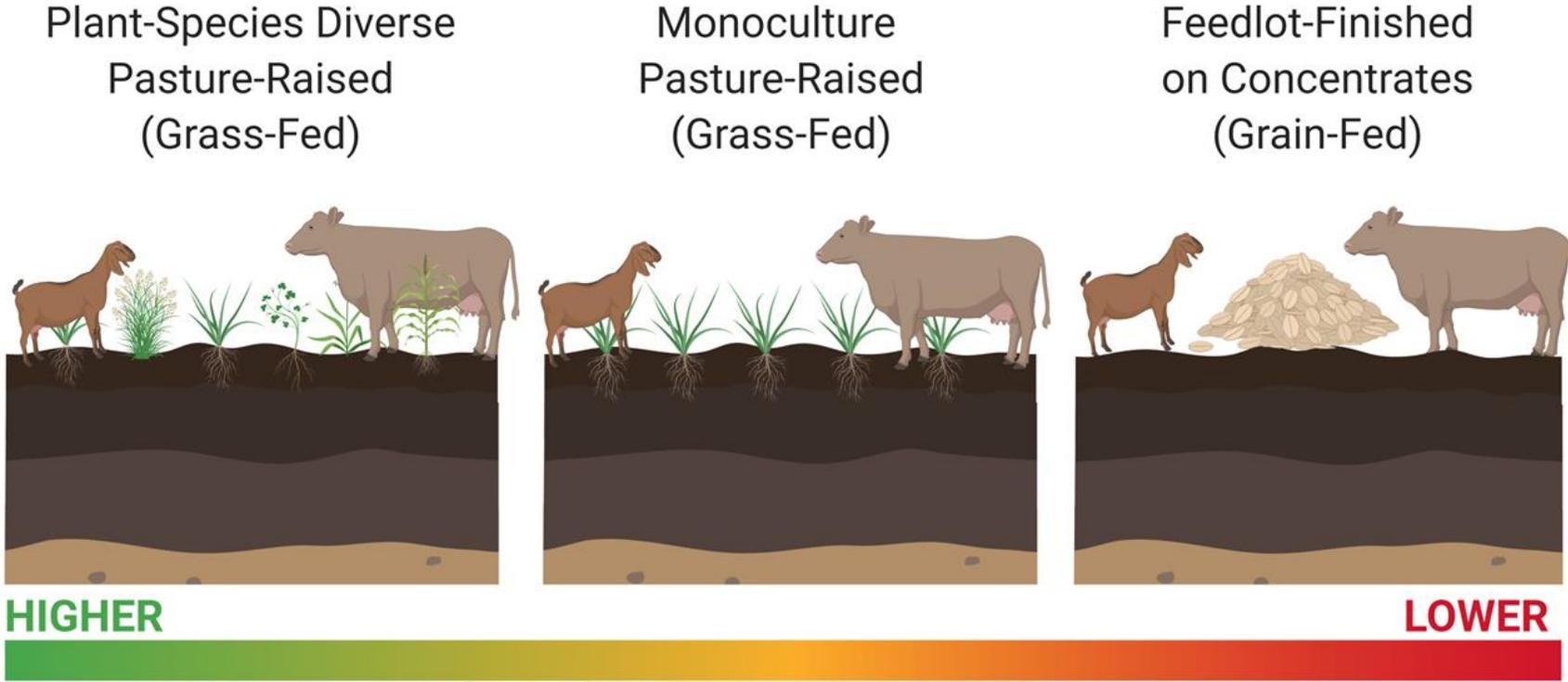


Diversified pasture
➤ 8 major species
perennial ryegrass +
orchard grass (50%)

Several potential health-promoting terpenes
are found **exclusively** or in **↑higher**
concentrations in beef on diverse pastures



Greater plant diversity results in a higher microcontent



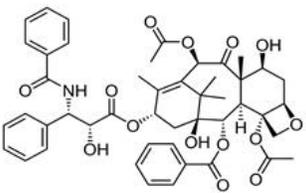
Biodiverse pasture seeding



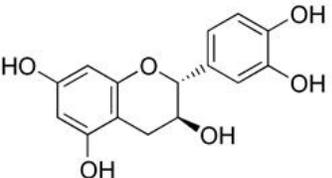
Cover crop grazing



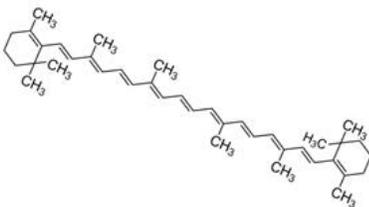
← Phytochemical Richness of Meat and Milk



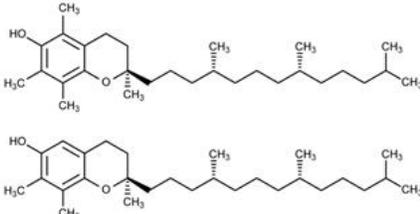
Terpenoids



Phenols



Carotenoids

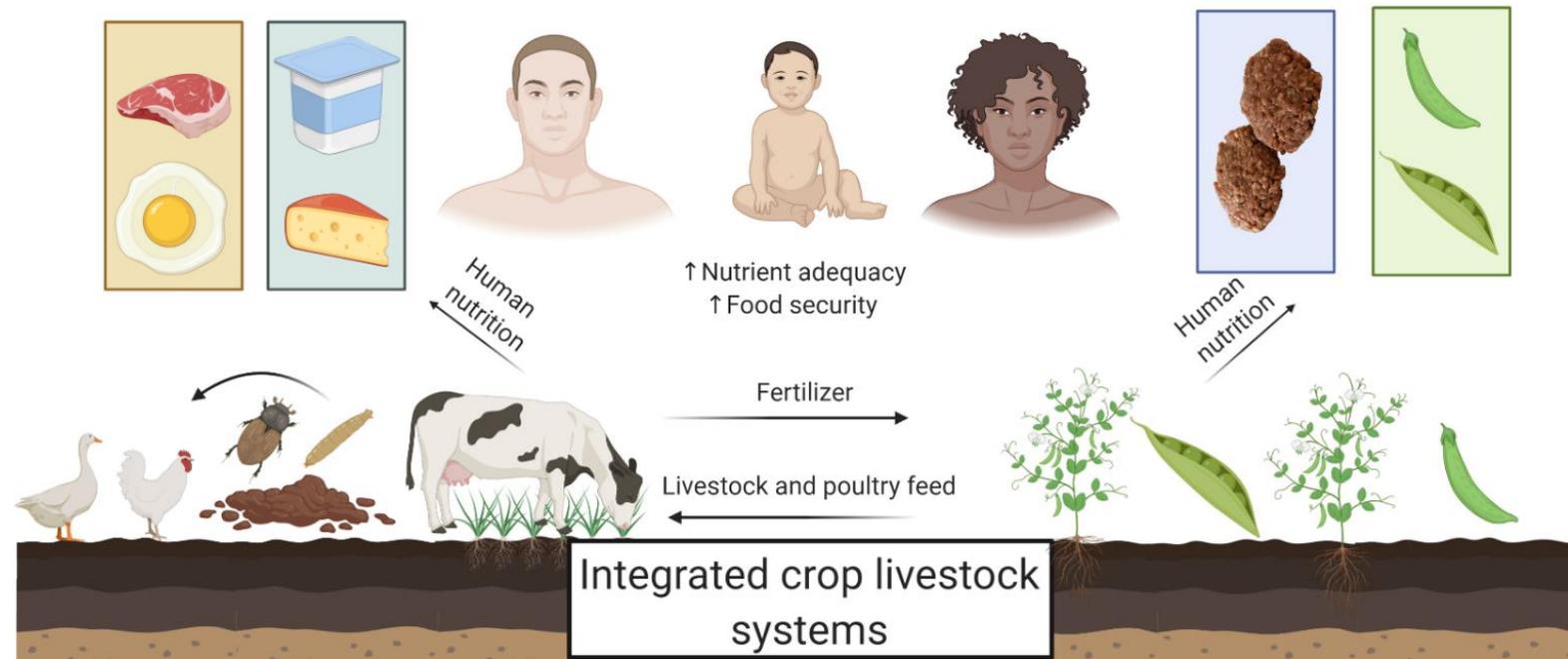


Tocopherols

S. van Vliet et al. Health-Promoting Phytonutrients are Higher in Grass-fed Meat and Milk. *Frontiers in Sustainable Food Systems*. doi: <https://doi.org/10.3389/fsufs.2020.555426>, 2020

Final conclusions

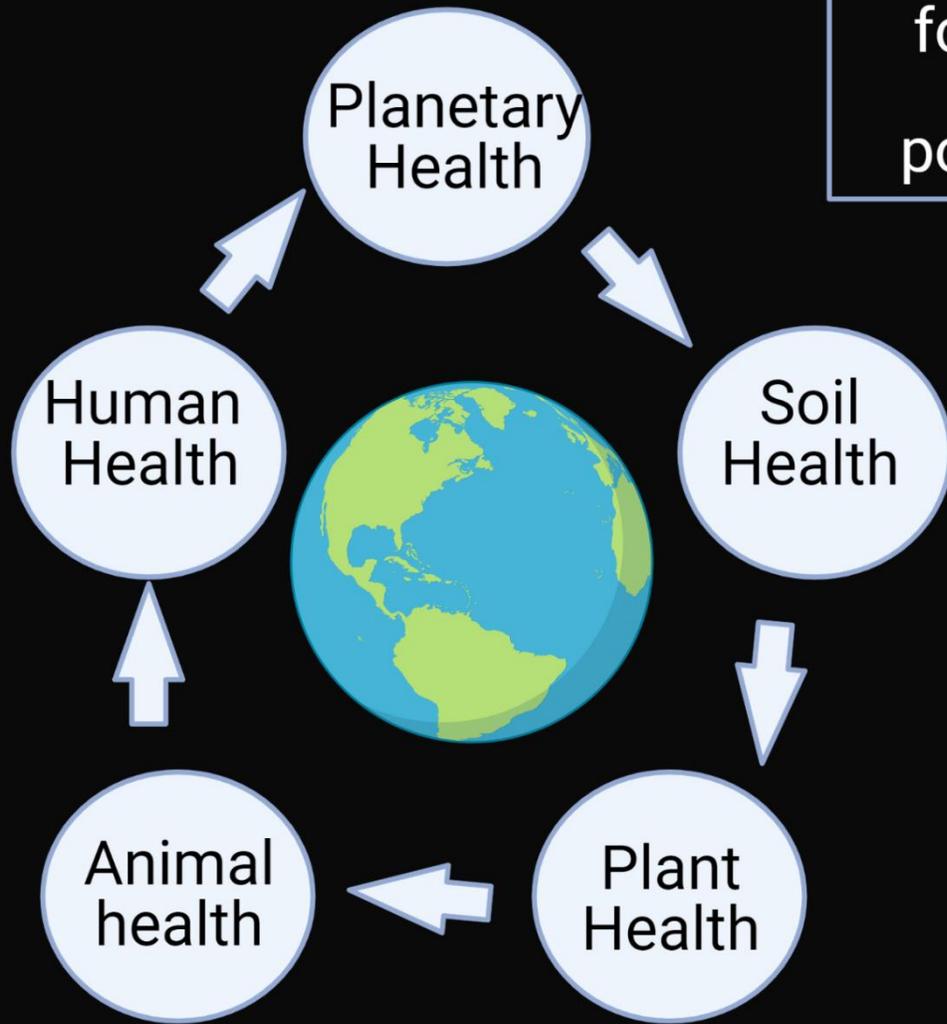
- Animal foods from agro-ecological production systems contain meaningful amounts of phytonutrients and anti-oxidants and contain a healthier fat profile.
- Shift towards regenerative and sustainable production systems for all foods, using diverse agro-ecosystems that integrate crops, livestock, and trees as much as possible.
- Prioritize production of foods and animal species that are suitable for local ecosystems.
- Do not see Nature, Agriculture, and Human Living as separate entities. Integrate these aspects and learn to co-exist.





10 billion humans by 2050:
Creating a Healthy, Sustainable,
and Equitable Future

Regenerative practices that can
improve health of the planet,
humans, animals and plants.



Linking the fields of
food production,
nutrition, and
population health

Diets link human and
environmental health

Thank you!

Questions and Discussions

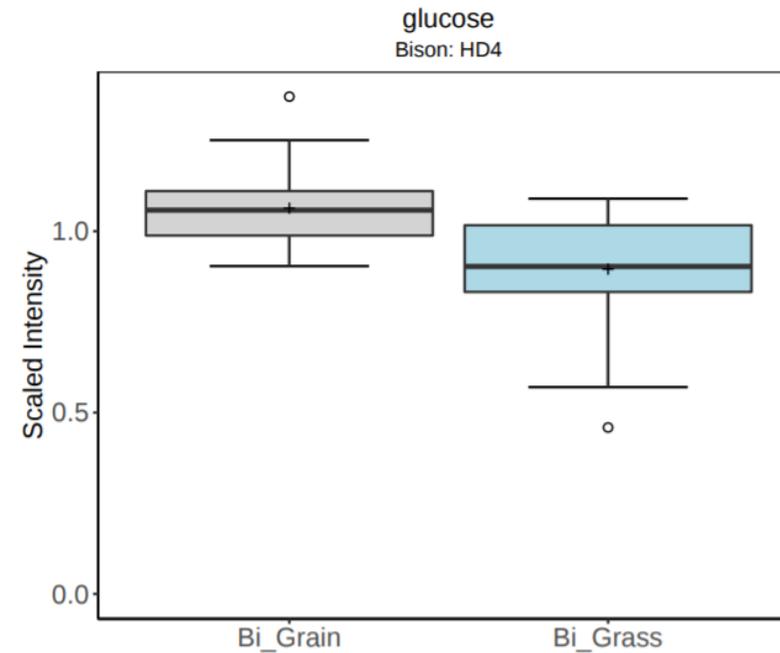
Stephan van Vliet, PhD

Center for Human Nutrition Studies
College of Agriculture and Applied Sciences
Utah State University

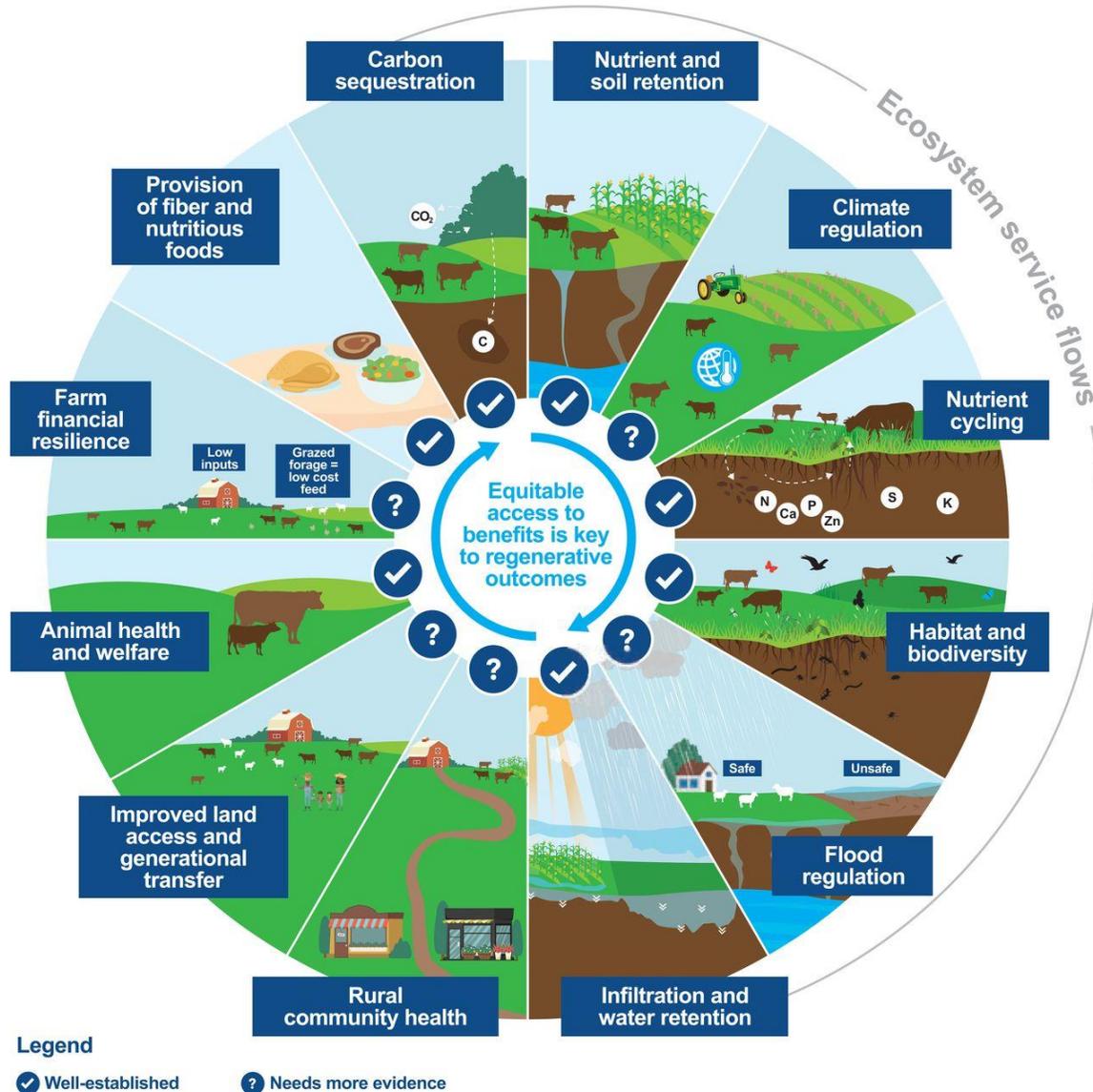


Meat metabolites give clues about animal health...

| Sub Pathway | Biochemical Name | Fold of Change |
|--|---|----------------------|
| | | Bi_Grass Bi_Grain |
| Glycolysis, Gluconeogen- esis, and Pyruvate Metabolism | glucose | 0.84 |
| | glucose 6-phosphate | 0.84 |
| | fructose 1,6- diphosphate/glucose 1,6-diphosphate/myo- inositol diphosphates | 0.84 |
| | pyruvate | 0.96 |
| | fructose | 0.77 |
| Fructose, Mannose and Galactose Metabolism | mannitol/sorbitol | 0.83 |
| | mannose | 0.74 |
| | galactonate | 0.73 |
| | citrate | 1.04 |
| TCA Cycle | aconitate [cis or trans] | 1.25 |
| | isocitrate | 0.72 |
| | succinylcarnitine (C4- DC) | 1.25 |
| | succinate | 1.24 |
| | malate | 1.53 |



Agro-ecological systems: linking plant, animal, and human health



- ✓ Regularly move animals to mimic predation-migratory patterns
- ✓ DO NOT OVERGRAZE (leave 30-50% vegetation)
- ✓ Limit chemical, physical, and biological disturbance
- ✓ Add diversity of plants to provide wildlife habitat for birds, insects, and other mammals
- ✓ Keep the soil covered