Learning Objectives

- Identify dietary factors that impact the human gastrointestinal (GI) microbiota.
- Compare and contract how different types of foods, which contain fiber, differentially impact the GI microbiota.
- Establish a connection between the GI microbiota and health.

Definitions and Overview

**Microbiome** - a collection of microbial genomes

**Microbiota** – a collection of microbes

- As many bacteria as host cells in human body\(^1\)
- > 150x more bacterial genes than our human genome\(^2\)

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**Definitions: Fiber & Prebiotic**

**Dietary Fiber:** Non-digestible soluble and insoluble carbohydrates (> 3 monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (> 3 or more monomeric units) determined by FDA to have physiological effects that are beneficial to human health.¹

**Prebiotic:** A substrate that is selectively utilized by host microorganisms **conferring a health benefit.**²

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**Diet & GI Microbiota**

- The composition of the diet impacts **digestive secretions, transit time, and absorption.**
- Diet provides a **source of nutrients** for us and the GI microbiota.
- Diet provides a **source of microbes.**

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**Diet, GI Physiology, & Microbiota**

**Nutrient composition affects GI secretions & transit time**

- **Stomach**
  - Acidic pH
  - Oxygen
- **Duodenum**
  - Neutral pH
  - Rapid Transit
  - Bile Acids
- **Jejunum & Ileum**
  - Bile Acids
  - Reduced Oxygen
  - Mucin Layer
- **Colon**
  - Neutral pH
  - Slow Transit
  - Minimal Bile Acids
  - Anaerobic
  - Thick Mucin Layer
Diet Impacts GI Microbiota

- **Habitual diet** is related to the composition of the GI microbiota.¹
- **Acute changes** in macronutrient composition can rapidly (within 2-4 days) change the composition and function of gut microbes.²
- Individuals that consume more plants have greater GI bacterial diversity.³
- **Dietary fiber and prebiotic** intake differentially impacts GI microbiota composition and function.⁴

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Cross-sectional analysis of > 10,000 fecal samples from participants in the US, UK, and Australia

Individuals completed health status and dietary questionnaires

Individuals that consumed more plants had greater GI bacterial diversity

Plants consumed per week:
- More than 30
- Less than 10

Dietary Fibers in Foods

Common Dietary Plants

Insoluble, poorly to moderately fermentable
Soluble, viscous, readily fermentable
Soluble, readily fermentable
Soluble, non-viscous, fermentable

Fructans, pectins, cellulose, β-glucans, hemicelluloses

Which of these are fermentable? Soluble? Insoluble? Viscous?
Which of these are fermentable? Soluble? Insoluble? Viscous?

Dietary Fibers in Foods

Common Dietary Plants

- Brans
- Cereals
- Legumes
- Nuts
- Peas
- Fruits
- Vegetables
- Potato
- Sugar beets
- Oats
- Barley
- Rye
- Chicory root
- Onion
- Agave
- Wheat
- Bananas
- Garlic

Fructans, pectins, cellulose, β-glucans, hemicelluloses
Dietary Fibers in Foods

Which of these are fermentable? Soluble? Insoluble? Viscous?

Dietary Fiber Health Benefits

- **Insoluble (cellulose, bran)**
  - Laxative effect

- **Soluble, viscous, non-fermented (psyllium)**
  - Cholesterol-lowering, improve glycemia, weight loss, stool normalization

- **Soluble, viscous, readily fermented (β-glucan, pectin)**
  - Cholesterol-lowering, improve glycemia


Dietary Fiber Health Benefits

- **Soluble, non-viscous, fermentable:**
  - Fructooligosaccharides (FOS)
  - Galactooligosaccharides (GOS)
  - Inulin
  - Polydextrose

- Accumulating data on health benefits


Diet & GI Microbiota

Dietary intervention trials allow for characterization of the impact of foods on the GI microbiota


Broccoli

Oats & Barley

Agave inulin

Walnuts

Almonds

Fruits

Grains

Dairy

Protein

Vegetables

Oats & Barley

Agave inulin

Broccoli

Almonds

Walnuts

**Inulin Type Fibers**

**Plant Sources**
- Wheat
- Bananas
- Garlic
- Onion
- Agave
- Chicory root

**Food Sources**
- Bars
- Cereals
- Yogurt
- Ice cream

**Structures**
- Fructose polymer linked by β-2,1 linkages
- Varying degrees of polymerization (2-60)
- Fructooligosaccharides (FOS) → Inulin

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**Microbes Ferment Dietary Fiber**

**Amylose**: α-1,4 glucosidic bonds

**Cellulose**: β-1,4 glucosidic bonds

**β-Glucan**: mixed β-1,3 and β-1,4 glucosidic bonds

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Image adapted from Linus Pauling Institute, OSU
Microbiota-Derived Signaling


Peptide YY (PYY)
SCFAs
Inflammation
Serotonin

Inulin Type Fibers & Microbiota

**Microbial**
- 16 g/d inulin and oligofructose (50/50) for 12 wk increased *Bifidobacteria* spp. and *Faecalibacterium prausnitzii*.
- 5 & 7.5 g/d agave inulin increased *Bifidobacteria* spp. and SCFA.
- Positive relations between *Faecalibacterium* spp. and butyrate concentrations.
- 12 g/d inulin increased *Bifidobacteria* spp. and decreased *Bilophila* spp., no change in SCFA.


Inulin: Phenotypic Responses

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**LEGEND** (% change)
- 0 to 0.9% increase
- 1.0 to 4.9% increase
- 5.0 to 9.9% increase
- 10 to 14.9% increase
- >15% increase
- 0 to 0.9% decrease
- 1 to 5% decrease
- 5.0 to 9.9% decrease
- 10 to 14.9% decrease

Inulin-Type Fibers & Health

**Immunomodulation**
- Reduced high-sensitivity CRP, IL-6 and/or TNF-α, and endotoxin
- 10 g/d for 60 days decreased IL-6 and TNF-α

**Appetite and Food Intake**
- 21 g/d for 12 wk increased ghrelin, and reduced food intake.
- 16 g/d for 2 wk increased plasma glucagon-like peptide 1 and PYY

**Body Composition**
- 21 g/d oligofructose for 12 wk reduced body weight, fat mass and trunk fat.
- 16 g/d combination of inulin and oligofructose for 12 wk did not change body composition, fat mass tended to decrease.

**Glycemia**
- 16 g/d for 2 wk decreased postprandial glucose responses after a meal.

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3. Parnell JA. Weight loss during oligofructose supplementation is associated with decreased ghrelin and increased peptide YY in overweight and obese adults. AJCN 2009; 89:1751–59.

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Walnuts

Randomized, controlled, cross-over design

- 8 Female
- 10 Male
- Age: 53 y (35-67 y)
- BMI: 28.8 kg/m² (20-35 kg/m²)

Base Diet Typical American Diet

3-wk intervention with 1-week washout

Base Diet (scaled down) + 1.5 servings/d (42 g/d) walnut pieces

Walnuts Impacted GI Microbiota

Faecalibacterium Roseburia Dialister

% of sequences

Control Walnut

*P<0.05

Holscher HD, et al., J. Nutr 2018

3/21/2019
Walnuts Reduced Secondary Bile Acids

![Graph showing concentration (µg/mg) of Deoxycholic and Lithocholic acids for Control and Walnut groups. *P<0.05](image)

Roseburia (% of sequences) vs. Lithocholic Acid (µg/mg) with correlation coefficient r = -0.42; P = 0.08

Almonds

Randomized, controlled, cross-over design

- n=18
- Age: 57 y (33-72 y)
- BMI: 30 kg/m2 (22-36 kg/m2)

3 Week Treatment

- Control
- Whole Almonds
- Roasted Almonds
- Chopped Almonds
- Almond Butter

Wash Out Period

Almonds
Randomized, controlled, cross-over design

3 Week Treatment

Wash Out Period

Almonds Impact GI Microbiota

Chopped Almonds Increased Roseburia
**Broccoli & GI Microbiota**

Randomized, controlled, cross-over design

Healthy Adults

N=18

Age (y): 47 (37-65)
BMI (kg/m²): 26.2 (19.0-36.6)

**INTERVENTION**
200 g Broccoli + 20 g radish
16 days

**CONTROL**
0 g Broccoli/radish
16 days

14 DAY WASHOUT

**INTERVENTION**
200 g Broccoli + 20 g radish
16 days

**CONTROL**
0 g Broccoli/radish
16 days


**Broccoli Increased Bacteroides**

![Graph showing the increase of Bacteroides with broccoli consumption compared to control.]

Control vs Broccoli

ΔBacteroidetes (% of sequences)

ΔBacteroides

Kaczmarek JL, et al., J Nutr Biochem 2019

**Whole Grain Oats & Barley**

- 7-day menu cycle of standard American diet items
- Treatments included cereal, granola, trail mix, and fruit cereal bars

**Healthy Adults (n=68)**

<table>
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<tr>
<th>Treatment</th>
<th>Baseline Visit</th>
<th>Post-Treatment Visit</th>
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<tbody>
<tr>
<td>CONTROL</td>
<td>0.8 servings per 1800 kcal</td>
<td>0.8 servings per 1800 kcal</td>
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<tr>
<td>OATS</td>
<td>4.4 servings per 1000 kcal</td>
<td>4.4 servings per 1000 kcal</td>
</tr>
<tr>
<td>BARLEY</td>
<td>4.4 servings per 1000 kcal</td>
<td>4.4 servings per 1000 kcal</td>
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</tbody>
</table>
Whole Grain Barley Increased *Roseburia*

- From Baseline
- Treatment: Control, Oats, Barley
- Thompson, S.V et al., FASEB 2016

**Which macronutrients can impact the GI microbiota?**

- **Total Fat**: 4g (6%)
- **Saturated Fat**: 2g (10%)
- **Trans Fat**: 0g
- **Polyunsaturated Fat**: 0g
- **Monounsaturated Fat**: 0g
- **Cholesterol**: 0mg (0%)
- **Sodium**: 120mg (5%)
- **Potassium**: 1600mg (5%)
- **Total Carbohydrate**: 44g (15%)
- **Dietary Fiber**: 8g (33%)
- **Soluble Fiber**: 5g
- **Insoluble Fiber**: 3g
- **Sugars**: 12g
- **Protein**: 4g (15%)
- **Vitamin A**: 0% (0%)
- **Vitamin C**: 10% (8%)
- **Calcium**: 0% (8%)
- **Iron**: 8% (8%)

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**Diet & GI Microbiota**

*Eating a diet rich in different types and sources of fibers helps support a more diverse GI microbiota*

- **Agave inulin**: Bifidobacteria
- **Oats & Barley**: *Roseburia*
- **Broccoli**: Bacteroides
- **Almonds**: Faecalibacterium, Roseburia, Dialister
- **Walnuts**: Faecalibacterium, Roseburia, Dialister

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Diet & GI Microbiota

Food (fiber) source, dose, & form matter

Oats & Barley

Broccoli

Agave inulin

Bacteroides

Walnuts

Almonds

Oats & Barley

Broccoli

Agave inulin

Bacteroides

Diet impacts the human GI microbiota.

Consumption of different types of foods, which contain fiber, differentially impact the GI microbiota.

Increasingly, microbes and microbial metabolites are linked to human health.

Key Takeaways

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Questions

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Twitter: @HolscherLab

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