

More than keeping you regular: how fiber-microbiome interactions shape health

Steve Lindemann

IAND Annual Meeting

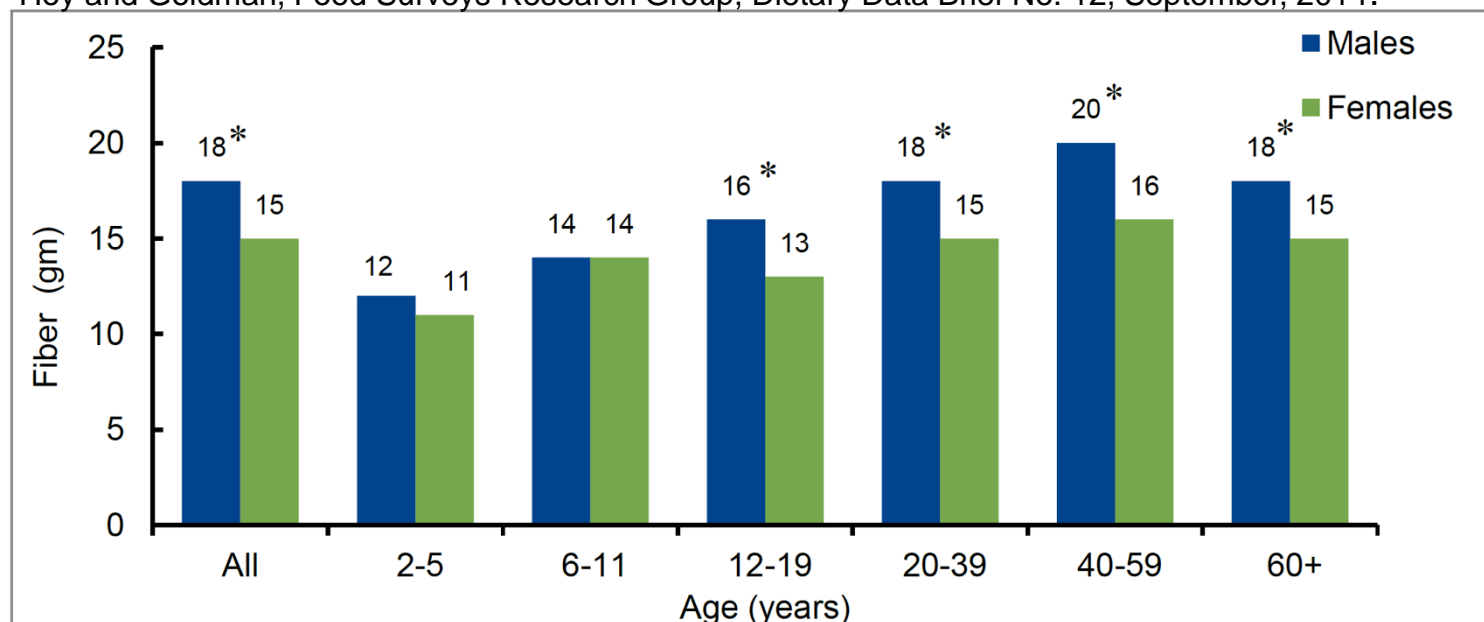
4/11/18

- Introduction to “dietary fiber” and its interactions with the microbiome and health
- All “dietary fibers” are not created equal
#1: insoluble wheat bran particles
- All “dietary fibers” are not created equal
#2: soluble wheat arabinoxylans
- Summary and recommendations

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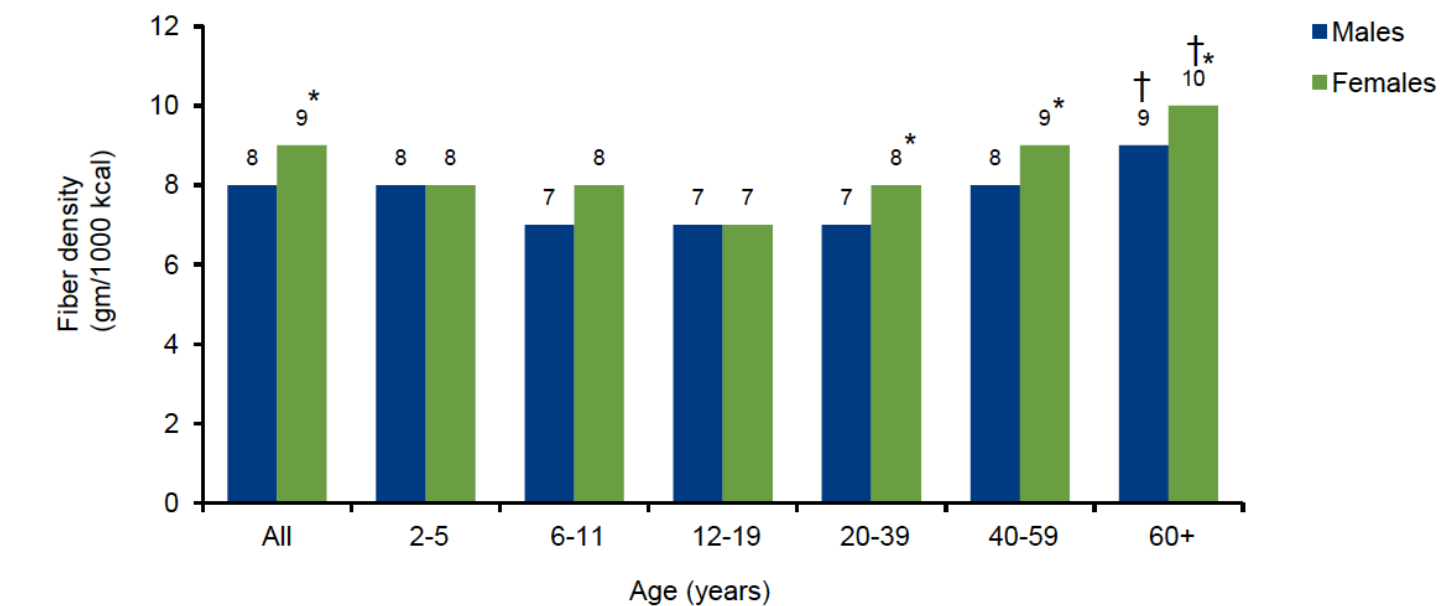
Figure 1. Fiber intake of U.S. population, WWEIA, NHANES 2009-2010

Hoy and Goldman, Food Surveys Research Group, Dietary Data Brief No. 12, September, 2014.



*Significantly different from females ($p < 0.001$)

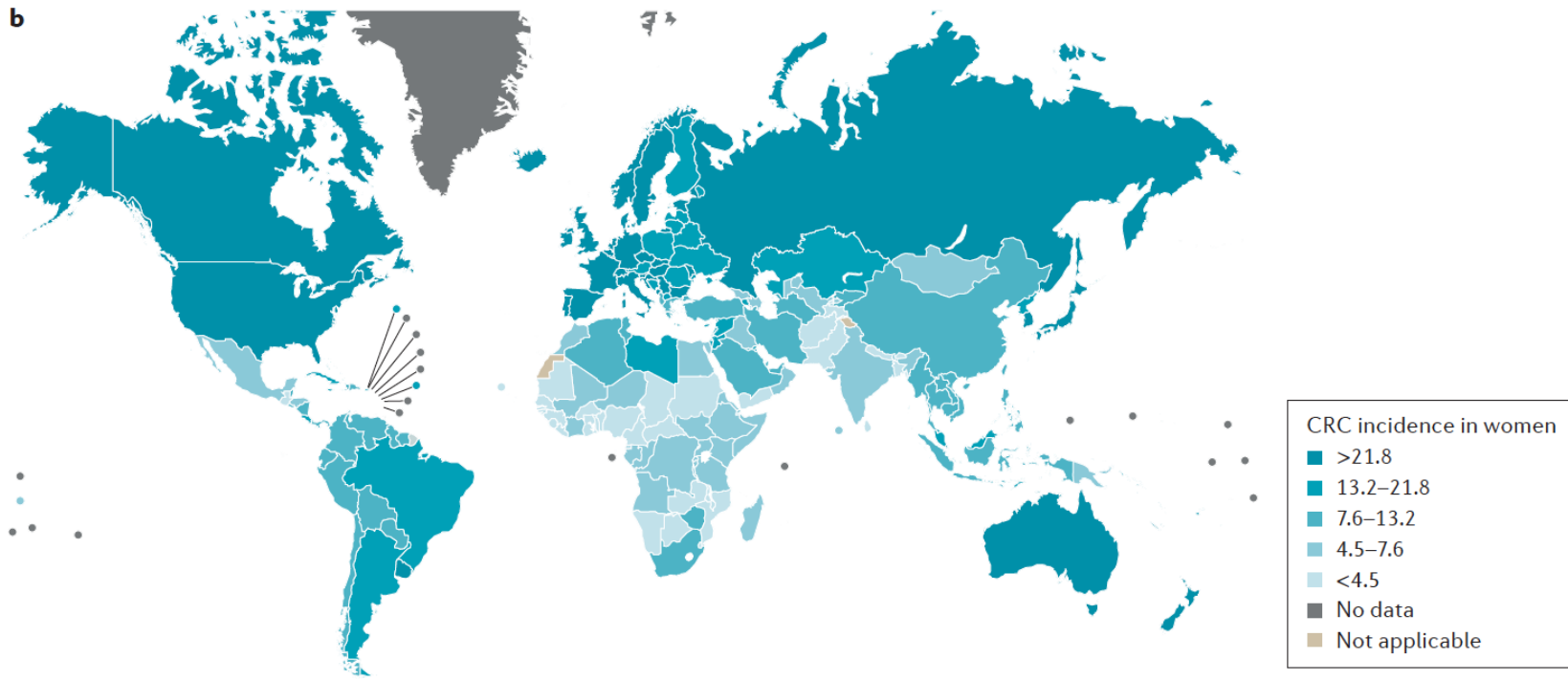
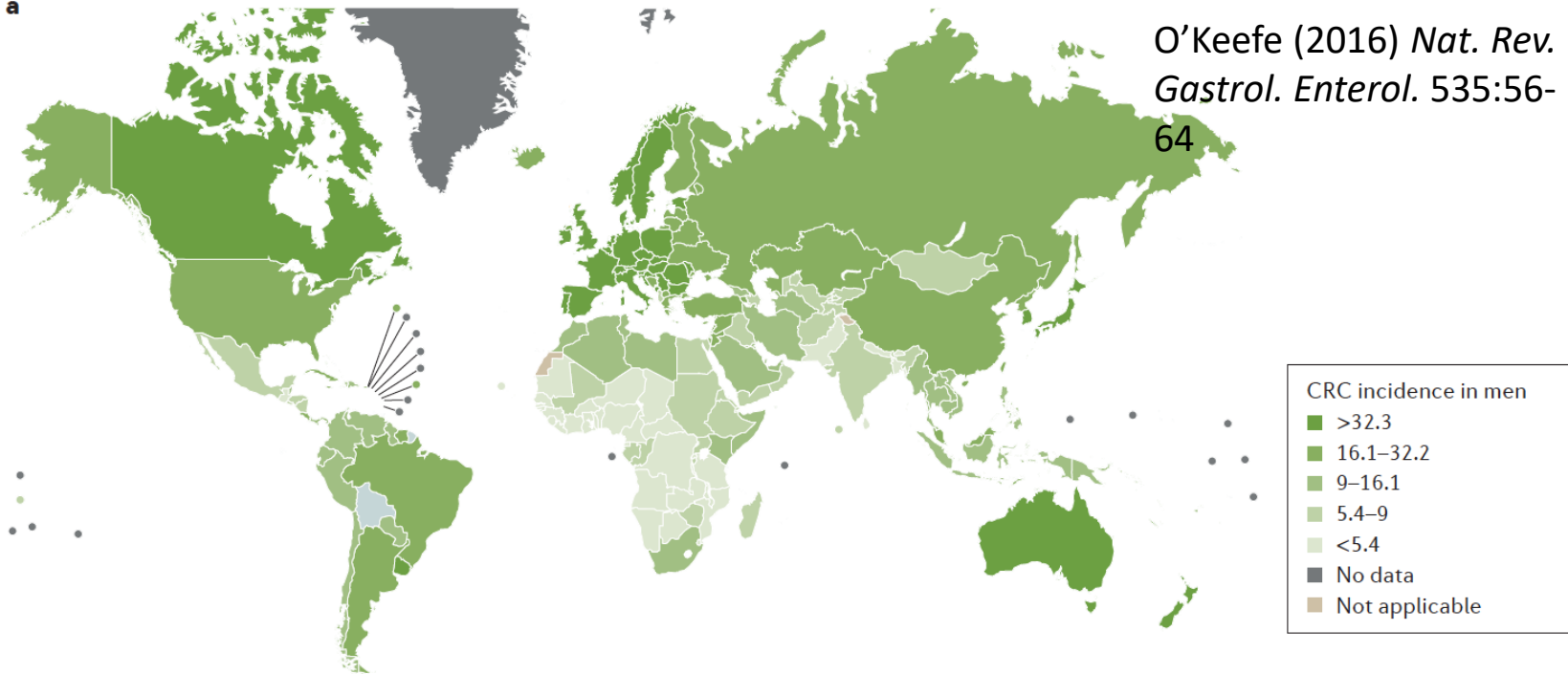
+SOURCE: What We Eat in America, NHANES 2009-2010, day 1, individuals 2+ years



Western Diseases their emergence & prevention

H.C. Trowell / D.P. Burkitt

O'Keefe (2016) *Nat. Rev. Gastroenterol. Enterol.* 535:56-64



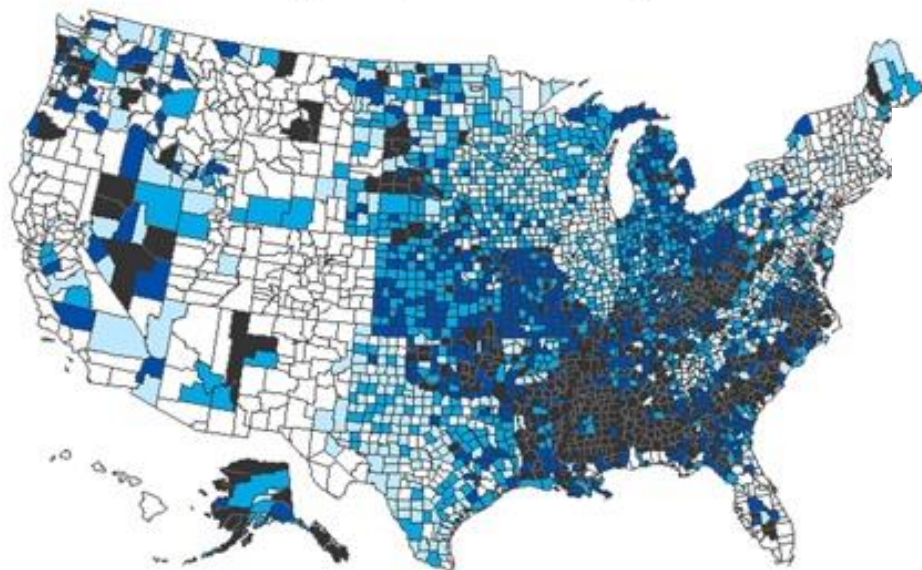
Denis Burkitt



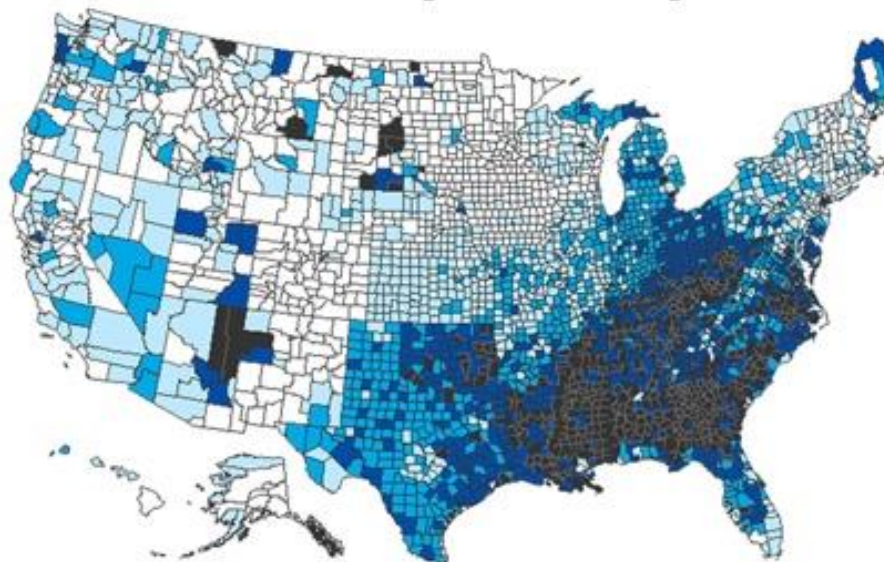
Hugh Trowell

Obesity by county

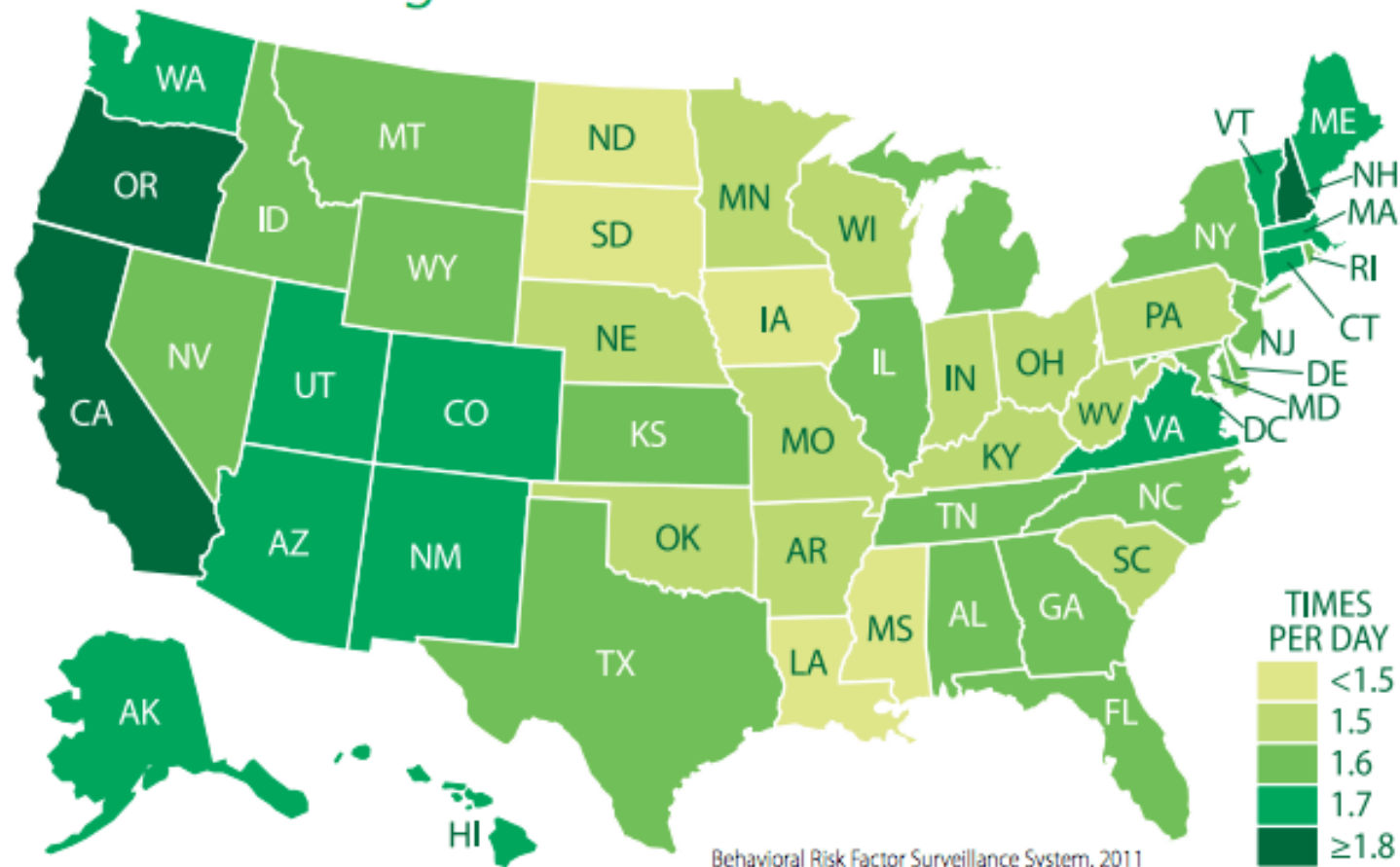
DeNoon, Harvard Health Blog, June 19, 2013. Data: CDC

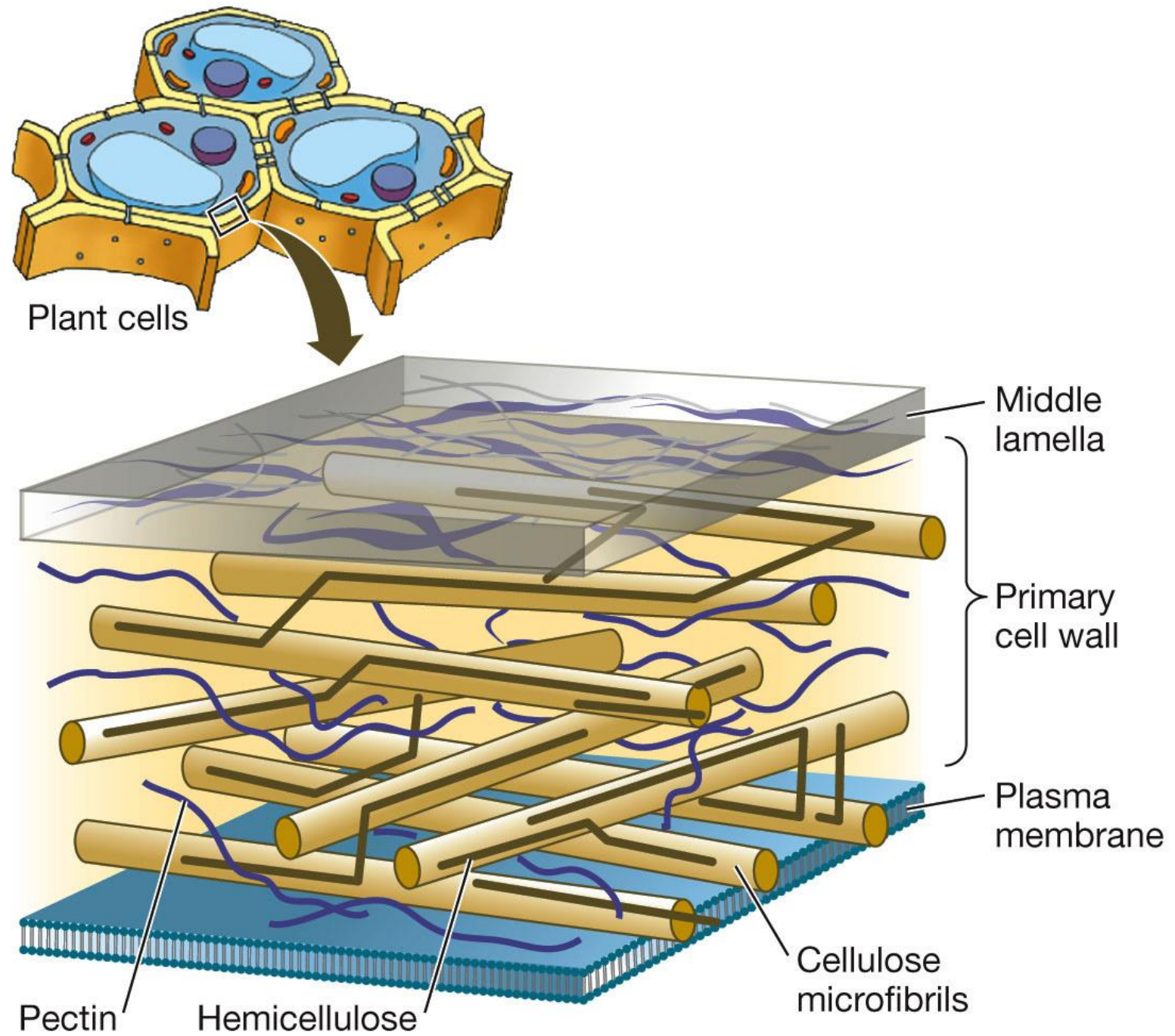


Diabetes by county



Median **Daily Vegetable Intake** Among Adults in the United States

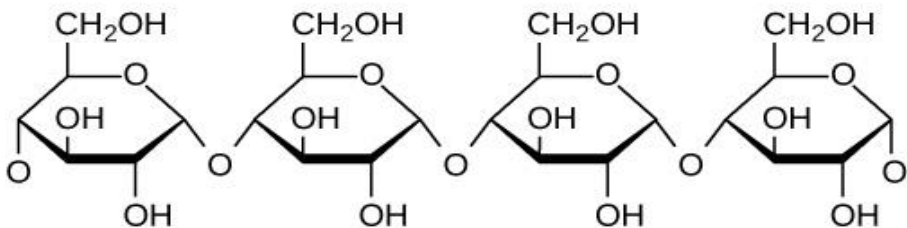




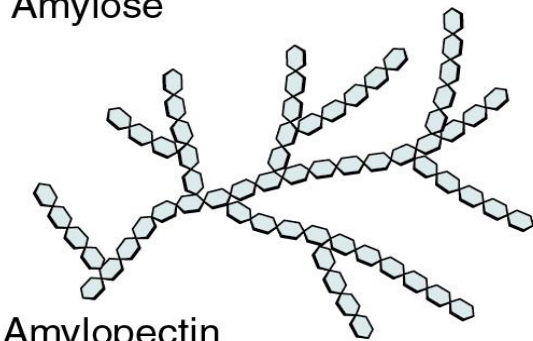
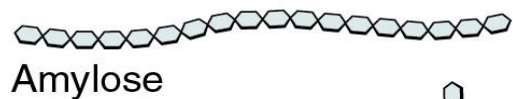
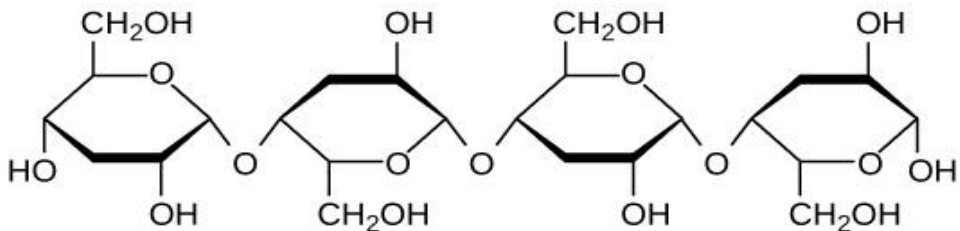
LIFE 9e, Figure 34.5

"FIBER" STRUCTURE, PROPERTIES, AND DEGRADATION DEPEND ON LINKAGES BETWEEN SUGARS

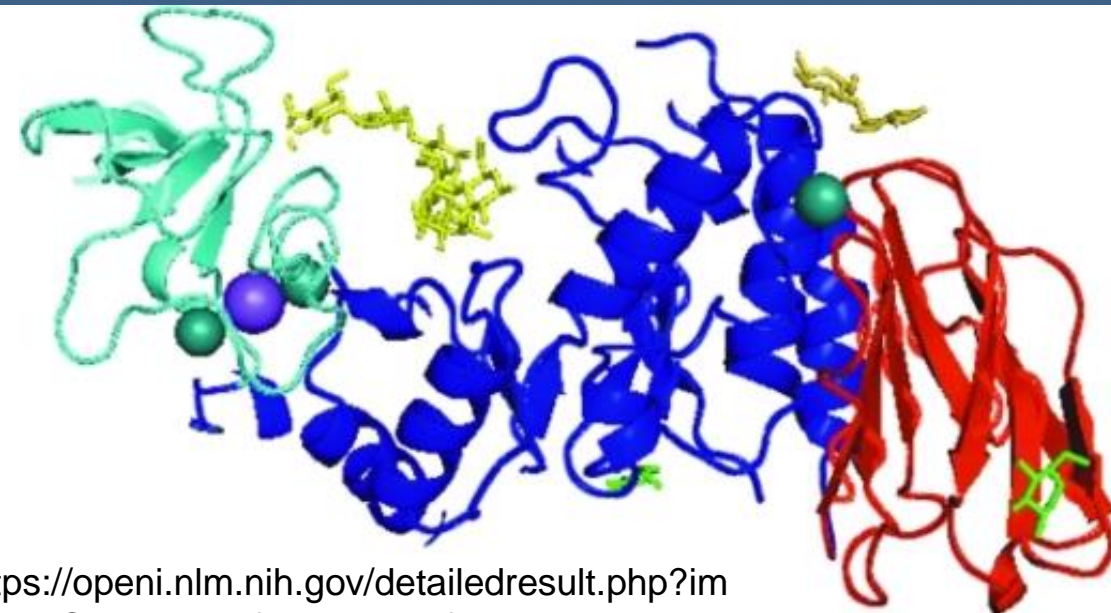
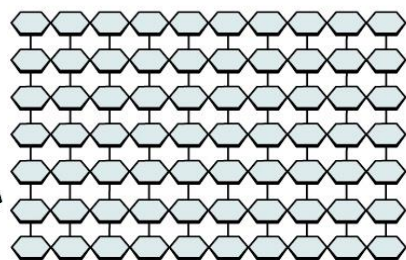
Starch



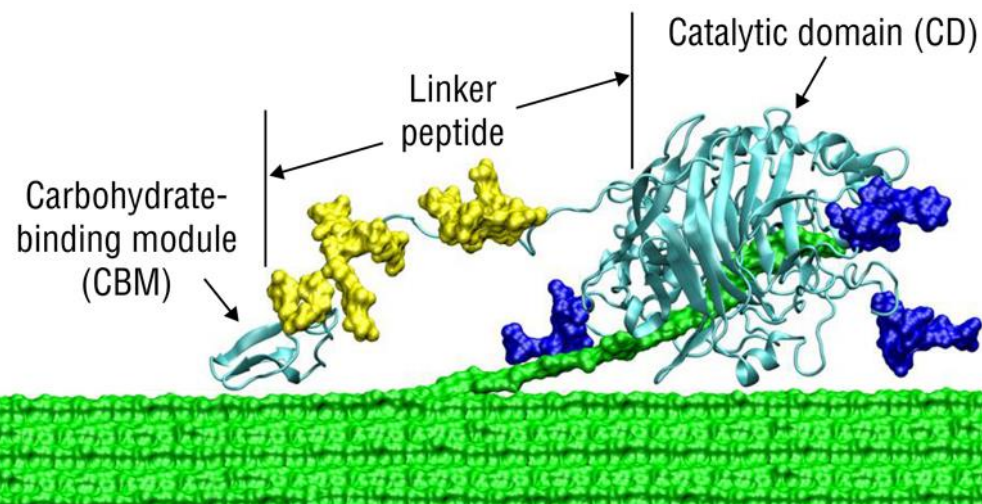
Cellulose



Starch

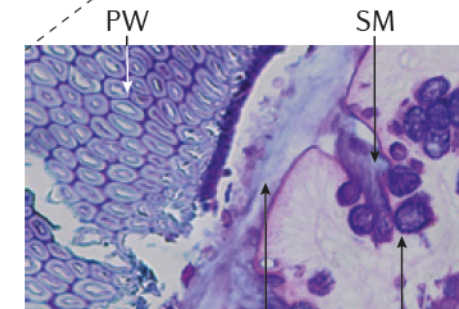
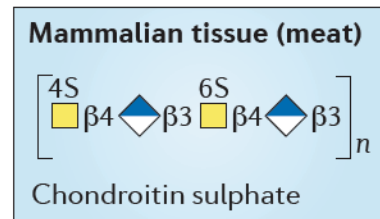
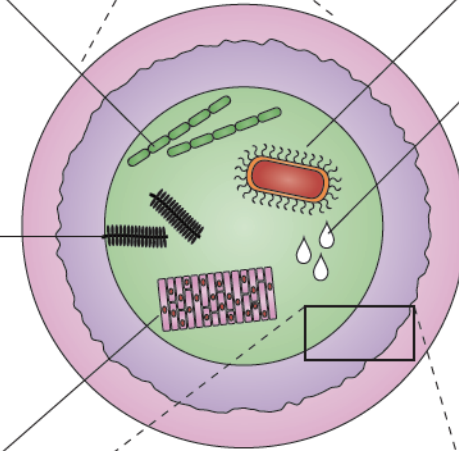
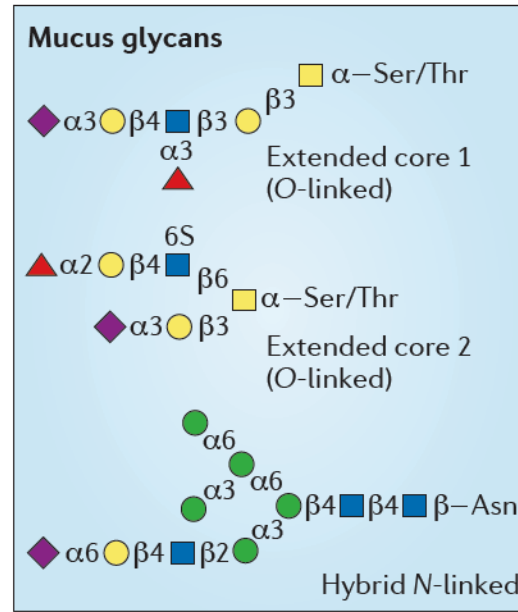
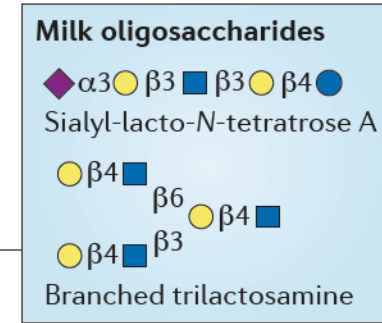
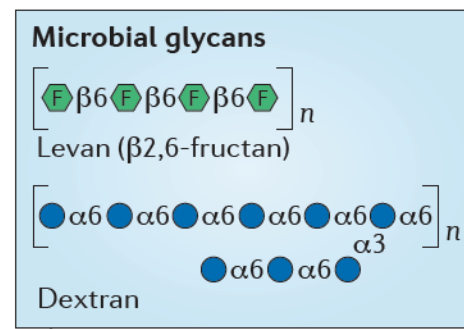
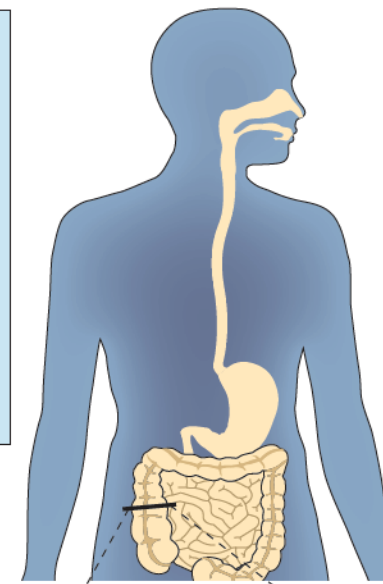
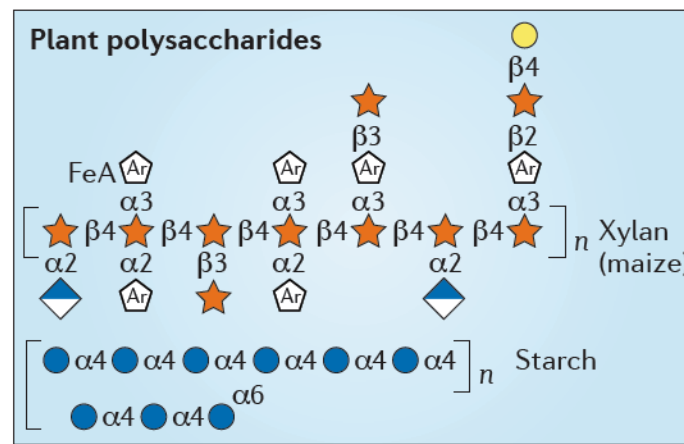


https://openi.nlm.nih.gov/detailedresult.php?img=PMC2242873_f-62-00849-fig3&req=4



<https://www.e-education.psu.edu/egee439/node/670>

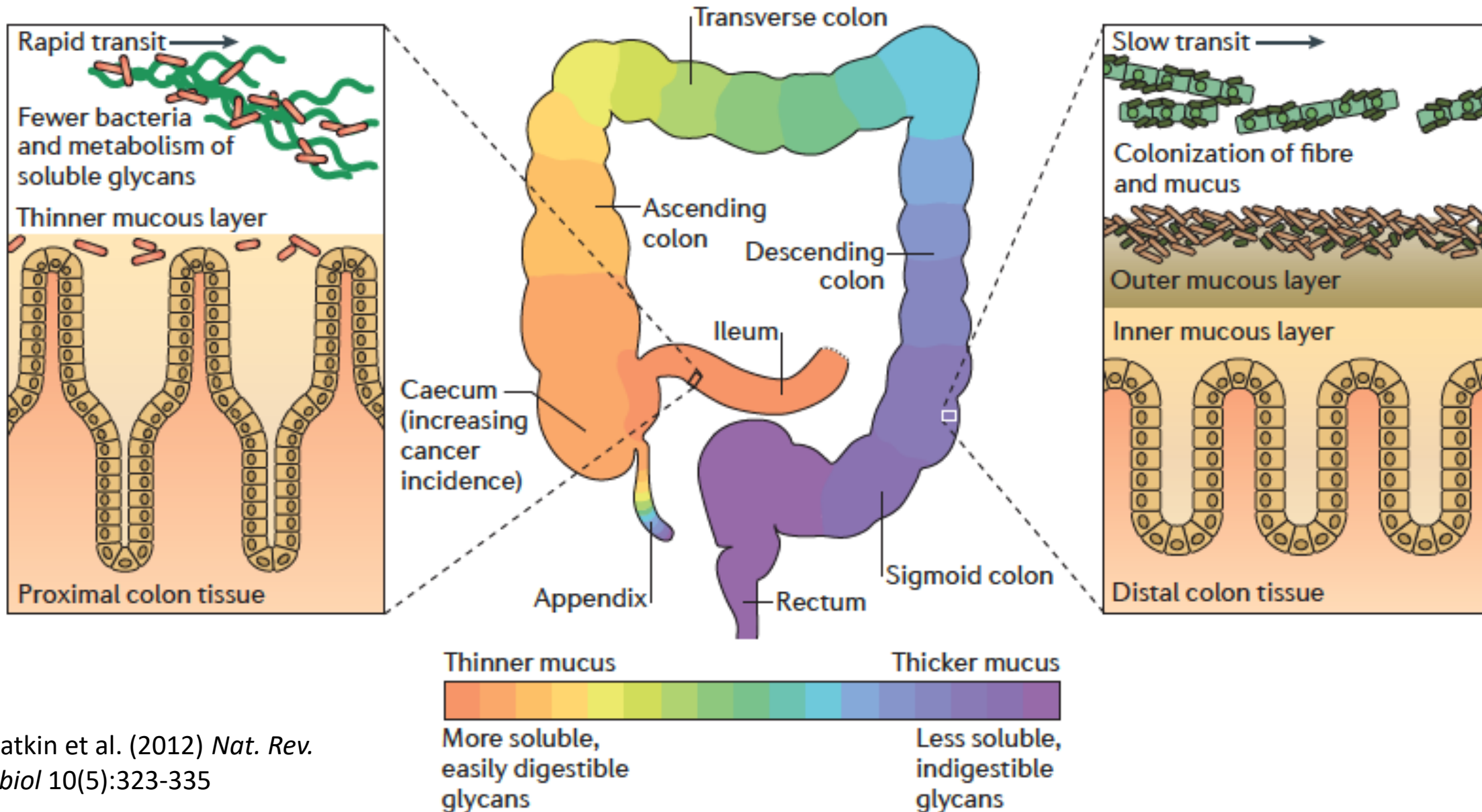
- Microbes utilize carbohydrate resources of diverse origin and structure in the colonic environment
- Carbohydrates are incredibly diverse in structure:
 - Pentapeptide: 3,200,000 possible structures
 - Pentasaccharide: Estimated 1,569,745,920 possible structures (Pérez, S. & Tvaroška, 2014)



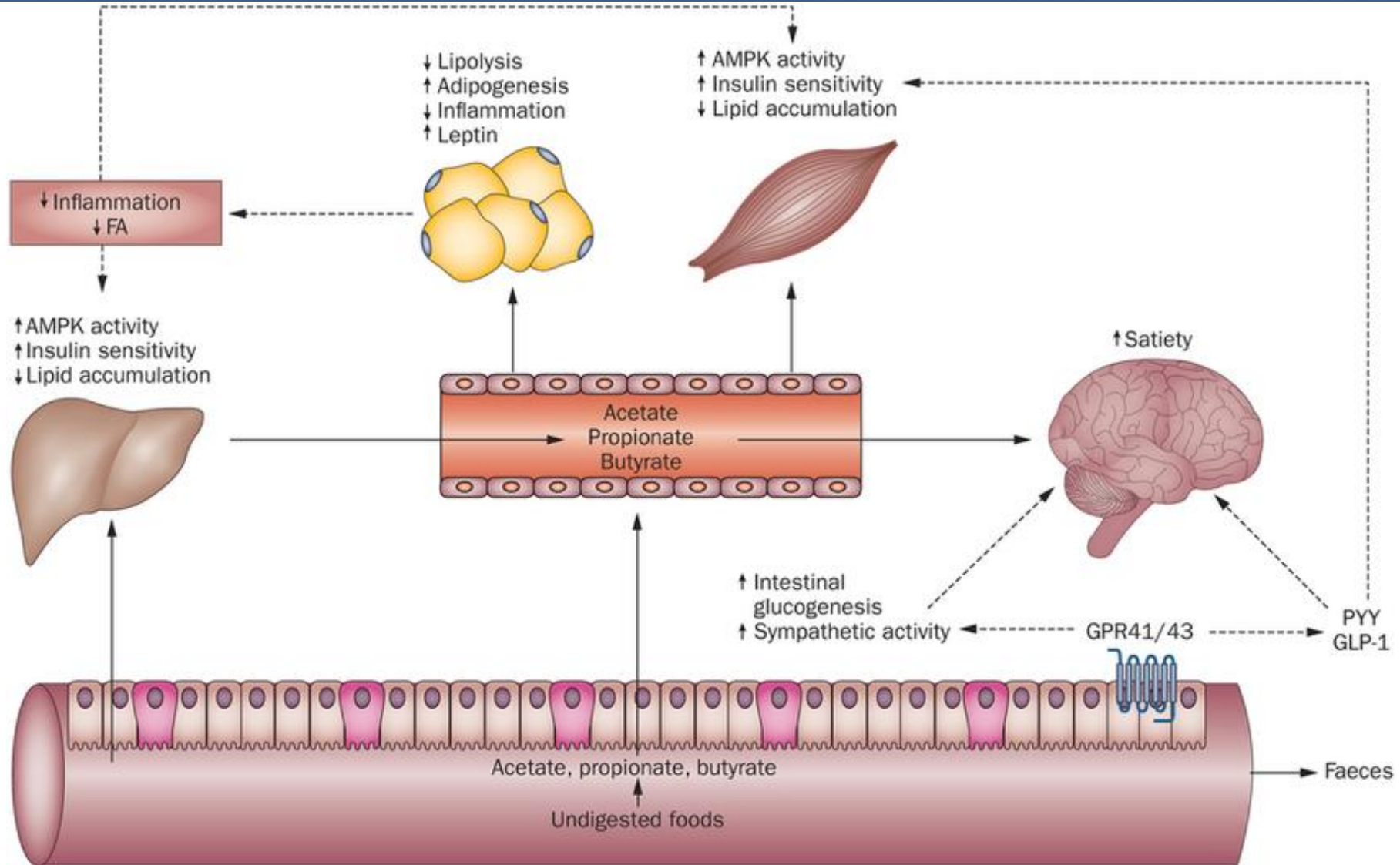
Key

- Glucose
- Mannose
- N-acetylglucosamine
- N-acetylgalactosamine
- ◆ N-acetylneuraminic acid
- Galactose
- ★ Xylose
- ⬠ Arabinose
- ⬠ Fructose
- ▲ Fucose
- ⬠ Glucuronic acid
- FeA Ferulic acid
- S Sulphate

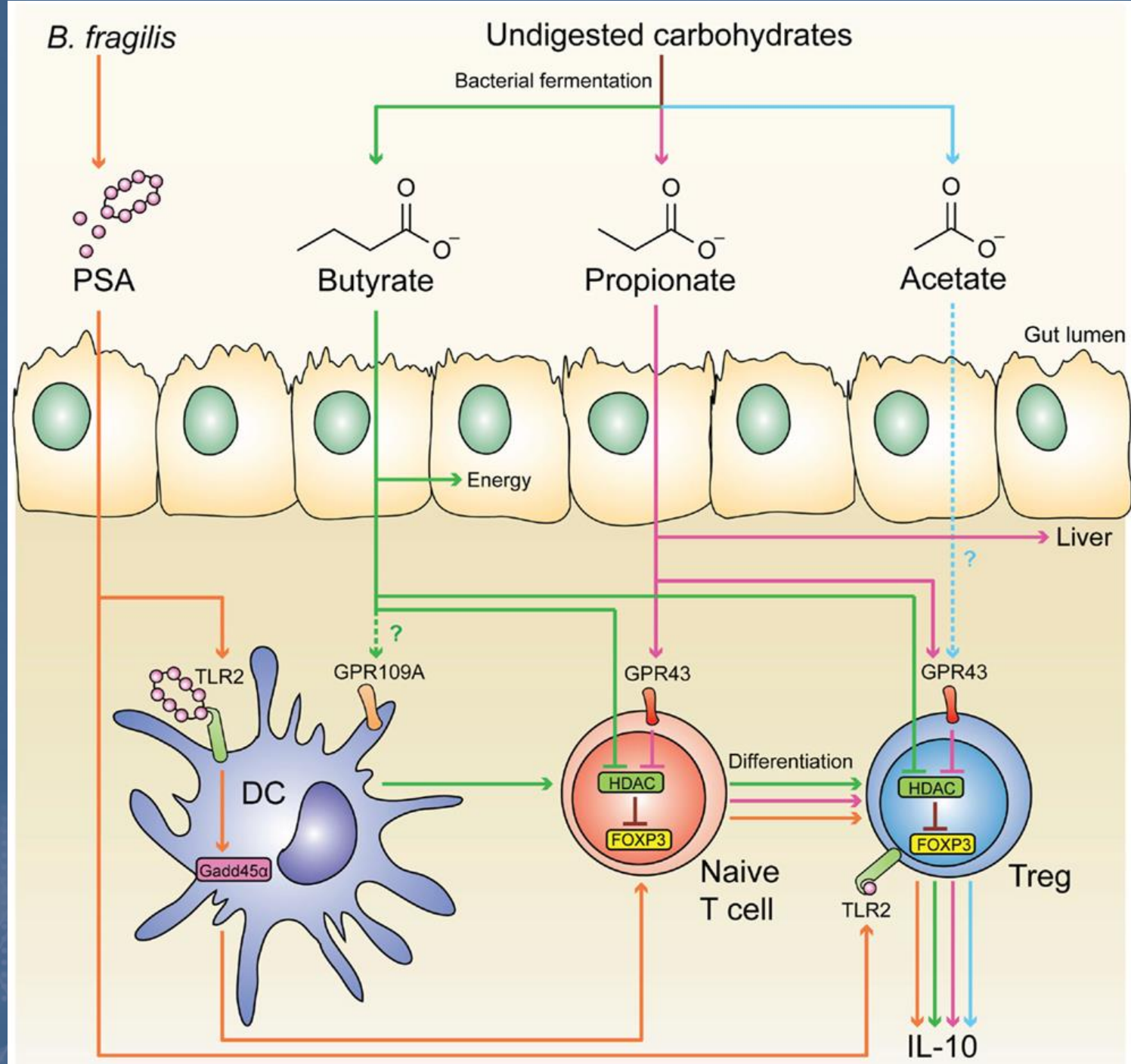
COMPETITION FOR DIVERSE FIBERS SETS UP GRADIENTS IN THE COLON



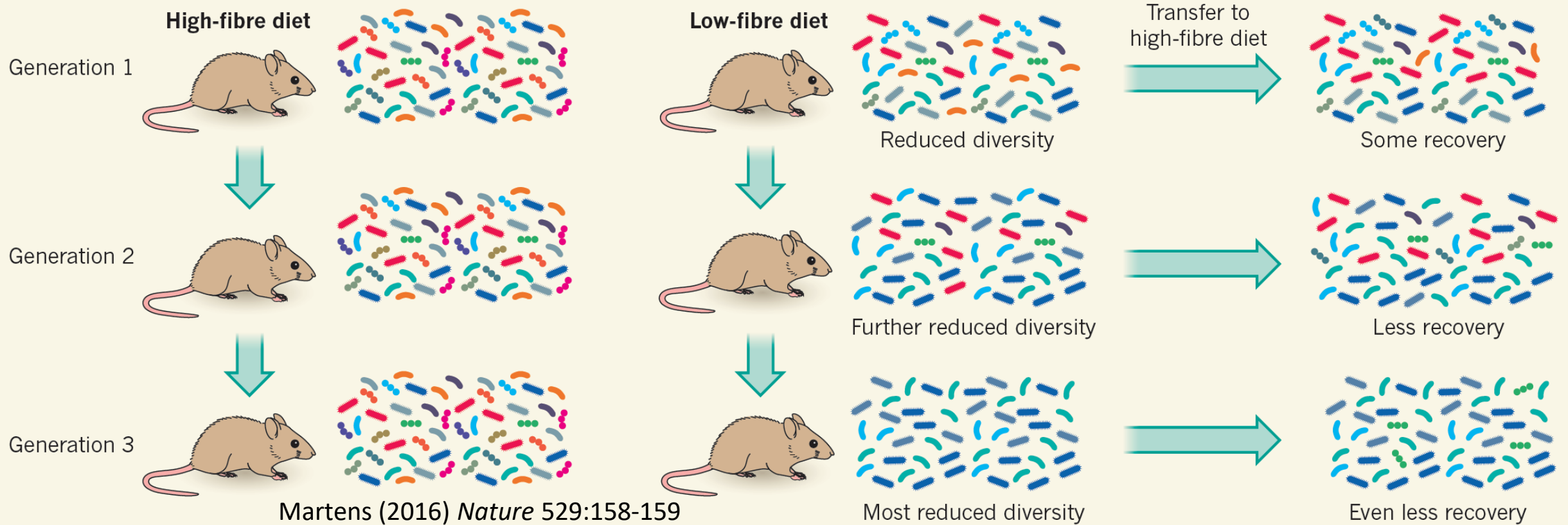
SCFAS GLOBALLY REGULATE HUMAN METABOLISM: SATIETY, GLUCOSE, AND LIPID BALANCES



- Terminal SCFAs of fiber fermentation are known to exert impact on immune cell differentiation and response to bacterial structures
- SCFAs are thought to exert generally anti-inflammatory effects on the gut epithelium



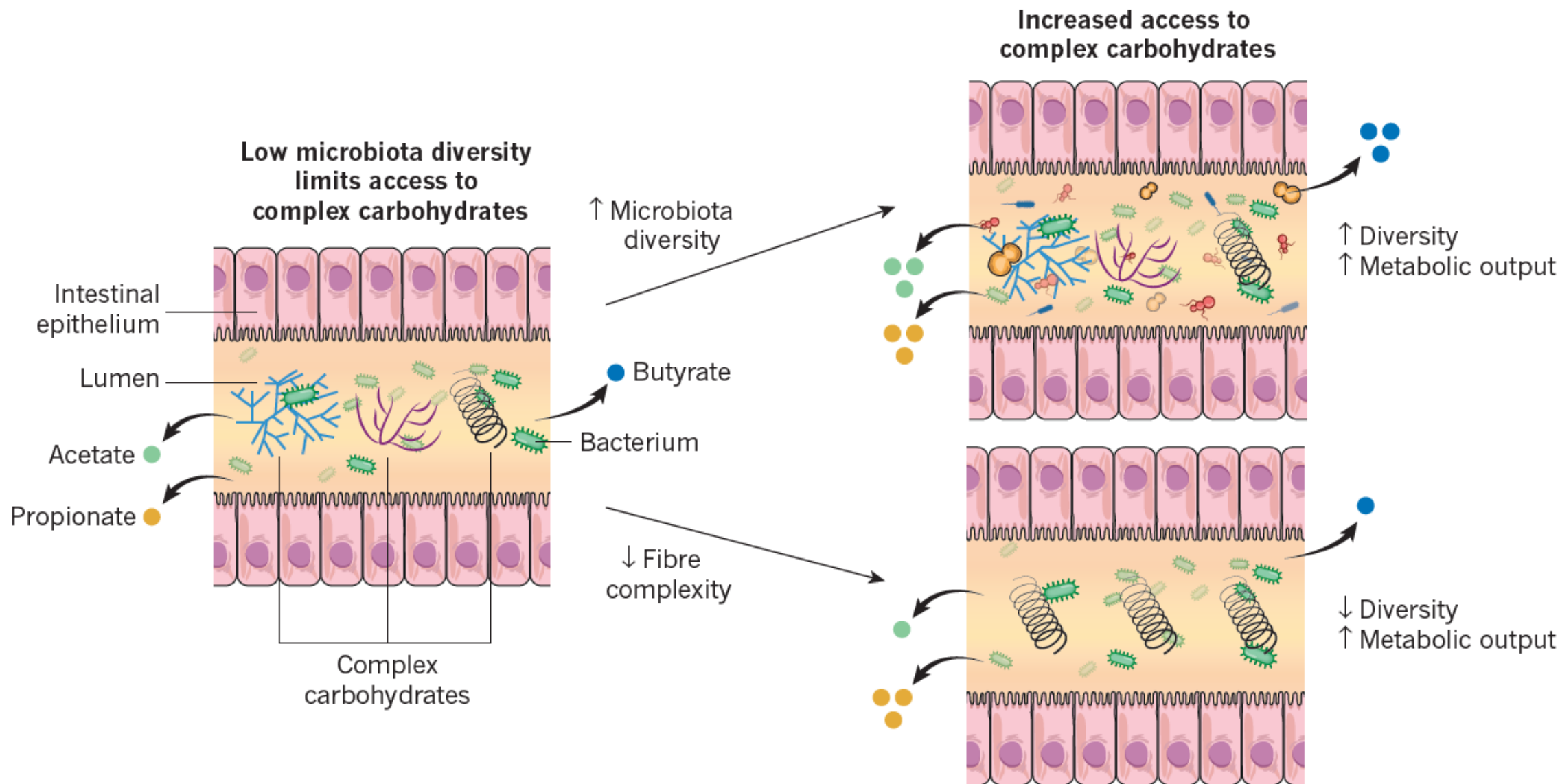
"FIBER" SUSTAINS HIGH MICROBIAL DIVERSITY IN THE GUT



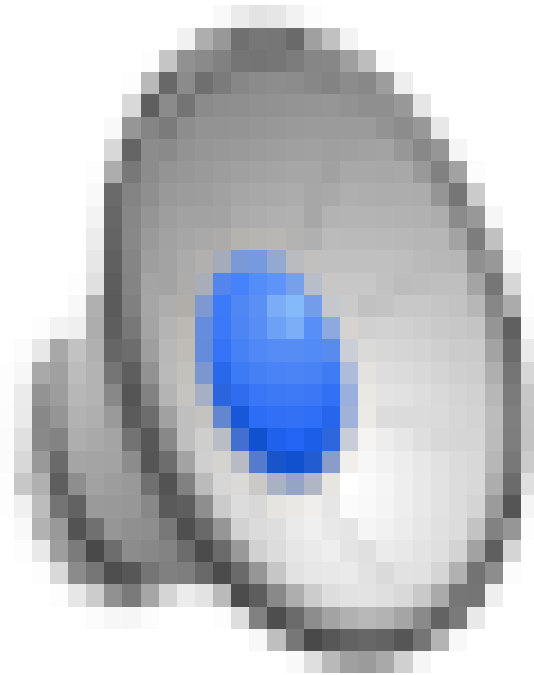
Low gut microbial diversity is linked to:

- Metabolic syndrome
- Inflammatory bowel disease
- Type 2 diabetes
- Colorectal cancer

THE FATE OF FIBERS IN THE GUT ARE TIED TO THE MICROBES PRESENT AND HOW THEY PROCESS THEM

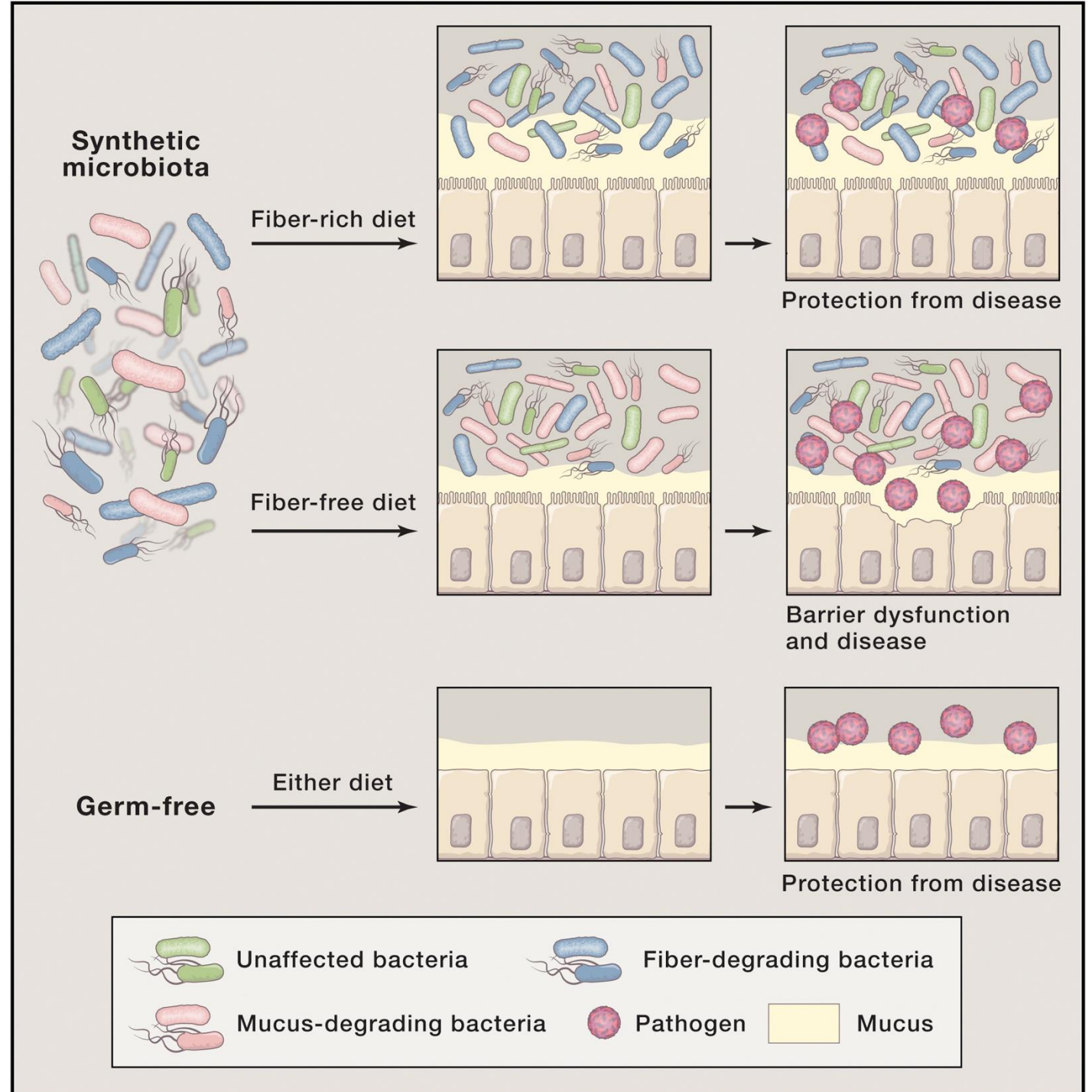


THE HUMAN GUT IS A MICROBIAL ISLAND – WHERE DOES DIVERSITY COME FROM?



- Fiber consumption has recently been linked to resistance to pathogens in a microbiota-dependent manner
- Consumption of fiber is inversely correlated with consumption of host mucin, thinning the barrier with luminal pathogens

Gazzanga and Kaspar (2016) *Cell* 167(5)1161-1162



Nutrition Facts

Serving Size 21 Biscuits (54g)

Amount Per Serving	Cereal	with 1/2 cup skim milk
Calories	190	230
Calories from Fat	10	10
% Daily Value**		
Total Fat 1g*	2%	2%
Saturated Fat 0g	0%	0%
Trans Fat 0g		
Polyunsaturated Fat 0.5g		
Monounsaturated Fat 0g		
Cholesterol 0mg	0%	0%
Sodium 0mg	0%	3%
Potassium 200mg	6%	11%
Total Carbohydrate 46g	15%	17%
Dietary Fiber 6g	23%	23%
Sugars 11g		
Protein 5g		

Fiber 101: Soluble Fiber vs Insoluble Fiber

Written By [Gloria Tsang, RD](#) on Jan 29, 2013



“When making a food choice decision, don’t worry about choosing a specific type of fiber.”

-Gloria Tsang, RD

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WESTERNIZATION OF DIET IS CLOSELY ASSOCIATED WITH DECREASING PARTICLE SIZES OF CEREAL FLOURS



<https://fellowsblog.ted.com/how-ghanaian-food-changed-my-life-and-how-to-make-it-yourself-3b59e035278a>



<https://byleaveswelive.wordpress.com/about/>



<http://www.flourmillsmachine.com/>

DIRECT SEPARATION OF MILLER-PROVIDED BRAN PARTICLES



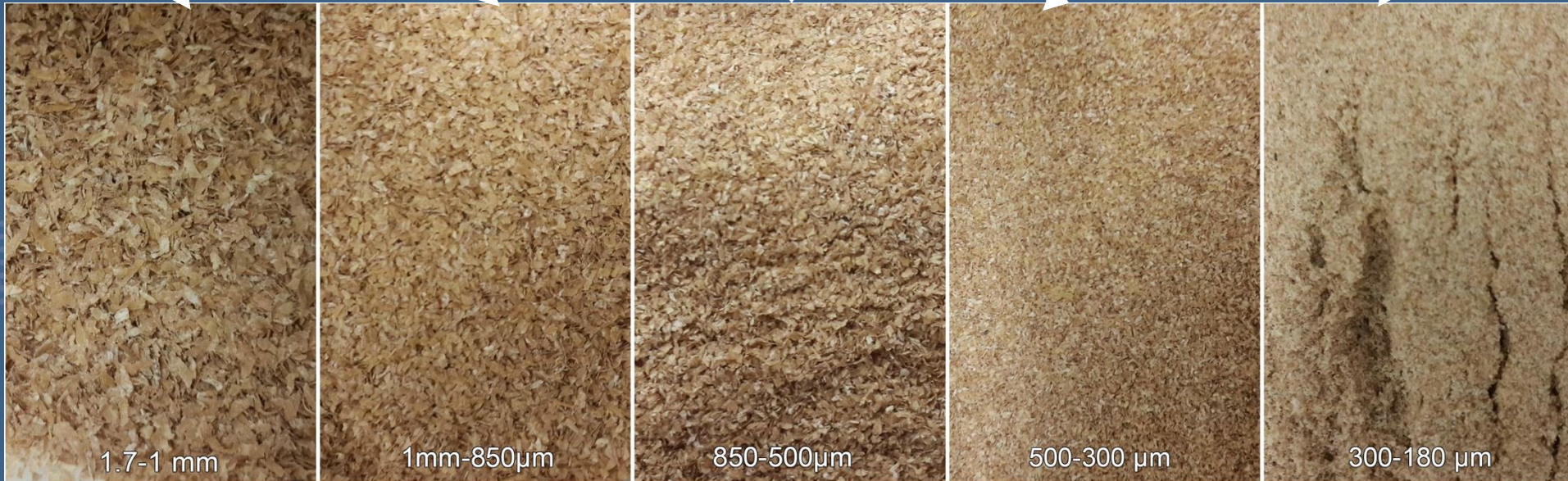
HRS wheat bran



Sieving
Process

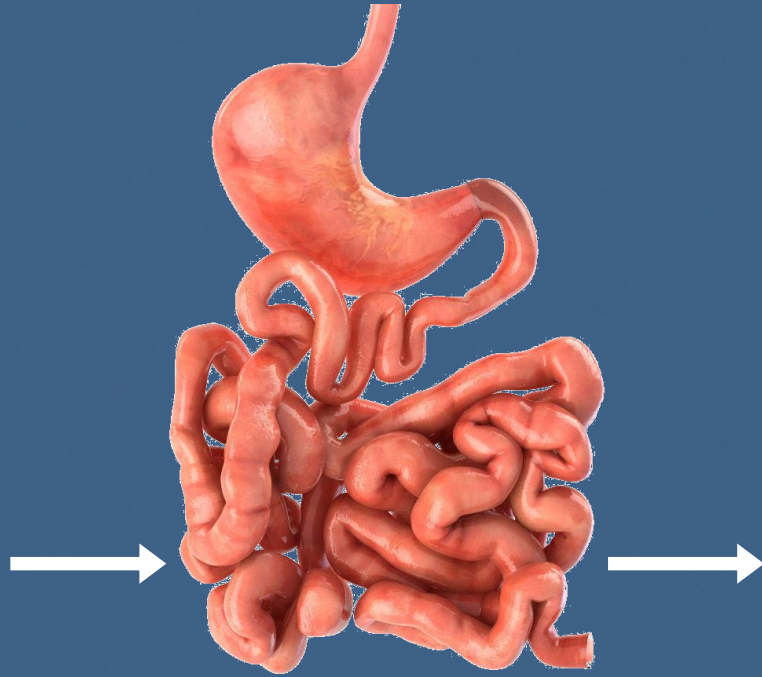


Arianna
Romero

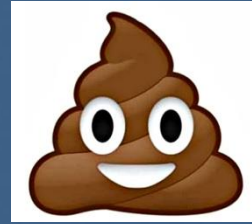


IN VITRO FERMENTATION EXPERIMENTS EXAMINE PARTICLE SIZE APART FROM OTHER VARIABLES

Range of particle sizes



In vitro digestion
mimicking stomach
and small intestinal
transit



3 "healthy
donors"

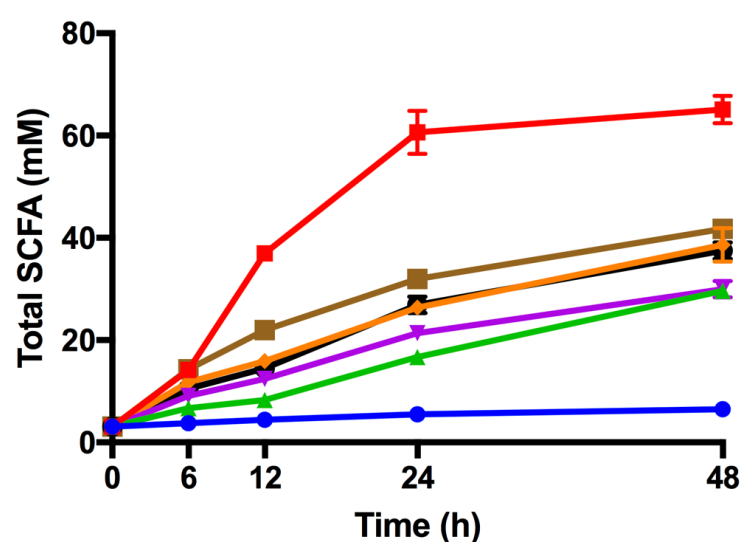
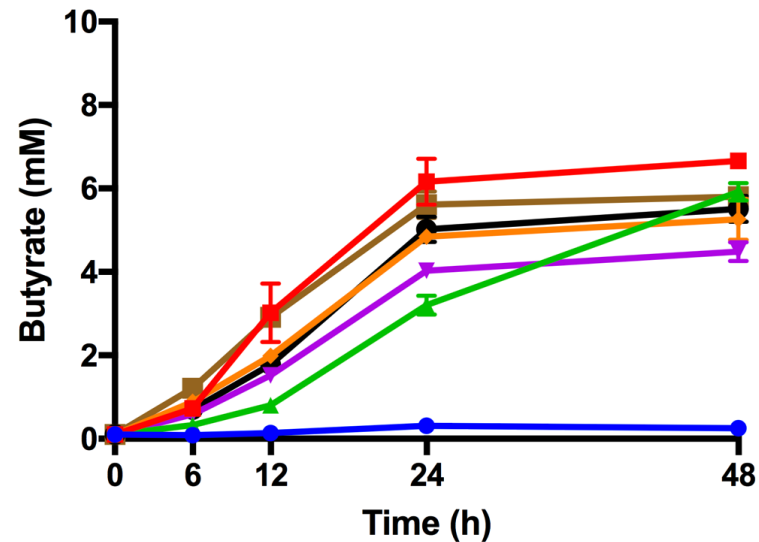
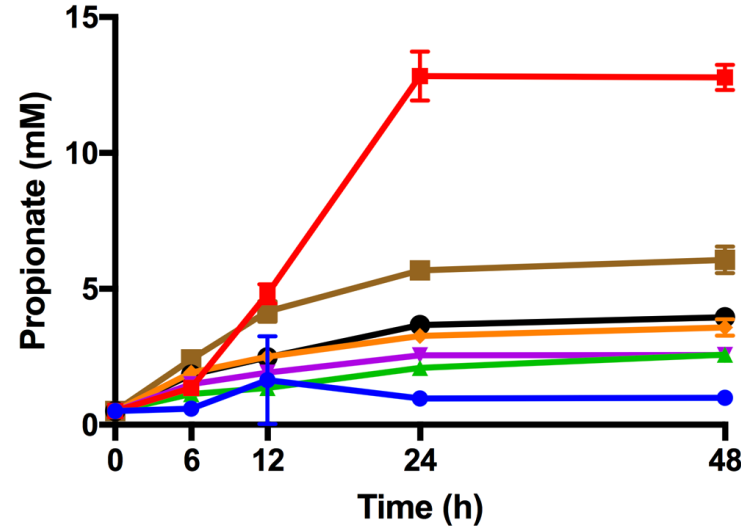
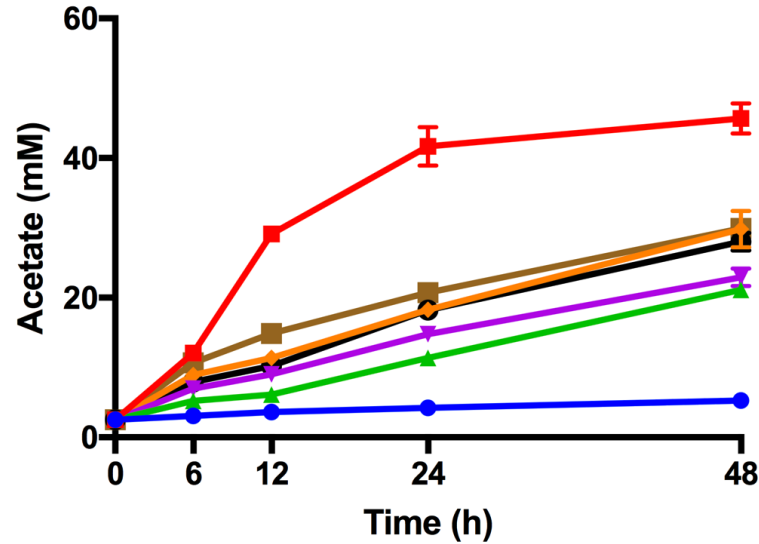


Batch anaerobic
fermentation

16S
Sequencing

SCFA
analysis
(GC)

SIZE DETERMINES FERMENTATION RATE OF DIRECTLY-SEPARATED PARTICLES



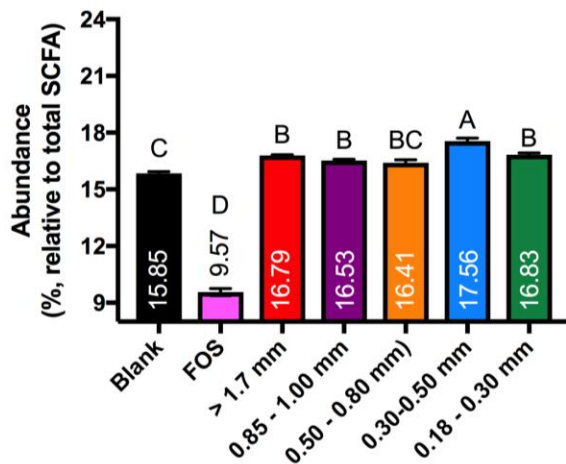
- Blank
- FOS
- Wheat Bran (coarse, >1.7 mm)
- Wheat Bran (0.85-1 mm)
- Wheat Bran (0.5-0.8 mm)
- Wheat Bran (0.3-0.5 mm)
- Wheat Bran (Fine, 0.18-0.30 mm)



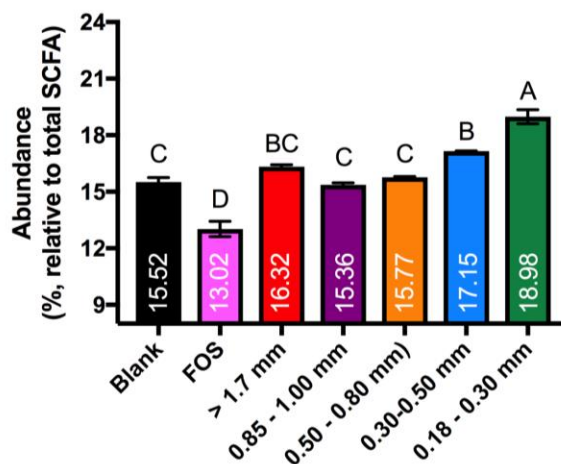
Yunus
Tunçil

PARTICLE SIZE DETERMINED THE BALANCE OF PROPIONATE AND BUTYRATE

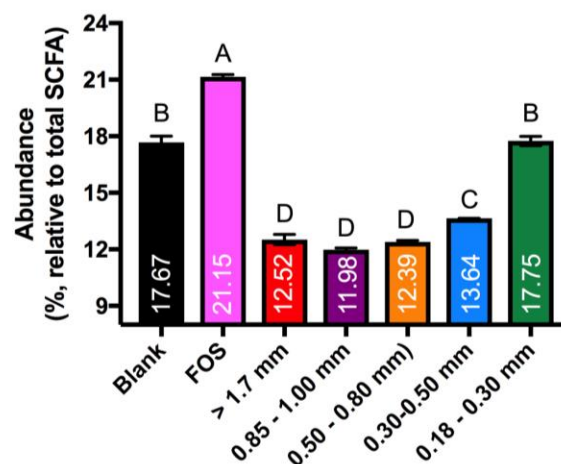
Propionate_6h



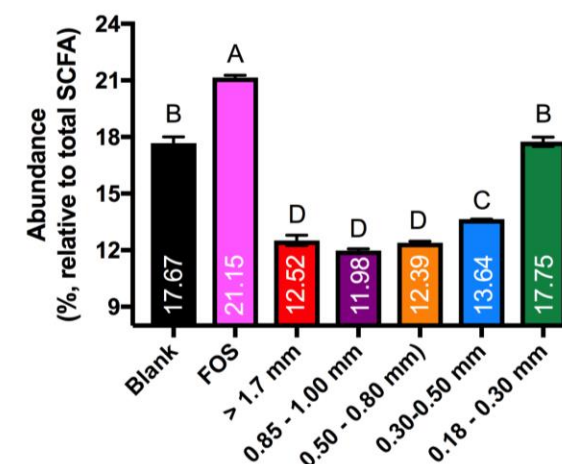
Propionate_12h



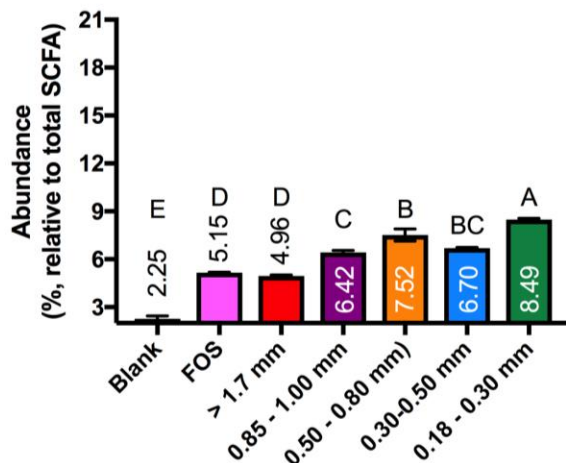
Propionate_24h



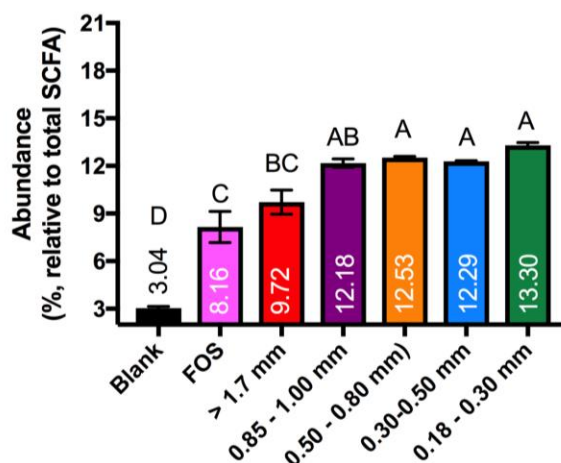
Propionate_24h



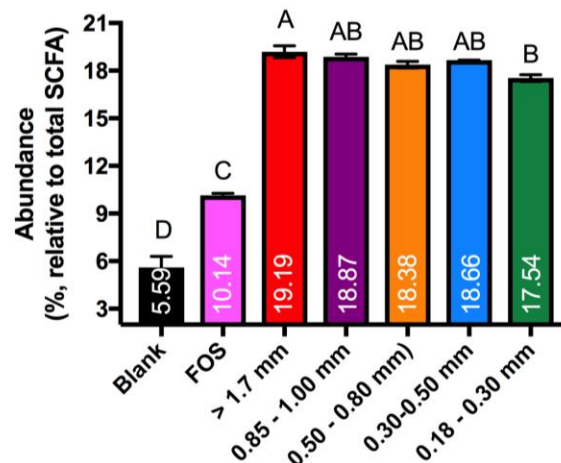
Butyrate_6h



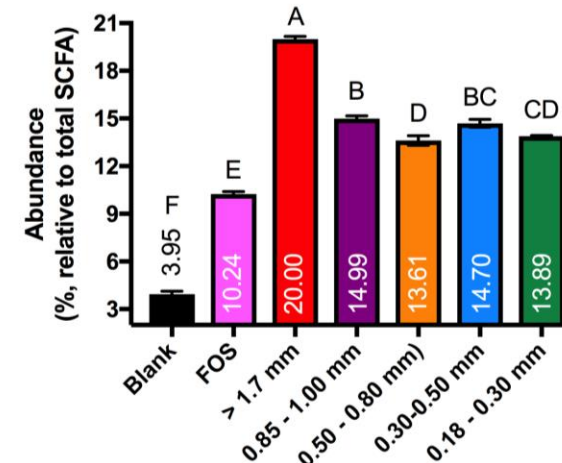
Butyrate_12h

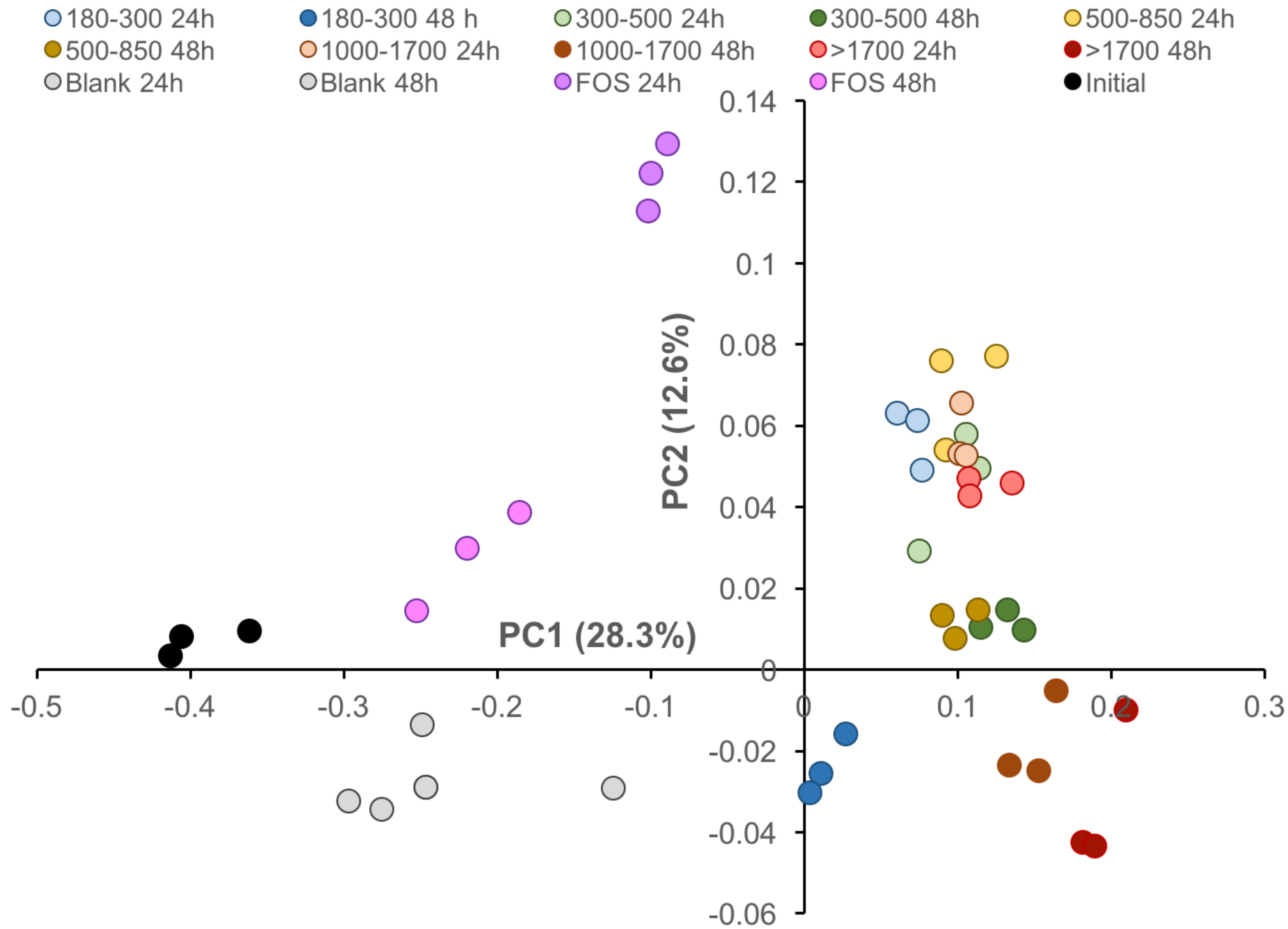


Butyrate_24h



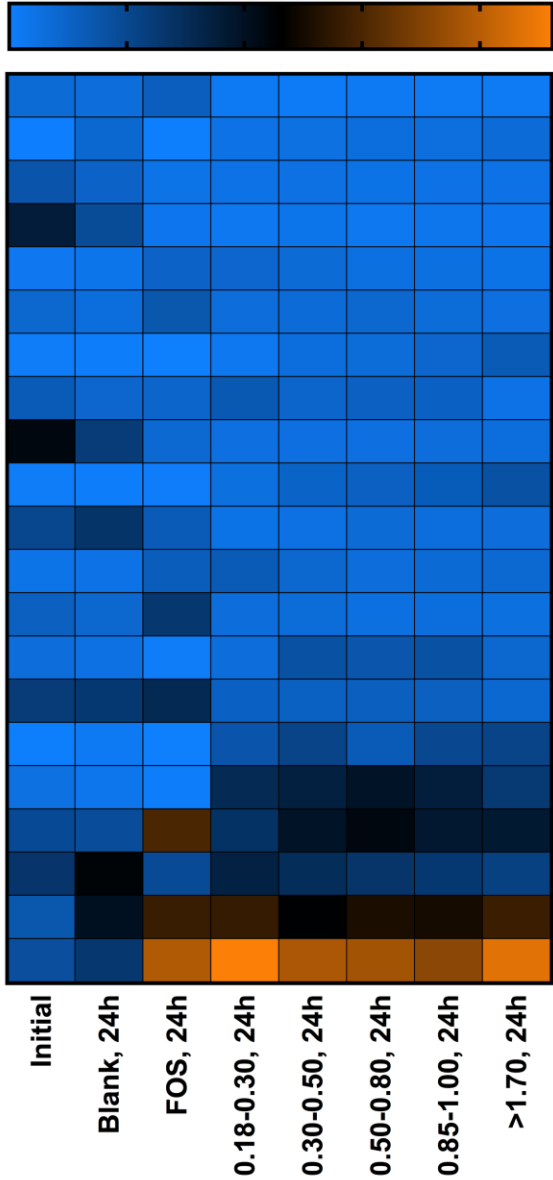
Butyrate_48h





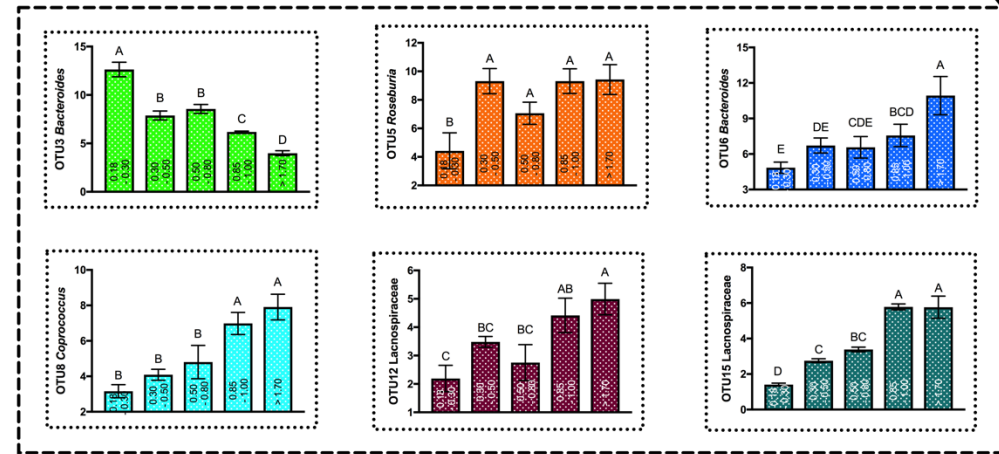
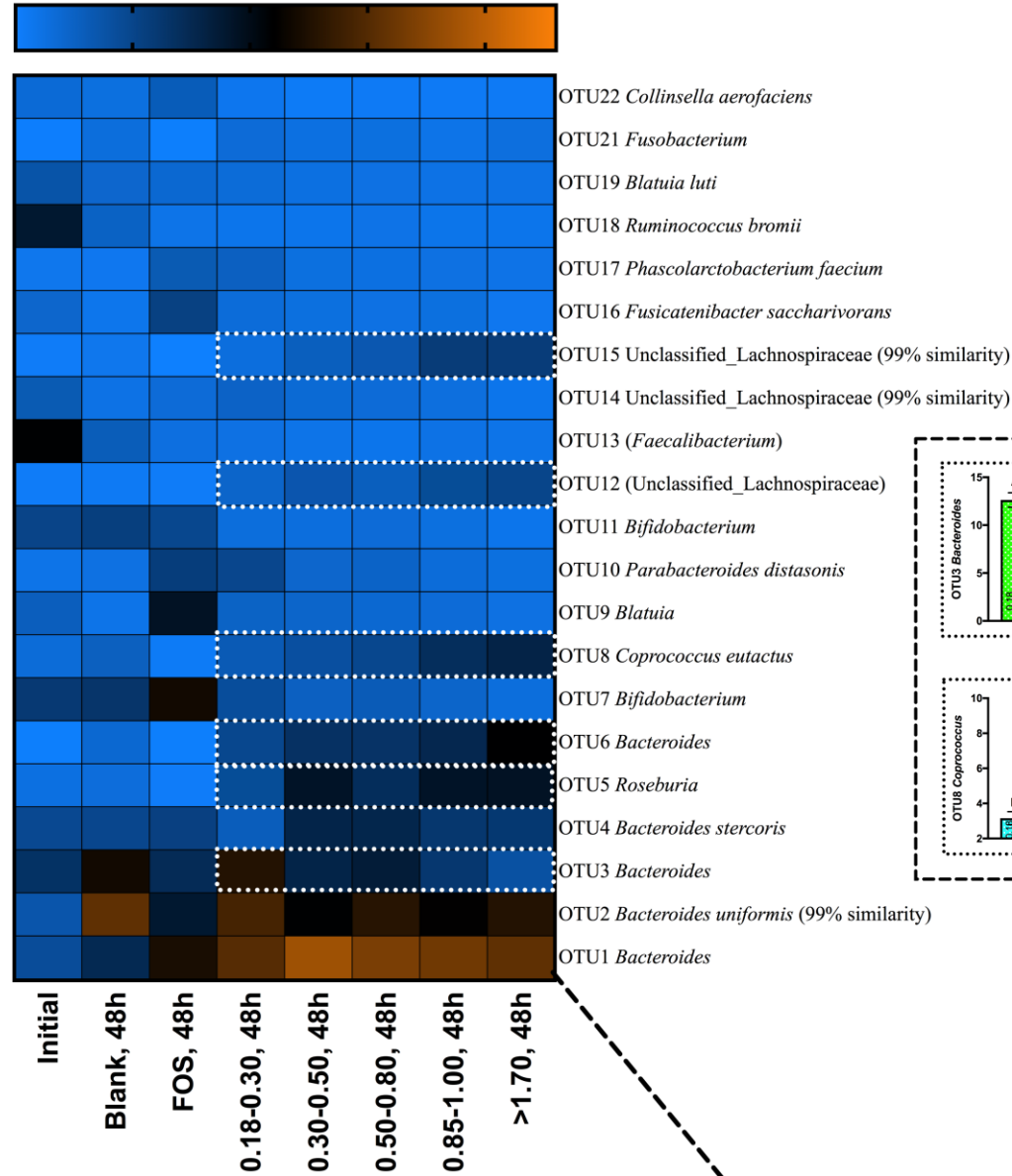
Relative abundance (%)*

5 10 15 20

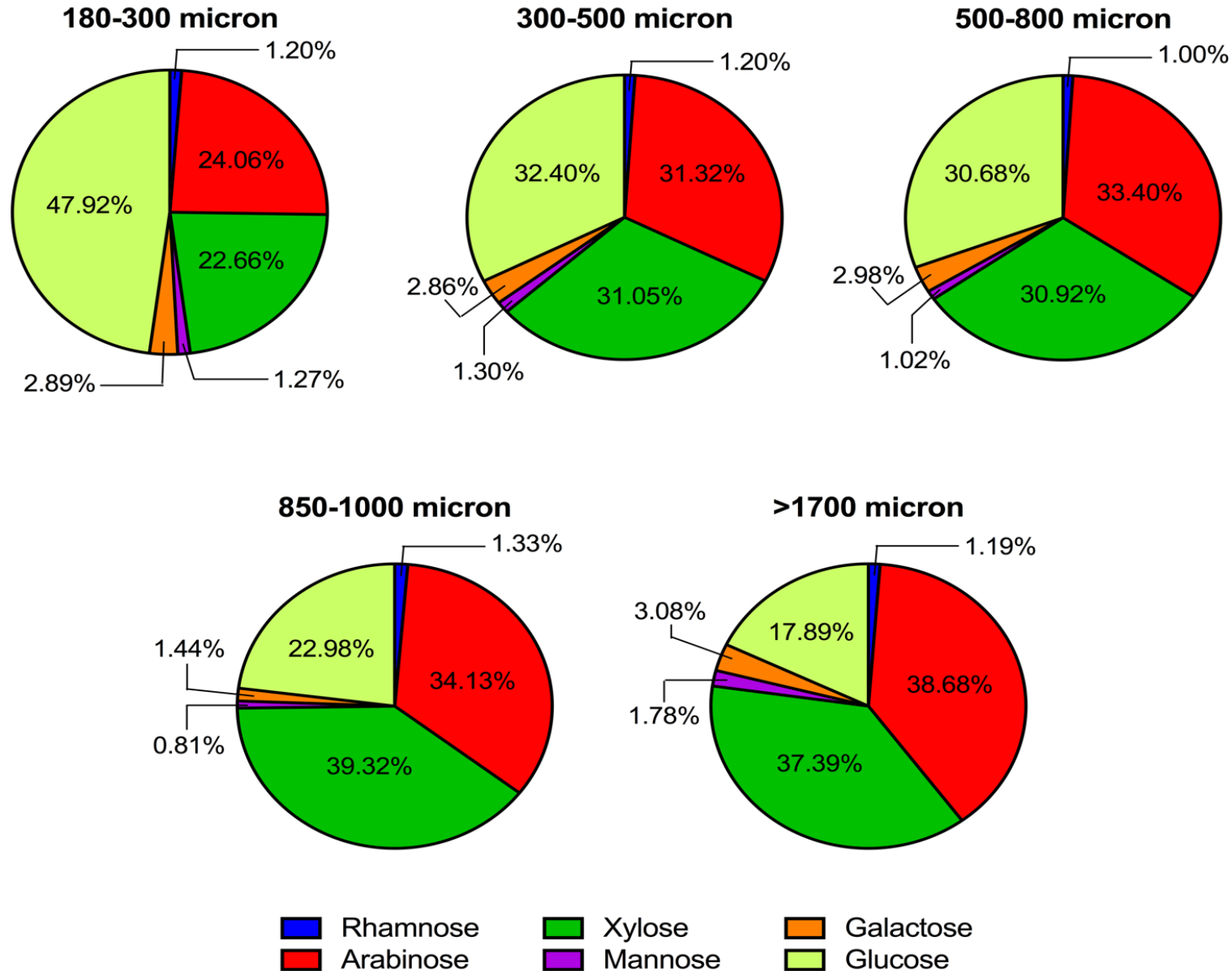


Relative abundance (%)*

5 10 15 20



PARTICLE SIZES WERE CHEMICALLY DIFFERENT



DO WE SEE THE SAME SIZE EFFECT WITH CHEMICALLY-IDENTICAL PARENT BRANS?



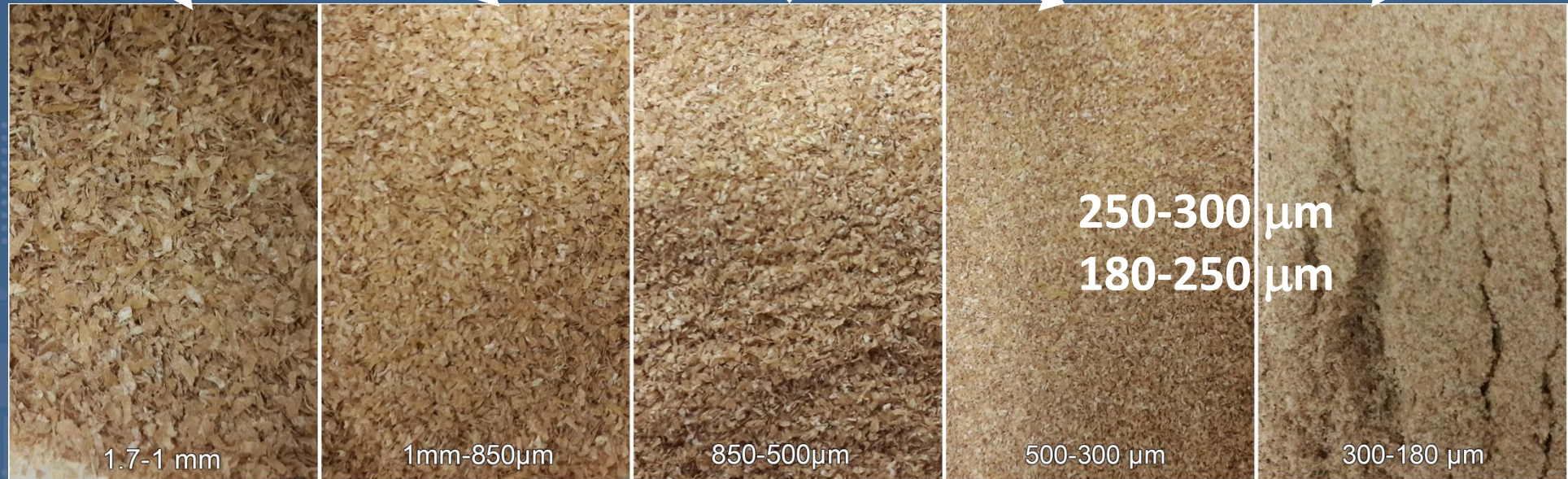
Sieving
Process



Arianna
Romero

>1.7 mm bran

Cyclone mill



1.7-1 mm

1mm-850µm

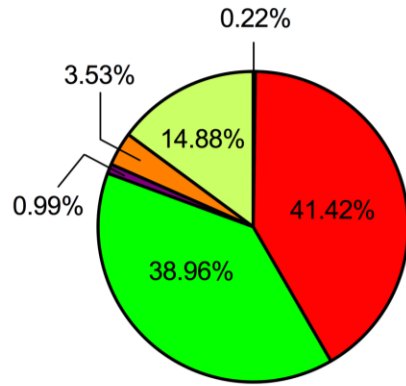
850-500µm

500-300 µm

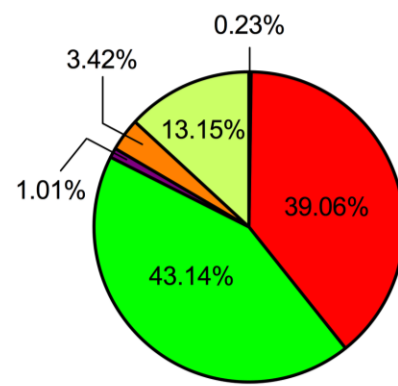
300-180 µm

250-300 µm
180-250 µm

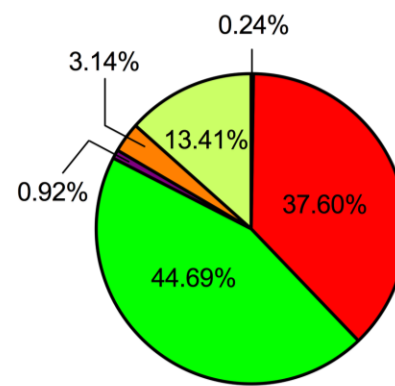
180-250 micron



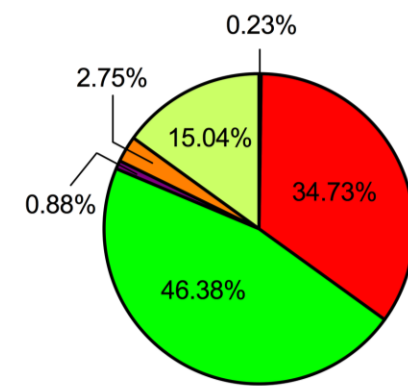
250-300 micron



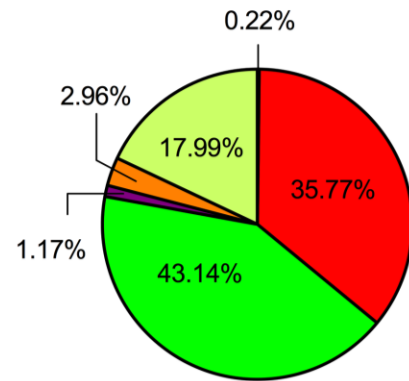
300-500 micron



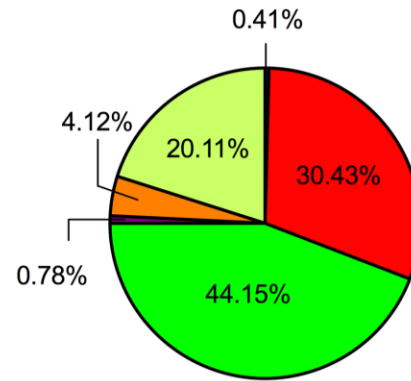
500-850 micron



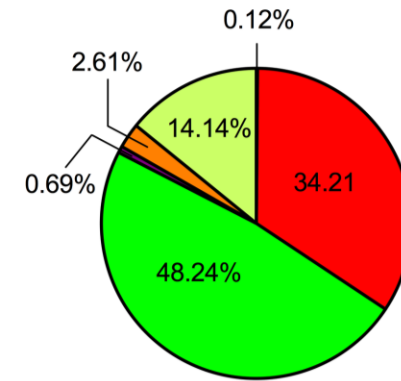
850-1000 micron



1000-1700 micron



> 1700 micron

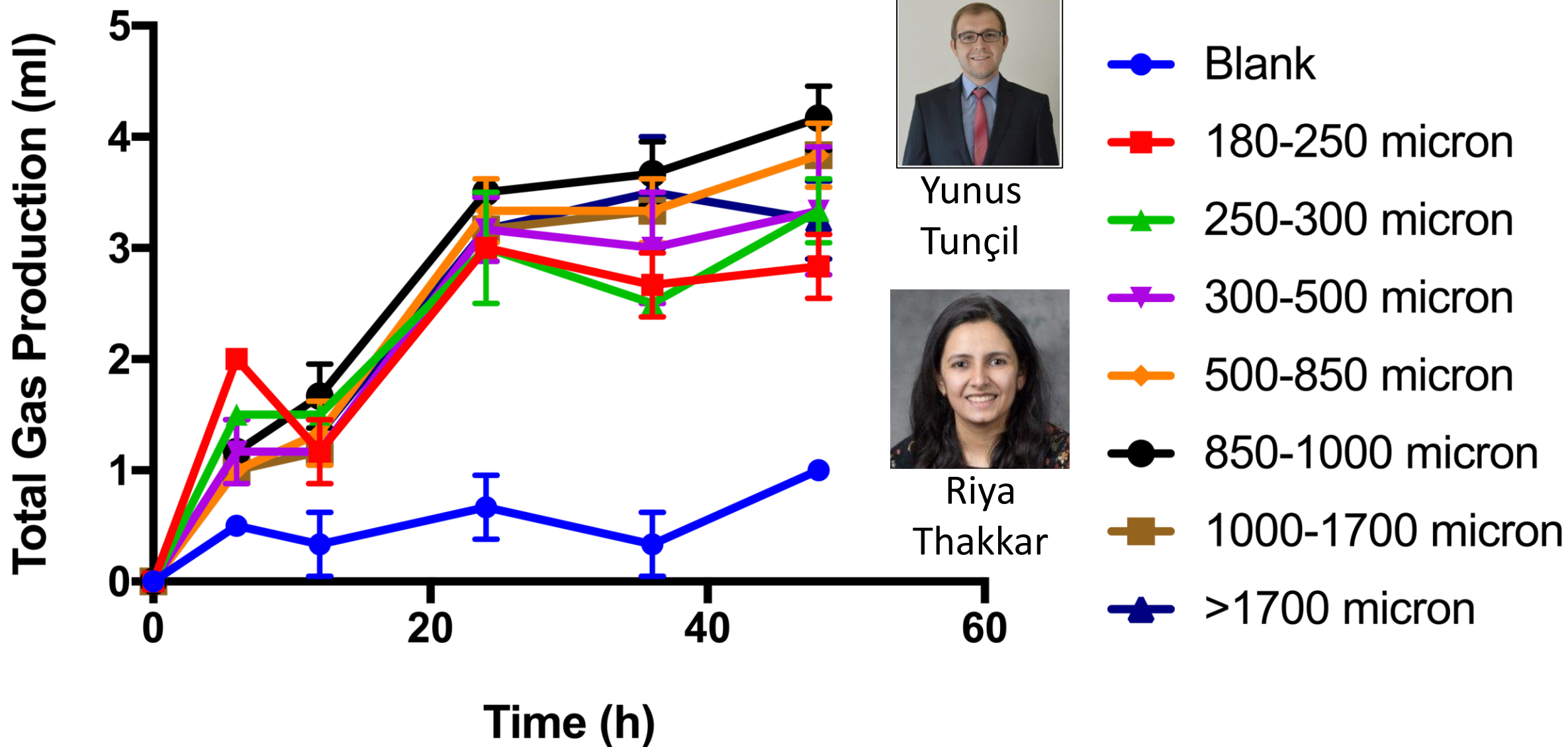


■ Rhamnose
■ Arabinose

■ Xylose
■ Mannose

■ Galactose
■ Glucose

FERMENTATION RATE DIFFERENCES WERE MUCH MORE MUTED

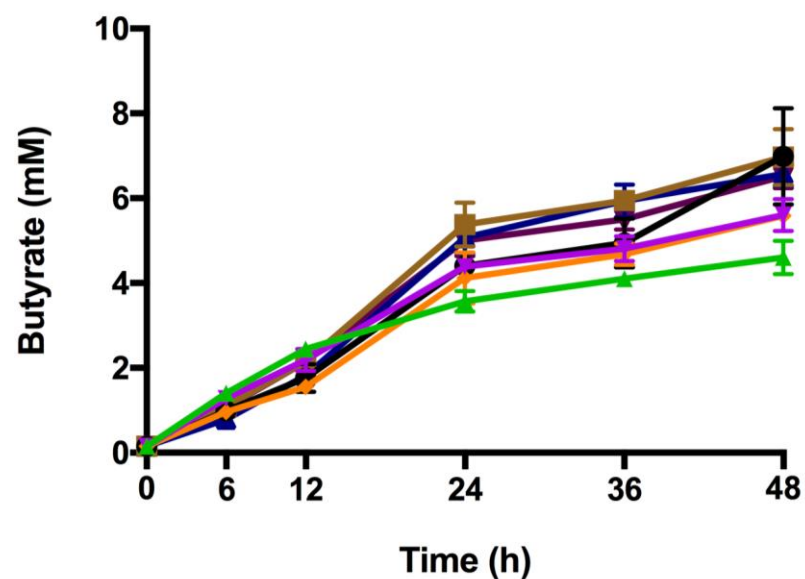
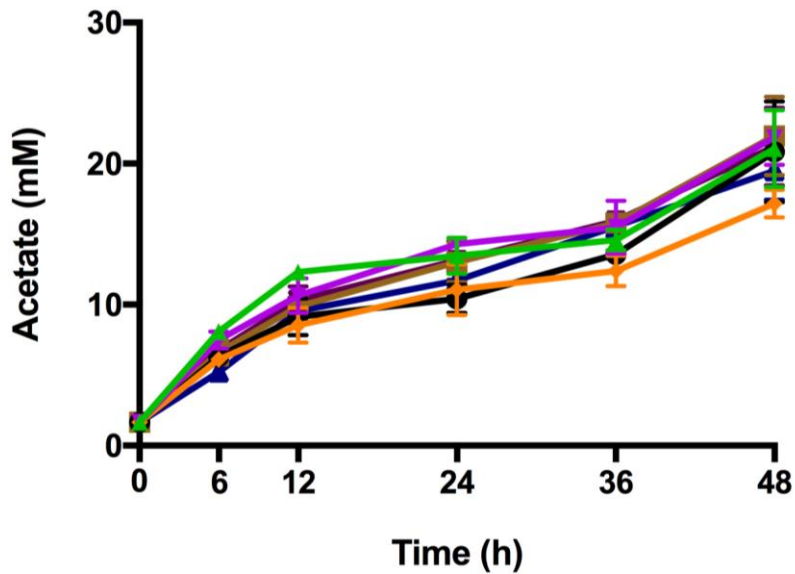
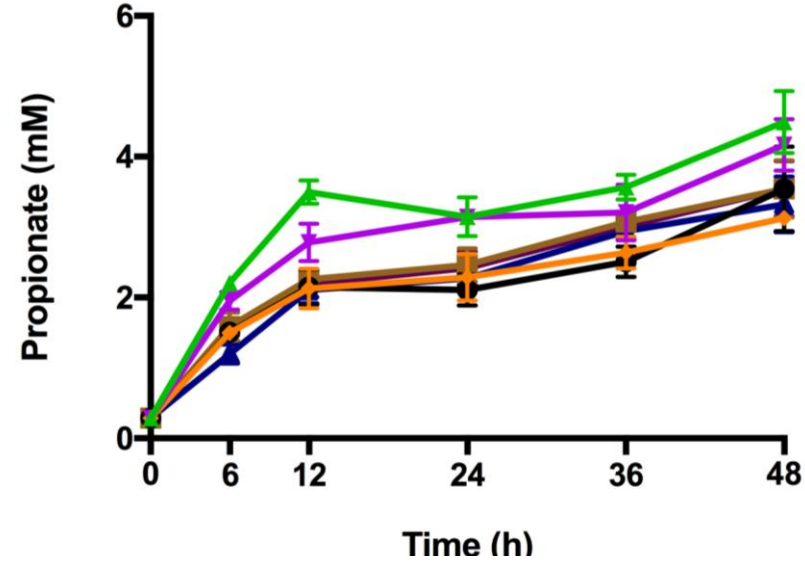
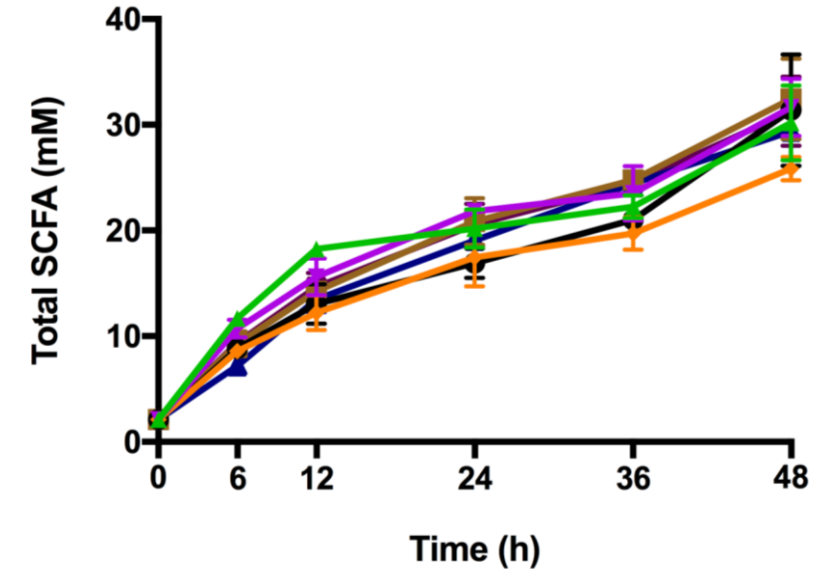


Yunus
Tunçil



Riya
Thakkar

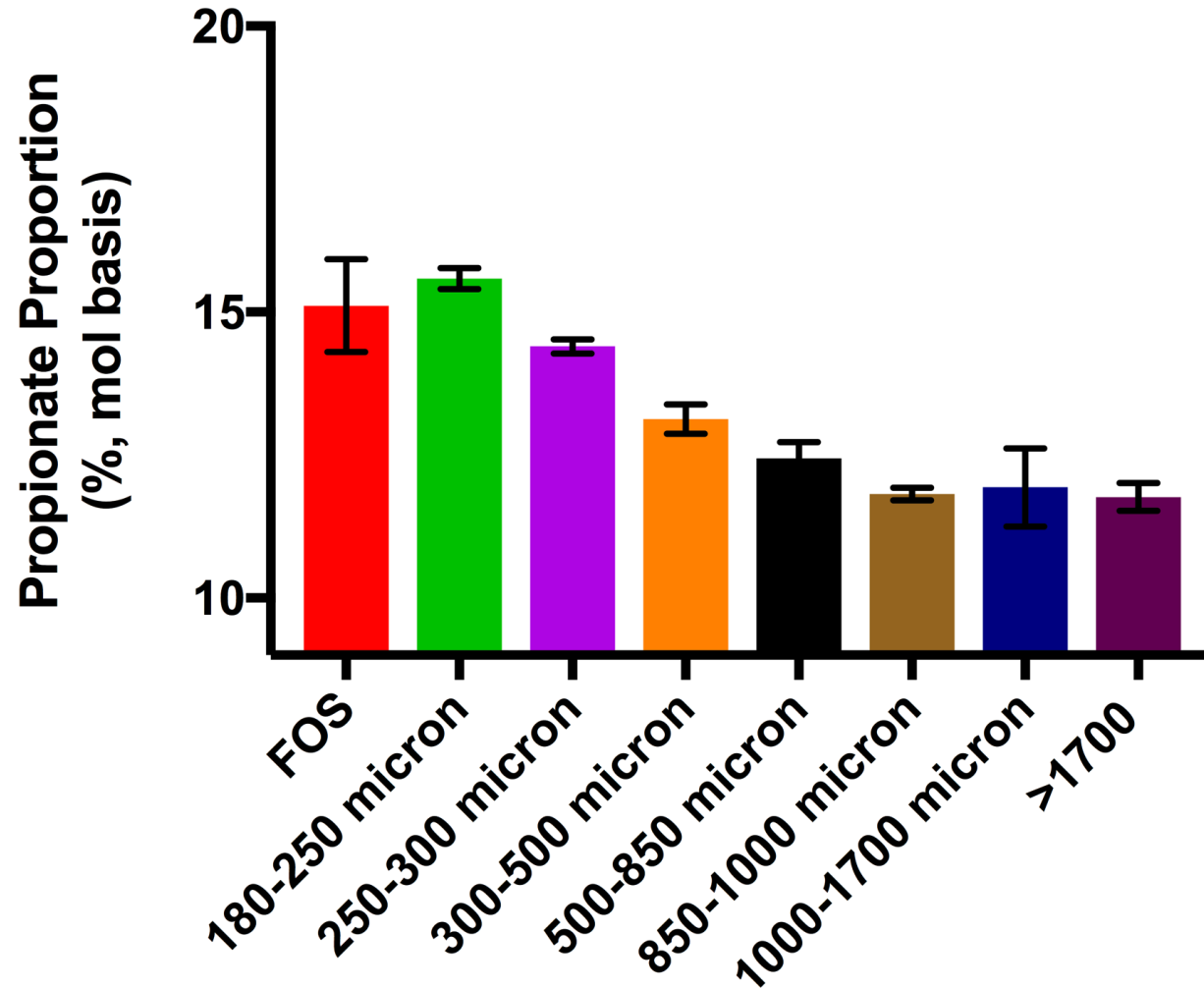
PARTICLE SIZE ALTERED SCFA BALANCE BUT NOT OVERALL PRODUCTION RATE



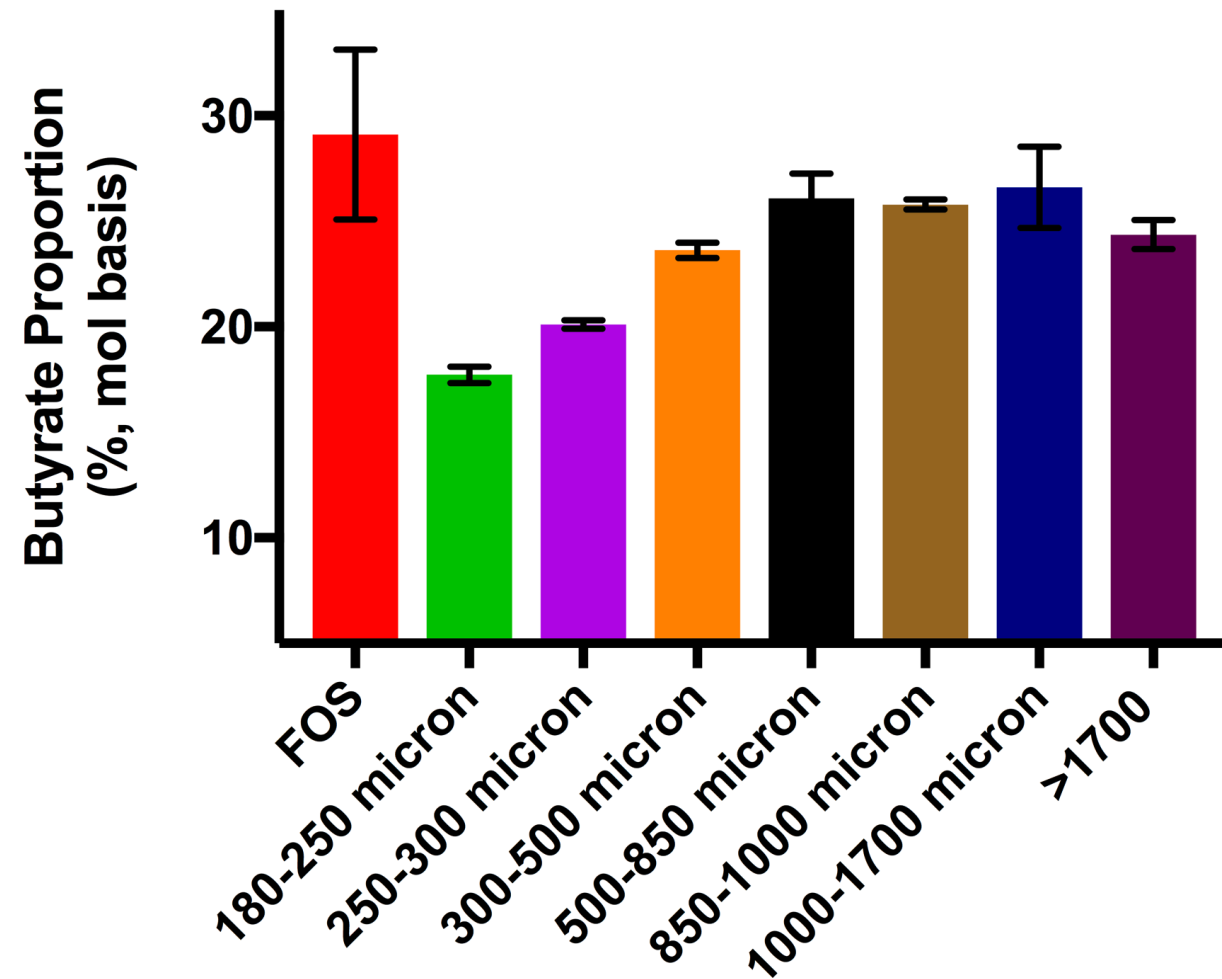
- 180-250 micron
- 250-300 micron
- 300-500 micron
- 500-850 micron
- 850-1000 micron
- 1000-1700 micron
- >1700

PROPIONATE AND BUTYRATE WERE INVERSELY CORRELATED BY SIZE

Propionate_24h



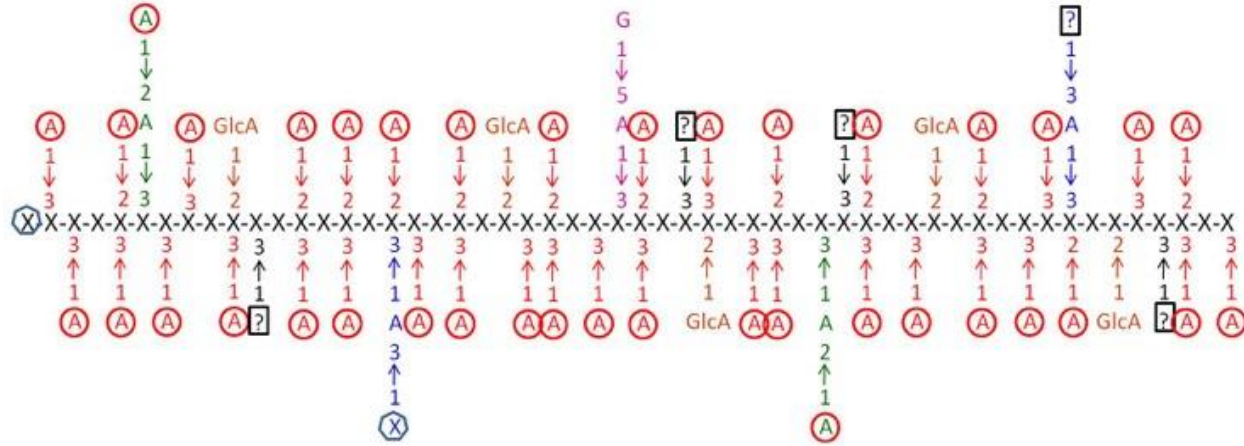
Butyrate_24h



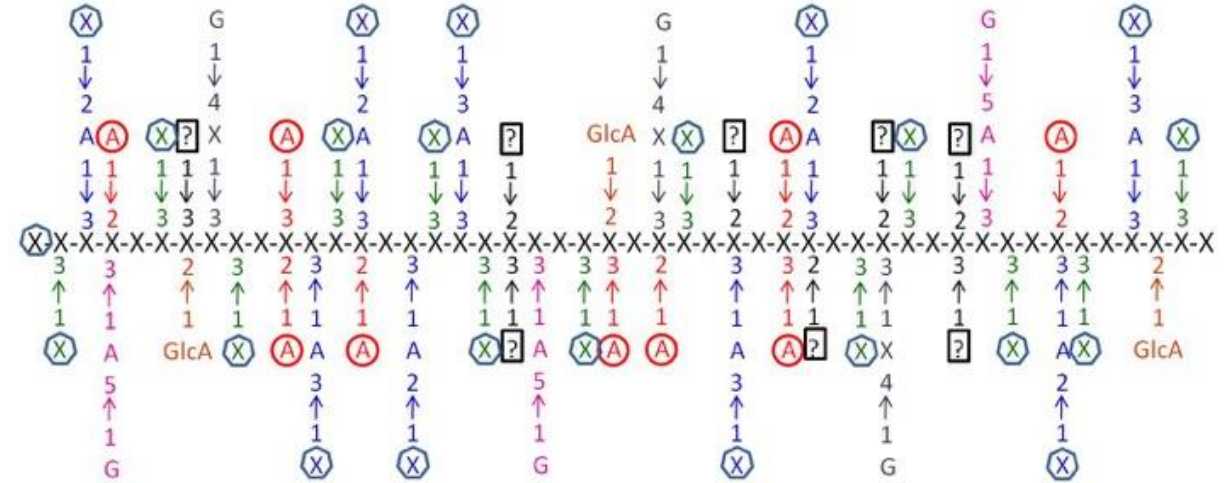
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ARABINOXYLANS ARE STRUCTURALLY-DIVERSE HEMICELLULOSES THAT COMPOSE MUCH OF BRAN'S "FIBER"

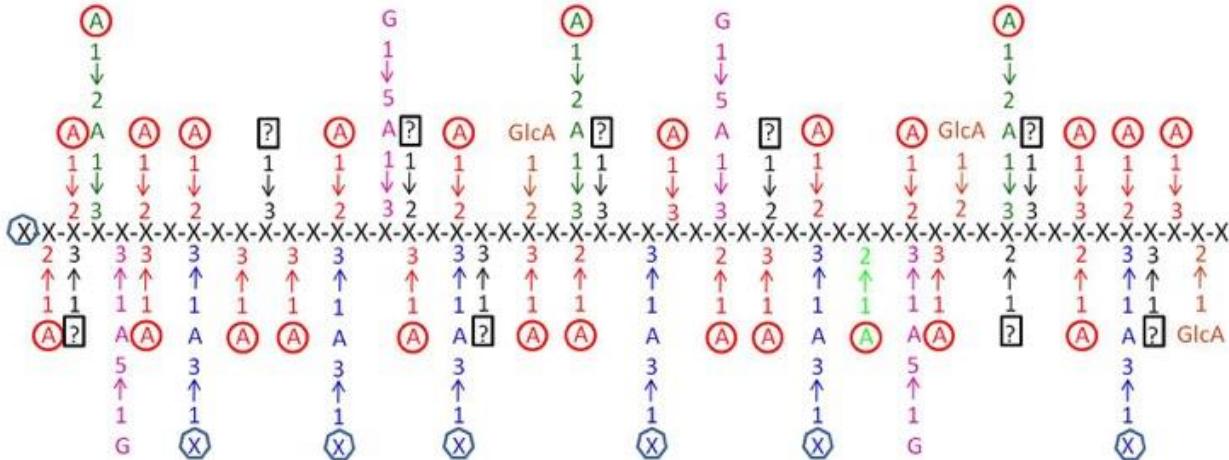
Sorghum



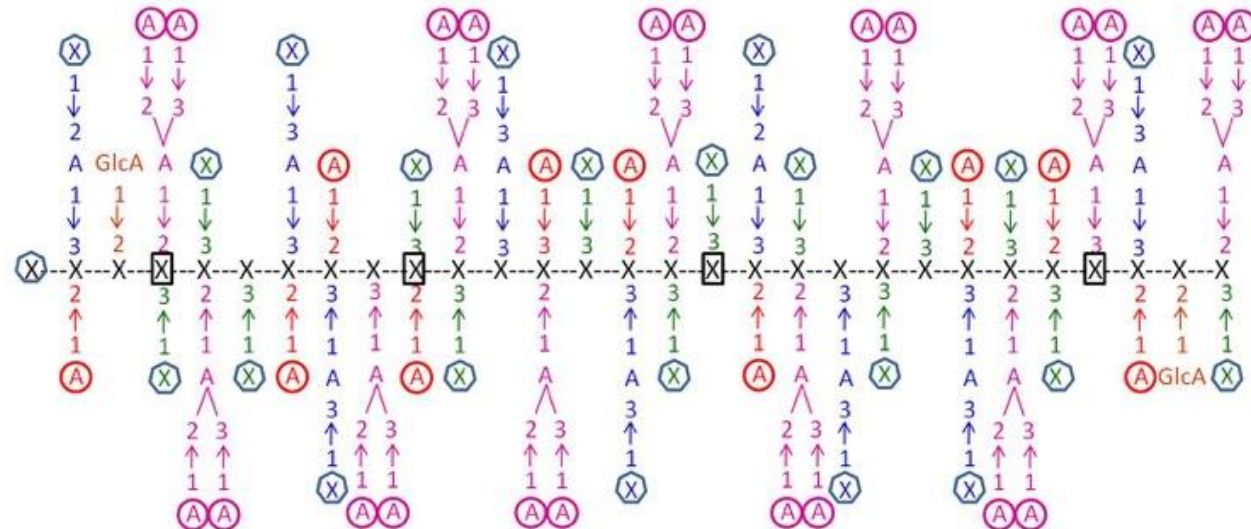
Corn Hydrolyzate



Rice Hydrolyzate



Wheat Fraction





Red Hard Spring Wheat

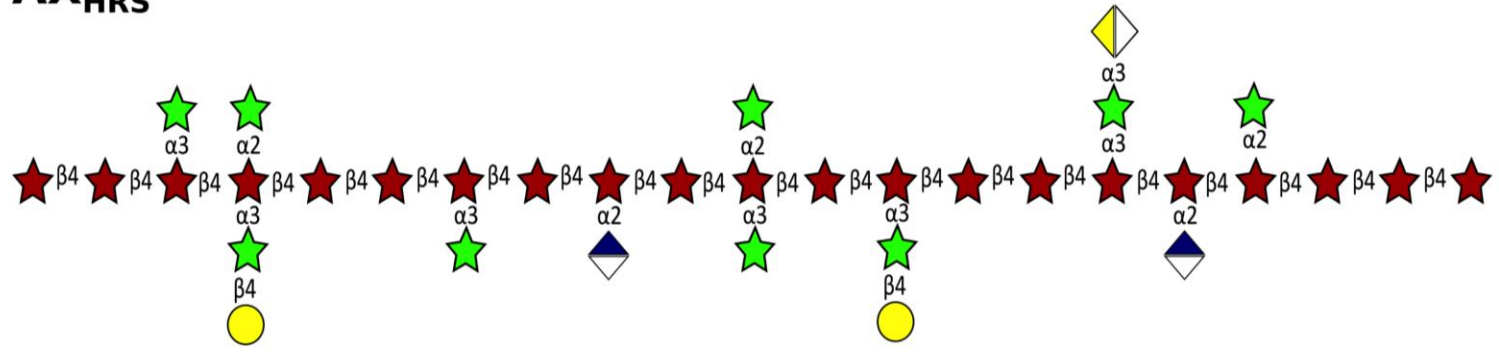


Red Hard Winter Wheat

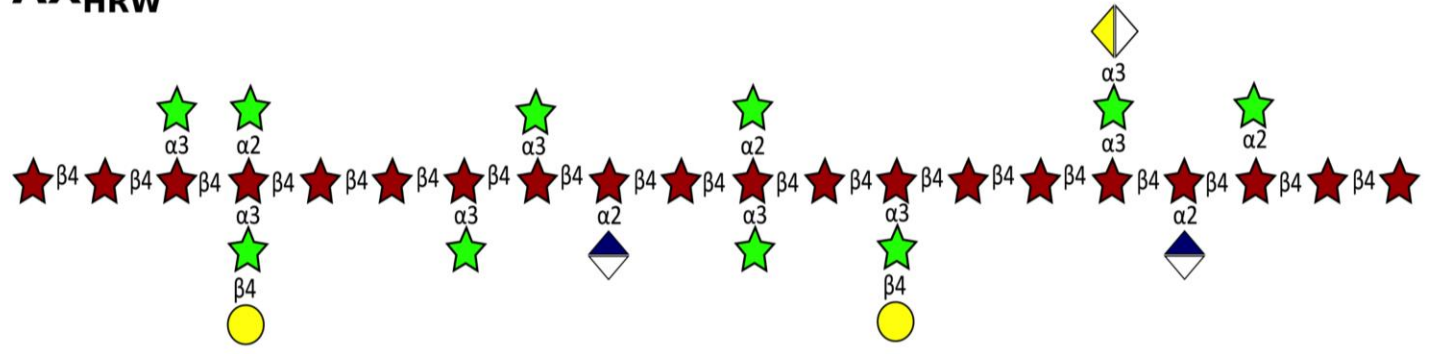


Soft Wheat

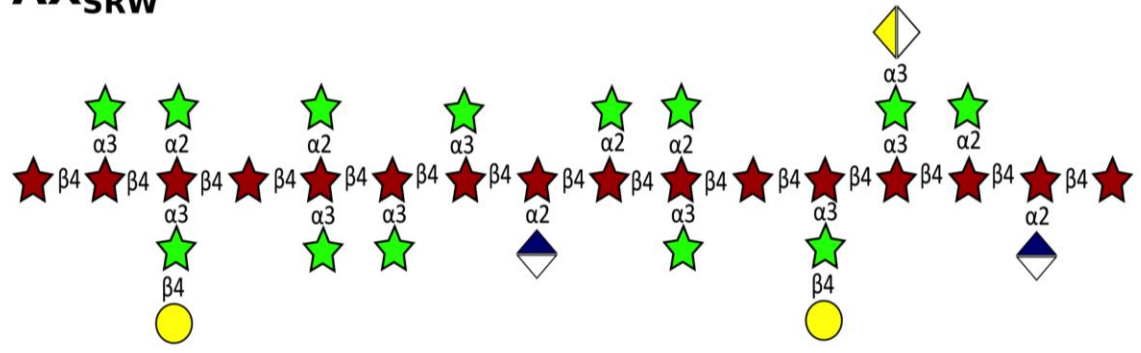
e) AX_{HRS}



AX_{HRW}



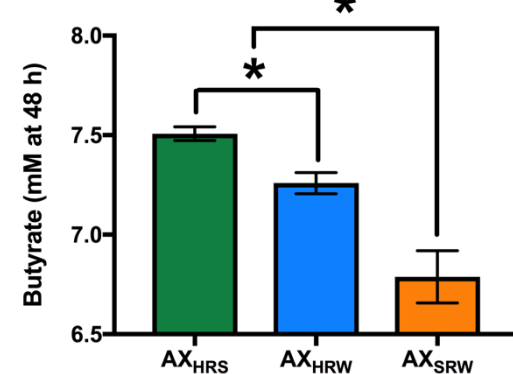
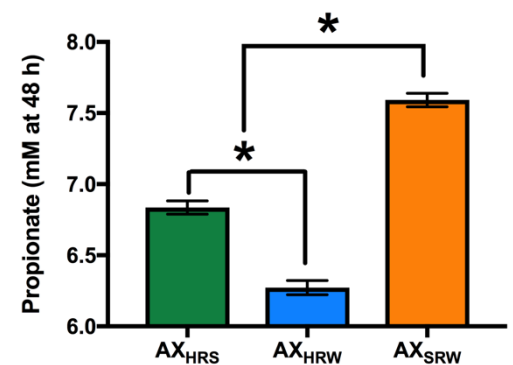
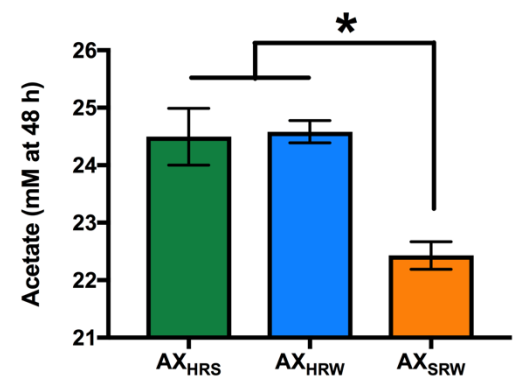
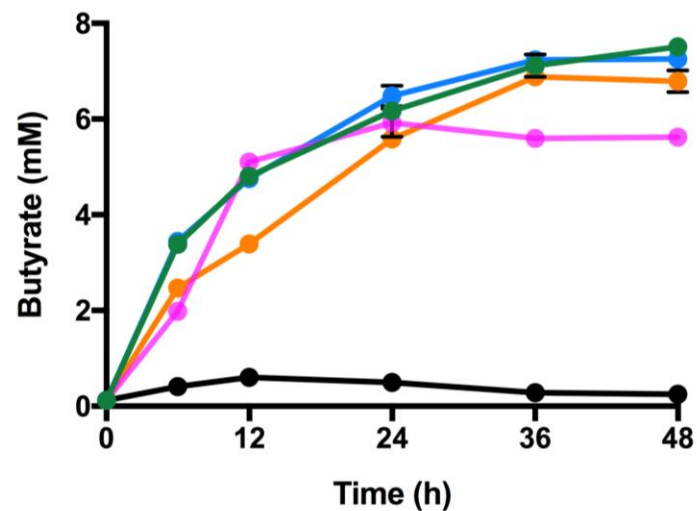
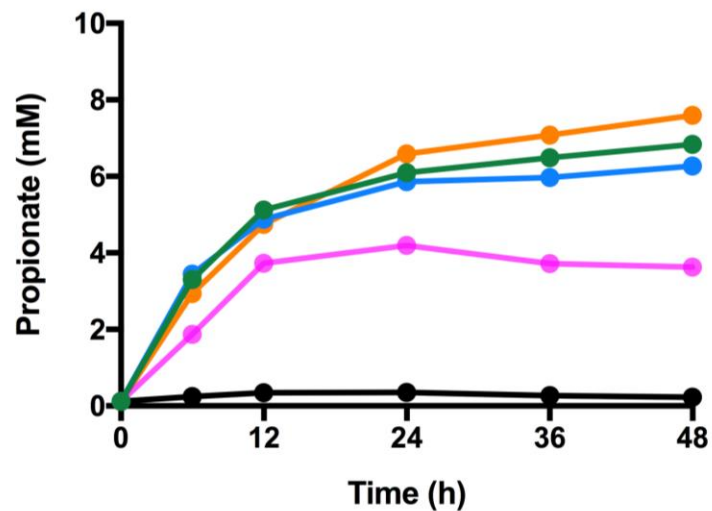
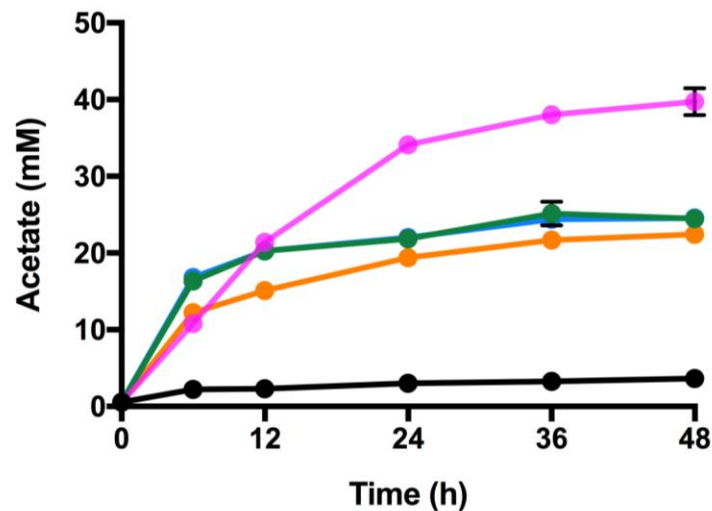
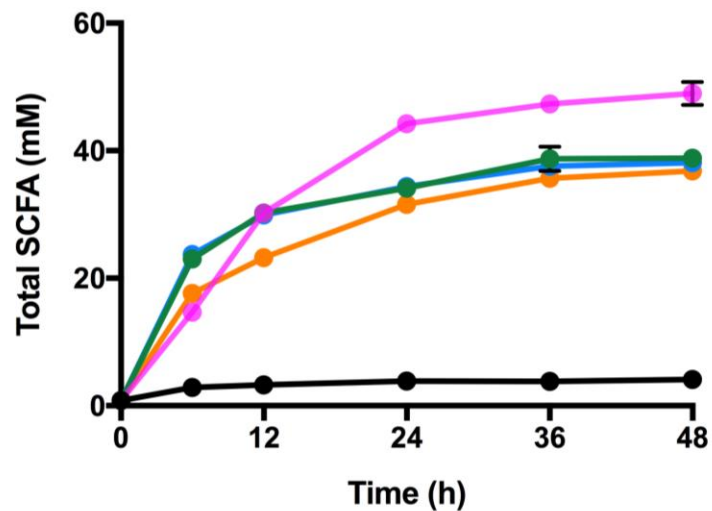
AX_{SRW}



SYMBOLS

- ★ D - xylose
- ★ L - arabinose
- D - galactose
- ◊ Galacturonic acid
- ◊ Glucuronic acid

ARABINOXYLANS FROM DIFFERENT WHEAT VARIETIES ARE FERMENTED DIFFERENTLY BY FECAL MICROBIOTA



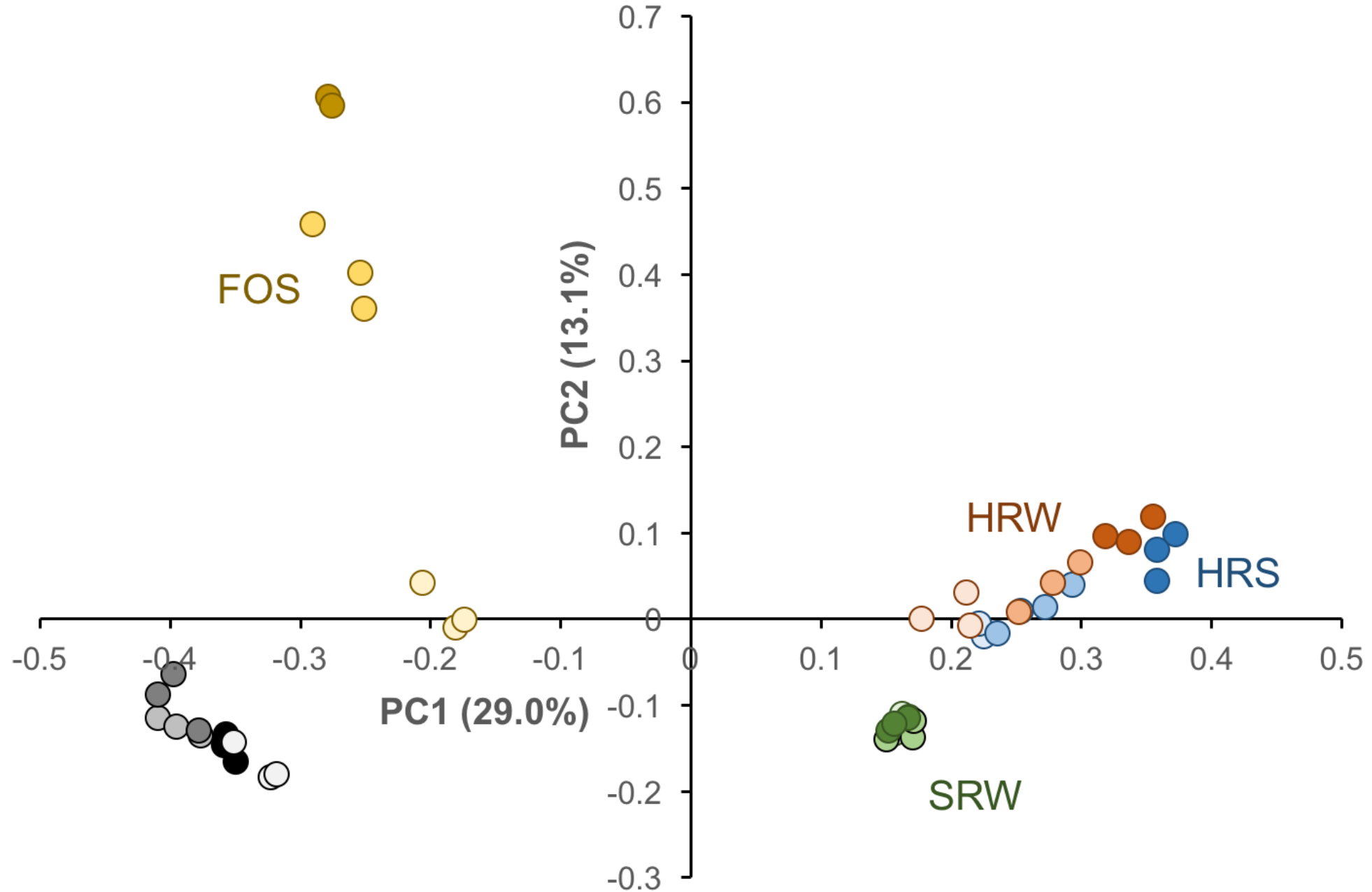
Yunus
Tunçil



Riya
Thakkar

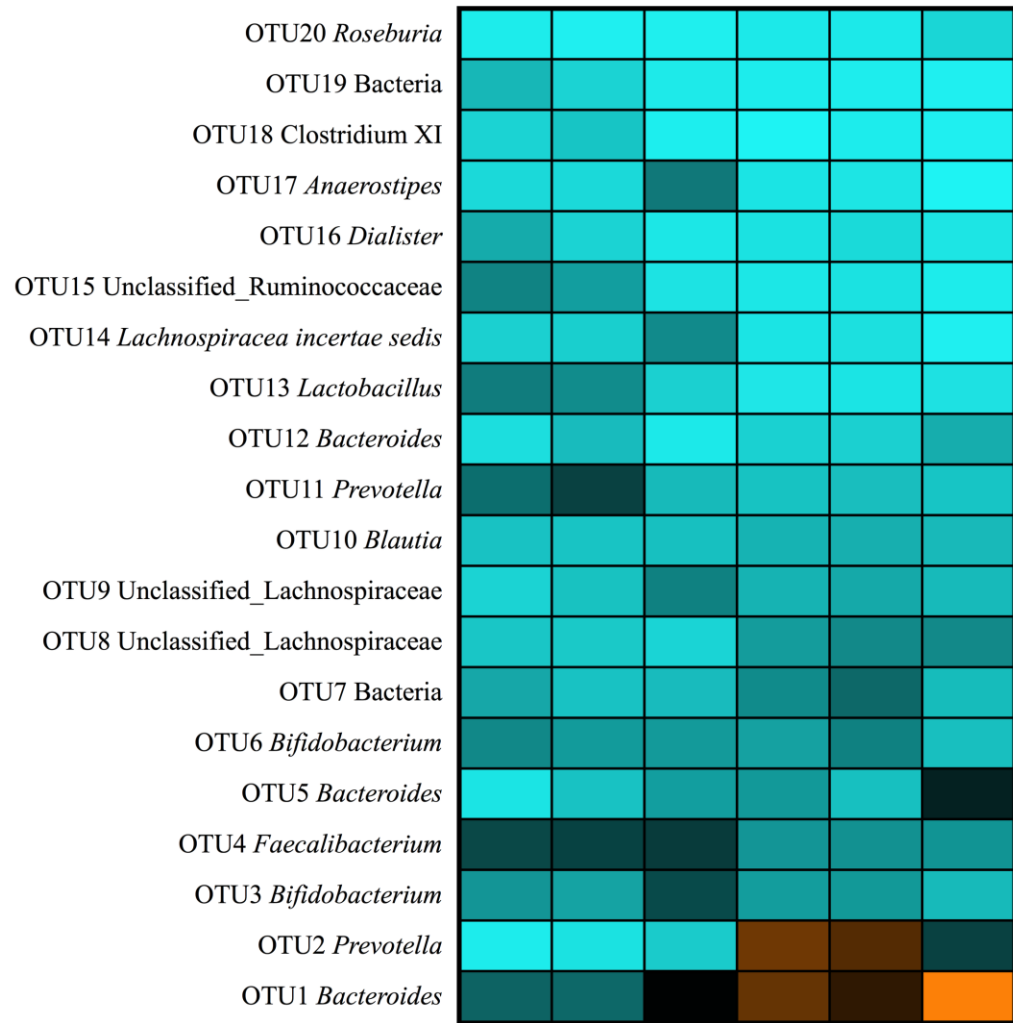
● Blank ● FOS ● AX_{HRS} ● AX_{HRW} ● AX_{SRW}

● Initial ○ Blank 12h ○ Blank 24h ○ Blank 48h ○ FOS 12h ○ FOS 24h ● FOS 48h ○ HRS 12h
○ HRS 24h ● HRS 48h ○ HRW 12h ○ HRW 24h ● HRW 48h ○ SRW 12h ○ SRW 24h ● SRW 48h



Relative abundance (% , 12h)

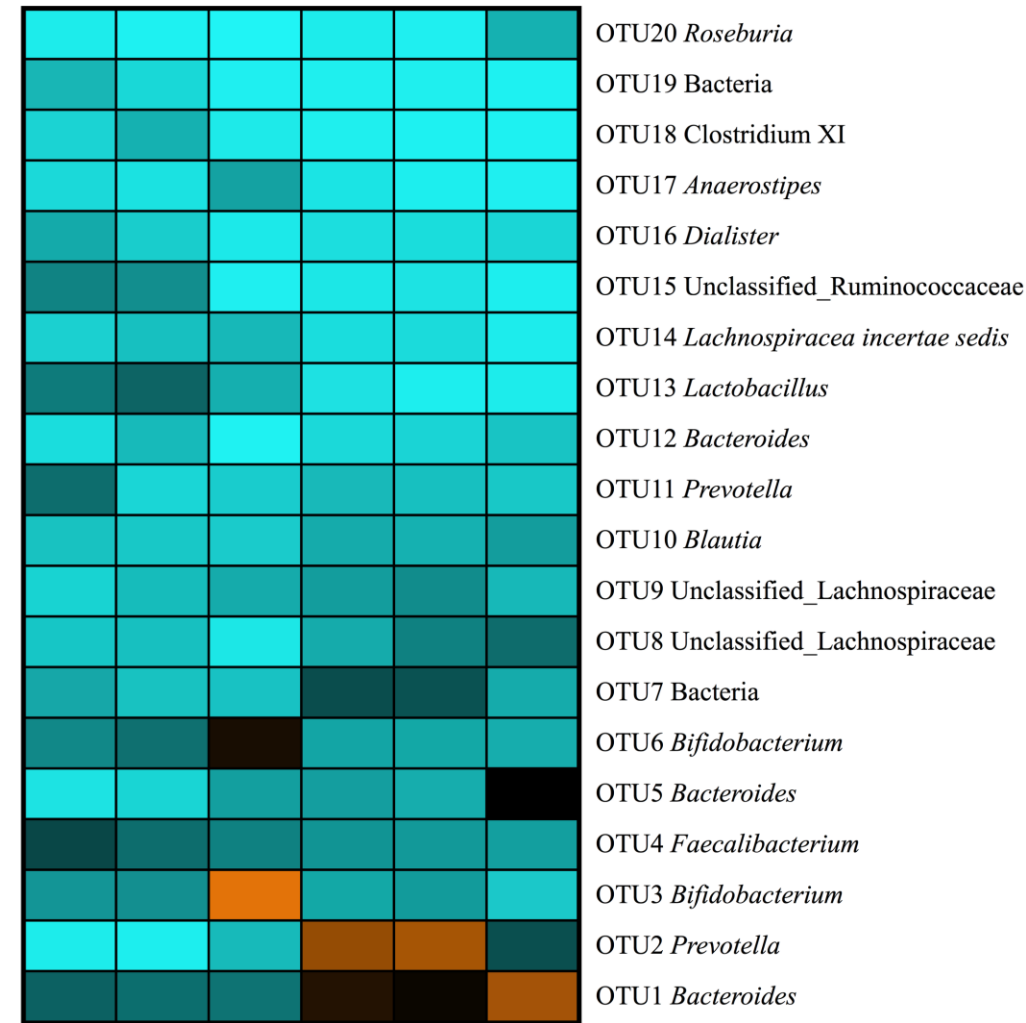
0 5 10 15 20



Initial
Blank_12h
FOS_12h
HRS_12h
HRW_12h
SRW_12h

Relative abundance (% , 24h)

0 5 10 15 20



Initial
Blank_24h
FOS_24h
HRS_24h
HRW_24h
SRW_24h

- Introduction to “dietary fiber” and its interactions with the microbiome
- All “dietary fibers” are not created equal
#1: insoluble wheat bran particles
- All “dietary fibers” are not created equal
#2: soluble wheat arabinoxylans
- Summary and recommendations

MY PREDICTION: DIETICIANS WILL BE THE FUTURE FRONT-LINE MICROBIOME MANAGERS

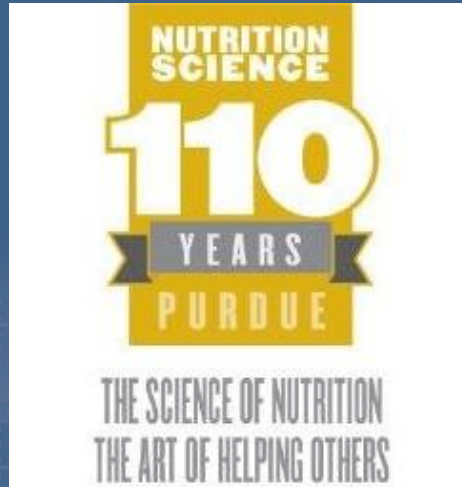
- “Fiber” variables as specific as the size of a wheat bran particle or the arabinoxylans from distinct wheat types drive significant differences in how they will be processed by the microbiome (at least *in vitro*).
- “Fiber,” even separated into “soluble” and “insoluble” fractions, is not yet finely resolved enough in food labeling to be actionable.
- Recommended targets:
 - Increase total fiber to decrease transit time – stool consistency
 - Increase fermentable fiber to increase colonic SCFA production – flatulence
 - Increase diversity of fiber sources, but steady doses of “beans and brans”
 - Consider gradual supplementation with soluble and insoluble fibers

WHISTLER CENTER
for Carbohydrate Research

THANK YOU!

- Yunus Tunçil
- Riya Thakkar
- Arianna Romero
- Jennifer Norka
- Melissa Robins

- Bruce Hamaker



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● 180 ● 250 ● 300 ● 500 ● 850 ● 1000 ● 1700 ● Initial ● Blank ● FOS

