Bacterial Fermentation of Carbohydrates

Erin McKenney[1], Laura Ott[2], Katie French[1], Parker Shoaf[2]
[1]North Carolina State University [2]University of North Carolina at Chapel Hill

In-person: Please sit with two others to form groups of three and ensure that you have a kit (one kit per group). Download guided-inquiry document and kit instructions.

Zoom: Please download guided-inquiry document and kit instructions. You will also need the digital playground document and remote card deck pulled up on your computer.

Question

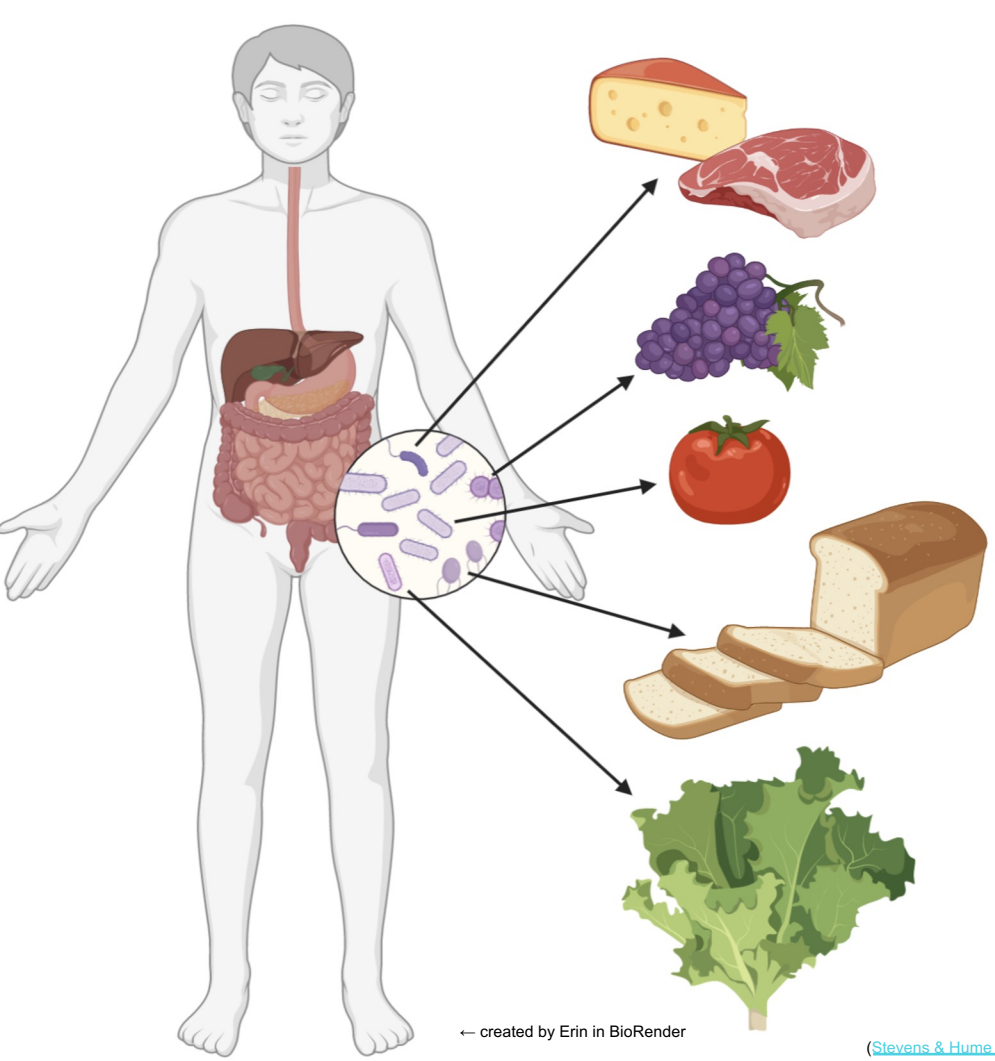
How are you attending class today?

A. In-person
B. Virtually

Learning Objectives

After completing this activity, students should be able to:

- Compare the role of different bacteria in the digestion of different carbohydrates
- Explain the process by which bacteria ferment carbohydrates to produce short chain fatty acids
- Predict the consequences of different diets and bacteria in the digestive system (for overall health)



← created by Erin in BioRender

(Stevens & Hume 1998) →

Cellulose
Hemicellulose
Pectin
Fructans
Starch
Pentoses
Uronic acids
Galactose
Dextrans
Pentose pathway
Cellobiose
Sucrose
Glucose
Fructose
Maltose
ATP
Pyruvate
Lactate
Oxalacetate
Formate
CO_2
H_2
Acetyl-CoA
Malate
Fumarate
+ ATP
+ 2H
ATP
Aceto-acetyl-CoA
Succinate
Succinyl-CoA
Acetaldehyde
Methylmalonyl-CoA
Acrylate
2 ATP
ATP
Propionyl-CoA
Ethanol
+ ATP
CH_4
Acetate
Butyrate
Propionate

Who digests these foods?
(You or your microbes?)

Part 1: Carbohydrate metabolism

Carbohydrate Structures

4 Grey half-circles 

8 Dark blue rods 

4 Flexible yellow rods 

2 Small dark green rods 

1 Orange connector 

In your groups, complete the entirety of Part 1

- Carbohydrate Structures
- Bacterial Digestion
- Fermentation Products

Wait to start part 2 until instructed.

In person -- you will need:

- Kit
- Guided-inquiry document
- Kit instructions

Virtual -- you will need:

- Guided-inquiry document
- Kit instructions
- Digital playground and remote card dec

APPLY YOUR UNDERSTANDING

Based on their carbohydrate composition, which food is the easiest to digest *without the help of any gut microbes*? Explain why.

Glucose is the raw material for ATP production.

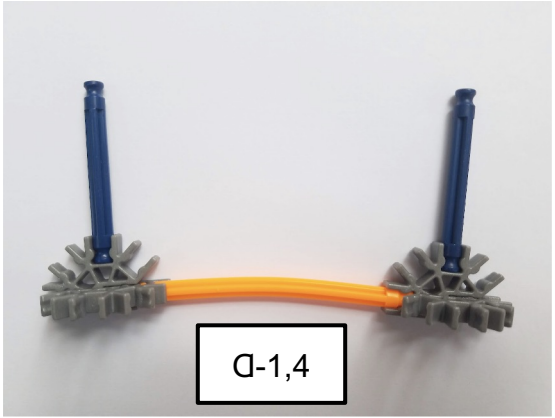
ENERGY!!!

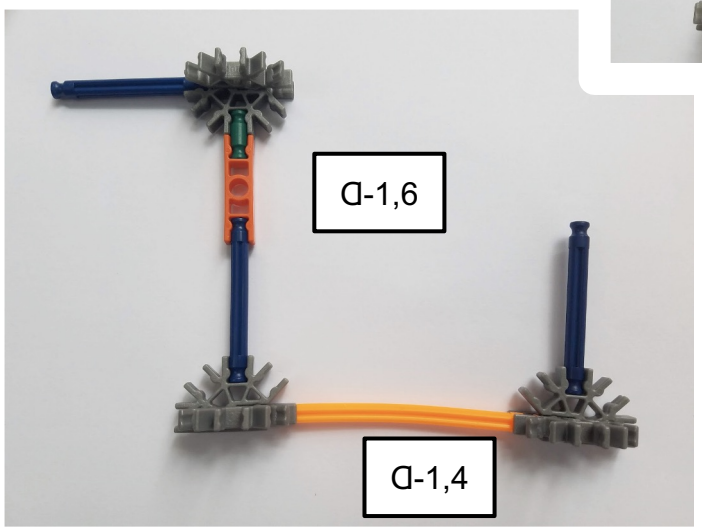
APPLY YOUR UNDERSTANDING

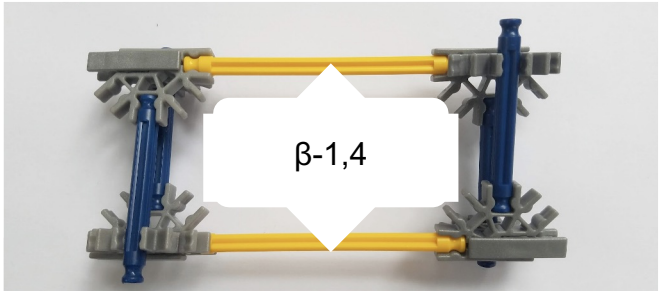
Based on their carbohydrate composition, which food is the easiest to digest *without the help of any gut microbes*? Explain why.

Based on their carbohydrate composition, which food(s) do we need the most microbial help to digest?

Which carbohydrate structure is easiest to digest? Why?







APPLY YOUR UNDERSTANDING

Based on their carbohydrate composition, which food is the easiest to digest *without the help of any gut microbes*? Explain why.

Based on their carbohydrate composition, which food(s) do we need the most microbial help to digest?

How might the gut microbial community and fermentation products differ for a classmate who consumes a different diet?

Gut microbial community and fermentation products produced will vary based on the diet that the individual consumes.

Part 2: Effects on the host

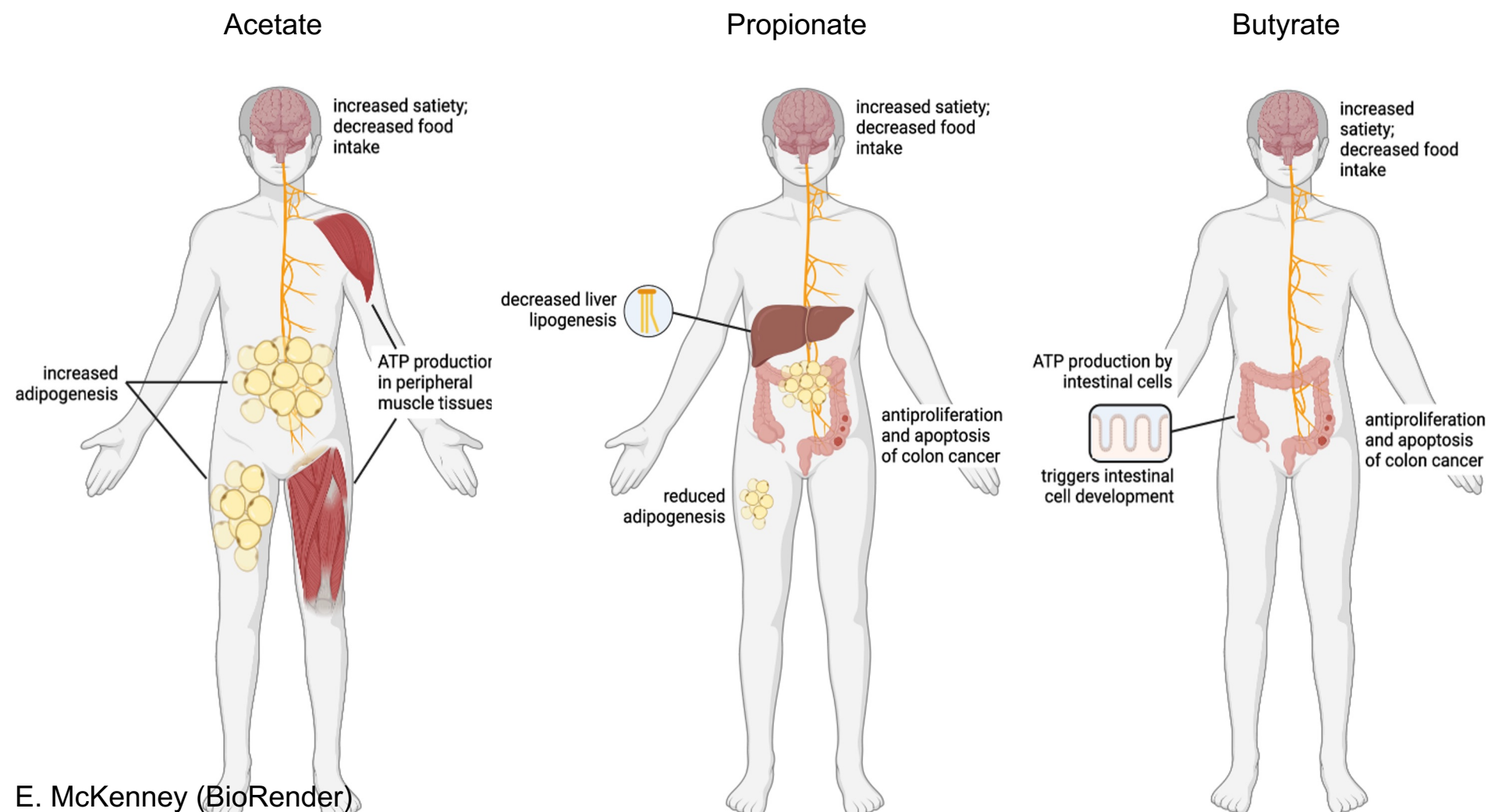
Fermentation Products

52 Acetate

11 Propionate

23 Butyrate

In your groups, complete as much of Part 2 as you're able. Be sure to finish any remaining questions on your own after class (representative answers will be posted).



E. McKenney (BioRender)

Short chain fatty acids

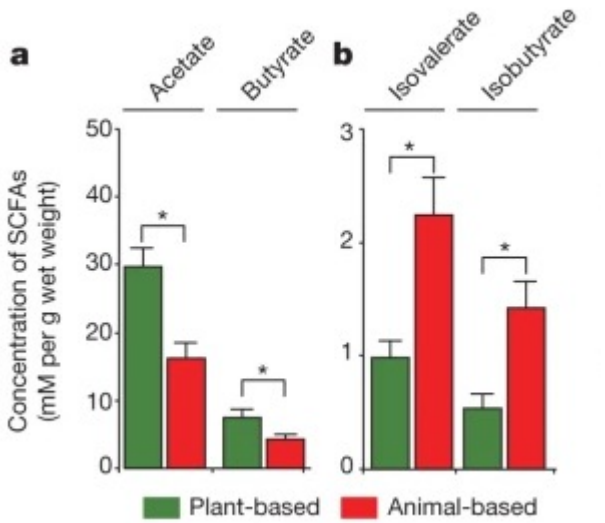
What are the benefits of each SCFA?

- Stimulate hormone production from the gut to signal satiety (e.g., leptin)
- Acetate – ATP production in muscle tissue
- Propionate – protection from colon cancer; reduced adipogenesis; reduced lipogenesis in the liver
- Butyrate – protection from colon cancer; ATP production by intestinal cells

Drawbacks of over- or under-production of SCFA?

- Too much acetate could result in increased fat deposition.
- Too little propionate or butyrate could result in colon cancer
- Too little of any of the SCFAs could result in increased hunger

CASE STUDY

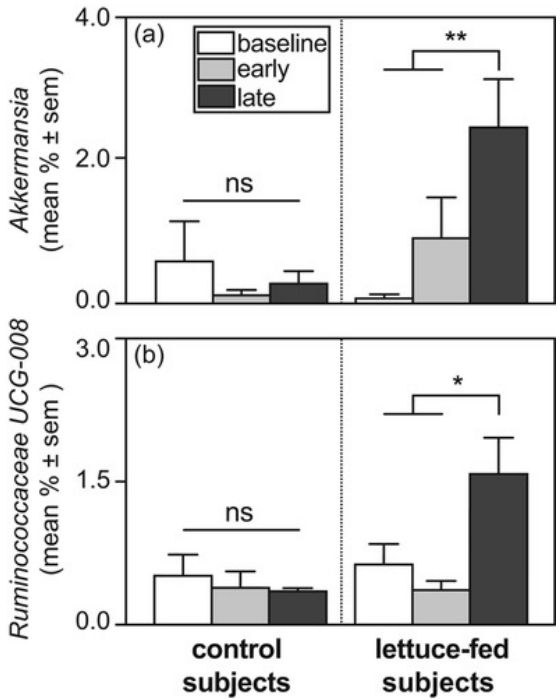


Compared to animal-based diets, plant-based diets favor the production of acetate and butyrate. Animal-based diets favor precursor SCFA molecules.

Individuals who consume plant-based diets are likely to have a microbiome that favors the production of acetate and butyrate. This could be associated with both the benefits (e.g., greater ATP generation tissue, reduced rates of colon cancer, increased satiety) **and drawbacks** (e.g., increased fat deposition).

David, et al. (2014). *Nature*

CASE STUDY



Lemurs who received lettuce-supplemented diets had higher levels of gut microbes (*Akkermansia* and *Ruminococcaceae*) compared to those who received standard, fruit-based diets.

Knowing that lettuce is primarily cellulose (β-1,4 bonds), we would expect the presence of microbes that generate acetate and butyrate.

Greene, *et al*. (2020). *Zoo Biology*