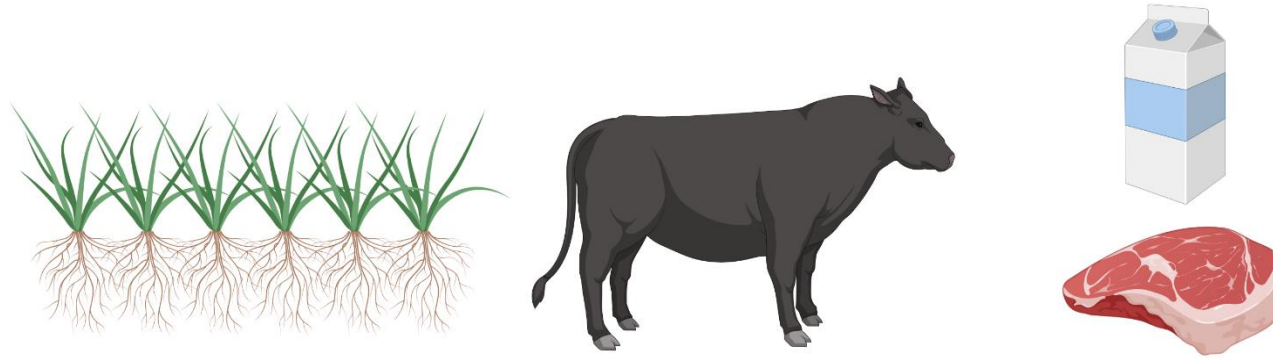


# Red Meat, Health, and Sustainability: Consumption Trends in the USA and Globally



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Stephan van Vliet

August 17<sup>th</sup>, 2022



**UtahStateUniversity**

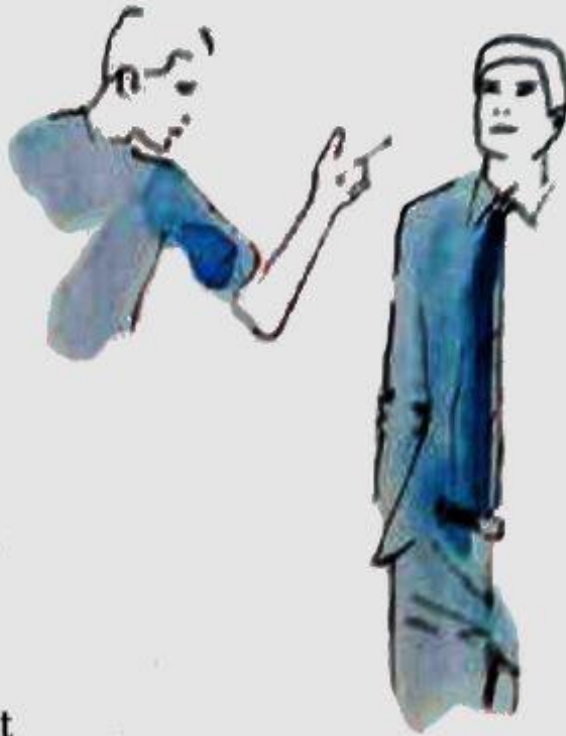


# My background

## 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

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## Red Meat and Human Health

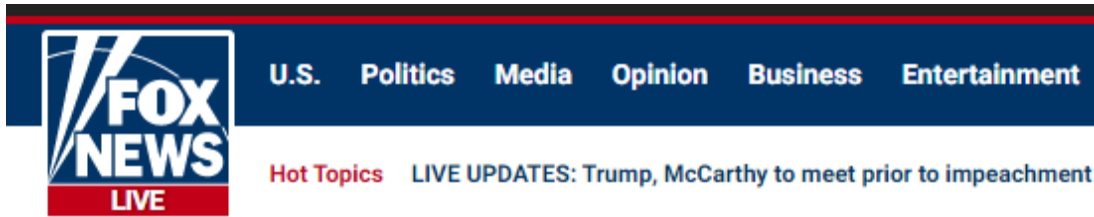
- Part 1: Red Meat, Diet Quality, and Disease (10 min)
- Part 2: Contribution of Red Meat and Animal Foods to Nutrient Adequacy in US Diets and Globally

## 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?

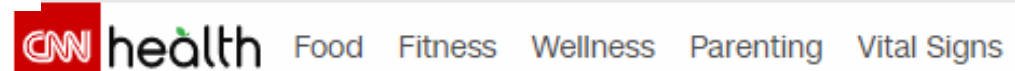


## Red meat eaters may have a higher risk of dying from these 9 diseases

## Annals of Internal Medicine®

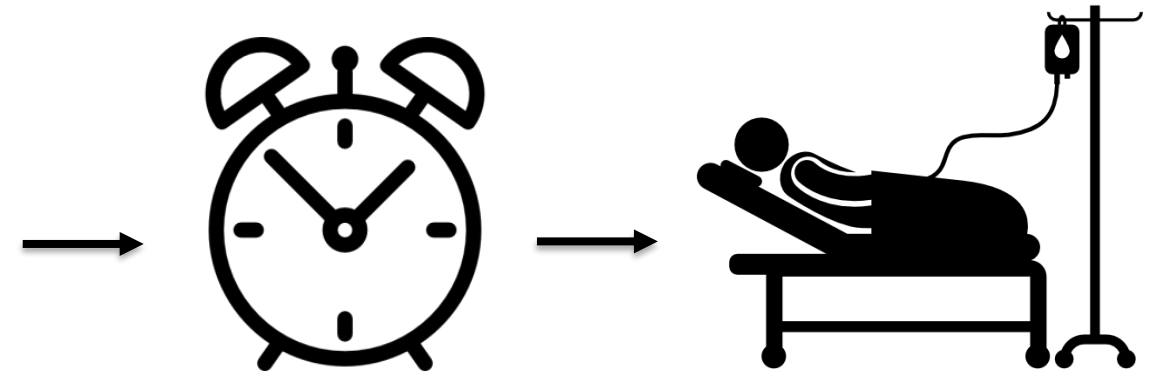
### *Eat Less Red Meat, Scientists Said. Now Some Believe That Was Bad Advice.*

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.



## 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”



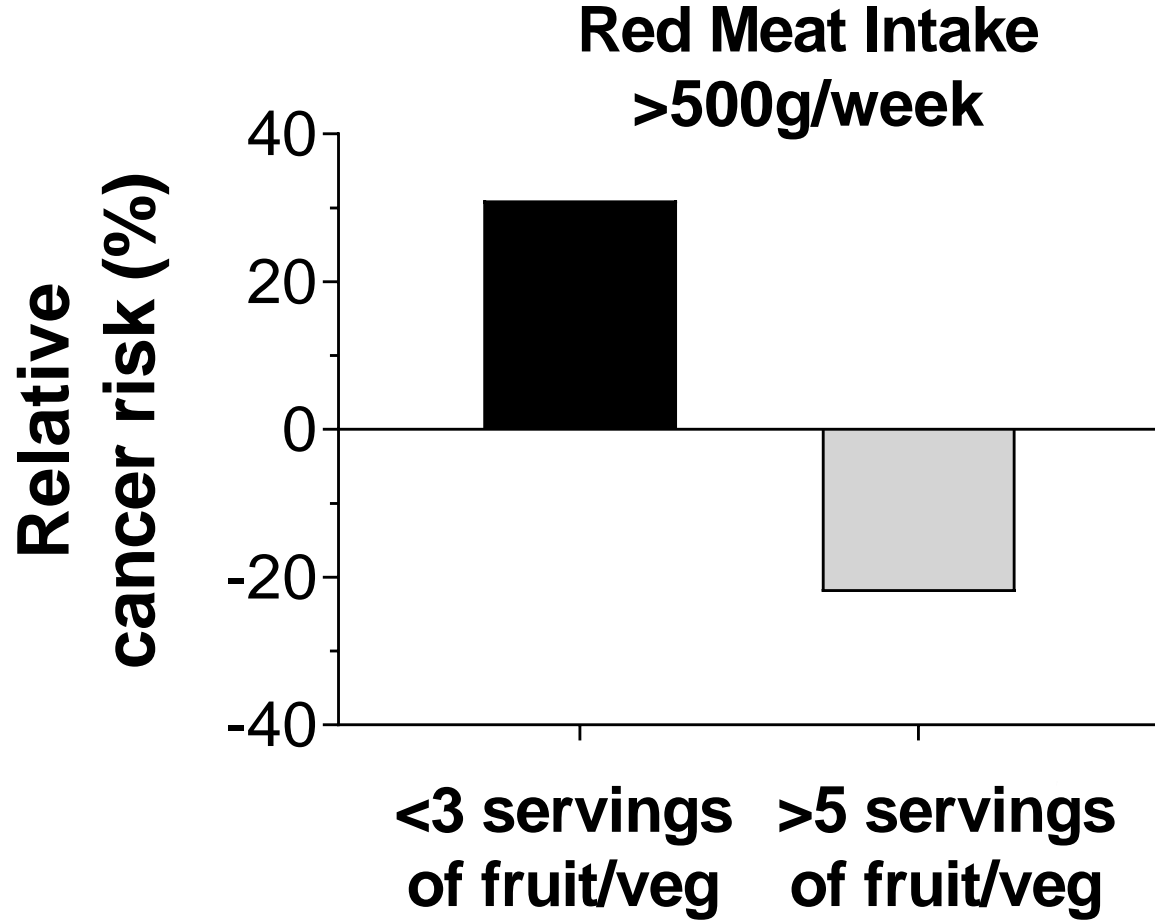
Neutral or protective



Increased risk of heart disease,  
cancer, diabetes

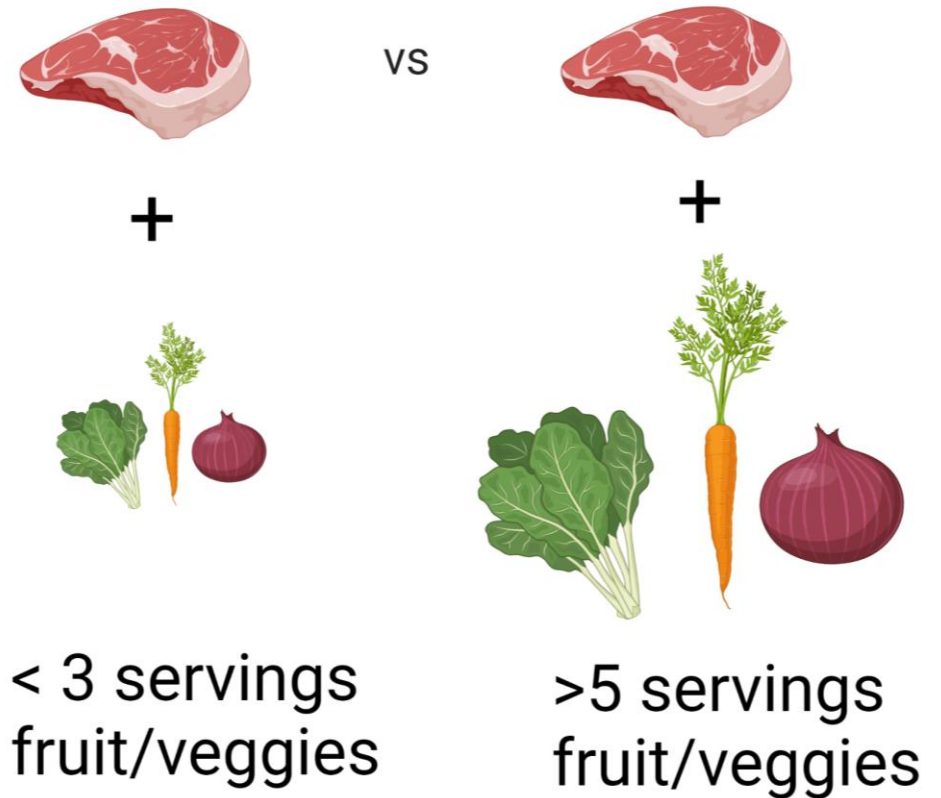
(how most people consume red meat  
unfortunately)

# 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 <sup>2</sup> (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”.

Zheng et al. Biomarker-Calibrated Red and Combined Red and Processed Meat Intakes with Chronic Disease Risk in a Cohort of Postmenopausal Women. *The Journal of Nutrition*. 2020. doi: <https://doi.org/10.1093/jn/nxac067>



# 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)

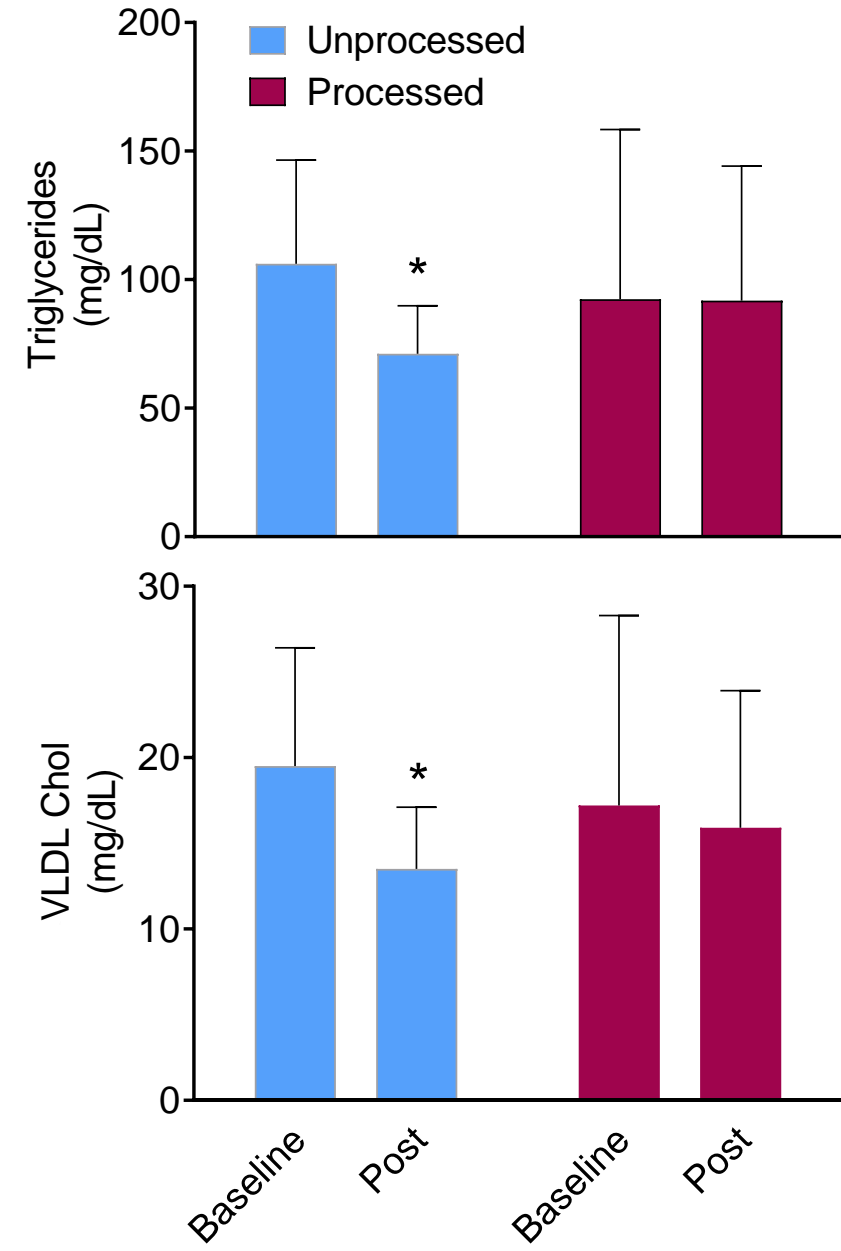
Standard Western “Processed” Diet



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,<sup>1,2,●</sup> Raúl Zamora-Ros, PhD,<sup>1,3,\*</sup> Nicole Hidalgo-Liberona, PhD,<sup>1,2,●</sup> Montserrat Rabassa, PhD,<sup>1</sup> Stefania Bandinelli, MD,<sup>4</sup> 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.**

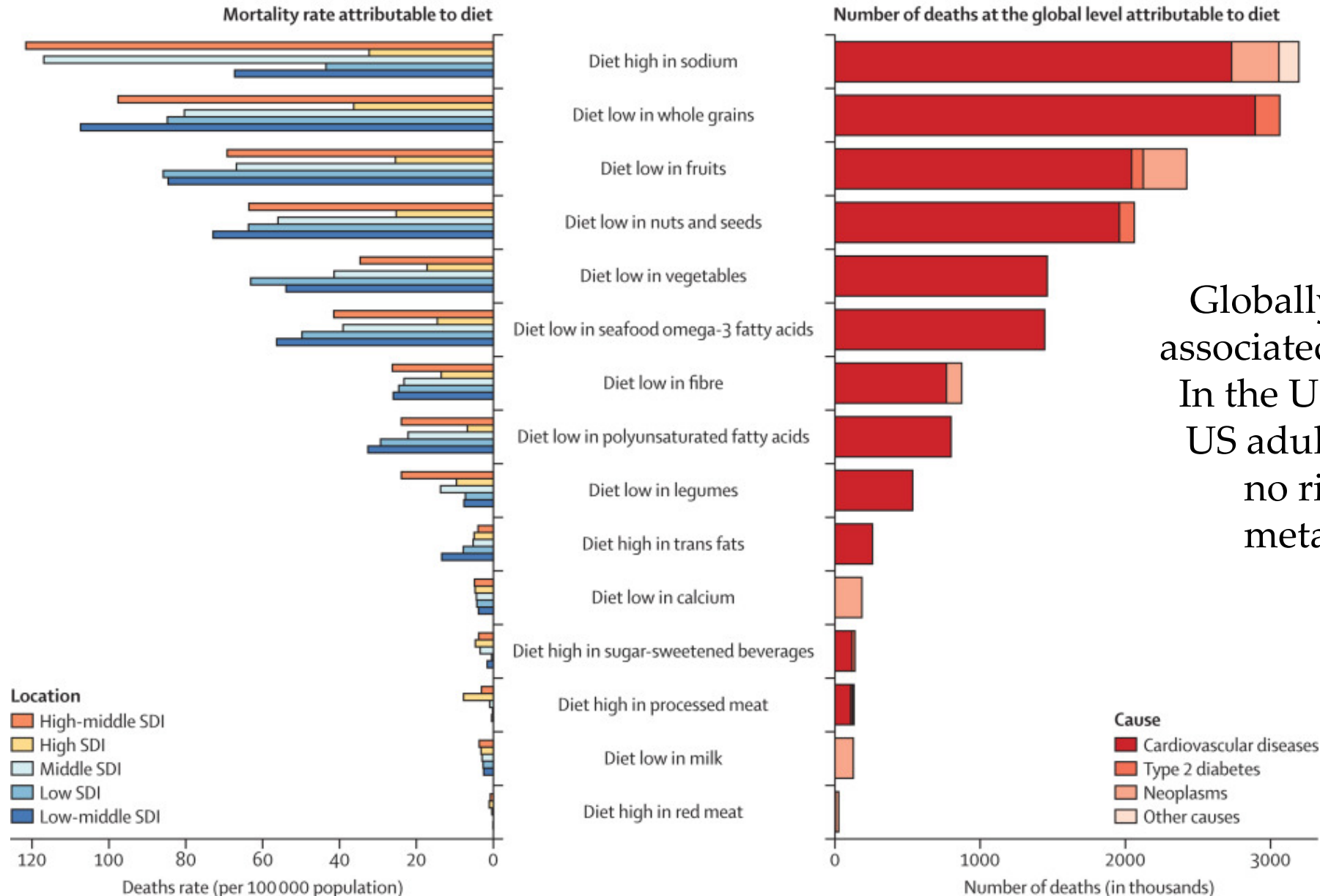


## Part 2: Contribution of animal sourced foods to nutrient adequacy in US diets and globally (10 min)





# Global burden of metabolic disease



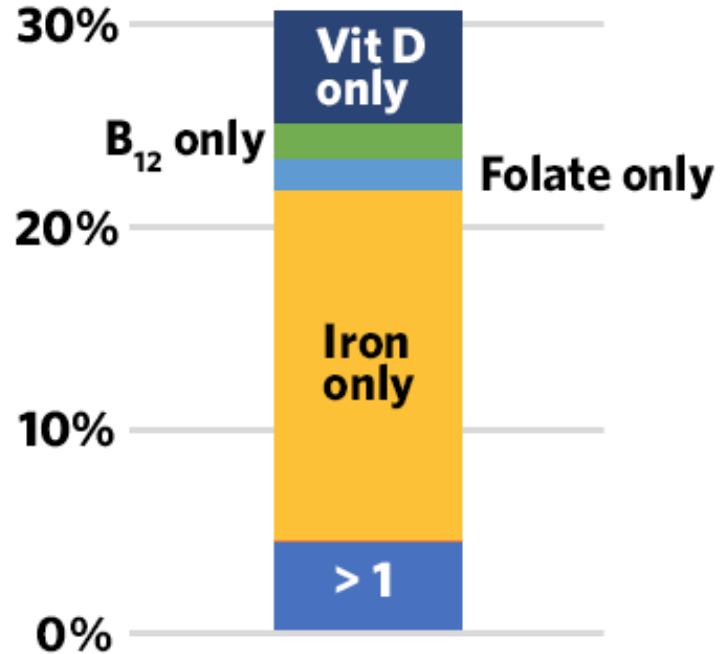
Globally 1 in 5 deaths is associated with poor diet...  
In the US, only 10-30% of US adults are “healthy”:  
no risk factors for metabolic disease

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

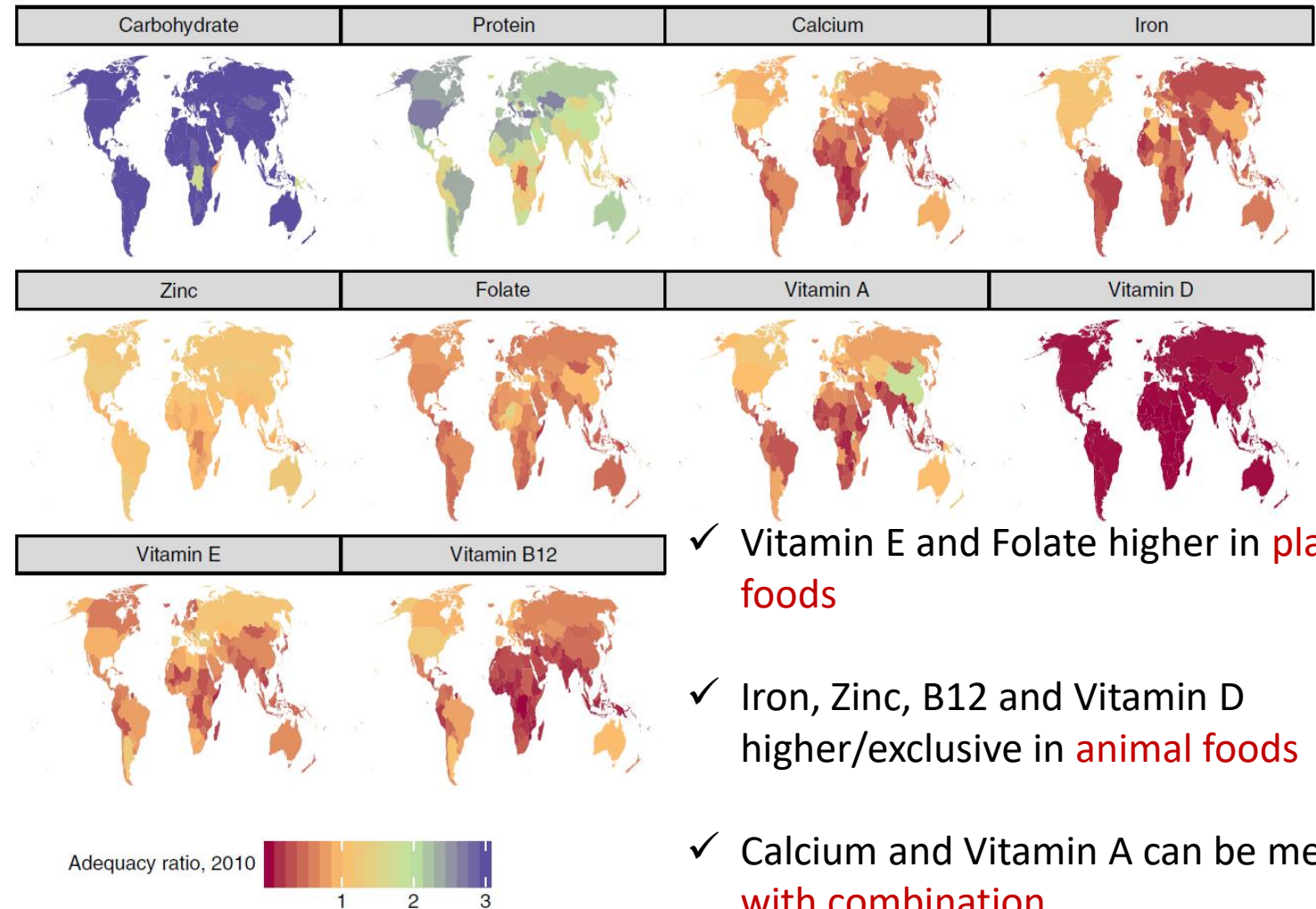
[https://doi.org/10.1016/S0140-6736\(18\)32225-6](https://doi.org/10.1016/S0140-6736(18)32225-6)

# 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%).

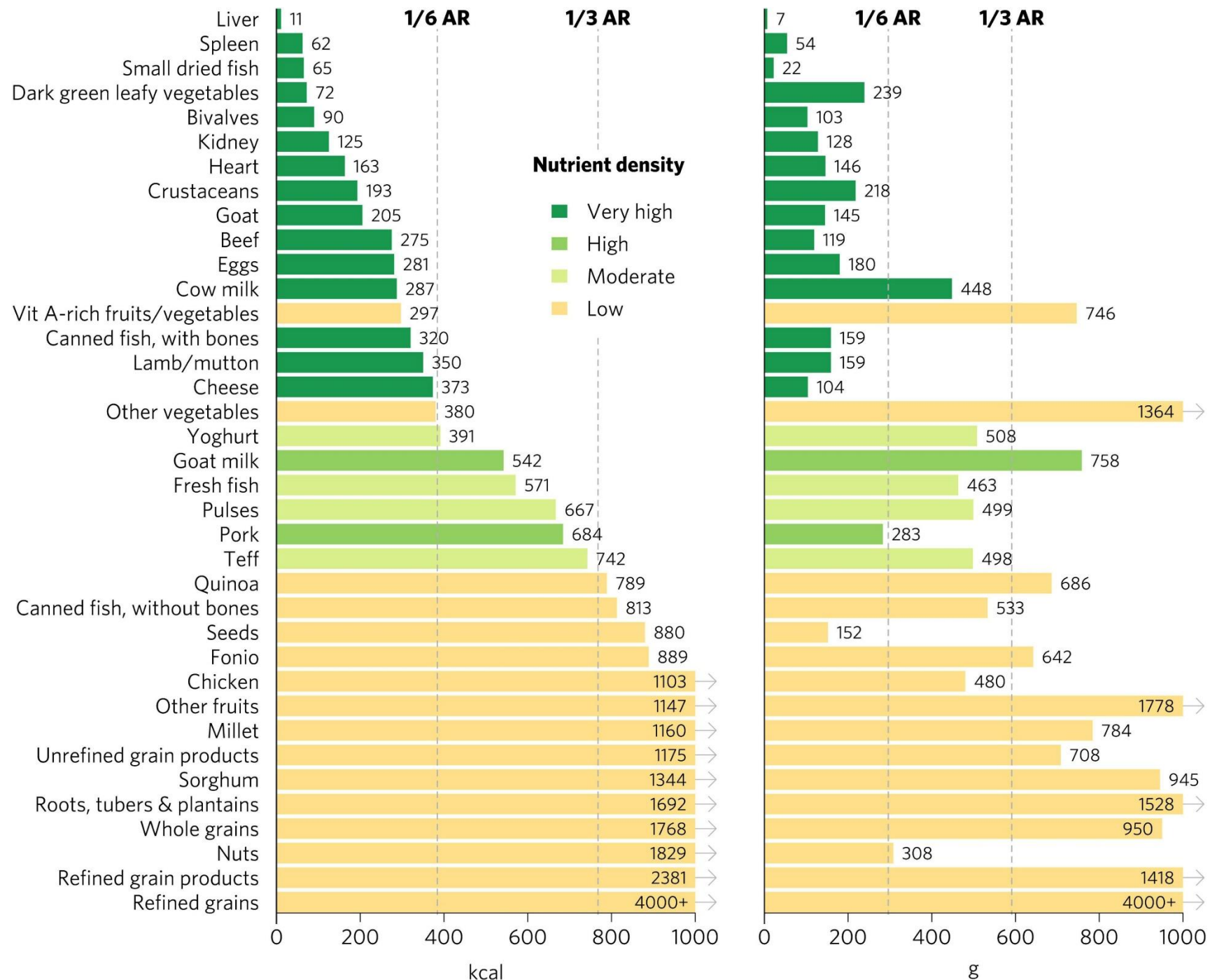


- ✓ Vitamin E and Folate higher in **plant foods**
- ✓ Iron, Zinc, B12 and Vitamin D higher/exclusive in **animal foods**
- ✓ Calcium and Vitamin A can be met **with combination**
- ✓ Synergy in animal and plant foods: **complementary contributions**

# 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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[Editor's choice: nutrition and perception](#)

Sections

Figures

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	
<b>Calories</b>	<b>220</b>
% Daily Value*	
<b>Total Fat</b> 14g	<b>18%</b>
Saturated Fat 5g	<b>25%</b>
Trans Fat 0g	
<b>Cholesterol</b> 60mg	<b>20%</b>
<b>Sodium</b> 70mg	<b>3%</b>
<b>Total Carbohydrate</b> 0g	<b>0%</b>
Dietary Fiber 0g	<b>0%</b>
Total Sugars 0g	
Includes 0g Added Sugars	<b>0%</b>
<b>Protein</b> 23g	<b>46%</b>
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?



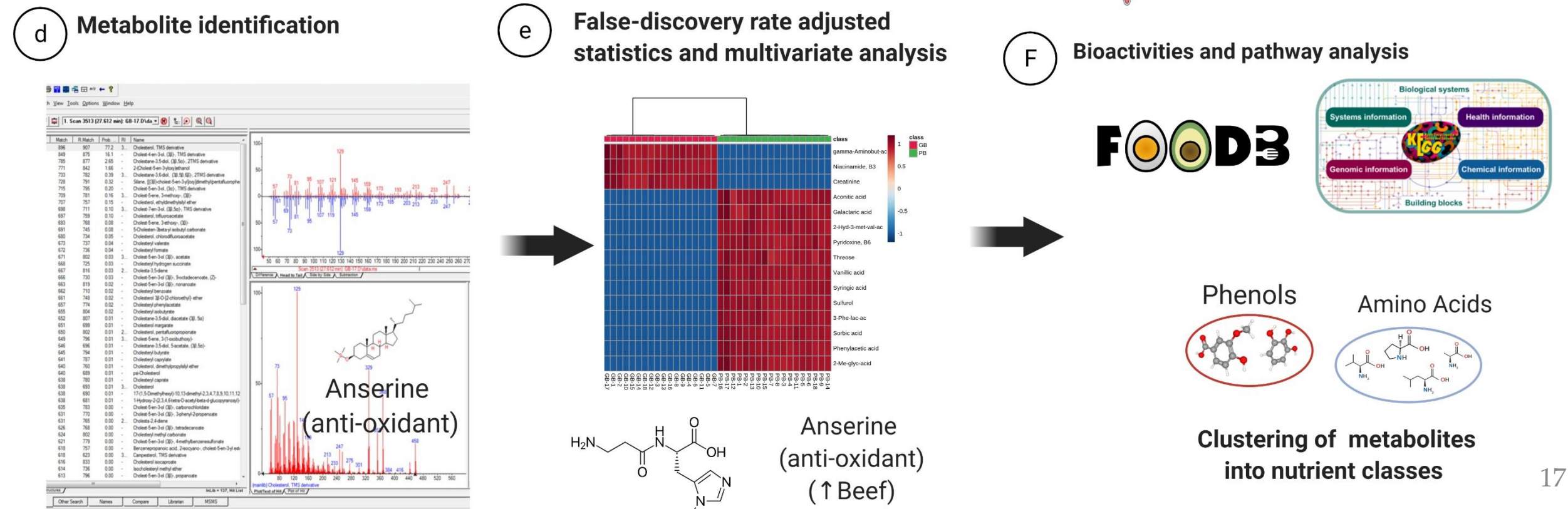
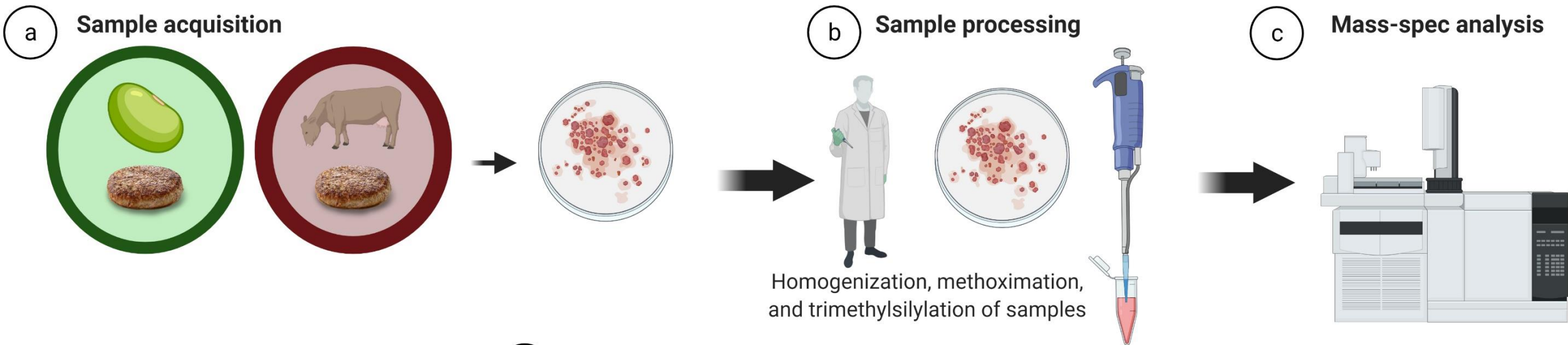
## Plant Alternative

Nutrition Facts	
Serving size	(113g)
Amount Per Serving	
<b>Calories</b>	<b>250</b>
% Daily Value*	
<b>Total Fat</b> 14g	<b>18%</b>
Saturated Fat 8g	<b>40%</b>
Trans Fat 0g	
<b>Cholesterol</b> 0mg	<b>0%</b>
<b>Sodium</b> 370mg	<b>16%</b>
<b>Total Carbohydrate</b> 9g	<b>3%</b>
Dietary Fiber 3g	<b>11%</b>
Total Sugars 0g	
Includes 0g Added Sugars	<b>0%</b>
<b>Protein</b> 19g	<b>38%</b>
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.

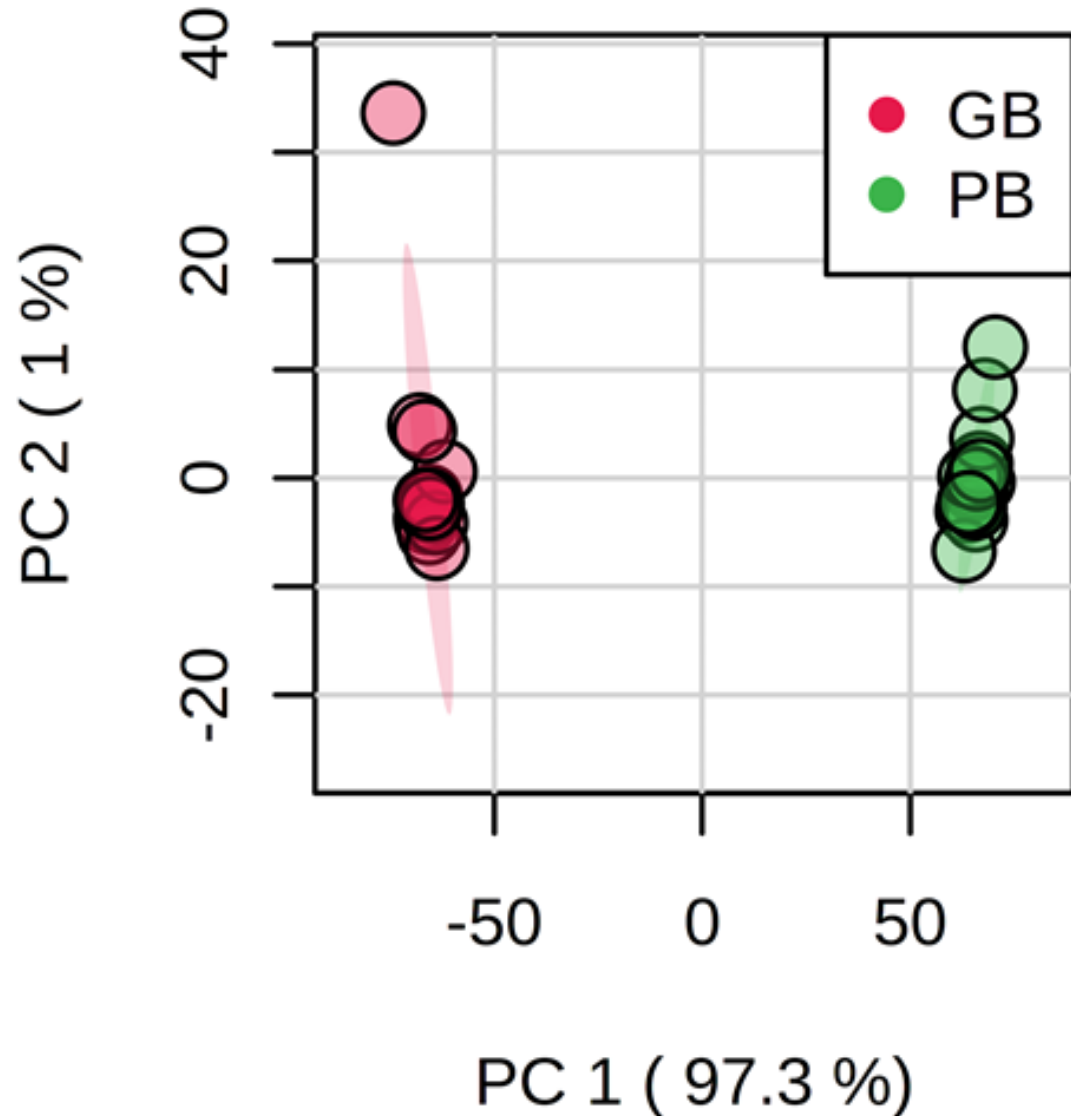


# Study Workflow



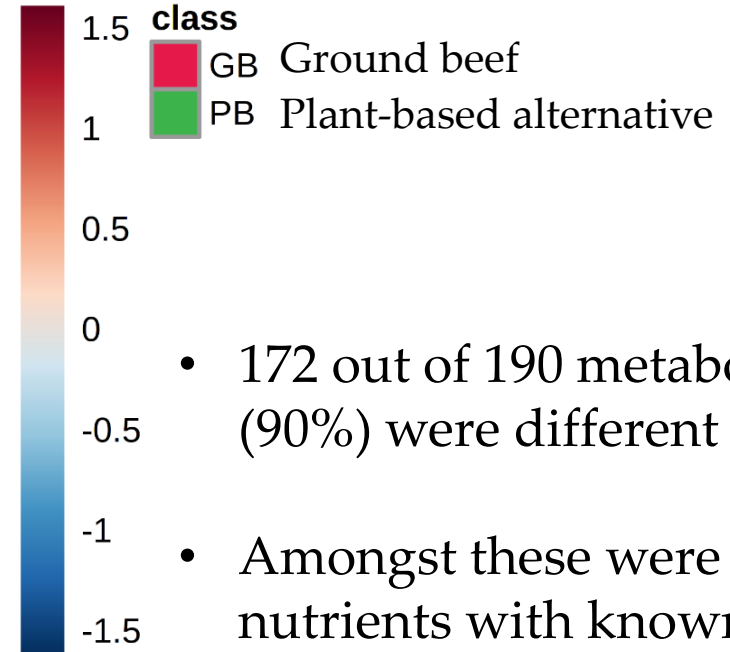
# Principal Component Analysis

## 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.

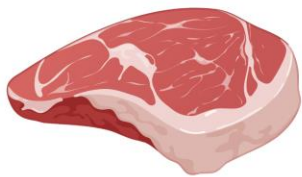
1.5 class



- 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	
<b>Calories</b>	<b>140</b>
% Daily Value*	
<b>Total Fat</b> 4.5g	6%
Saturated Fat 2g	10%
Trans Fat 0g	
<b>Cholesterol</b> 65mg	22%
<b>Sodium</b> 20mg	1%
<b>Total Carbohydrate</b> 0g	0%
Dietary Fiber 0g	0%
Total Sugars 0g	
Includes 0g Added Sugars	0%
<b>Protein</b> 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



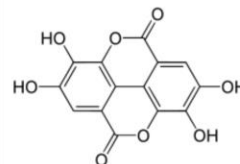
Food labels contain **<13 nutrients**;  
USDA Database tracks **150 components**.

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



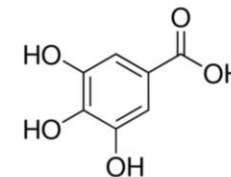
Food matrix contain **>10,000s metabolites** potentially capable of  
impacting human health  
(Their importance should  
not be ignored!)

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



Creatine  
Dipeptide, muscle  
health, brain  
health

Hydroxyproline  
Important for connective  
tissue and collagen  
synthesis  
blood cells



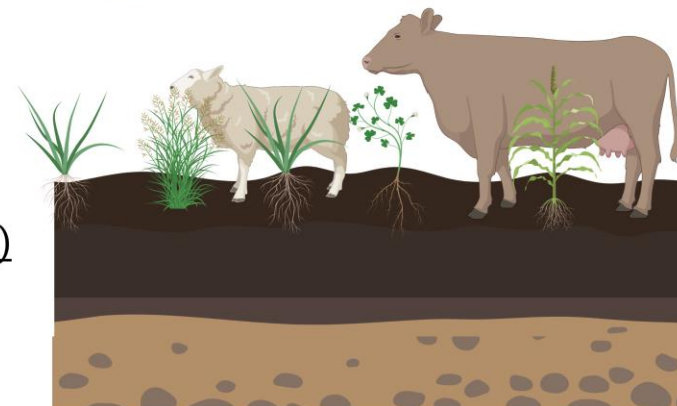
Cysteamine  
Anti-inflammatory,  
neuroprotective, and  
liver protective

Anserine  
Dipeptide, anti-  
oxidant, brain  
protective

Phytochemicals  
Unique medicinal plant  
compounds from plants  
otherwise not  
consumed by humans

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

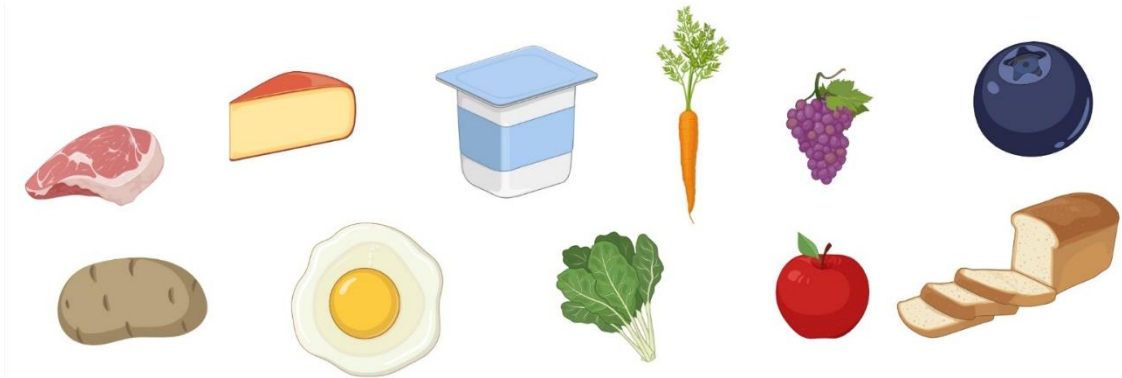
DHA, DPA, and EPA (Omega 3 fats)  
Anti-inflammatory, anti-oxidant,  
neuro-protective, cardiovascular  
protective



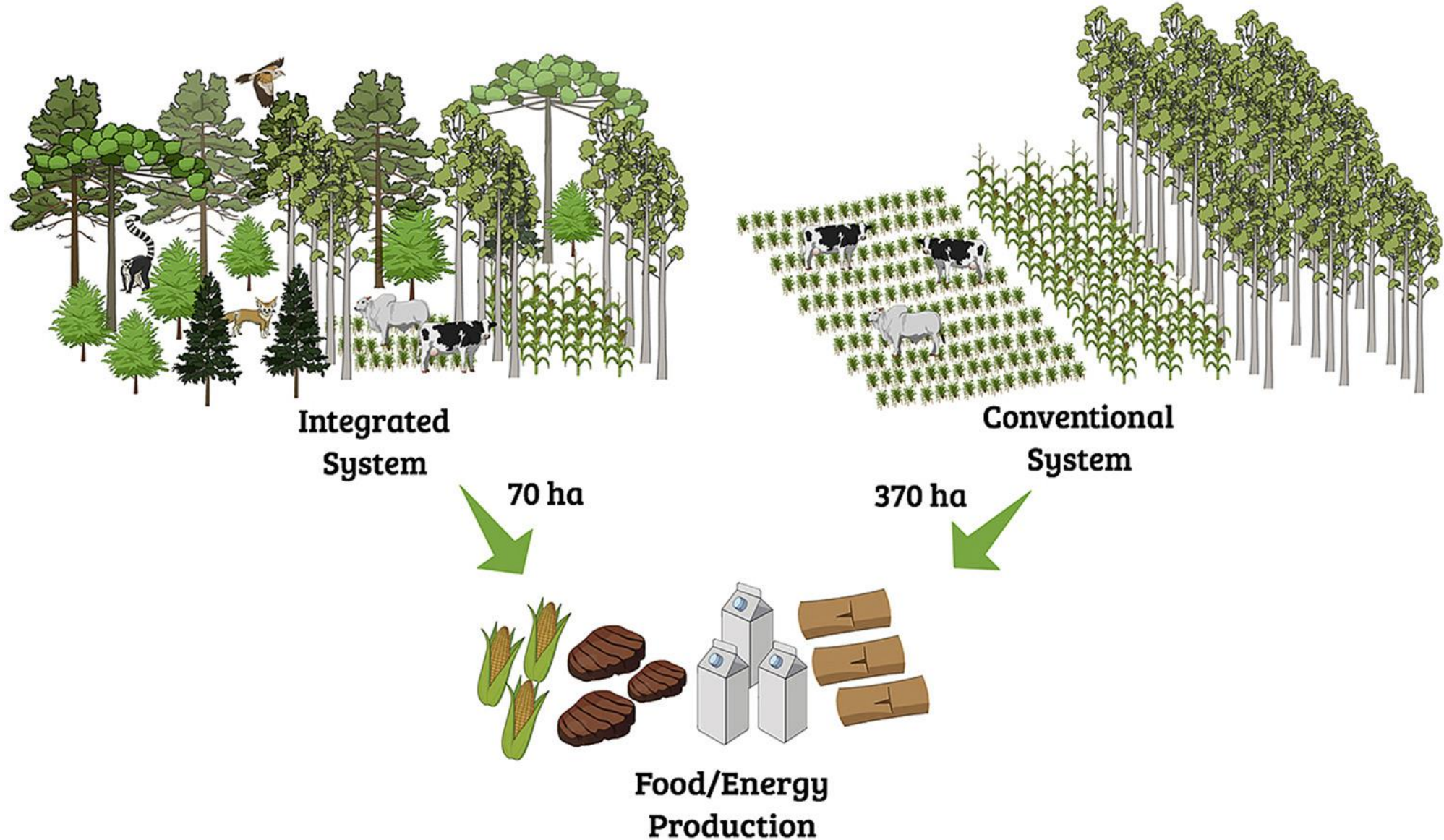
We do not eat nutrients, we eat foods. Food is more than the sum of nutrients.

# 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”.

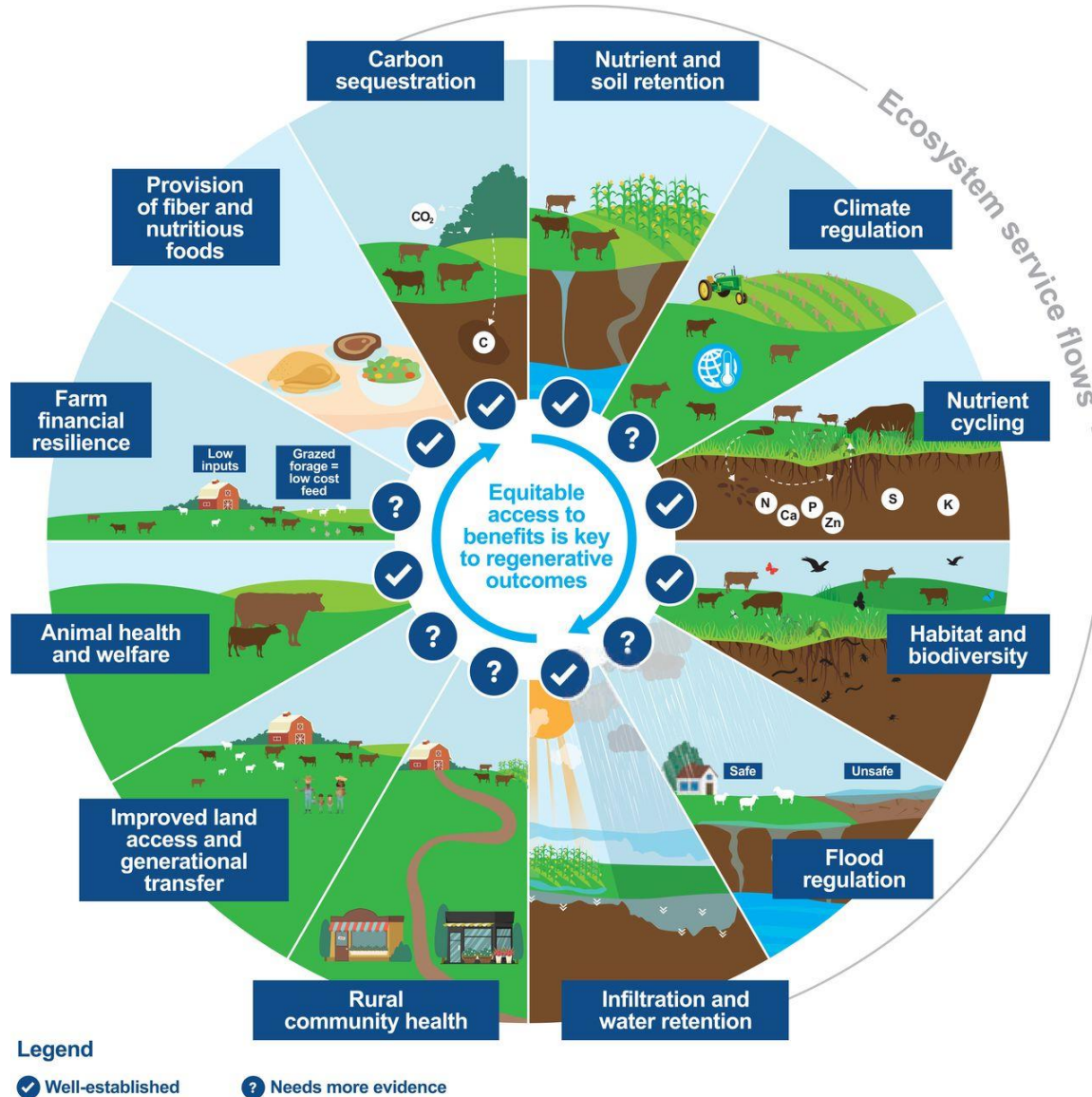
Five principles for sustainable food and agriculture (FAO, 2019):

- (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<sup>1\*</sup>,



Scott L. Kronberg<sup>2</sup> and

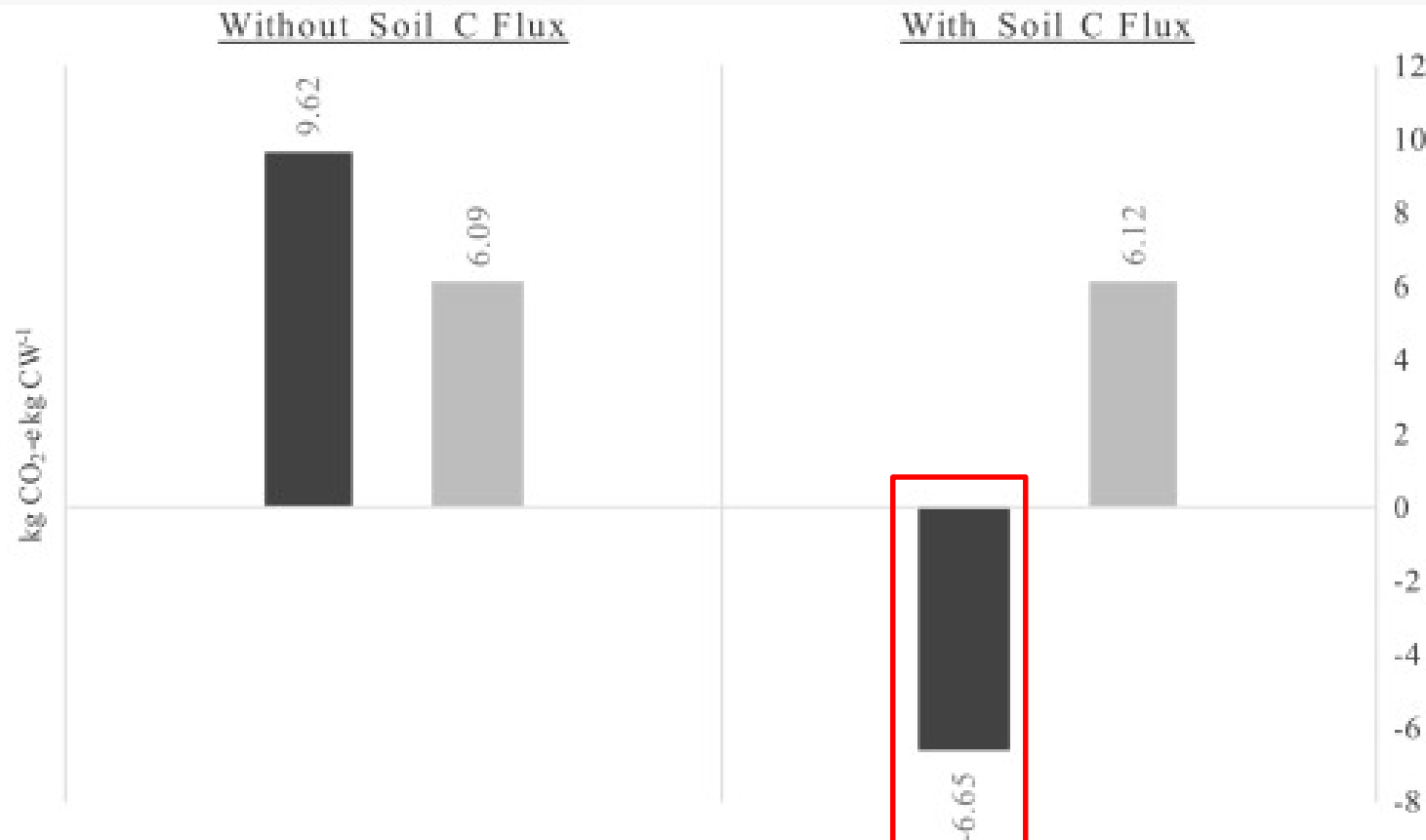


Frederick D. Provenza<sup>3</sup>

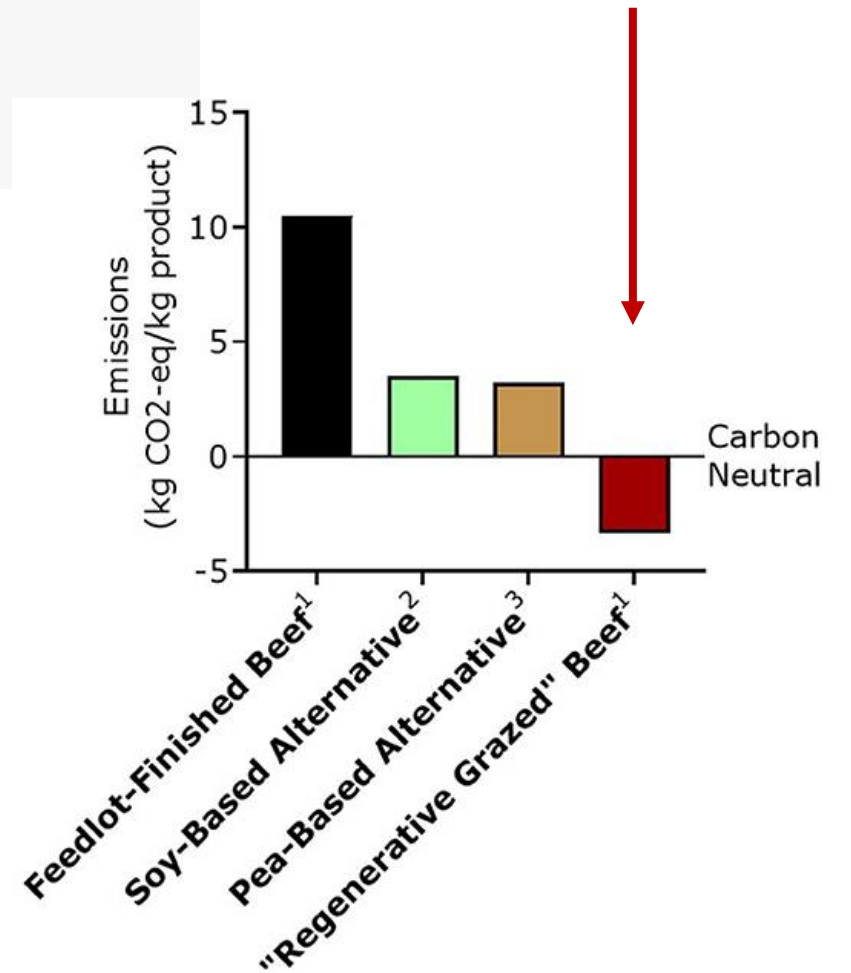
<sup>1</sup> Duke Molecular Physiology Institute, Duke University Medical Center, Durham, NC, United States

<sup>2</sup> Northern Great Plains Research Laboratory, USDA-Agricultural Research Service, Mandan, ND, United States

<sup>3</sup> Department of Wildland Resources, Utah State University, Logan, UT, United States



## Considering carbon sequestration in soil

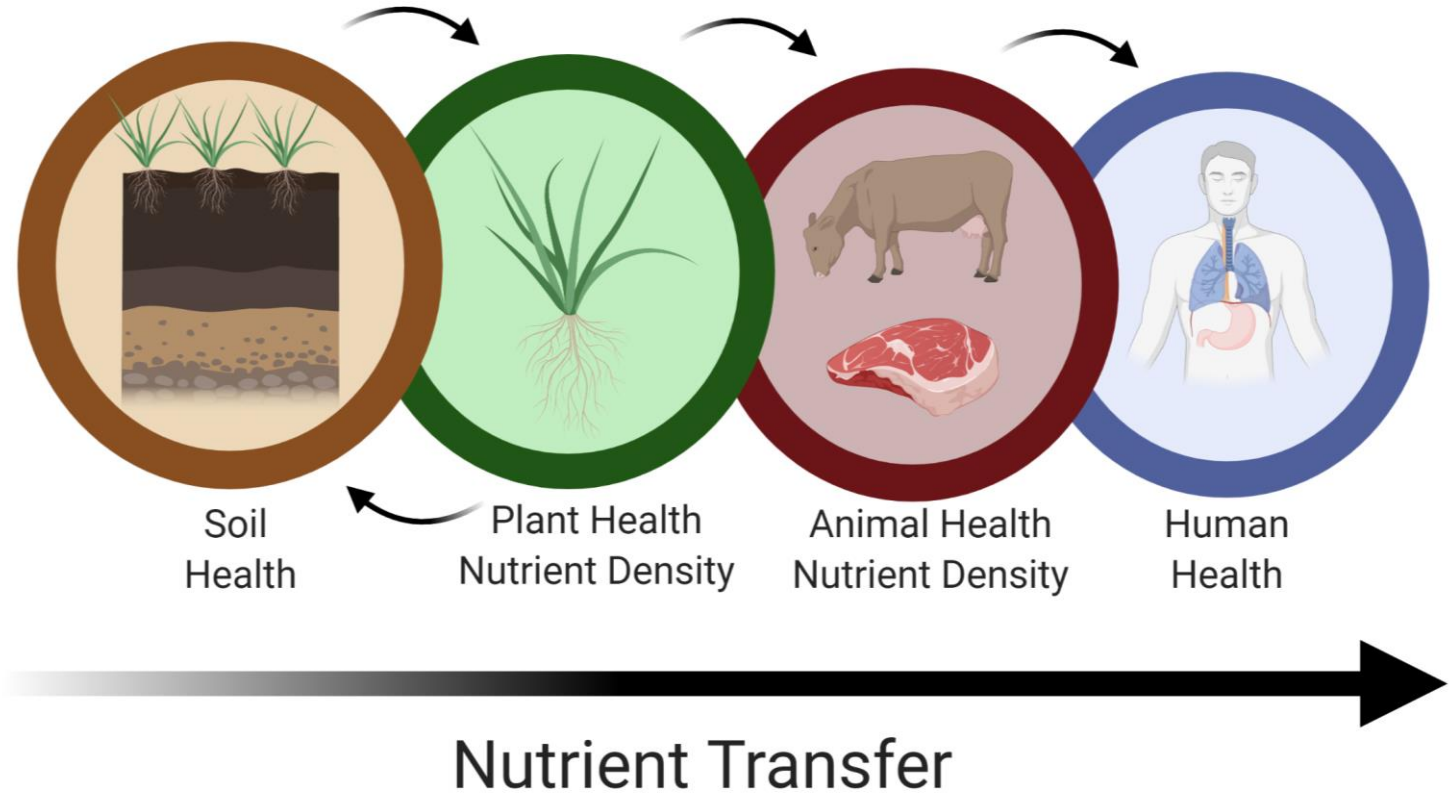


# Part 4: The impact of grazing practices on nutrient density and animal health in North American ruminants





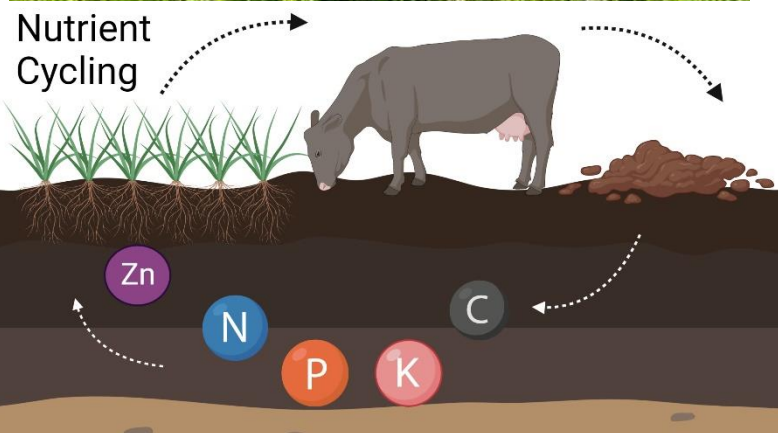
# Linking livestock systems and human health: From farm to table to us!



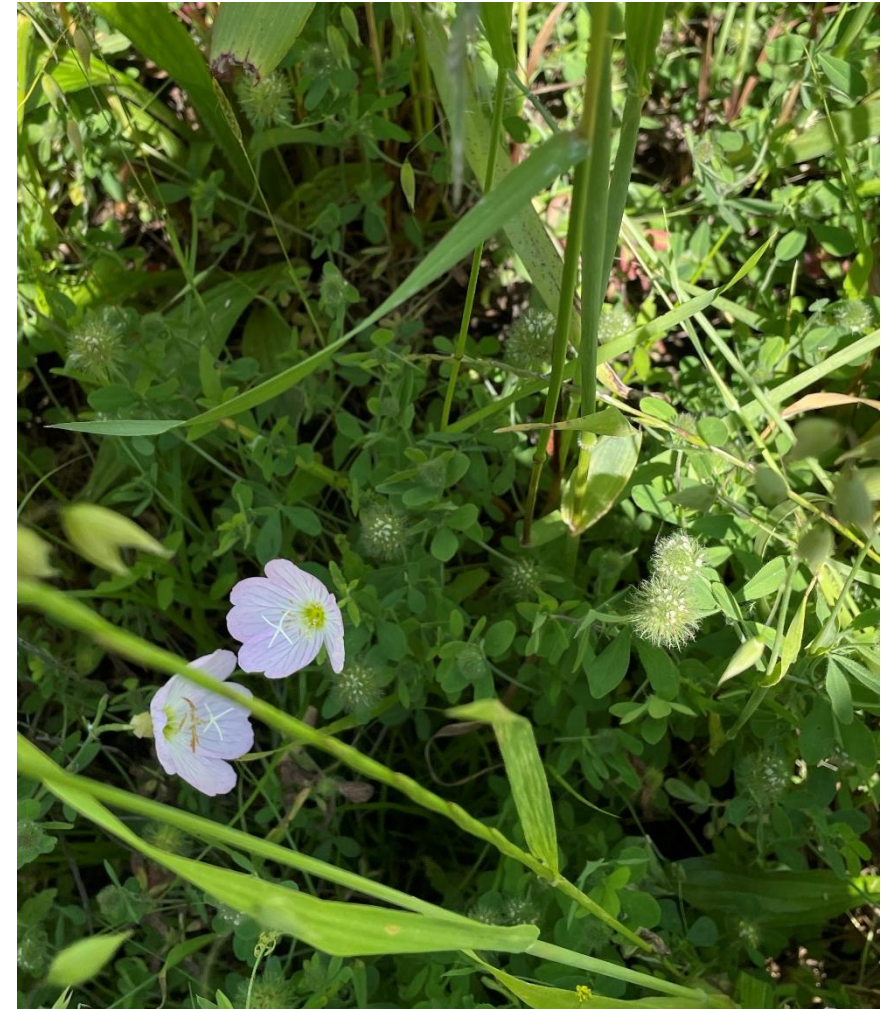
Healthy soils, healthy plants,  
healthy animals, healthy humans?



# 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

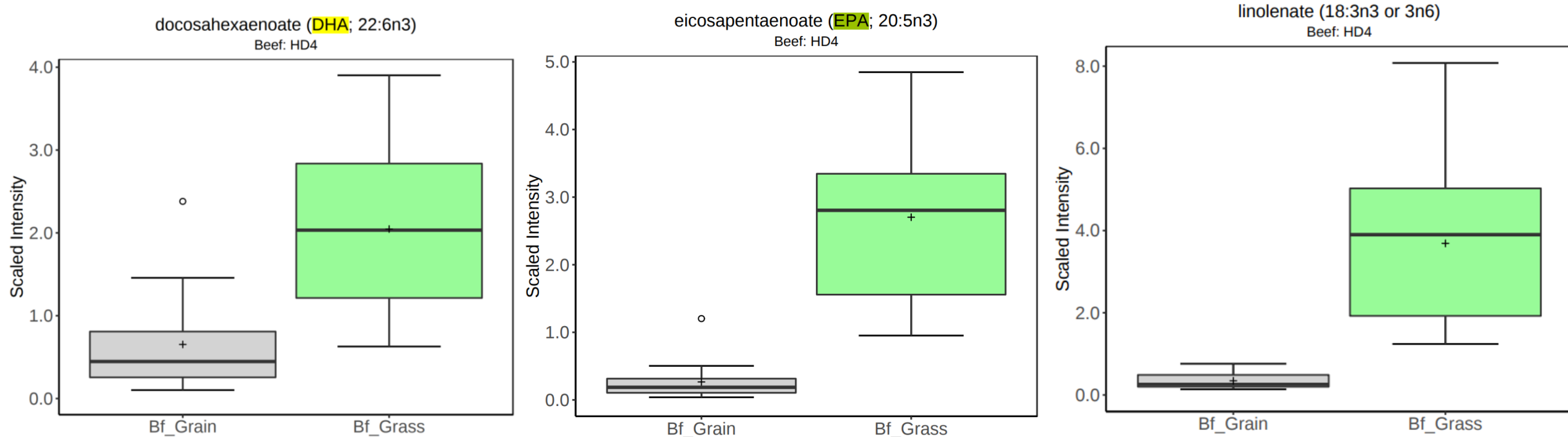


Biodiverse Pasture-Finished





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

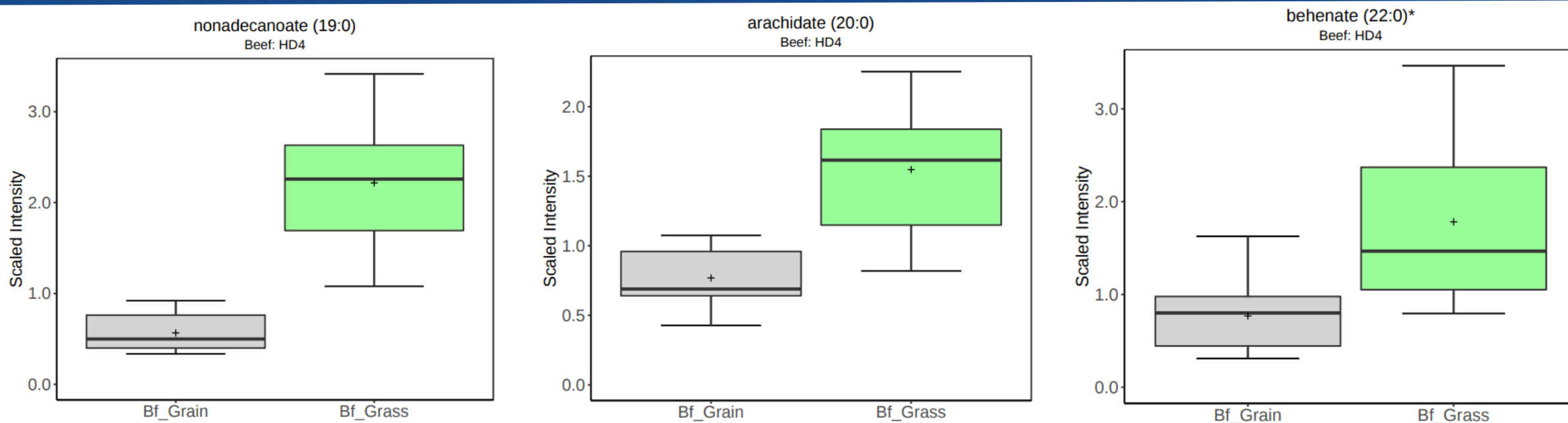


**Docosahexanoic acid (DHA), Eicosapentaenoic acid (EPA) and Linolenic acid (ALA) are omega-3 fats.**

**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.**

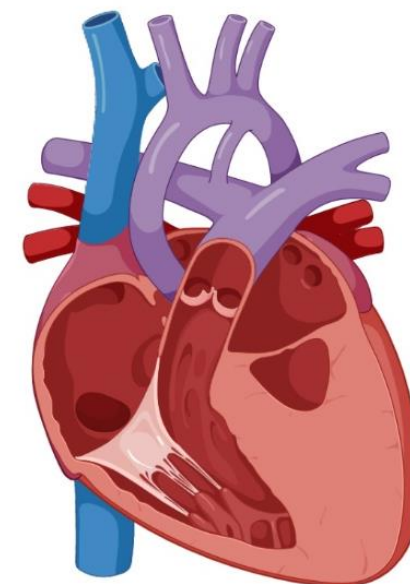
# Healthier saturated fatty acids



**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.**

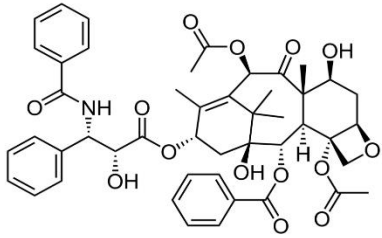
**Beef isn't beef isn't beef; how you raise the animal matters!**



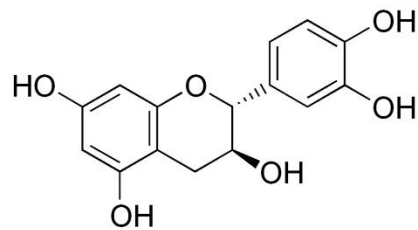
# Phytochemicals (plant-produced metabolites) and health



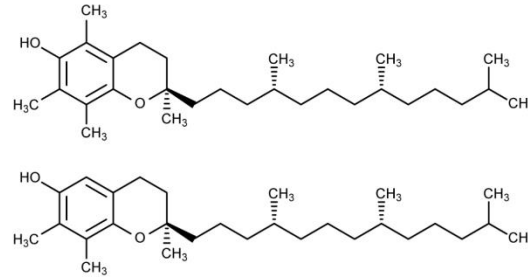
Plants respond biochemically to sunlight, moisture, nutrients, other plants, and herbivores by producing phytochemicals (10,000-100,000s)



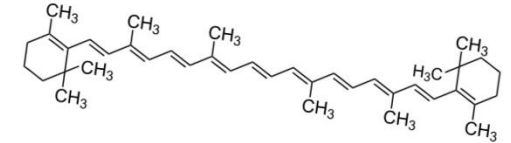
Terpenes



Phenols



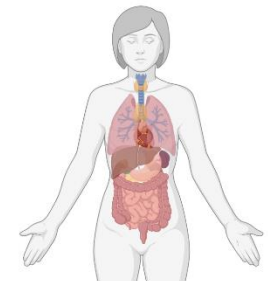
Tocopherols



Carotenoids

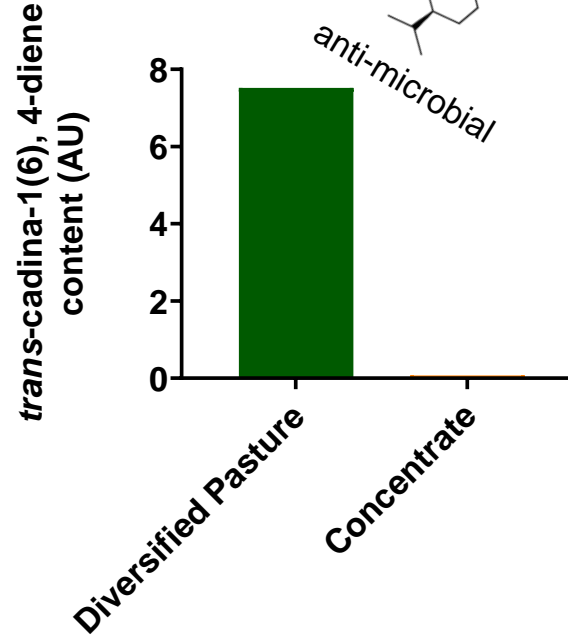
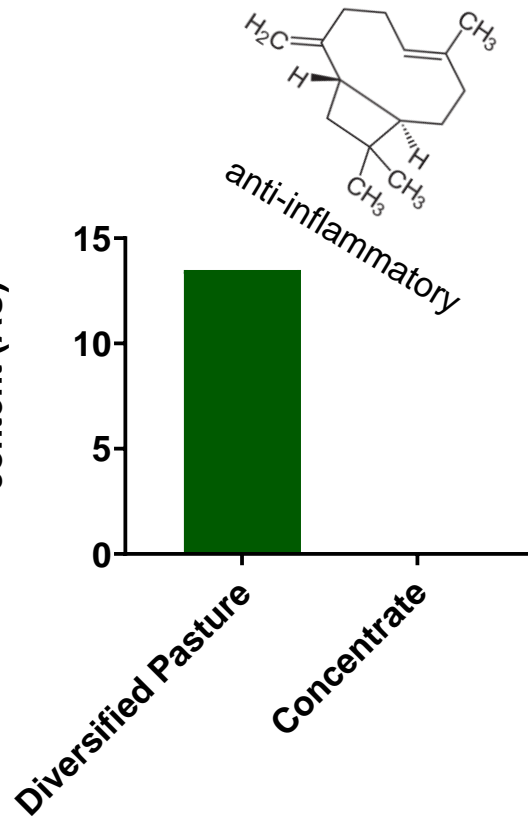
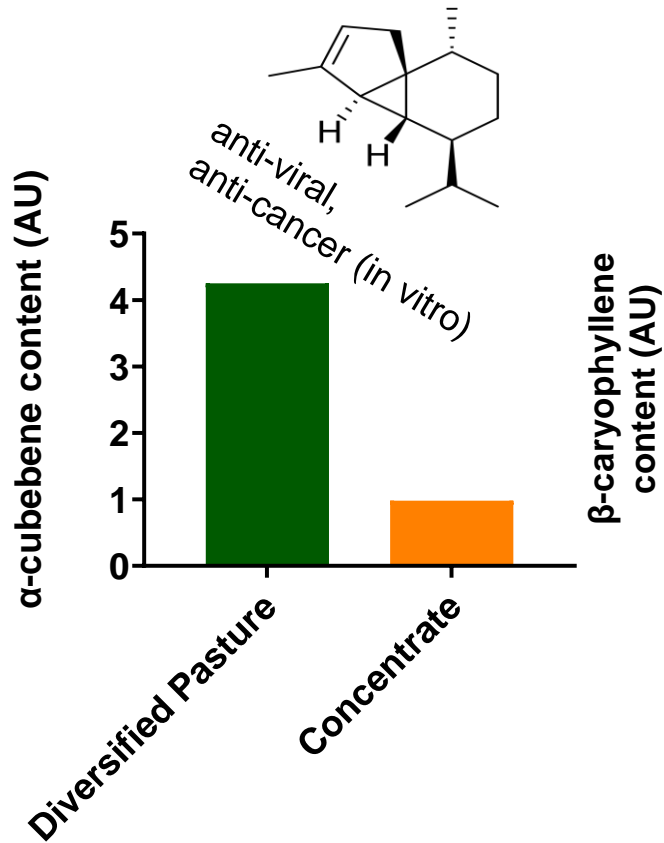


**Phytochemicals: potentially anti-inflammatory, anti-bacterial, anti-oxidant, brain-protective etc.**



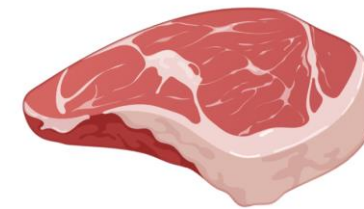


# Pasture grazing accumulates phytochemicals in meat



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



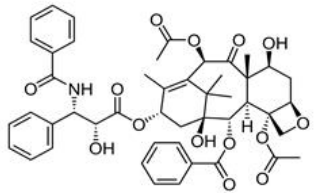
The diagram shows three scenarios of livestock management and their effect on soil carbon sequestration, represented by a color gradient from green (higher) to red (lower).

- Plant-Species Diverse Pasture-Raised (Grass-Fed):** Shows a diverse pasture with various plant species and a cow. This scenario is associated with **HIGHER** soil carbon sequestration (green).
- Monoculture Pasture-Raised (Grass-Fed):** Shows a monoculture pasture with a single plant species and a cow. This scenario is associated with **LOW** soil carbon sequestration (yellow).
- Feedlot-Finished on Concentrates (Grain-Fed):** Shows a cow in a feedlot with a large pile of grain. This scenario is associated with **LOWER** soil carbon sequestration (red).

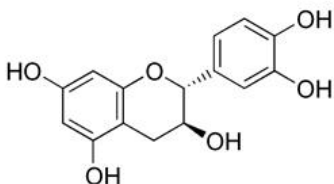
A photograph of a cow grazing in a lush green field. The field is filled with tall green grass and numerous yellow wildflowers. The cow is standing in the middle ground, facing left. The background shows a line of trees and a cloudy sky.

A black cow is shown in profile, grazing on a lush green field. The field is filled with tall grass and numerous small, pink, bell-shaped flowers. The cow's head is lowered towards the ground, and its tongue is visible as it eats. The background is a dense expanse of similar vegetation under bright, natural light.

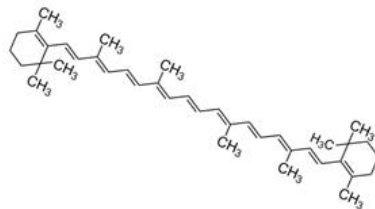
## Phytochemical Richness of Meat and Milk



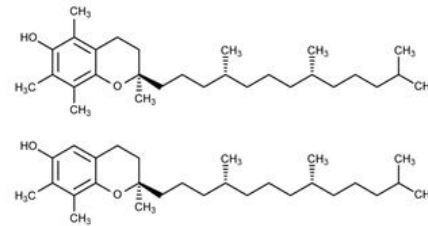
## Terpenoids



## Phenols



## Carotenoids

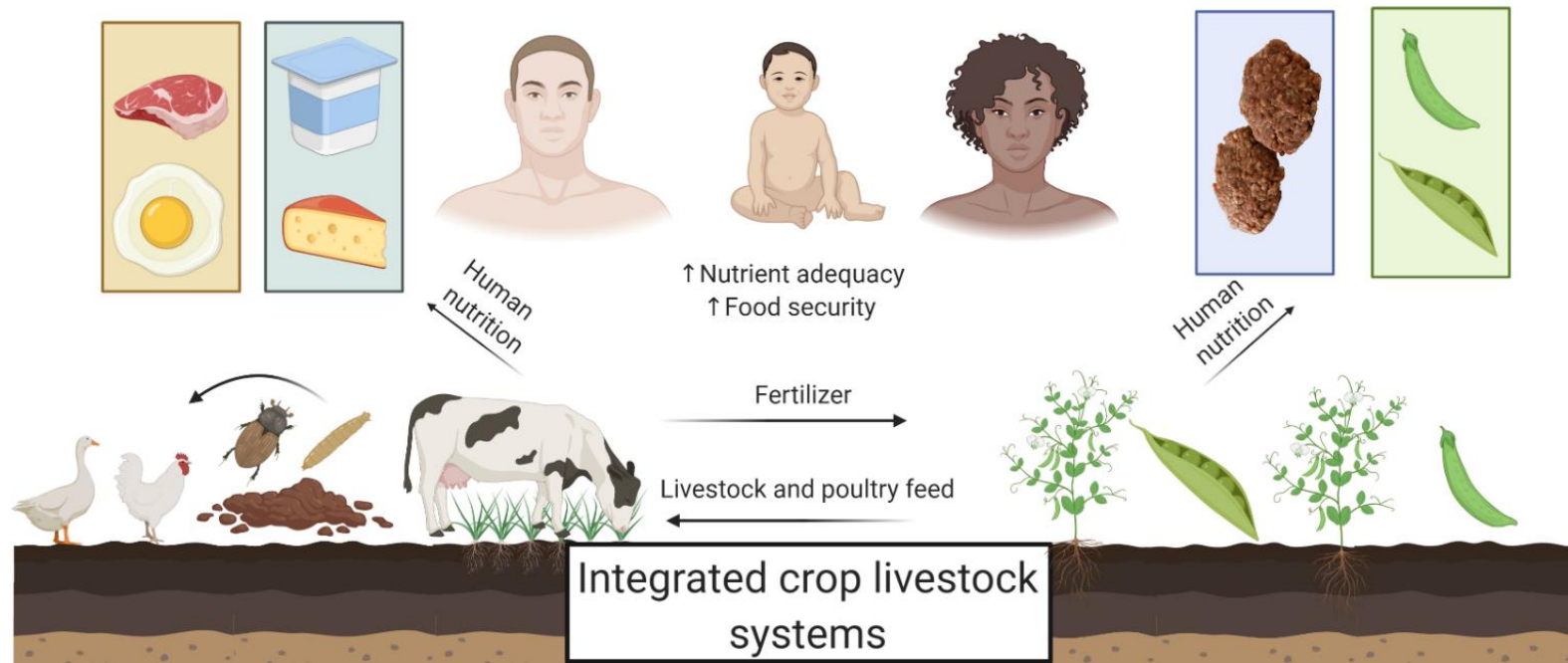


## Tocopherols



# 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.

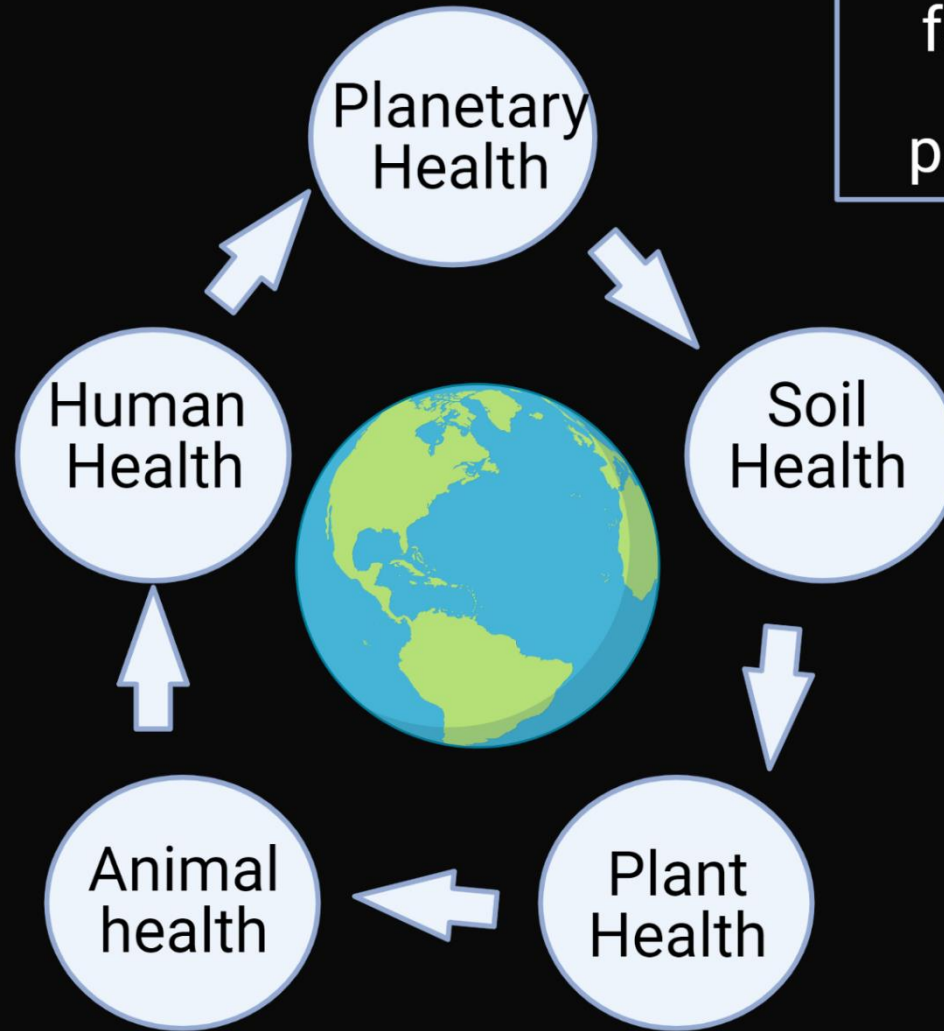






10 billion humans by 2050:  
Creating a Healthy, Sustainable,  
and Equitable Future

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  
envorinmental health

# Thank you!

## Questions and Discussions

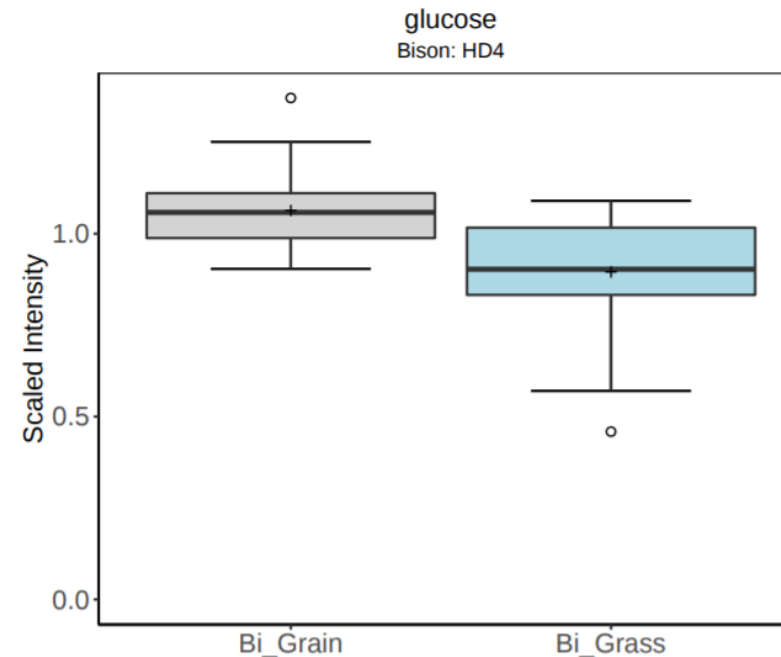
**Stephan van Vliet, PhD**

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



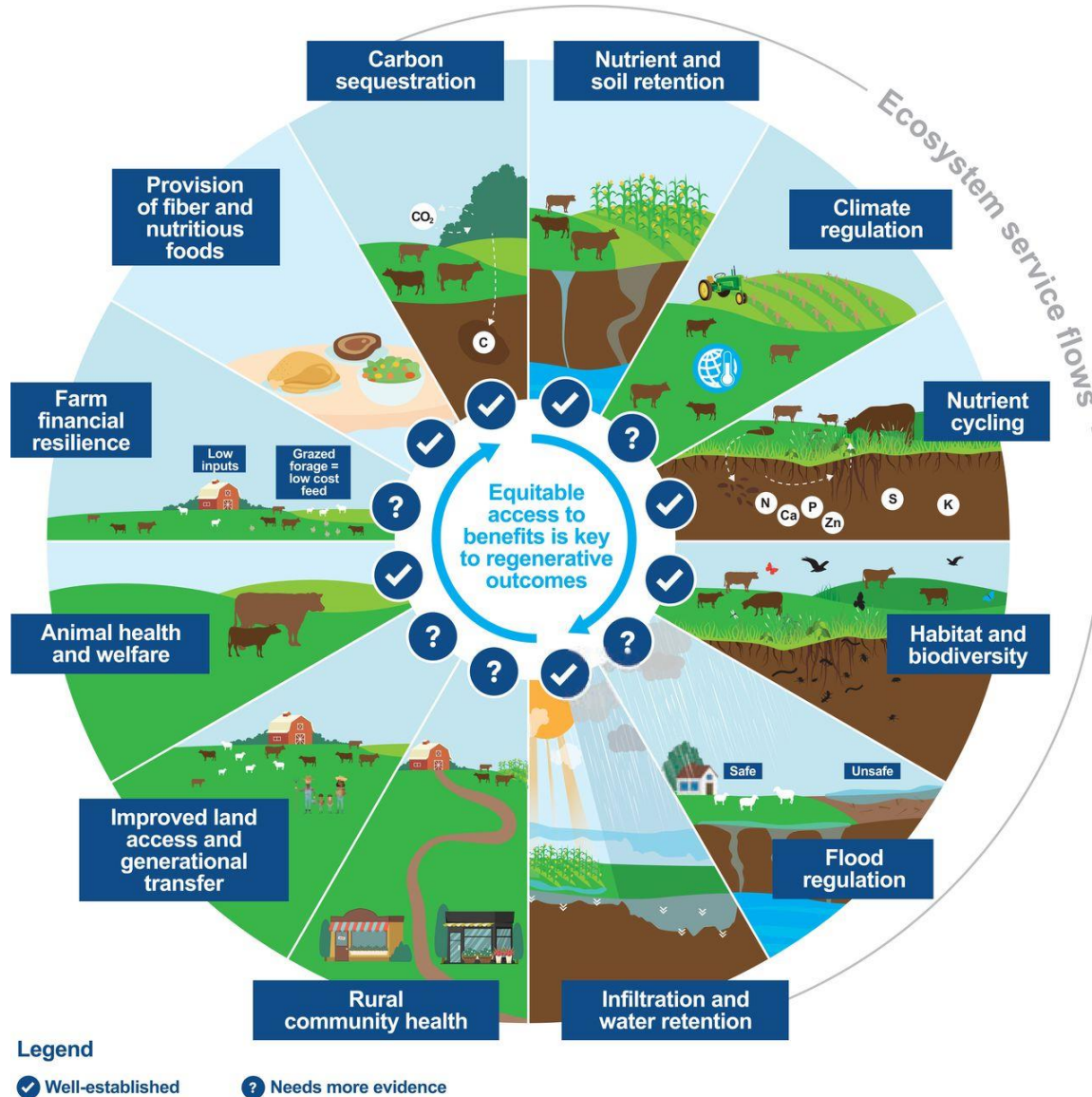
# Meat metabolites give clues about animal health...

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, Mannose and Galactose Metabolism	fructose	0.77
	mannitol/sorbitol	0.83
	mannose	0.74
	galactonate	0.73
TCA Cycle	citrate	1.04
	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