

Fiber

Olivia Anderson and Dave Bridges

June 9, 2026

For this lecture we will review the basic structure of fiber and go over several definitions used by the general population. We will discuss the varying types of fibers and their characteristics. The characteristics of each fiber type are indication of how they affect digestive and absorptive processes. The digestive and absorptive effects of fiber can influence several health outcomes in humans.

Contents

<i>Learning Objectives</i>	2
<i>Fiber Basics</i>	2
<i>Key Characteristics (and Physiological Effects)</i>	3
<i>Solubility</i>	3
<i>Fermentable</i>	3
<i>Functionality</i>	3
<i>Other Characteristics</i>	4
<i>Types of Fiber</i>	5
<i>Prebiotics</i>	5
<i>Resistant Starch</i>	5
<i>Reflection Questions</i>	6

Learning Objectives

- Review structure of fiber
- Compare various types of fibers
- Describe the various properties of fiber
- Apply the structural properties of fiber to physiological effects on humans

Fiber Basics

We discuss fiber within the carbohydrate unit because its structure is very similar except that the glycosidic bonds are resistant to digestive breakdown and will forgo absorption in the digestive tract. For example, recall the polysaccharide cellulose. It is a linear homopolymer of beta-D glucose linked by beta 1, 4 bonds which are resistant to glycosidases in the digestive tract such as alpha amylase (enzyme specificity to alpha 1, 4 glycosidic bonds). This results in cellulose passing through the digestive tract intact and reaching the large intestine. Fiber is found in plants, specifically within the cellular walls. Common dietary sources of fiber include fruits, vegetables, grains and legumes. Fiber can also be synthetically added to food sources such as cereals, yogurt, juices, and even artificial sweeteners.

MOST PEOPLE DO NOT CONSUME THE RECOMMENDED AMOUNT OF FIBER which is 25g per day for women and 38g per day for men [Institute of Medicine, 2005]. The average American consumes only 16g of fiber per day [Hoy and Goldman, 2010]. The low intake of fiber is concerning because it has been shown to have several health benefits including the prevention of constipation, diverticular disease, and colorectal cancer [Slavin, 2013]. In addition, fiber can help with weight management by increasing satiety and decreasing hunger [Clark and Slavin, 2013].

Consider what you perceive to be some high fiber foods, and look up the amount of fiber per serving. Calculate how many servings of that food you need to achieve 38g, the recommendation for males.

Defining Fiber

The term crude fiber was coined by two scientists in the 1800's who first discovered that there was material leftover from plants after an extraction in an acidic dilute followed by an alkali dilute which mimicked the digestive tract environment. As an understanding of how the digestive tract works and what this leftover fraction was, the definition of crude fiber evolved over time to what we most commonly refer to as dietary fiber or in other words, "the plant polysaccharides

and lignin which are resistant to hydrolysis by the digestive enzymes of a man” [Trowell, 1978]. For research and policy purposes, several definitions beyond dietary fiber have been developed by scientific and regulatory agencies. The definitions either encompass a physiological character of the fiber such as soluble or fermentable or refer to an analytical method (i.e., can be synthetically made) associated with the fiber like functional fiber.

Key Characteristics (and Physiological Effects)

Solubility

As the name of the characteristic suggests, fibers defined as water-soluble will dissolve in water whereas water-insoluble will not. The solubility of a fiber results in unique physiological effects. Fibers with a higher water solubility form a more gel-like substance as they move through the tract. They also tend to have a high viscosity, ability to adsorb and are typically fermentable¹. Alternatively, insoluble fibers will stay intact as they travel through the digestive tract. Upon reaching the colon insoluble fiber will add to the bulk of fecal matter decreasing its transit time through the large intestine. This property of insoluble fibers helps with the relief of constipation.

¹ See other characteristics sections below for more detail

Fermentable

Whether a fiber is fermentable or not depends on whether the bacteria in our large intestine can ferment it (*i.e.*, metabolize it). Byproducts of fermentation include short-chained fatty acids (acetate, propionate, and butyrate), carbon dioxide and hydrogen. The short chained fatty acids that are produced as by-products can either be used by colon cells for their own energy provision or they can be absorbed at the large intestine entering general circulation and used for energy by non-colon tissue.. Particularly notable among the short-chained fatty acids is butyrate, which is the preferred energy source for colonocytes.

Functionality

The most widely used definition established by the Institute of Medicine is based on functionality [Institute of Medicine, 2005]. Dietary fibers are used specifically for nondigestible carbohydrates that are still intact and intrinsic in plant food sources. Dietary fibers encompass the naturally occurring fibers in food. Functional fibers are non-digestible carbohydrates that have been isolated from plant sources or synthesized in laboratory conditions — according to its

definition, the isolated fiber alone has to provide benefits for human health. Thus, functional fibers encompass either natural fiber that has been separated from the original food or synthetic fiber produced by a human.

Other Characteristics

Water-soluble fibers are typically viscous. The viscosity turns the material more gel-like and slows the movement of food through the digestive tract. Viscous fibers delay gastric emptying leaving chyme in the stomach for a longer period of time and increase the time of feeling full [Willis et al., 2009]. The slower gastric emptying can play a role in the rate of glucose absorption at the small intestine which aides in the well-controlled flux of glucose levels into circulation following food intake. In addition to sequestering carbohydrates, viscous fibers can also sequester proteins and lipids inhibiting their exposure to digestive enzymes. This can impede absorption of these macronutrients at the small intestine. Some fibers have the ability to adsorb (*i.e.*, to bind) to molecules and nutrients. Relevant to human health, some fibers bind fatty acids, cholesterol and bile acids within the digestive tract. Once bound, the material travels to the large intestine, is added to the bulk of fecal matter and is excreted. If it does not get added to fecal matter, bacteria in the large intestine can metabolize the bound molecules. Focusing on the potential of increased bile excretion by fiber via feces, the liver will need to synthesize more bile to keep up with lipid digestion and absorption. Remember that part of the basic structure of bile includes cholesterol, thus LDL cholesterol will be taken from circulation and incorporated into bile ultimately decreasing serum cholesterol [Brown et al., 1999].

Although, this is a well-proposed mechanism, evidence shows that high intake of fiber (equivalent to >3 servings of oatmeal per day) on a regular basis is needed to result in a significant decrease in blood cholesterol. Fiber can also adsorb to specific minerals like calcium and iron. This can have either a positive or negative consequence. If the fiber is also highly fermentable with bound minerals, the breakdown of the fiber by gut bacteria will release the minerals and allow for additional mineral absorption at the large intestine (some minerals actually have efficient transport systems at the colonocytes). On the other hand, if the fiber is poorly fermentable, the minerals will remain intact with the fiber material and be incorporated into fecal matter.²

² **Reflection:** Use table 1 to fill in the second column based on what you just read.

Table 1: Properties of fiber and their physiological effects

Property	Physiological Effect
Insoluble	
Soluble	
Fermentable	
Viscous	
Adsorbent	

Types of Fiber

The different types of fiber we find in our dietary sources vary greatly in structure and function. Please refer to Table to see a list of common dietary fibers and what types of food sources they are found in, whether they can be synthesized for consumer products and the types of properties they hold.

Prebiotics

Prebiotics are a subset of dietary fibers and related compounds that selectively stimulate the growth and/or activity of beneficial microorganisms³ in the gut, conferring health benefits to the host. *Not all fibers are prebiotics*; a compound must show selective utilization by beneficial gut bacteria and a positive health outcome to qualify. Common prebiotics include inulin-type fructans and galactooligosaccharides, but emerging candidates such as resistant starches are also being recognized. The prebiotic effect is central to the relationship between diet, the gut microbiome, and human health outcomes including modulation of inflammation, metabolic health, and possibly mental health through the gut-brain axis [Gibson et al., 2017].

³ The actual bacteria, when consumed and able to colonize the gut are probiotics

Resistant Starch

Resistant starch (RS) refers to starch and starch-degradation products that escape digestion in the small intestine and reach the colon, where they undergo fermentation by colonic bacteria[Sajilata et al., 2006]. There are five types (RS₁—RS₅), each with different physical and chemical structures:

- RS₁: Physically inaccessible starch (*e.g.*, whole/partially milled grains, seeds)
- RS₂: Native granular starch (*e.g.*, raw potato, unripe banana)
- RS₃: Retrograded starch (formed during cooking and cooling, *e.g.*, chilled rice)
- RS₄: Chemically modified starches (industrial applications)
- RS₅: Starch-lipid complexes

Like other fermentable fibers, resistant starch can yield short-chain fatty acids upon bacterial fermentation. Some resistant starch types act as prebiotics. Resistant has been studied for beneficial effects on glycemic response, colonic health, and increasingly, metabolic parameters [Birt et al., 2013].

Fiber	Sources	Structure	Properties
Cellulose	Whole grains, root vegetables	beta-1,4 glucose	Insoluble, poorly fermented
Lignin	Wheat bran, nuts, flaxseeds, vegetables, unripe bananas	Complex, irregular polyphenolic polymer	Insoluble, poorly fermentable, provides structural rigidity and increases stool bulk
Hemicellulose	Bran, nuts, legumes	Branched, various units	Depends on branching
Pectin	Fruits	Highly branched, various units	Soluble, fermentable, adsorbent
Gums	Oatmeal, barley, tree	Branched, various units	Soluble, fermentable, adsorbent
β -Glucans	Oatmeal, Rice	beta-1,3 glucose, with branches	Soluble, fermentable
Fructans	Onions, Artichokes	polyfructose	Soluble, fermentable
Galactans	Chickpeas, Lentils	polygalactose	Soluble
Resistant Starch	Legumes, cooked/cooled starches, unripe bananas	Linear and/or branched glucose	Partially soluble, variably fermentable

Table 2: Types of fiber and their properties.

Reflection Questions

1. A patient presents with both elevated LDL cholesterol and chronic constipation. They ask whether they should prioritize oatmeal (rich in soluble, fermentable β -glucans) or wheat bran (insoluble, poorly fermentable) in their diet. Analyze the mechanisms by which each fiber type addresses each condition, and explain why a single fiber type may not optimally treat both problems simultaneously.
2. Resistant starch type 3 (RS₃) forms when cooked starch is cooled — for example, chilled rice contains more resistant starch than freshly cooked hot rice. A patient with type 2 diabetes consumes equal portions of hot rice and chilled rice. Apply your knowledge

of resistant starch and fiber properties to predict the difference in postprandial blood glucose response, and explain the structural basis for why cooling changes digestibility.

3. A person takes a calcium supplement alongside a high-fiber meal. Using your knowledge of fiber's adsorptive properties and the distinction between fermentable and non-fermentable fibers, evaluate whether the type of fiber consumed with the supplement matters for net calcium absorption, and predict the outcome for each scenario.

References

- Diane F. Birt, Terri Boylston, Suzanne Hendrich, Jay-Lin Jane, James Hollis, Li Li, John McClelland, Samuel Moore, Gregory J. Phillips, Matthew Rowling, Kevin Schalinske, M. Paul Scott, and Elizabeth M. Whitley. Resistant Starch: Promise for Improving Human Health¹². *Advances in Nutrition*, 4(6):587–601, November 2013. ISSN 2161-8313. DOI: 10.3945/an.113.004325.
- Lisa Brown, Bernard Rosner, Walter W Willett, and Frank M Sacks. Cholesterol-lowering effects of dietary fiber: A meta-analysis. *The American Journal of Clinical Nutrition*, 69(1):30–42, January 1999. ISSN 0002-9165. DOI: 10.1093/ajcn/69.1.30.
- Michelle J. Clark and Joanne L. Slavin. The effect of fiber on satiety and food intake: A systematic review. *Journal of the American College of Nutrition*, 32(3):200–211, 2013. ISSN 1541-1087. DOI: 10.1080/07315724.2013.791194.
- Glenn R. Gibson, Robert Hutkins, Mary Ellen Sanders, Susan L. Prescott, Raylene A. Reimer, Seppo J. Salminen, Karen Scott, Catherine Stanton, Kelly S. Swanson, Patrice D. Cani, Kristin Verbeke, and Gregor Reid. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nature Reviews. Gastroenterology & Hepatology*, 14(8):491–502, August 2017. ISSN 1759-5053. DOI: 10.1038/nrgastro.2017.75.
- M. Katherine Hoy and Joseph D. Goldman. Fiber intake of the U.S. population: What We Eat in America, NHANES 2009-2010. In *FSRG Dietary Data Briefs*. United States Department of Agriculture (USDA), Beltsville (MD), 2010.
- Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. The

National Academies Press, Washington, DC, 2005. ISBN 978-0-309-08537-3. DOI: 10.17226/10490. URL <https://doi.org/10.17226/10490>.

M. G. Sajilata, Rekha S. Singhal, and Pushpa R. Kulkarni. Resistant Starch-A Review. *Comprehensive Reviews in Food Science and Food Safety*, 5(1):1–17, January 2006. ISSN 1541-4337. DOI: 10.1111/j.1541-4337.2006.tb00076.x.

Joanne Slavin. Fiber and prebiotics: Mechanisms and health benefits. *Nutrients*, 5(4):1417–1435, April 2013. ISSN 2072-6643. DOI: 10.3390/nu5041417.

Hugh Trowell. The development fiber in human. (October), 1978.

Holly J. Willis, Alison L. Eldridge, Jeannemarie Beiseigel, William Thomas, and Joanne L. Slavin. Greater satiety response with resistant starch and corn bran in human subjects. *Nutrition Research*, 29(2):100–105, 2009. ISSN 02715317. DOI: 10.1016/j.nutres.2009.01.004.