FANTASTIC FIBER

UNLOCKING THE POWER OF THIS UNDERRATED NUTRIENT

by Dr. Sarah Ballantyne

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ABOUT THE AUTHOR

SARAH BALLANTYNE, PH.D. is the creator of the award-winning online resource The Paleo Mom; co-host of the syndicated top-rated The Paleo View Podcast; and New York Times bestselling author of The Paleo Approach, The Paleo Approach Cookbook, and The Healing Kitchen. Sarah earned her doctorate degree in medical biophysics at the age of 26 and spent the next four years doing research on critical care medicine, innate immunity, gene therapy and cell biology, earning a variety of awards for research excellence along the way. Sarah's transition from academic researcher to stay-at-home mom to award-winning and internationally recognized health advocate and educator was driven by her own health journey, which included losing 120 pounds and using both diet and lifestyle to mitigate and reverse a dozen diagnosed health conditions. As a scientist both by training and by nature, Sarah is deeply interested in understanding how the foods we eat interact with our gut barriers, immune systems, and hormones to influence health. Sarah's innate curiosity goes further than just understanding diet and she is also deeply interested in the impact of lifestyle factors like sleep, stress and activity. Her passion for scientific literacy and her talent for distilling scientific concepts into straightforward and accessible explanations form the foundation of her work and her dedication to improving public health. Learn more by checking out Sarah's website, podcast and books. You can also find Sarah on Facebook, Twitter, Instagram and Pinterest.

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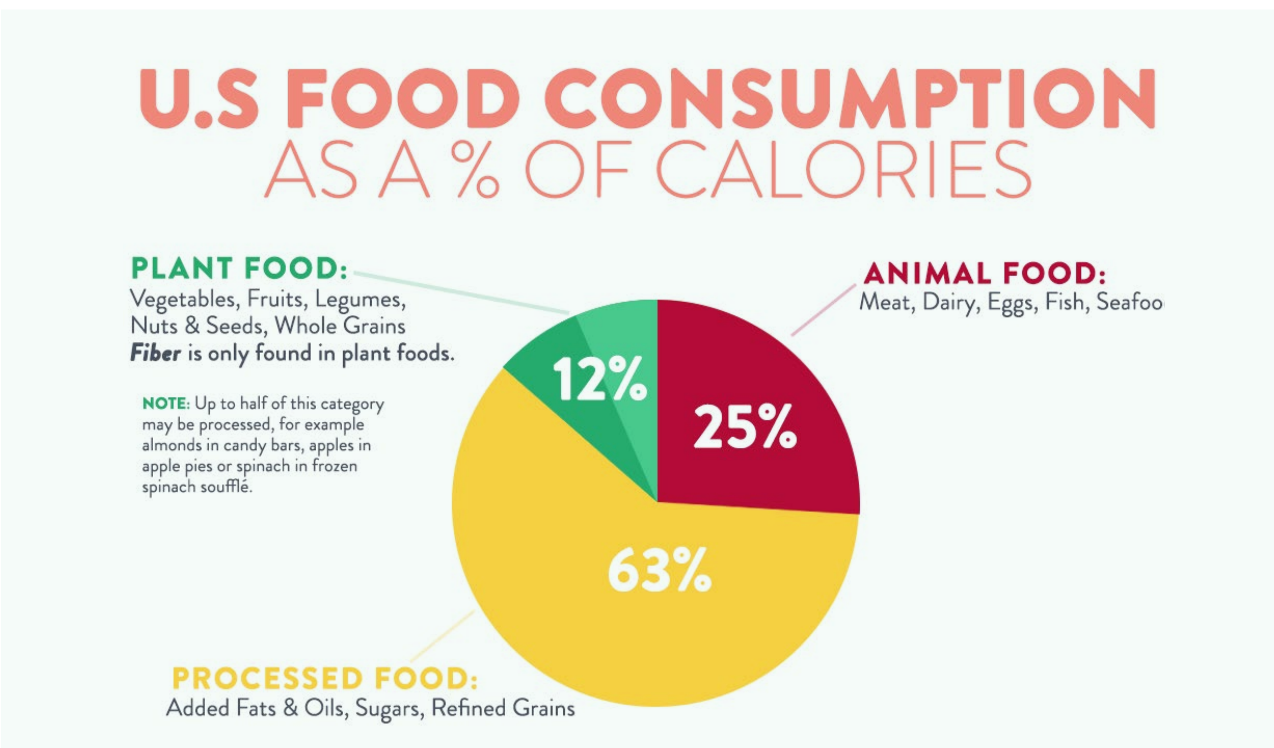
INTRODUCTION

One of the biggest changes in the Western diet over the last fifty years is the huge decrease in dietary fiber as a percentage of carbohydrate intake. This shift from fiber-rich foods to refined carbohydrates is the strongest correlate between any aspect of diet and the rise in cardiovascular disease, type 2 diabetes, and obesity (that's right—refined carbohydrates, not saturated fat!). In fact, how much dietary fiber you eat may be far a more important determinant of health than the total amount of carbohydrates you consume. Fiber is not considered an essential nutrient, but I believe it should be. Just think of all the health benefits of increased fiber intake!!!!!

> **FIBER IS IMPORTANT.** *It regulates digestion and slows the release of insulin. It increases the absorption of magnesium. It also may have an essential role in controlling systemic inflammation. Fiber-rich diets have been shown to result in lower levels of inflammation. Fiber also helps bind toxins and excess hormones in the gut to help us eliminate them instead of reabsorbing them into our bodies.*



Fiber is the main food for the 70-100 trillion microorganisms that live in your digestive tract. And when you eat plenty of fiber, it's harder for pathogenic bacteria to grow in your digestive tract. This is because the fermentation of vegetable and fruit fiber by probiotic bacteria create a variety of organic acids that lower the pH of the environment inside your intestines. This makes for a very hospitable environment for the good guys who are supposed to live there and at the same time makes it hard for the bad guys to survive. Plus those organic acids help make the cells that line your intestine healthier and even have anti-inflammatory properties and potentially prevent cancer (both in the gut and in the liver).

Having a healthy diversity of gut bacteria is known to help regulate the immune system, reduce inflammation in the body, alter genes in the liver that control fat storage and metabolism, and even support brain health by both controlling the integrity of the gut-brain barrier and by influencing the neurotransmitters produced by your brain with the effect of boosting your mood and reducing stress! And a fiber-rich diet is what supports a healthy diversity of gut bacteria. It does matter where you get your fiber though. There's more and more research pointing to vegetable and fruit fibers as being optimal for feeding the right kinds of microorganisms in your digestive tract. In contrast, fiber from grains seems to feed a different set of bacteria, ones that aren't linked to health benefits or that may even be linked to health problems.

Of course, vegetables and fruit have other wonderful nutrients, including essential vitamins, minerals and phytochemicals. Maybe it's because of all these other great nutrients that the importance of fiber gets overlooked. Fiber may not be a nutrient in the sense that our bodies use it for energy (although we do use the short chain fatty acids produced by our gut bacteria when they ferment fiber for energy!) or that it provides the raw materials for chemical reactions in our cells, but it's still pretty darned essential!

WHAT IS FIBER? AND WHY IS IT GOOD?

Fiber is a type of carbohydrate, meaning that fiber is simply a long string of sugar molecules (saccharides). Fiber comes from the cell walls of plants. In plant cells, it acts as a skeleton and helps to maintain the plants' shape and structure. There are many, many different types of fiber (different length strings composed of different saccharides, some with branches and some without). The only dietary source of fiber are plant-based foods.

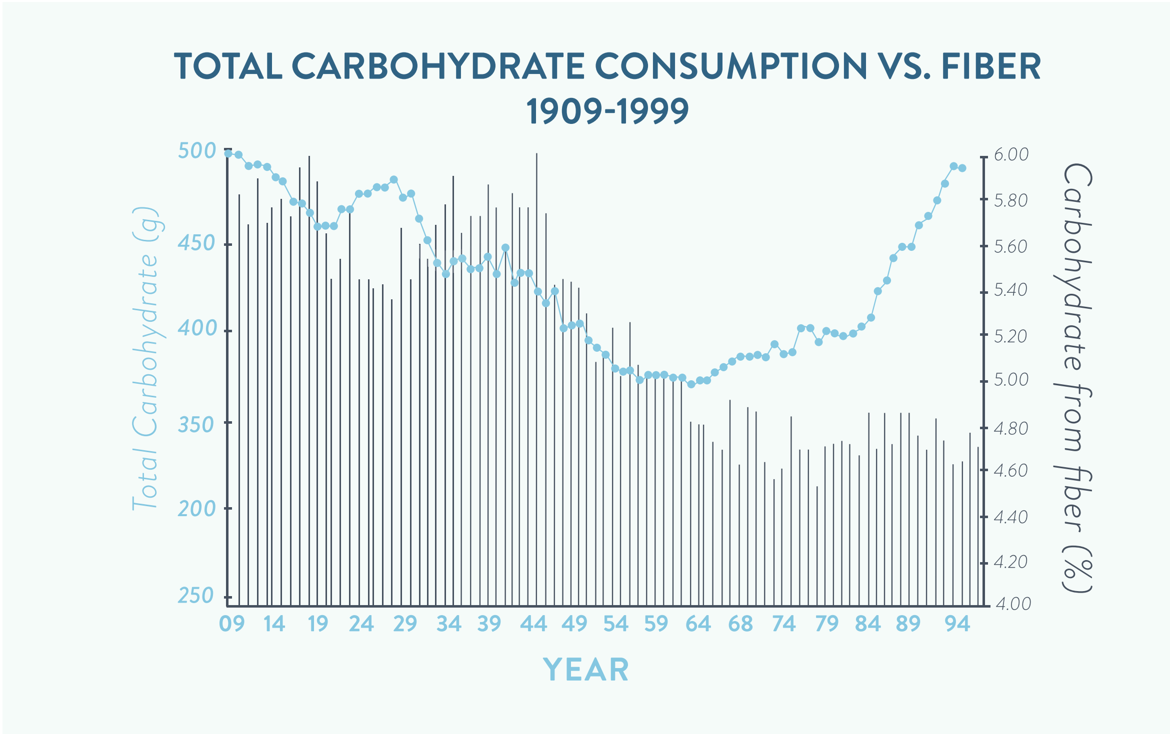
What separates fiber from other carbohydrates (starches and sugars), is that the digestive enzymes produced by our bodies that digest carbohydrates by breaking them down into simple sugars (monosaccharides, which are then absorbed across the intestinal barrier and into the body) are not able to break fiber apart into monosaccharides. Instead, fiber passes through the digestive tract, mainly intact.

Some types of fiber (called fermentable fibers) can be digested by the bacteria in our intestines (these bacteria mainly reside in the large intestine but there are some in the small intestine too). In fact, fiber serves two main functions in the digestive tract: it adds bulk to stool (this makes it easier to pass) and it feed the probiotic bacteria that live in there (there are many ways that this benefits us). When probiotic bacteria eat fiber, they produce short-chain fatty acids—such as acetic acid, propionic acid, and butyric acid. These are extremely beneficial energy sources for the body, including the cells that line the digestive tract and help to maintain a healthy gut barrier. Short-chain fatty acids are also essential for regulating metabolism and they aid in the absorption of minerals, such as calcium, magnesium, copper, zinc, and iron. Healthy gut bacteria have many other important beneficial effects in the body, such as aiding digestion (they release important vitamins and minerals from our food so we can absorb them) and regulating the immune system.

Fiber has other effects, like regulating peristalsis of the intestines (the rhythmic motion of muscles around the intestines that pushes food through the digestive tract), stimulating the release of the suppression of the hunger hormone ghrelin (so you feel more full), slowing down the absorption of simple sugars into the blood stream to regulate blood sugar levels and avoid the excess production of insulin. Fiber also binds to various substances in the digestive tract (like hormones, bile salts, cholesterol and toxins) and depending on the type of fiber, can either facilitate elimination or reabsorption (for the purpose of recycling, which is an important normal function for many substances like bile salts and cholesterol), both of which can be extremely beneficial if not essential for human health.

So, even though fiber doesn't provide us with energy (like other carbohydrates, fat and protein) and isn't an essential micronutrient (like vitamins, minerals and phytochemicals), it's pretty darned important (in fact, one might argue that its classification as non-essential is erroneous).

In fact, one of the biggest culprits in the rise of chronic disease seen in the last 50 years is the decrease in fiber consumption relative to total carbohydrates (you know, the part where the carbohydrates we eat are becoming more and more refined, meaning the fiber is stripped out of them).



Change in total carbohydrate consumption (·) and the percentage of carbohydrate from fiber (vertical bars) in the United States between 1909 and 1997." Graph from L. S. Gross et al., "Increased Consumption of Refined Carbohydrates and the Epidemic of Type 2 Diabetes in the United States: An Ecologic Assessment," American Journal of Clinical Nutrition 79 (2004):774–779.

Take this graph for instance, which I find fascinating. It shows that the current "high carb" consumption in the Standard American Diet isn't actually that different from a hundred years ago. But how refined those carbohydrates are has changed dramatically. And, during the last 50 years, while the percentage of carbohydrates we consume that come from refined sources has been steadily increasing, so too has obesity, type 2 diabetes, cardiovascular diseases, immune diseases like asthma and autoimmune diseases like rheumatoid arthritis.

Certainly, there have been some other important changes in the typical American diet in this time as well. The amount of omega-6 polyunsaturated fats we consume has skyrocketed. The total caloric intake has increased. Our vegetables are less nutrient dense (due to a variety of factors, one of which being that there's typically a longer period of time between when they are picked and when you buy them and eat them). But, the authors of this paper were able to tease out a very important role for fiber intake, by looking at food availability data (the best measurement we have on what the population as a whole eats) and incidence rates of diabetes over the last 100 years.

THEY FOUND :

1. Dietary fiber is inversely correlated with the prevalence of type 2 diabetes (meaning the lower your fiber intake the higher your risk of developing T2D),
2. Corn syrup intake (marking refined carbohydrates) is positively correlated with the prevalence of type 2 diabetes (meaning the more corn syrup you consume, the higher your risk of developing T2D), and
3. There is no correlation with dietary protein or dietary fat with diabetes incidence once you accounted for total energy intake.

The take-home message is that eating whole foods (and therefore avoiding refined carbohydrates) reduces risk of type 2 diabetes. And that it's much more important that your carbohydrates are coming from whole foods rather than how many grams of them you are eating. Just look at total carbohydrate consumption in the early 1900s versus now... pretty similar, but ten times as many people suffer from type 2 diabetes now compared to 100 years ago. The implication is that you're health is far more dependent on fiber intake compared to total carbohydrate intake. This can be inferred from the high carbohydrate intake in the first half of the twentieth century, when the percentage of fiber in the diet was also much higher and disease rates were lower.

Diets rich in fiber also reduce the risk of many cancers (especially colorectal cancer, but also liver, pancreas and others) and cardiovascular disease, as well as overall lower inflammation. Prospective studies have confirmed that the higher your intake of fiber, the lower your inflammation (as measured by C-reactive protein). And in fact, a new study showed that the only dietary factor that correlated with incidence of ischemic cardiovascular disease is low fiber intake (and not saturated fat!); and the more fiber you eat, the lower your risk. If you have kidney disease, a high fiber diet reduces your risk of mortality. If you have diabetes, a high fiber diet reduces your risk of mortality. High fiber intake can even reduce your chances of dying from an infection.

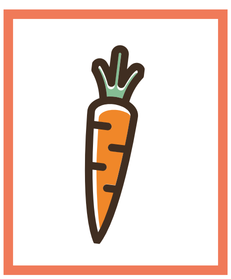
So, does it matter what types of foods your fiber comes from (and thus what types of fiber you're eating)? There are an increasing number of studies supporting that the health benefits of high-fiber diets really come from those diets high in vegetables (so vegetable fiber) and, to a lesser extent, fruit and nuts (the health benefits are not experienced with diets high in cereal grains). These high vegetable diets also reduce cardiovascular disease risk factors and markers of colon cancer risk. How much of this can be directly attributed to the types of fiber in vegetables (mainly insoluble) versus the high vitamin, mineral and phytonutrient content of vegetables compared to other carbohydrate sources remains unknown. Probably, the benefits come from both.

The take home message is: **EAT VEGETABLES. LOTS OF THEM.**

THE MANY TYPES OF FIBER

Carbohydrates, including fiber, are chains of monosaccharides (simple sugars) and of chemical derivatives of monosaccharides. Both the types of simple sugar (and their derivatives) in the chain and the ways they link together to form chains (both overall structure and the types of chemical bonds between sugar molecules) determine what type of carbohydrate it is. What separates fiber from other carbohydrates is that the way the sugars link together are not compatible with our digestive enzymes—our bodies just aren't capable of breaking apart those types of molecular bonds.

Most of us are familiar with soluble and insoluble fiber, at least the terms if not the details of the definition. Broadly, soluble fiber are types of fiber that dissolve in water and insoluble fibers don't. This greatly affects how they behave in the digestive tract.



SOLUBLE FIBER forms a gel-like material in the gut and tends to slow the movement of material through the digestive system. Soluble fiber is typically readily fermented by the bacteria in the colon (although not all soluble fibers are fermentable), producing gases and physiologically active by-products (like short-chain fatty acids and vitamins).

INSOLUBLE FIBER tends to speed up the movement of material through the digestive system. Fermentable insoluble fibers also produce gases and physiologically active by-products (like short-chain fatty acids and vitamins). Nonfermentable insoluble fiber increases stool bulk by absorbing water as it moves through the digestive tract (which is believed to be very beneficial in regulating bowel movements and managing constipation).

Within these two broad categories, there are actually many different types of fiber, classified based on the types of simple sugars and other components they are made from, the types of bonds between sugars, and the overall structure of the molecule. The major classes of fiber will be discussed in more detail below, but this is how they divide among the soluble versus insoluble categories:

INSOLUBLE	SOLUBLE
Hemicellulose (most)	*Hemicellulose (some)*
Chitosan (neutral pH)	*Chitosan (acidic pH)*
Beta-Glucan (some)	*Beta-Glucan (most)*
Cellulose	*Fructan*
Lignin	*Pectin*
Chitin	*Gum*
Resistant Starch	*Mucilage*

Depending on the food in question, some foods have more insoluble fiber types and some have more soluble.

However, classifying a fiber as either soluble or insoluble is only one way to describe a particular fiber. They can also be classified based on whether or not they are fermentable (if they are, they are considered to be "prebiotics", which just means that they are food for the bacteria that live in our digestive tracts). While soluble fibers have the reputation of being the fermentable fibers, there are plenty of types of insoluble fiber which are fermentable as well and even some types of soluble fiber which aren't fermentable (or are only weakly fermentable). Fibers can also be classified based on whether or not they are viscous, meaning how thick they are when they mix with water and other substances in your digestive tract (this classification is used to classify soluble fibers because insoluble fiber doesn't dissolve in water). Many of the health benefits of soluble fiber are specific to high viscosity fibers. Functional fiber is the term for an isolated fiber used as a supplement.

The fibers discussed in more detail below can also be categorized based on whether or not they are fermentable:

FERMENTABLE	NONFERMENTABLE
Hemicellulose (most)	*Hemicellulose (some)*
Chitosan	*Lignin*
Beta-Glucan	*Chitin*
Fructan	*Mucilage*
Resistant Starch	
Gum	
Pectin	

You might be surprised to see that most types of fiber are actually fermentable (some more readily than others, of course)... not just soluble fiber. I want to point this out because it's a myth that soluble fiber is "the fermentable kind of fiber."

As already mentioned, there are actually many types of fiber (which are then either lumped into the soluble or insoluble categories or lumped into the fermentable or nonfermentable categories). And, it turns out that if you want to understand what types of fiber (or whole food sources of fiber) are most beneficial for you, you actually need to go into far more detail than just whether a fiber is soluble or insoluble.

THE MAIN CLASSES OF FIBER

CELLULOSE is the main component of plant cell walls. Celluloses are identical to starch in the sense that they are long straight chains of glucose molecules (anywhere from several hundred to over ten thousand glucose molecules long); however, the links between the glucose molecules are different than starch (they are in what is called a beta configuration) which make cellulose indigestible to humans. Celluloses are insoluble dietary fibers. The bacteria in your intestinal tract cannot ferment most cellulose particularly well (although cellulose is partially fermentable). Cellulose is found in all plants, but foods that contain particularly large amounts of cellulose include bran, legumes, nuts, peas, root vegetables, celery, broccoli, peppers, cabbage and other substantial leafy greens like collards, and apple skins.

HEMICELLULOSE is a common component of the cell walls of plants. In contrast to cellulose, hemicellulose is made of several types of sugar in addition to glucose, especially xylose but also mannose, galactose, rhamnose, and arabinose. Rather than forming long straight chains like cellulose, hemicellulose may have side chains and branches. Because of these variations, some hemicelluloses are soluble in water and some are insoluble, plus some forms are fermented by bacteria while others are not. Hemicellulose is particularly high in bran, nuts, legumes and whole grains as well as many green and leafy vegetables.

PECTIN is soluble in water and highly fermentable (very little passes through to the colon since it is so readily fermented by bacteria in the small intestine). Pectins are rich in sugar, are rich in galacturonic acid, and can be found in several types of configurations (further subdividing this class of fibers by structure). Pectins are found in all fruits and vegetables but are particularly rich in certain fruits, including apples and citrus fruits, and are also found in legumes and nuts.

LIGNIN is a type of fiber with lots of branches made of chemicals called phenols (rather than sugar molecules). Phenols are currently being studied for a variety of health- related effects including anti-oxidant actions (for example, it is the phenolic compounds in olive oil that appear to be responsible for its cardiovascular health benefits). Lignin is unusual because it lacks an overall defining structure. Instead, it consists of various types of substructures that appear to repeat in a haphazard manner. Lignins are insoluble and are not fermentable. Most commonly a component of wood, food sources include root vegetables, vegetable filaments (like the stems of leafy greens and the strings in celery), many green, leafy vegetables, wheat and the edible seeds of fruit (such as berry seeds and kiwi seeds).

AN ASIDE: *Hemicellulose, cellulose, and pectin bind together to from a network of cross-linked fibers and together form the cell wall of most plant cells. Lignin fills the spaces in the cell wall between cellulose, hemicellulose, and pectin components. You get some form of all four of these whenever you eat any plant-based food.*

CHITIN is similar to cellulose in the sense that it is made of long chains of glucose (in the case of chitin, it's actually long chains of a particular derivative of glucose called N-acetylglucosamine) and also has amino acids attached. Chitins are insoluble in water and are fermentable, albeit weakly. Chitin is interesting because this fiber is found not only in plants and fungi but also in the exoskeletons of insects and in the shells of crustaceans.

CHITOSAN is similar to chitin in the sense that is composed of a long chain of N-acetylglucosamine molecules, but it also contains randomly distributed D-glucosamine molecules (like cellulose, linked in a beta configuration). Chitosans are naturally found in the cell walls of fungi but are also produced as a functional fiber by treating shrimp and other crustacean shells with sodium hydroxide. Chitosan is a very unique fiber. It is soluble in acidic environments so it starts its journey through the digestive tract as a soluble fiber in the stomach, but when the acidity of the chime (stomach contents) is neutralized in the small intestine (by pancreatic secretions), it becomes insoluble. It is also fermentable (much more so than chitin).

GUMS are a diverse group of fibers that plants secrete when they are damaged. They are very complex molecules that contain a variety of types of sugars as well as acids, proteins, and minerals. Gums are soluble and highly viscous fibers and are also fermentable. Isolated (functional fiber) versions are used in food manufacturing as thickening and gelling agents (like guar gum and xanthan gum). Some gums used in food manufacturing increase intestinal permeability through an action on the tight junctions between epithelial cells (one of those cases of the isolated concentrated compound being a problem but the small amount naturally occurring in whole foods being fine).

BETA-GLUCANS (more technically Beta(1,3)-glucans) are closely related to gums and are also soluble (a minority are insoluble), viscous and fermentable. They are found in some grains (mainly oats and barley, but also rye and wheat), fungi (yeast and mushrooms, particularly those mushrooms that are used medicinally like shiitake and maitake), and some types of seaweed (mainly algae). Beta-glucans are the fiber in oats that are mainly responsible for the cholesterol lowering properties of oats and, as functional fibers in supplement form, are also known to activate the immune system. They may even act as an adjuvant (that could be helpful if you're battling cancer but definitely not good if you have an immune or autoimmune disease).

MUCILAGES are rich in the simple sugars xylose, arabinose, and rhamnose and have very complex structures. They are soluble and very viscous fibers, forming a thick gluey substance, and are produced by nearly all plants and some microorganisms. They are particularly concentrated in cacti and other succulents (like aloe), many types of seaweed (like agar agar algae), flax, chia and psyllium. They can also be found in relatively large amounts in a variety of fruits and vegetables, including plantains, bananas, taro root, cassava, and berries. While soluble, mucilages are not particularly fermentable (only partially degraded by bacteria in our digestive tracts). Mucilaginous extracts are often used medicinally, and many of these extracts are known as immune modulators or stimulators.

FRUCTANS are fructose-rich soluble and highly fermentable fibers with simple structures (long chains, some with branches–like the fructose equivalent of cellulose). Shorter chain fructans are called fructooligosaccharides, whereas longer chain fructans are called inulins. Inulin fiber is one of the most heavily studied functional fibers. They are naturally occurring in a variety of plants including chicory, onions, and Jerusalem artichoke (see FODMAPs).

RESISTANT STARCH is really starch (also sometimes called oligosaccharides) and doesn't fit the original technical definition of fiber, which was limited to plant cell wall constituents. Resistant starch is considered to be a fiber because amylase, the enzyme that breaks starch into individual glucose units, doesn't work on this type of starch. Resistant starch is insoluble yet highly fermentable. Green bananas, green plantains, potatoes and legumes are all sources of resistant starch (particularly when eaten raw).

Would you believe that these are only the major classes of fiber?

Most of these types of fiber can be further divided into sub-sub classes of fiber. They are almost all found to some degree in almost all plants, so when you eat whole vegetables, fruits, nuts and seeds, you're getting a mix of many of these. You're also getting different forms: the cellulose in an apple peel is different than the cellulose in cabbage and this may have a slightly different effect in your digestive tract (like so many things in biology/physiology/nutrition, the details have yet to be worked out).

What's most important to emphasize is that different fibers feed different bacteria and produce different organic acids when fermented. As we talk about some of the scientific studies evaluating the health benefits (and maybe less beneficial properties) of different classes of fiber, the important thing to keep in mind is that when you eat a variety of vegetables and fruit, you naturally consume a variety of fiber types. This may be the single best thing you can do to ensure a healthy diversity of gut bacteria and reap all the benefits of a resilient and diverse microbiome.

There are actually very few studies that have even measured the different types of fiber found in different fruits and vegetables. While generalizations can be made, such as leafy greens being high in insoluble fiber and starchy tubers being high in soluble fiber, the truth is that the exact amount of solute versus insoluble fiber in most plant-based foods remains a mystery.

POLYPHENOLS

Lignin fiber is particularly interesting fiber because of its phenolic compound content. In fact, polyphenols (molecules made up of several phenols) are another "non-essential" nutrient found in vegetables and fruit that are worthy of discussion. Polyphenols are part of the plant's natural defense against ultraviolet radiation from the sun. Epidemiological studies strongly suggest that long term consumption of diets rich in plant polyphenols offer protection against development of cancers, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases. In fact, some scientists postulate that all of the health benefits of olive oil, red wine, and a Mediterranean diet are attributable to polyphenols.

As mentioned, polyphenols are actually a class of compounds--more than 8,000 different polyphenols have been identified! The main classes include phenolic acids, flavonoids, stilbenes and lignans (not to be confused with lignins). Some polyphenols can be directly absorbed across the small intestine as is. Others need to be broken apart by digestive enzymes and/or probiotic bacteria in the gut before they are absorbed into the body. Once in the bloodstream, they accumulate in tissues all over the body, and that's where they exert their magic!

Polyphenols improve health because they are extremely potent antioxidants. They neutralize the destructive reactivity of undesired oxygen radicals produced as byproduct of cellular metabolism. As such, they improve cellular health which benefits just about every system in the body. Antioxidants are also especially important for the immune system to function optimally! Studies have shown that supplementation with polyphenols can improve asthma, diabetes, cardiovascular disease, cancer, infections, high-blood pressure and even reduce the signs of aging. Yes, they're pretty darned awesome.

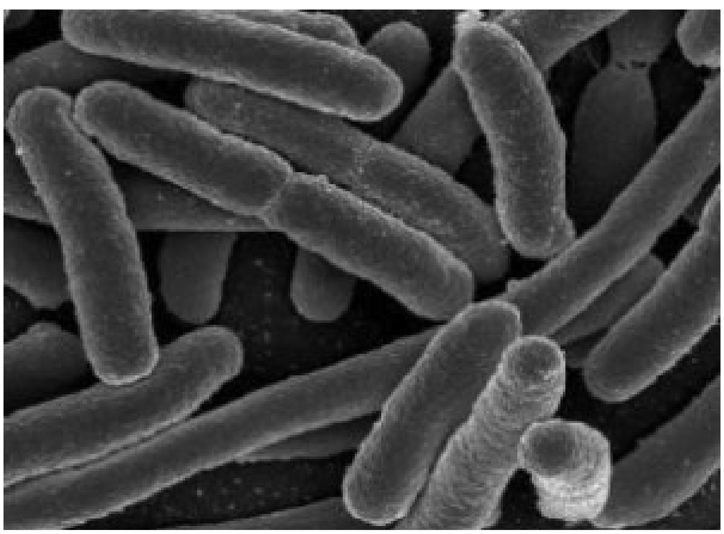
Polyphenols aren't considered essential nutrients. We haven't found a process in the human body that absolutely requires polyphenols from the diet in order to function. That being said, they are clearly critical for good health.

Fruits and vegetables are rich in polyphenols, typically containing 200-300mg per 100g serving. A really high quality fresh-pressed olive oil may contain 300mg per quart. Dark chocolate contains a whopping 700-800mg per ounce! Typically, a glass of red wine or a cup of tea or coffee contains about 100mg polyphenols. Klio Tea is a great brand of antioxidant-rich herbal teas, including Greek Mountain Tea, which has 120mg polyphenols per cup while also being caffeine-free. However, as you can see, it's hard to compete with fruits and veggies when it comes to the polyphenol content (not to mention all the other phytochemicals, vitamins, minerals and of course fiber!). Yet another reason to pile the veggies on your plate!

PRODUCE NAME	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)	CELLULOSE g/100g (Dry Weight)	LIGNIN g/100g (Dry Weight)
Asparagus, canned	32.23	5.8	7.04	14.52	4.87
Beets, canned	24.27	7.5	6.95	9.22	0.6
Broccoli, frozen	30.4	13.63	6.43	8.88	1.46
Brussels Sprouts, frozen	26.94	10.86	7.17	8.29	0.62
Cabbage, raw	23.24	8.68	5.39	8.34	0.83
Carrots, raw	23.76	11.32	3.62	7.81	1.01
Cauliflower, frozen	26.7	8.92	7.19	9.95	0.64
Kale, frozen	33.48	9.94	8.39	11.79	3.36
Lettuce, raw	21.02	4.7	5.64	8.66	2.02
Potato, White, raw	9.48	4.91	1.34	2.33	0.9
Sweet Potato, canned	7.08	2.71	1.2	2.9	0.27
Spinach, frozen	28.75	6.56	9.23	8.86	4.1
Squash, frozen	19.79	7.39	4.82	5.66	1.92
Tomato, raw	13.13	2.13	2.73	6.58	1.69
Apple, raw	12.73	4.48	2.45	3.57	2.23
Applesauce, canned	13.29	5.12	2.86	4.38	0.93
Banana, raw	7.35	2.14	0.96	1.03	3.22
Grapefruit, raw; Florida yellow	11.8	7.24	1.91	2.23	0.42
Orange, raw, seedless, California naval	11.45	6.7	1.97	2.47	0.31
Peach, canned	18.8	7.6	3.72	5.74	1.74
Pear, canned	32.18	6.89	8.48	11.87	4.94
Pineapple, canned	9.54	1.22	3.9	4.21	0.21
Plum, purple, canned	22.81	9.92	3.98	5.81	3.1

FIBER AND THE GUT MICROBIOME

Each of our guts contains approximately 500 to 1,000 species of microorganisms (with about 35,000 species total for all humankind), although about 99 percent of the microorganisms come from thirty to forty species of bacteria. Different species tend to prefer living in different areas of the digestive tract, so the bacteria growing in the first part of your small intestine (the duodenum) won't be the same as those living in your colon. Some bacteria prefer to live embedded in the mucus layer in close proximity to the gut epithelium, whereas others like the mass of material being digested far out from the walls of the gut (the part of your intestine called the lumen). These bacteria are collectively referred to as our gut microbiota. Because they are beneficial to our health, they are also called probiotics.



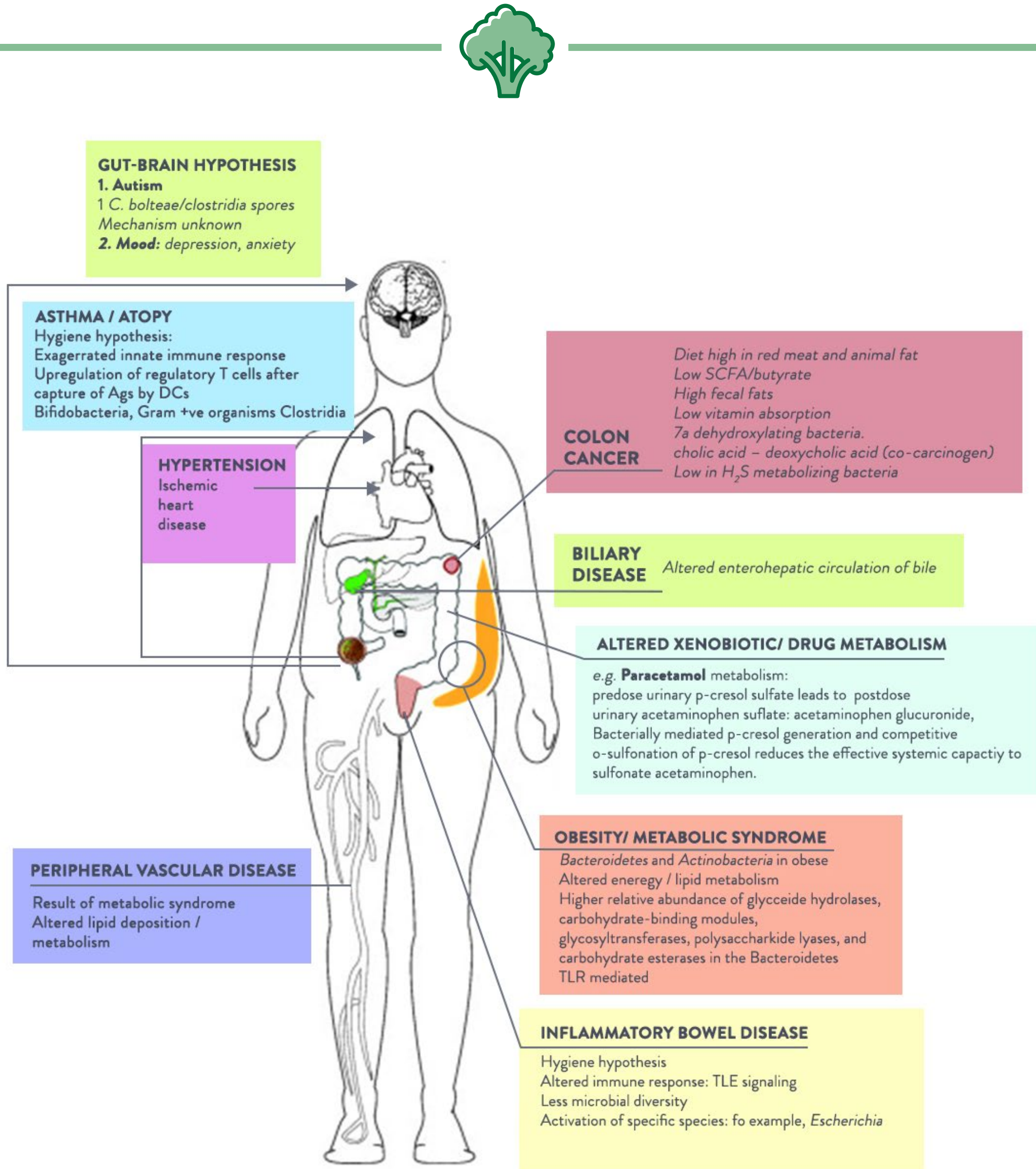
Our guts are inhabited by other microorganisms besides bacteria, including archaea (similar to bacteria), viruses, and single-cell eukaryotes (like yeast). In fact, it is estimated that there are seven to ten times as many microorganisms living in our guts as there are total number of cells in the entire human body! These microorganisms are collectively referred to as our gut microflora (the term microflora includes other types of beneficial organisms, like yeast, in addition to bacteria) or sometimes just gut flora, and we depend on them for health and survival.

Bacteria actually live in your entire digestive tract, from your mouth to your colon—not just in your large intestine, as you may have thought. The number of bacteria does, however, vary significantly, generally increasing progressively down the gastrointestinal tract. For example, there are only between ten and one thousand bacteria per gram of material (the stuff you are digesting) in the stomach and the duodenum. The second and third segments of the small intestine (the jejunum and the ileum, respectively) contain between ten thousand and ten million bacteria per gram of material. The colon contains between a hundred billion and a trillion (!) bacteria per gram of material.

The intestinal microbiota of healthy individuals is known to confer a number of health benefits relating to, for example, pathogen protection, nutrition, host metabolism and immune modulation.

The gut microflora perform diverse functions essential to our health. Perhaps best understood is their role in digestion. Our gut microflora have enzymes that break down certain types of sugars, starches, and fiber from foods so that we can digest them and absorb their nutrients. Bacteria also ferment certain carbohydrates in our digestive tracts, producing short-chain fatty acids—such as acetic acid, propionic acid, and butyric acid—which are extremely beneficial energy sources for the body and are essential for regulating metabolism. These short-chain fatty acids also aid in the absorption of minerals, such as calcium, magnesium, copper, zinc, and iron. Our gut bacteria aid in the absorption of minerals in other ways, too. They liberate minerals that are complexed with phytate (an antinutrient present to varying degrees in all plant-based foods that binds minerals and makes them less absorbable; see page XX), making those minerals available for absorption.

Our gut bacteria also synthesize vitamins—B and K vitamins in particular— which our bodies then absorb (and which provide us with important micronutrients that we may not get enough of otherwise). Gut bacteria may also play a key role in facilitating absorption of dietary fatty acids, thereby increasing absorption of important fat-soluble vitamins A, D, E, and K. Deficiencies in many of the micronutrients mentioned above are known to be contributing factors to autoimmune disease and are discussed further in chapter 2. Clearly, our gut microflora are important.



Diseases influenced by gut microbial metabolism. The variety of systemic diseases that are directly influenced by gut microbial metabolism and its influence on other mammalian pathways, such as the innate immune system, are shown. Specifically highlighted are the metabolic pathways involved in drug metabolism and obesity that are directly influenced by the gut microbial content. Ags, antigens; C. bolteae, Clostridium bolteae; DCs; dendritic cells; SCFA, short-chain fatty acid; TLR, Toll-like receptor. Figure from: Kinross et al. Genome Medicine 2011 3:14 doi:10.1186/gm228

Our gut microbiota also have a direct impact on the immune system, the details of which are still being heavily studied. Healthy gut microbiota are critical for the development and maturation of the immune system, and different bacterial components modulate different aspects of the immune system. For example, a complete lack of gut microbiota is known to result in severe deficiencies of most CD4+ T cells but an increase of Th2 cells (see The Paleo Approach). Some bacterial components are known to balance Th1, Th2, and Th3 cell populations through regulation of dendritic cell activation (increasing or decreasing dendritic cell activation, depending on the circumstance). Some bacterial components stimulate the production of Th17 cells, some modulate the activation of natural killer cells, and some influence the interaction between antigen receptors on the immune cell surfaces and the antigens themselves. These friendly bacteria not only keep the immune system in check during times of health but also help contribute to the immune defense against invading pathogens; for example, by stimulating the production of antibodies against foreign microorganisms.

The microorganisms in our gut help maintain the delicate balance required by our immune system, keeping the various populations of immune cells in check and modulating their activity. Achieving a healthy balance in the immune system is therefore reliant on having a healthy population of gut microflora, growing in the correct numbers in the correct locations and with appropriate diversity.

Another important role of the gut microbiome is its influence on brain function via production of cytokines that regulate the permeability of the gut-brain barrier, production of neurotransmitter, and regulation of neurologic inflammation. Alterations to the gut microbiome are linked to depression, anxiety, rumination, and senility. The gut microbiome also has a profound influence on energy metabolism, and it is now believed that the type of bacteria that thrive in a high-fat environment contribute to the hormone and metabolic shifts that lead to obesity and metabolic syndrome. In fact, correcting the gut microbiota (with prebiotics and/or probiotics) may help to control of the development of metabolic diseases associated with obesity.

What makes a healthy gut microbiome is diversity. In fact, microbial richness (i.e., bacterial diversity), is considered an excellent indicator of a healthy status. In contrast, reduced bacterial diversity has been linked to obesity and immune-related and inflammatory diseases. So, how do you achieve a robust and diverse gut microbiome? You have almost certainly heard the expression "You are what you eat." And while certainly your health depends greatly on your diet, there's another very important aspect to your health: the relationship between what you eat and which bacteria like to grow in your gut. You could just as easily say, "Your gut bacteria are what you eat."

When the microbiota of people living in Western cultures was analyzed in comparison with that of people living in rural settings who had hunter-gatherer–type lifestyles and with that of wild primates like chimpanzees, our gut microflora was found to be significantly lacking in terms of both richness and biodiversity. This is directly attributable to diets high in industrially processed foods (which are also low in fiber), which don't supply enough of the right nutrition for our microbiota (or us!) to thrive. Interestingly, there is even less diversity of gut bacteria in obese people than in lean people: more food does not equal more nutrition, and the worse your diet, the more your gut microflora suffers.

Diet is the single biggest influence on microflora composition. In fact, your diet is directly responsible for more than 60 percent of the variation in bacterial species in your gut. What's more, the population of microflora in your gut (types, total and relative quantities, and location) adapts quite rapidly to changes in your diet, in a matter of a few days to a few weeks. That's good news.

It's not just a question of which kinds of bacteria your diet nourishes but also a question of bacterial metabolism. Just as a high-sugar diet causes oxidative stress in our bodies, a high-sugar diet causes oxidative stress in our gut bacteria. Those bacteria adapt by altering their metabolism, which greatly affects our health.

Your diet affects gut motility and colonic contractibility, which then influence gut microflora composition. However, your diet also affects gut microflora composition directly, which then affects gut motility and colonic contractibility. The impact of gut bacteria on transit largely depends on the amount and type (fermentable versus nonfermentable) of starches and fibers in the diet. Generally, transit is well regulated when diets are high in vegetables and fruits. Yet another reason to avoid grains and legumes as a source of carbohydrates.

The relationship between your diet, your lifestyle (stress, sleep, circadian rhythms, etc.), and your gut microflora is complex, and it's only beginning to be understood in the scientific community. However, research is starting to show that altering gut microflora can be a powerful way to improve immune function and control autoimmune disease—but doing so isn't as easy as supplementing with probiotics. You need to feed your gut bacteria the right food to encourage the growth of the right diversity and relative quantities of beneficial microorganisms. To do so, we can take a cue from contemporary hunter-gatherer populations: the right foods are quality meats, seafood, fruits, and vegetables. The takeaway is that by improving your diet, you not only improve your health directly but also bolster your gut microflora, which will then further improve your health.

Eating more fiber-rich vegetables and fruit, as well as a variety of them, is the single best thing you can do to support your gut microbiome (second most important is plenty of long-chain omega-3 polyunsaturated fats like those found in seafood, and the third most important thing is to manage stress and get plenty of sleep!).

It is because of this link between dietary fiber and the gut microbiome and the link between the gut microbiome and our health that fiber needs to find its way higher up on the diet priority list.

SOLUBLE VS. INSOLUBLE FIBER

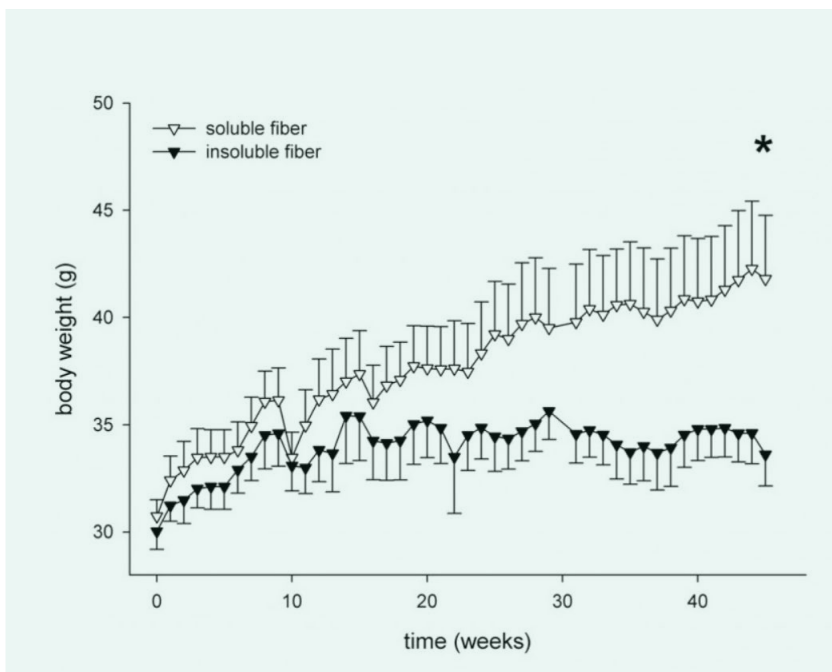
What's better for you? Soluble or insoluble fiber? Many people will tell you that the answer is soluble. In fact, most of the proposed beneficial effects of fiber consumption are attributed to the viscous and fermentable properties of soluble fiber. In contrast, most studies that evaluate the benefits of soluble versus insoluble fiber show that insoluble is better.

To date, the vast majority of studies evaluating the health benefits of fiber are either correlative studies or studies using fiber supplements. Correlative studies look at a particular group of people, get them to fill out surveys about what foods they eat, and then monitor them for health problems. Then, the researchers look to see if there are patterns (like people who ate a particularly high amount of X or Y tended to get Z disease). Fiber supplement studies almost always supplement with soluble, fermentable fibers, most typically inulin or beta-glucans. Most of these studies don't (or can't) separate out soluble versus insoluble (and good luck getting more detailed than that!)—so, mostly what they tell us is that your chances of a variety of diseases are lower if you eat a fiber-rich diet (but they can't tell us why or whether the fiber itself is the part that's making the difference). The good news is that there are some studies that are starting to tease out the differences between soluble and insoluble fiber when it comes to health and these are proving to be very interesting!

Results from prospective cohort studies fairly consistently show that insoluble fiber intake is strongly linked to reduced risk of diabetes. And, while total fiber correlates with decreased risk of cardiovascular disease, this association is much stronger for insoluble fiber compared to soluble. Of course, as is typical in medical research, consensus is hard won and there are certainly studies which show the opposite. For example a study evaluating diet and mortality in type 1 diabetics showed that soluble fiber correlated more strongly than insoluble with reduced risk of complications including death (although both soluble and insoluble fiber reduced risk). Another study in women showed that high soluble fiber intake correlated with reduced risk of developing insulin resistance (but insoluble did not).

Nevertheless, there seems to be a stronger case for health benefits for insoluble fiber compared to soluble, although explanations for why are still lacking. One possible explanation are the anti-inflammatory effects of insoluble fiber. One prospective study showed that the higher your dietary fiber, the lower your C-reactive protein (a bloodborne marker of inflammation). The correlation between high fiber and low C-reactive protein levels was even stronger for insoluble fiber than soluble fiber (although both were good).

In one of the most fascinating papers I've read in a long time, a team of researchers evaluated the long-term effect of two variations of a diet in mice that would normally cause them to become obese. Two groups of mice were fed high-fat diets identical in every respect (and calorie matched) except one diet contained soluble gum type fiber and the other contained insoluble cellulose type fiber. Over the course of the experiment (a year), the mice

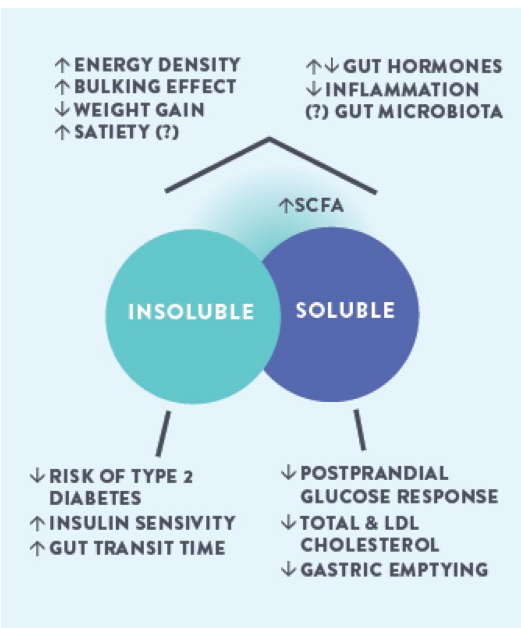


Two groups of mice were fed isocaloric diets that were identical except for fiber type included. Those fed the diet with soluble fiber became obese and those fed the diet with insoluble fiber didn't. From Isken F, et al, Effects of long-term soluble vs. insoluble dietary fiber intake on high-fat diet-induced obesity in C57BL/6J mice. J Nutr Biochem. 2010 Apr;21(4):278-84.

fed the soluble fiber diet became obese but the mice fed the diet that contained insoluble fiber didn't (and remember calories were matched and the composition of the two diets were identical other than the type of fiber). The insoluble fiber group had lower blood sugar levels too. The researchers also made some headway in explaining why. The soluble fiber group showed higher markers of happy gut bacteria, like higher breath hydrogen levels and indicators of higher short-chain fatty acid production (which you would expect since gums are highly fermentable but celluloses are only partially fermentable). But, the insoluble fiber group had lower liver triglycerides and had markers of increased fat metabolism. The authors speculate that this is a direct effect on gene expression from the excess short-chain fatty acids produced with the high soluble fiber diet (and show some convincing preliminary evidence to support this explanation). This right here could explain why the rate of obesity increases with lower fiber intake—an beneficial effect on metabolism from insoluble fiber. This also provides a warning against overdoing soluble fiber (whether through foods sources or supplements).

The fact that this study was long term (almost a year long, where the average lifespan of a mouse is about 2 years) was important because an amazing cross-over in the effects was observed after about the ten-week mark. Early on, the benefits of soluble fiber seemed greater or the same as insoluble fiber. At the ten week mark, insoluble fiber started to take over as the clear winner and the effects just kept magnifying over time. This might also explain why some studies show that soluble fiber is better… over the short term, it is (probably due to supporting growth of good bacteria). And it explains why prospective studies that look at long term effects of diet show insoluble fiber to be more beneficial. Soluble fiber is great for feeding our gut bacteria. And soluble fiber is the type that has been shown to have cholesterol-lowering properties. The short-chain fatty acids that are produced as a result of fiber fermentation are known to be very beneficial (so much so that they are being investigated as a possible supplement, called "postbiotics")—although too much of a good thing might be a problem (the cause of the changes in fat metabolism in the study I just talked about). What about insoluble fiber? Most types are still fermentable (at least moderately). Insoluble fiber is also one of the most important dietary factors suppressing ghrelin after a meal (ghrelin is the main hormone responsible for the feeling of hunger and it is also an important immune modulator, so having high ghrelin before you eat is very important and then having very low ghrelin after you eat is also very important). Insoluble fiber binds toxins and surplus hormones in the gastrointestinal tract, facilitating their elimination from the body. Furthermore, bile salts are bound by soluble but not insoluble fiber, implying that insoluble fiber supports normal bile salt resorption (recycling) as well as fat digestion, and absorption of essential fatty acids and fat-soluble vitamins.

What about the different subtypes of fiber? As already explained, there are many types of fiber and the health effects are far more complicated than simply evaluating whether a type of fiber is soluble or insoluble. A recent study evaluated the effects of dietary fiber on pancreatic cancer risk and found that both soluble and insoluble fiber reduced cancer risk but that the associations were strongest for cellulose and lignin. (This study further showed that fruit and vegetable fiber reduced cancer risk but not grain fiber.) This reduced risk might be explained, at least in part, by the phenolic content of lignin fibers. Another study showed that the phenols derived from lignin fibers reduced inflammation, decreased oxidative stress, and protected the kidneys of diabetic rats. Another study evaluating the effects of dietary chitin showed that this fiber is especially good at reducing the proinflammatory oxidized low-density lipoproteins (oxidized LDL) in particular (implicated in atherosclerosis), but didn't affect the good high density lipoproteins (HDL); and lignin-derived phenols were even more effective than supplementation with olive oil extract. Of course, this is contrasted by a study showing that both chitin and chitosan stimulate a subset of the adaptive immune system (Th1, or type 1 helper T cells which can help some immune and autoimmune diseases but make others worse). Beta-glucans on the other hand also stimulate a different subset of the adaptive immune system (Th2, or type 2 helper T cells this time). Pectins seem to have little to no effect on inflammation. And finally, a pair of studies show that hemicellulose supplementation dramatically reduces inflammation and disease activity in a mouse model of colitis.



Yes, the points seem to be adding up for insoluble fiber. But, this isn't to say that soluble fiber isn't beneficial. Hundreds of studies have shown otherwise. This is more to say that soluble fiber isn't the only show in town and that the often overlooked insoluble fiber may actually be the true star. There's also a strong argument to be made for whole food sources of dietary fiber. Not only are diets rich in vegetables especially linked to reduced inflammation and lower risk of disease, but the complex ways that different fibers interact with the body (including the health of gut bacteria, gut motility, rate of macronutrient absorption, a variety of hormones, and the immune system) mean that the best way to protect against possible negative effects of a specific fiber type is to increase variety (which means avoiding supplements).

TAKE-HOME MESSAGE: stop thinking of soluble fiber as "the good fiber". Both insoluble and soluble fibers are beneficial. And you need them both.

FIBER, CHOLESTEROL AND BILE SALTS

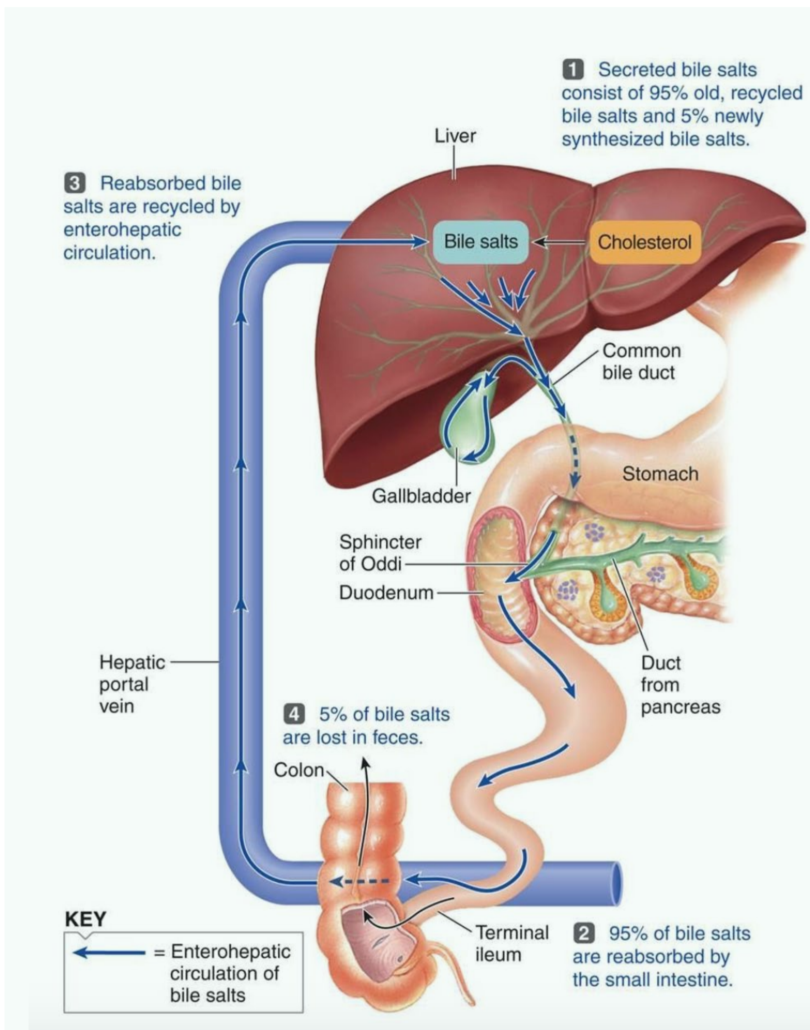
One of the reasons that fiber is recommended as part of our diets is its cholesterol-lowering effects. A`nd, I feel any discussion on the health benefits of fiber would be incomplete without discussing this aspect of dietary fiber. Of course, this also opens a whole can of worms.

Probably the first place to start is the fact that high blood cholesterol is not the cause of cardiovascular disease. This recent article in the British Medical Journal explains the current state of knowledge with regards to saturated fats (also not the cause of heart disease and in fact low saturated fat increases your chances of dying from cardiovascular disease… I told you this was a can of worms!) and cholesterol with regards to cardiovascular disease, obesity, and metabolic syndrome.

Having high blood cholesterol is analogous to having a runny nose when you have a cold. It's a symptom, not a cause. And just like taking a pseudoephedrine to decongest your nose doesn't help your body fight the cold virus (although it does make you feel better), taking cholesterol lowering drugs or artificially lowering your cholesterol through high soluble fiber intake or supplements just reduces the symptom and doesn't do anything to address the root causes.

To understand how soluble fiber reduces cholesterol, it's important to understand a little bit about enterohepatic circulation.

Bile salts (also called conjugated bile acids) are produced by the liver, stored in the gallbladder, and then secreted into the small intestine after eating. They are necessary to digest fats. Bile salts act as an emulsifier (or detergent), by breaking apart large fat globules so that lipases (digestive enzymes produced by the pancreas that break down fats into individual fatty acids) can more effectively do their job. Bile acids also facilitate absorption of fats and fat-soluble vitamins by creating structures called micelles—aggregates of fatty acids, lipids, cholesterol, and fat-soluble vitamins—which are water soluble and easily absorbed by the cells that line the small intestine (the enterocytes).



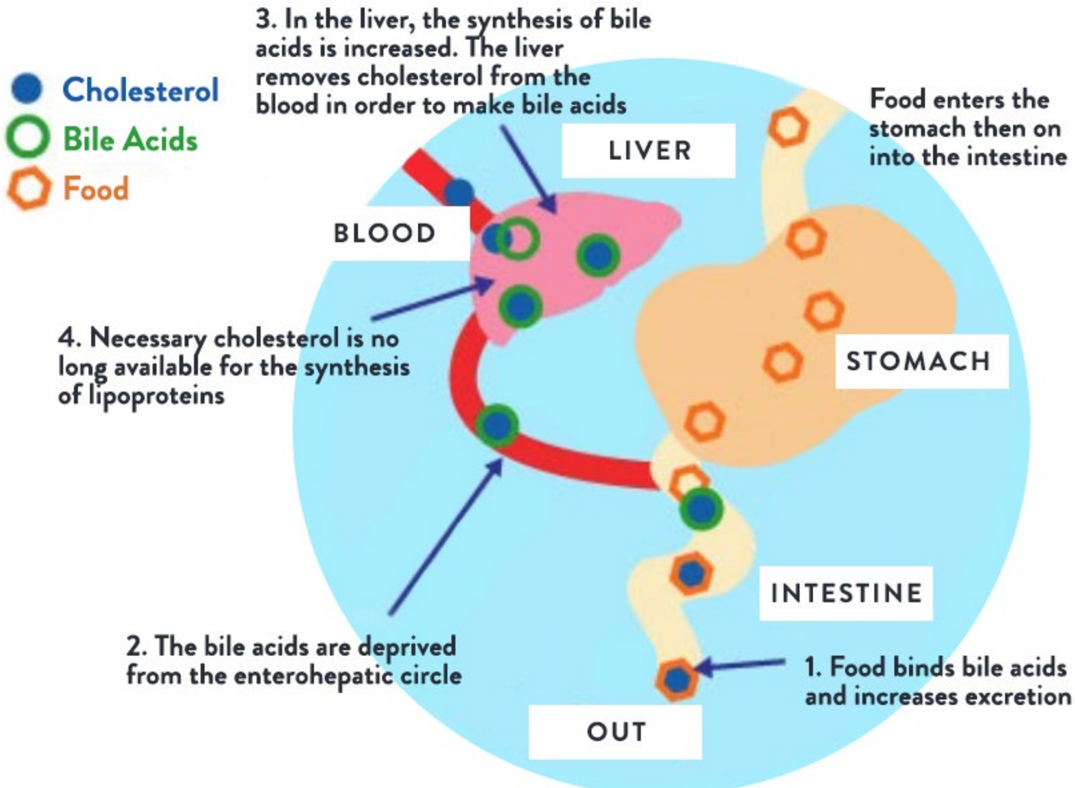
Bile salts are created from cholesterol. Cholesterol molecules (which also form the backbone of all steroid hormones like vitamin D, cortisol and estrogen) is first converted into one of two types of fatty acid (cholic acid and chenodeoxycholic acid) and then conjugated (joined together) with the amino acids glycine or taurine to create a detergentlike structure—bile salts (that's also where the name conjugated bile acids comes from).

Cholesterol itself is also secreted into the small intestine in the bile. The main function of this cholesterol is facilitating absorption of fat and fat-soluble micronutrients as a critical component of micelles. Cholesterol is also an essential component of another important structure called chylomicrons. After fatty acids, cholesterol and fat-soluble vitamins are absorbed by the cells that line the small intestine (the enterocytes), the cells repackage these components into structures called chylomicrons. Chylomicrons are delivered to the other side of the enterocyte and then circulate through the body via the lymphatic system. Without either cholesterol or bile acids in the gastrointestinal tract, the body cannot digest and absorb essential fatty acids nor fat-soluble vitamins.

The majority (up to 90 percent) of bile salts and cholesterol molecules secreted into the gastrointestinal tract are reabsorbed by the small intestine and recycled back to the liver for reuse (this process is called enterohepatic circulation). This recycling is important because the liver would not otherwise be able to keep up with the demand for bile salts.

Many types of soluble fiber have strong cholesterol-binding and bile salt-binding properties (especially beta glucans, psyllium, mucilages, and gums and to a lesser degree inulins and pectins). This binding in the gastrointestinal tract stops the incorporation of cholesterol and bile salts into micelles and therefore stops the absorption or reabsorption of these molecules. (This, by the way is also how two different classes of cholesterol lowering drugs work: bile acid resins like Colestid, and cholesterol absorption inhibitors like ezetimibe.) This then has the effect of lowering total blood cholesterol, both because less cholesterol is reabsorbed and because the liver is required to synthesize more new bile salts. This sounds like a good thing, right? However, don't forget that not only is blood cholesterol not the cause of cardiovascular disease but that cholesterol serves important physiological functions in the body. Although high blood cholesterol is not desirable, stopping the reabsorption of cholesterol in the intestines is an artificial way to lower it and does not address the root problems (inflammation).

In fact, some studies are showing that cholesterol-lowering drugs and functional fibers (isolated fiber used for supplementation) can lead to deficiency in some fat-soluble vitamins. While statins work through a different mechanism (they stop cholesterol synthesis in the liver), vitamin E deficiency can be a result of their use. Chitosan, which is under investigation as a functional fiber supplement to lower cholesterol, also causes vitamin E deficiency (but no effect on Vitamin A). Of course, inulin fiber supplementation has been shown to increase calcium and magnesium absorption and improve bone health, so clearly the effects are complicated.



WHAT IS THE TAKEAWAY MESSAGE HERE? Eating soluble fiber-rich foods in order to lower your cholesterol level is not going to actually reduce your risk of cardiovascular disease. Much more important factors are: that you aren't consuming more calories than you need; that you aren't consuming large amounts of refined carbohydrates (especially high fructose content processed foods); and that you leading an active lifestyle, managing stress and getting enough sleep. Insoluble fiber will protect the normal recycling of bile salts and cholesterol, enabling optimal digestion and absorption of essential fatty acids and fat-soluble vitamins. Not that soluble fiber is bad for you, because it isn't, but here is another reason to stop focusing on soluble as the "good fiber" because the arguments for its superiority are disappearing rapidly.

BUSTING THE ABRASIVE INSOLUBLE FIBER MYTH

As I researched my first book, The Paleo Approach, it was very important to me to make sure that every recommendation was backed up by modern science.

My starting point for the diet recommendations in The Paleo Approach was the paleo autoimmune caveat as originally outlined in The Paleo Solution, plus the focus on vegetables suggested by Dr. Terry Wahls, and of course my own research for many blog posts explaining the why's behind the paleo Autoimmune Protocol that I had already tackled before I started writing the book (as I tried to optimize my own health). Through the last year of researching and writing, I made a point of reading through the scientific literature to make sure that every aspect of my recommendations could be backed up by science... and this led to some surprises for me. Some of the common recommendations made for those with autoimmune disease in the paleo community could not be validated by science. An example is the traditional recommendation to avoid cruciferous veggies (because of their goitrogenic properties) for those with thyroid disorders, a myth which is busted in this article. And another of these topics is the avoidance of insoluble fiber for those with severe gastrointestinal symptoms and gut pathologies... turns out that this recommendation is not supported by science either.

As I researched the benefits of fiber, it became clear that a diet rich in vegetables and fruit (but not too high in fructose) was going to be essential for anyone to heal from an immune or autoimmune disease (or even to just be optimally healthy for that matter!). But, more than supporting the intake of fiber-rich foods in general, I kept finding studies supporting the benefits of insoluble fiber compared to soluble fiber (although there are clearly health benefits to soluble fiber as well, especially as prebiotic fibers).

But, insoluble fiber gets a bad rap. Both conventional medical doctors and alternative healthcare providers typically warn against consuming foods rich in insoluble fibers for those with a severely damaged gut (so common in autoimmune disease) because insoluble fiber is rough and abrasive. It has been likened to eating sandpaper, and supposedly causes damage to the gut as it scrapes its way through our digestive tract. Both conventional and alternative healthcare providers (including some leaders in the paleo community) recommend avoiding insoluble fiber for people with IBD, IBS, diverticulitis and severely leaky guts. So what is the evidence?

Diets rich in fiber reduce the risk of developing many gut pathologies. High fiber diets (especially insoluble) reduce the risk of diverticular disease (diverticulitis and diverticulosis). Very few perspective studies have been performed to investigate diet factors increasing risk of irritable bowel syndrome (IBS), but preliminary studies indicate that low fiber intake is a risk factor. High fiber and high fruit intake are both associated with decreased risk of Crohn's disease. High vegetable intake is associated with decreased risk of developing ulcerative colitis.

However, decreasing the risk of developing the disease is different than what happens when you eat insoluble fiber-rich foods after the disease has developed. So, let's look at that scenario.

If insoluble fiber were abrasive and irritating to the gastrointestinal tract, clinical trials where patients with diseases such as IBD, IBS and diverticulitis are supplemented with insoluble fiber should show exacerbation (or worsening) of their diseases. But, the handful of studies that have investigated the effects of insoluble fiber in these severe gut pathologies have not borne this out.

The impact of insoluble fiber on disease activity is best understood with diverticular disease. In diverticular disease, tiny pouches form in the colon due to weakening of the wall of muscles around the colon. These pouches are called diverticula, and the diagnosis when these pouches are discovered is diverticulosis. When these pouches become inflamed, diverticulitis is diagnosed. When inflammation is severe, diverticula can bleed. Traditionally, a diagnosis of diverticulitis or diverticulosis comes with a lifetime ban on insoluble fiber-rich foods like corn, popcorn, nuts, and seeds, and often low-residue diets (very low fiber) are recommended. However, the evidence supporting these diet recommendations has never actually existed. And in fact, the opposite has been proven: high dietary fiber intake not only prevents new diverticula from forming, but it also reduces the risk of complications (such as bleeding and diverticulitis) in patients with diagnosed diverticular disease.

One fascinating prospective study looked at whether dietary fiber increased or decreased the risk of complications in patients with diagnosed diverticular disease. This study showed that high intake of fiber from fruits and vegetables decreased risk of complications, but not cereal grain fiber (they were also able to show that it was the fiber in fruits and vegetables rather than other nutrients that made the difference). They further showed that high insoluble fiber intake, and especially cellulose (but also lignin and to a lesser degree hemicellulose)—but not soluble fiber—correlated with lowest risk of complications of diverticular disease. Even patients who suffered such severe diverticulitis that the diverticula were bleeding benefited from high insoluble fiber intake.

What about conditions affecting the small intestine rather than the large intestine, like Inflammatory Bowel Disease and Irritable Bowel Syndrome? In one large study, patients with Irritable Bowel Syndrome were blindly and randomly assigned either a soluble fiber supplement (psyllium), an insoluble fiber supplement (bran), or placebo. While soluble fiber significantly improved symptoms of IBS, insoluble fiber had only a marginal effect

compared to placebo—but, it didn't make things worse. A study using chitosan and vitamin C supplementation in Crohn's disease patients showed no real benefit but also no detriment to disease activity.

This topic has been more thoroughly investigated in animal models than in humans (specifically animal models of ulcerative colitis). Hemicellulose supplementation has been shown to greatly improve disease activity in mice with colitis. Not only did hemicellulose supplementation reduce symptoms (like diarrhea), but it accelerated repair of the mucosal barrier and reduced inflammation, attributable at least in part to improvements in the gut microflora. Cellulose supplementation was also shown to improve colitis in mice. Again these benefits were attributable to changes in gut microflora; and very interestingly, when cellulose supplementation was stopped, the beneficial effects only lasted about 10 days before the disease started to worsen again.

There have been no studies performed on the role that insoluble fiber may have on healing the gut in celiac disease patients. Celiac disease is hallmarked by a shortening (called pruning) of the intestinal villi (the fingerlike columns of gut epithelial cells that increases the surface area of the gut to maximize nutrient absorption). A study evaluating the effects of two types of insoluble fiber (one rich in both cellulose and hemicellulose versus one rich in lignin) on the morphology of the small intestine in piglets (not celiac, but rather the developing intestine which is still likely very relevant) showed that insoluble fiber increases the height of the intestinal villi in both the jejunum and the ileum (and that's a good thing).

It's worth noting that within the relatively limited body of scientific literature evaluating the actual effect of insoluble fiber on the gut barrier, there is one situation in which insoluble fiber has been shown to be potentially damaging: NSAID-induced small intestinal ulcers. In one study, cats were fed diets that differed in fiber content (high, low, normal) and type (either cellulose or pectin) before being given very high doses of NSAIDs. The researchers found that the cats developed more ulcers if they received the high fiber diet compared to control and fewer ulcers if they received a very low fiber diet. They also found that cats that received cellulose-enriched diets developed more ulcers, but not pectin. The authors conclude that insoluble fiber contributes to the development of NSAID-induced ulcers. So, I guess if you are taking large doses of NSAIDs (and especially if you are a carnivore), this may be an argument for a low fiber diet.

THE TAKE-HOME MESSAGE: there is no evidence that insoluble fiber is abrasive to the gastrointestinal tract and there is no scientific rationale for avoiding insoluble fiber for those with gut pathologies including irritable bowel syndrome, inflammatory bowel disease, and diverticular disease. In fact, eating plenty of fruits and vegetables will likely speed your healing.

DIFFICULTY DIGESTING FIBER

So what do you do if you have a condition like IBS or IBD and eating foods rich in insoluble fiber, like leafy greens, causes you increased gastrointestinal symptoms? What does it mean if you can see intact food particles in your stool after eating these high insoluble fiber foods? This is a reality for many people and one that helps to perpetuate the myth that insoluble fiber should be avoided. But, this isn't a case of insoluble fiber being the problem so much as it being a symptom—it's the big red flag indicating the need for digestive support.

The first step in improving digestion is always to follow good meal hygiene: don't rush, chew thoroughly, enjoy your meal, relax, don't stress, don't rush to the next activity when you're done, don't drink tons of liquid with your meals. Also avoid alcohol, caffeine, smoking, and high stress, which can all hinder digestion (by lowering stomach acid production, which then reduces the signals to the pancreas to release digestive enzymes and the gallbladder to release bile into the small intestine).

Next, consider digestive support supplements, especially plant enzymes which can be particularly beneficial in aiding digestion of fiber-rich foods (I recommend either Enriching Gifts or Thorne Research). Pancreatic enzymes (also called pancreatin, or simply, digestive enzymes), ox bile, and betaine HCl may also be very beneficial (careful with HCl supplements since these are contraindicated in a variety of conditions so always check with a healthcare professional before taking them) or an all-in-one supplement. It is generally recommended for patients with gastrointestinal diseases to increase dietary fiber slowly. That seems like prudent advice to me. You may also want to limit yourself to cooked or fermented vegetables as these are both easier to digest. Also, low FODMAP diets have been well documented to be beneficial in treating IBS and SIBO. But don't cut out insoluble fiber-rich foods altogether—there's no evidence that avoiding insoluble fiber-rich foods will help you (it might even slow your recovery!) and you'd be missing out on some of the most beneficial foods you can eat for your long term health.

RESISTANT STARCH: YAY OR NAY?

Resistant starch supplementation is all the rage now as a biohack designed to support your gut microbiome in the absence of vegetables and fruits in the diet. If you haven't encountered enthusiastic advice to add potato starch (just stirred into a glass of cool water, yum?!) to your diet in order to treat all manner of ills, you probably will soon! Unfortunately, while whole food sources of resistant starch provide health benefits, supplementation (especially as a substitute for a diet rich in a variety of fruits and veggies) is an approach that is not well supported by the scientific literature.

Resistant starch is a type of highly-fermentable insoluble fiber. Unlike most starches, resistant starch isn't fully broken down in your small intestine. It "resists" the action of your digestive enzymes because of its molecular structure; and instead of being a source of slow-burning carbohydrates for you, it becomes food for specific types of bacteria in your colon (which ferment it to produce beneficial short-chain fatty acids like acetic acid, propionic acid, and butyric acid).

THERE ARE FOUR MAIN CATEGORIES OF RESISTANT STARCH:

RS1: starch that resists digestion because it's trapped by intact plant cell walls (in legumes, grains, and seeds)

RS2: starch that's protected from digestion because of its molecular structure, and only becomes accessible to human digestive enzymes after being cooked (this one's found in raw potatoes, green bananas, and raw plantains)

RS3: also called "retrograded starch," which forms when you cool down certain starchy foods after they've been cooked (such as potatoes, rice, and other grains)

RS4: chemically modified starches that don't occur in nature, but are created to resist digestion

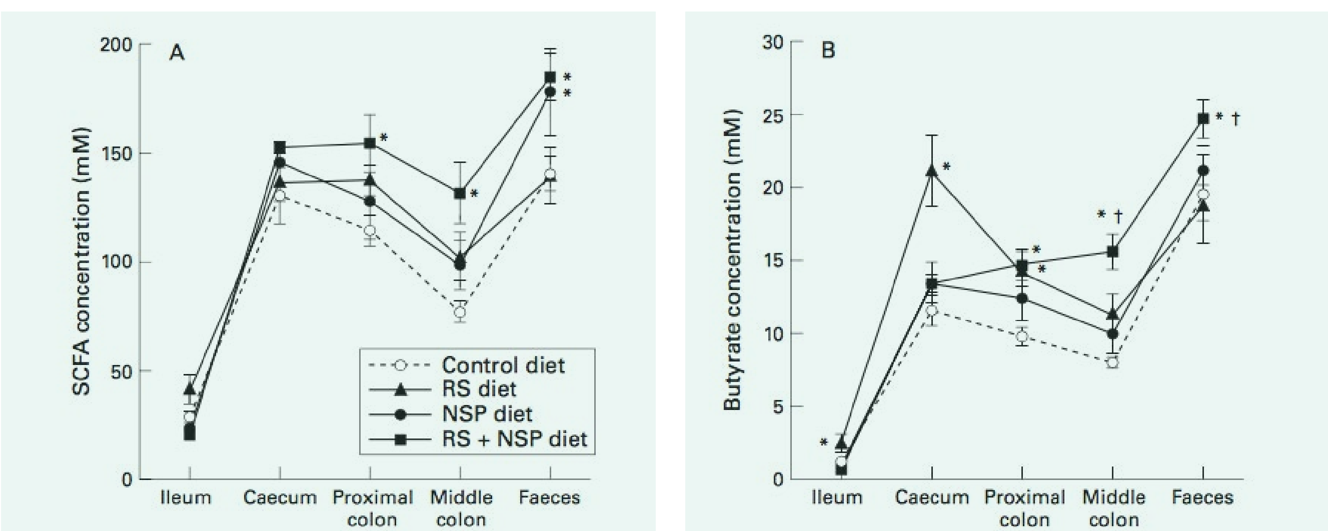
As previously discussed, fiber in general has been linked to reduced risk of diabetes, heart disease, and multiple cancers. It reduces inflammation, regulates hormones, and helps protect against many gut pathologies. And looking at the research on resistant starch in particular, it's not hard to see why it's becoming so heavily promoted as a supplement, especially in the paleo community. Both human and animal studies have confirmed a number of legitimate benefits, including improved insulin sensitivity (and lower blood sugar responses after high-carb meals), reduced hunger/better satiation, improved blood lipids, and even better immunity (due to the influence of resistant starch on immune cell production and inflammatory compounds in the gut).

Sounds pretty great, right? Let's toast with our glasses of potato starch stirred into water! Er, or not. There's another side of the resistant starch story that hasn't received as much airtime: the consequences of supplementing with an isolated starch, rather than eating resistant starch as it naturally occurs in whole foods (mixed with other compounds that all work in concert). It turns out that, while whole food sources of resistant starch may be a health boon to the body, supplementation of concentrated sources of resistant starch—which is becoming all-the-rage in the low-carb, ketogenic diet, alternative health and primal/paleo communities—isn't such a good idea. Let's evaluate resistant starch supplementation objectively by turning away from the hype and instead looking at the science.

As already mentioned, an array of studies prove that resistant starch provides tremendous benefits to our health. In addition to some of the more overt effects, like improved blood sugar regulation and cardiovascular disease risk factors, resistant starch can improve general health in more subtle, yet perhaps more profound, ways. For example, resistant starch can help increase absorption and bioavailability of many essential minerals from the diet, including: calcium, magnesium, zinc, iron and copper. Of course, other kinds of fiber can do this too, but this is likely one reason why supplementation with resistant starch can protect bone density during weight loss and positively impact the immune system.

Yet, multiple studies have highlighted the importance of consuming resistant starch in combination with other types of fermentable carbohydrate. This is important because these studies demonstrate the necessity to focus on whole food sources of resistant starch rather than jumping on the bandwagon with a supplement focus.

One study on pigs (whose large bowel is similar enough to humans' to make the results worth reading about!) found that RS2 alone gets rapidly fermented in the proximal (beginning) part of the colon, but fails to reach further down into the distal (lower) colon. That's bad news if we're trying to achieve maximum cancer protection: the lower parts of the colon are where tumors occur the most often, and flooding the area with plenty of butyrate (produced by bacterial fermentation of resistant starch) can help inhibit the growth and differentiation of colon cancer cells.



From: Govers M, et al. "Wheat bran affects the site of fermentation of resistant starch and luminal indexes related to colon cancer risk: a study in pigs." Gut. 1999 Dec; 45(6): 840–847.

But, in that same study, adding wheat bran (a soluble non-starch polysaccharide) to the pigs' diet nearly doubled the amount of resistant starch getting fermented between the lower colon and feces. Basically, the bulk from the wheat bran helped carry fermentation further through the colon, spreading cancer-protective butyrate in the process (and providing some other perks along the way, like lower ammonia concentrations—something we don't see in studies that use RS2 alone).

Another study, this one on humans, found something similar when wheat seed (RS1) was added to supplemental RS2 (in the form of green banana flour and high-amylose maize). The addition of wheat seed helped spread fermentation throughout the entire colon, as indicated by a decrease in fecal pH (which is a good thing!). In contrast, nearly all studies using RS2 on its own (from potato starch, high-amylose maize, and other sources) fail to show that fermentation reaches anywhere other than the very upper part of the colon.

So, does that mean you should add wheat to your diet to boost your gut health and cut your disease risk? No way! What these studies demonstrate isn't that we should tinker with the effects of one isolated carbohydrate by adding another isolated carbohydrate on top of it, but instead, that resistant starches work in harmony with other dietary components to exert their full benefits. That's another point in favor of eating resistant starch in whole-food form, since it already comes packaged with a variety of soluble and insoluble fibers (not to mention essential vitamins, minerals, and phytochemicals!) to keep your gut (and the rest of you!) healthy.

Another concern with aggressively supplementing with resistant starch (especially potato starch) is what happens to the composition of your gut microbiome. Different strains of bacteria have specific substrates they like to munch on, and while some are happy to dine on RS2, others prefer different forms of fiber. When we consume unnaturally high (e.g., supplemented) levels of one type of resistant starch (or one type of any fiber), we risk selectively feeding certain strains of bacteria while lowering the proportion of other beneficial kinds. Even beneficial probiotic strains of bacteria can overgrow, and this is especially a concern when this comes at the expense of microbial diversity—while much remains unknown about the optimum gut microbiome, one thing we know for sure is that a diverse microbiome is a resilient and healthy one.

A great paper examining this effect is from 2014, titled "Impacts of plant-based foods in ancestral hominin diets on the metabolism and function of gut microbiota in vitro." In this study, a raw potato diet (RS2) caused human-derived fecal communities to show a major rise in Bacteroides and Eubacterium rectale (beneficial bacteria that thrive on RS2), due to the diet over-feeding them with their preferred food source. But, the raw potato diet also suppressed levels of bifidobacteria and lactobacilli—two types of beneficial bacteria that favor RS3 over RS2 and which enjoy other fiber types like inulin. For people supplementing with potato starch, or other isolated resistant starches (and especially at the expense of a diet that includes varied fiber sources), we might expect to see a similar change in microbiome composition, including a loss of certain bacteria that typically benefit our health.

Hypothetically, if you've had a stool test to analyze your gut microbiome, this property of resistant starch could be exploited to produce rapid correction of certain undesirable bacterial genus patterns with a short-term supplementation course. Certainly, some practitioners are using potato starch supplementation as one tool in an arsenal to correct gut dysbiosis. Caution is advised even with medically-supervised resistant starch supplementation however (read on for more on why whole foods sources of resistant starch are still a preferable strategy), and I encourage detailed conversations with your practitioner about whether or not this is the best approach for you.

There's another concern for anyone with gastrointestinal symptoms. Even proponents of resistant starch supplementation caution its use for those with Small Intestinal Bacterial Overgrowth (SIBO). Although, let's be clear: how resistant starch may exacerbate SIBO has never been evaluated in a scientific study. It remains unknown whether resistant starch could propel an overgrowth of bacteria higher up the digestive tract by providing such a highly fermentable substrate where microbial density is supposed to be only a fraction of what it is in the large intestine. However, studies in both dogs and humans show that resistant start is fermented by bacteria in the ileum (the last segment of the small intestine before the large intestine), producing mainly butyrate and acetate short-chain fatty acids. So, while this "caution" has yet to be scientifically validated, it is certainly possible.

Now, for something a little more alarming. Several studies have demonstrated that, after exposure to a carcinogen, RS2 can actually enhance tumor growth (if it's not accompanied by other forms of dietary fiber). Yikes, right? One study using a rat model of colorectal cancer found that raw potato starch supplementation led to larger and more frequent tumors, compared to a low-resistant starch control diet. (After 20 weeks, 88% of the rats eating potato starch had tumors, compared to 74% of the rats on a control diet, and their tumor size averaged 191 mm2 compared to 87 mm2 on the control diet.) Here's the kicker though: when the rats were given potato starch plus wheat bran, those tumor-enhancing effects were suppressed (only 56% of the rats got tumors and the average tumor size was back down to 85 mm2). In other words, a soluble fiber coupled with resistant starch seemed to counteract the increased tumorigenesis.

Table 2. Effects of Diets on Tumor Incidence, Numbers and Size 20 weeks After the Last Dose of Carcinogen.

Diet	Basic	Potato Starch	Potato starch/ wheat bran
Incidence of rats with tumors	14/19 (74%)[a]	22/25 (88%)	14/25 (56%) [b]
No. of tumors per rat (mean ± SEM)	1.26 ± 0.25 [a]	2.0 ± 0.27 [b]	1.1 ± 0.24 [a]
Tumor size index (mm^2) (mean ± SEM)	87 ± 60 [a]	191 ± 40 [b]	85 ± 17 [a]

NOTE. Shared susperscripts denote a failure to reach statistical significane {X^2 test for incidence, Mann –Whitney test for tumor numbers, and ANOVA for tumor-size index}. Overal ANOVA for diet on tumor size index; P = 0.01

From: Young, et al. "Wheat bran suppresses potato starch-potentiated colorectal tumorigenesis at the aberrant crypt stage in a rat model." Gastroenterology. 1996 Feb;110(2):508-14.

Another study using a mouse model had a very similar outcome. In this experiment, carcinogen-exposed mice were fed different diets enhanced with aspirin, two forms of RS2 (raw potato starch and high-amylose corn), or a conventional rodent chow diet. Mice receiving the resistant starch had a significantly higher number of intestinal tumors than mice on any of the non-RS diets. (Interestingly, the addition of aspirin suppressed that effect—even though aspirin alone didn't appear to have any anti-tumor properties.) And yet another rat study found that resistant starch from either potato starch or high-amylose corn increased the absorption of a dietary carcinogen in the heterocyclic amine family—something humans are also exposed to.

Could this problem just be limited to rodents, though? While the majority of animal research does translate to humans, certainly not all of it does which is why studies in animals do need to be taken with a grain of salt. Unfortunately, in this case, it doesn't look like we can get away with the "but that's just in rats" justification to dismiss a scientific study. In a human study using controlled diets enriched with either RS2 (from high-amylose maize) or cornstarch, RS2 significantly increased the amount of DNA adducts in the colonic mucosa, which is a biomarker for the formation of colorectal cancer. The average number of adduct levels went from 2.69 during the study's low-RS period up to 3.83 during the high-RS period. That points to the potential of certain forms of resistant starch having a tumor-enhancing effect rather than a tumor-protective effect.

Keep in mind, this definitely isn't the same as saying "resistant starch causes cancer!" In these studies, a potent carcinogen was used to kick off the process of cancer initiation, and RS2 just served to promote growth once it had started. But, that's still a potentially dangerous situation, and it should serve as a warning that supplementing with isolated resistant starch may carry unforeseen risks—especially if it's not carefully balanced by other soluble and insoluble fibers.

There's little doubt that resistant starches play a beneficial role in our diet, and can go a long way in supporting healthy intestinal flora. In fact, the reduction in resistant-starch-rich foods may be a major reason low-carbohydrate diets tend to alter the gut microbiome in unfavorable ways (along with reductions in other fermentable fibers). But, we need to be careful when generalizing the effects of resistant starch in its whole-food form (potatoes, root veggies, bananas, plantains, etc.) to its effects as an isolated supplement. Unfortunately, the way potato starch supplementation is currently touted, as a gut microbiome-enhancing substitute for eating a variety of vegetables and fruit, doesn't look like a strategy that lives up to the hype.

So far, the science suggests that resistant starch, especially RS2, exerts the most benefits when consumed with additional fermentable carbohydrates, soluble fibers that add fecal bulk, and perhaps other dietary components that enhance its positive effects while counteracting its negative ones.

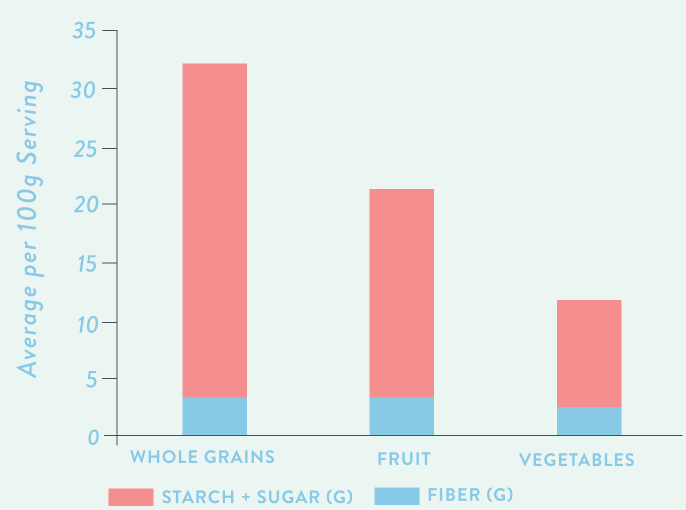
Does this mean that all you have to do is add your potato starch to a breakfast smoothie that contains spinach and berries too? The research so far can't tell us what the threshold amount of resistant starch relative to other fibers and carbohydrates is for optimal benefits (and avoiding detriments). It's likely that all of the negative effects of resistant starch supplementation discussed here are non-issues when potato starch is added to a diet already rich in a variety of vegetables and fruits (although, if you are eating a diet rich in a variety of vegetables and fruits, chances are good that your microbiome is doing well without additional supplementation). The bigger caution here is for those using potato starch as a substitute for vegetables and fruits in their diets.

The best solution? Eat resistant starch where it naturally occurs! Cooked potatoes (which contain RS2 and RS3, of course, there's even more RS2 in cooked and cooled potatoes), raw green bananas, plantains, yams, and other root vegetables provide not only resistant starch, but also a variety of other fibers and micronutrients that benefit health. Raw potato starch may be convenient, but in the long run, it's less likely to benefit your health than eating resistant-starch-rich whole foods.

HOW MUCH OF WHAT TYPE OF FIBER DO I NEED?

Does it matter which kind of fiber you eat? Most studies evaluating the impact of dietary fiber on human health do not differentiate between soluble and insoluble but show that fiber in general is beneficial. From the few studies that do differentiate between the two types, we know that a high intake of insoluble fiber reduces the risk of colon cancer, pancreatic cancer, and diverticulitis and correlates even more strongly with lower levels of C-reactive protein (a marker of inflammation) than soluble fiber (which also lowers inflammation). There is also evidence that insoluble fiber can improve insulin sensitivity, can help regulate blood-sugar levels after eating, supports reabsorption of bile acids, and is essential for regulating hunger hormones, especially ghrelin.

However, a great many studies on animals evaluating the health benefits of fiber specifically look at inulin (which is a highly fermentable, fructose-rich, soluble fiber found in sweet potatoes, coconuts, asparagus, leeks, onions, bananas, and garlic) and show that it reduces intestinal permeability and regulates the immune system. For this reason, soluble fiber gets a lot of attention. In contrast, studies also show that insoluble fiber can improve ulcerative colitis in animals, and there are studies suggesting some potential negative health effects from very high intake of soluble fiber in the absence of insoluble fiber. It may be that the health benefits of fiber are derived from whether the fiber is fermentable (meaning that the bacteria in your gut can eat it) rather than whether it's soluble or insoluble. While soluble fiber typically is more readily fermentable, most soluble and insoluble fibers are prebiotics. The medical literature currently offers no



Eating graints to get more fiber is like eating carrot cake to get more vegetables. There is far more sugar in whole grains compared with vegetables and even fruit.

clear answer as to whether soluble or insoluble fiber is more desirable. However, the wealth of studies showing health benefits to both imply that each is required for optimal health.

One important factor to consider is that non-starchy vegetables tend to have much higher fiber content per calorie than starchy vegetables which tend to have a little higher fiber content per calorie than most fruit. Of course, all of these choices are better than grains, which contain a ton of sugar, starch and a high glycemic load for relatively little vitamin, mineral and fiber content. We are accustomed to thinking that we have to eat "healthy whole grains" to get our dietary fiber, but the truth is that grains do not have any more or better fiber than fruits and vegetables.

Remember that cooking does break down fiber, which can make vegetables easier to digest, but also potentially reduce some of the benefits of high fiber intake. As a general rule, some nutrients are enhanced by cooking whereas others are degraded, so eating a mix of raw and cooked vegetables is a good way to optimize the benefits of each!

FIBER SUPPLEMENTATION

Fiber supplementation, sometimes labeled as Prebiotic Supplements, is not necessary, nor indeed recommended. There's a problem with fiber supplementation, whether concentrated inulin or the more trendy potato starch as a source or resistant starch: when you supplement with one type of fiber, you are selectively feeding one type (or small group) of bacteria.

Given that diversity of bacteria is the key to a healthy gut microbiome, this requires feeding your gut bacteria a diversity of substrates (i.e., different types of fiber). This can only be achieved with whole food sources of fiber. The best scenario is to focus on large servings (10-20 servings per day) of a huge variety of different types of vegetables (think "eating the rainbow" which offers a wider variety of other nutrients as well).

Another important factor to consider is that non-starchy vegetables, while high in insoluble fiber, are also good sources of soluble fiber. They also tend to have outstanding amounts of essential vitamins, minerals and phytochemicals. By focusing on non-starchy vegetables as the foundation of your fiber intake, and then having moderate portions of fruit and starchy vegetables as well, you are able to easily reach the recommended intakes without overconsumption of calories or carbohydrates.

How much fiber do we need? The Recommended Daily Allowance from the USDA is 25g of fiber (and most of us don't get that!). However, a variety of studies of hunter-gatherer diets show that most hunter-gatherers consume between 40g and 100g per day (with some populations eating as much as 250g per day!!!!). And that's with only typically 20-35% of their calories coming from plants!!!!!

It is exceedingly difficult to hit the 100g mark with the types of vegetables and fruit available to most of us. But, 40-50g per day is pretty doable with a little awareness of which vegetables pack the best fiber punch and a focus on covering two-thirds to three-quarters of every plate of food in vegetables!!

TIPS & TRICKS TO GET MORE FIBER

1. Eat vegetables with every meal. Yes, even breakfast.

2. Gradually increase your serving sizes of vegetables. This helps your gut microbiome adjust to higher fiber intake, which makes it easier to digest larger amounts of veggies.

3. Try wilted salads and lightly braised or sautéed greens like spinach. Since they are heated for a very short period of time, much of the fiber remains intact, but they decrease in volume greatly!

4. Add more vegetables to soups, stews and casseroles. Canned pumpkin or pureed cauliflower can be used as a thickener. Spinach is a very neutral flavor and works with most meals. You can even puree greens to add to a soup to make it "disappear".

5. Choose smoothies over vegetable juices. Remember that these are easier to digest as part of a meal.

6. Raw veggies like celery, carrots and radishes make a great portable snack. Think of ways you can bring veggies "on the road" with you during the day.

7. Add veggies to dessert! Vegetable smoothies freeze into ice pops very well. The Paleo community is embracing vegetable powders as flour alternatives for baking and treats!

FIBER TABLES

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Almond butter	1 TBSP	0.6	0.5	0.1
Almonds	1 CUP	15.9	14.3	1.6
Apple, baked with skin, unsweetened	1 MEDIUM	5.4	4	1.4
Apple, dried	1 CUP	7.5	3.4	4.1
Apple, with skin	1 MEDIUM	3.7	2.7	1
Apple, without skin	1 MEDIUM	2.4	1.7	0.7
Applesauce, canned, unsweetened	1 CUP	2.9	2	0.9
Apricot	1 CUP	3.7	1.7	2
Bamboo shoots, canned	1 CUP	1.8	1.3	0.5
Banana	1 MEDIUM	2.8	2.1	0.7
Beet greens, cooked	1 CUP	4.2	2.3	1.9
Beet greens, raw	1 CUP	1.4	1	0.4
Beets, canned	1 CUP	2.9	1.5	1.4
Beets, cooked fresh	1 CUP	3.4	1.4	2
Blackberries	1 CUP	7.6	6.2	1.4
Blueberries	1 CUP	3.9	3.5	0.4
Brazil nuts	1 CUP	7.5	5.7	1.8

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Broccoflower (green cauliflower) cooked	1 CUP	2.7	1.5	1.2
Broccoflower (green cauliflower), raw	1 CUP	2	1	1
Broccoli, cooked fresh	1 CUP	4.6	2.3	2.3
Broccoli, cooked frozen	1 CUP	5.5	2.7	2.8
Broccoli, raw	1 CUP	2.6	1.7	0.9
Brussels sprouts, cooked	1 CUP	6.4	2.5	3.9
Cabbage, green, cooked	1 CUP	3.4	1.9	1.5
Cabbage, green, raw	1 CUP	2	1.3	0.7
Cabbage, red, cooked	1 CUP	3	1.7	1.3
Cabbage, red, raw	1 CUP	1.8	1	0.8
Cantaloupe	1 CUP	1.3	1	0.3
Carambola (starfruit)	1 CUP	2.9	1.6	1.3
Carob powder	1 TSP	0.9	0.2	0.7
Carrots, canned	1 CUP	2.2	0.7	1.5
Carrots, cooked fresh	1 CUP	5.2	3	2.2
Carrots, cooked frozen	1 CUP	4.8	2.8	2
Carrots, raw	1 CUP	3.3	1.7	1.6
Cashew butter	1 TBSP	0.3	0.2	0.1
Cashews	1 CUP	4.9	4.5	0.4
Cassava (yuca), cooked	1 CUP	1.5	0.9	0.6

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Cauliflower, cooked fresh	1 CUP	3.4	2.5	0.9
Cauliflower, cooked frozen	1 CUP	4.9	3.6	1.3
Cauliflower, raw	1 CUP	2.5	1.6	0.9
Celeriac or celery root, cooked	1 CUP	1.9	1	0.9
Celery seed	1 TSP	0.3	0	0
Celery, cooked	1 CUP	2.4	1.7	0.7
Celery, raw	1 CUP	2	1.3	0.7
Chard, cooked	1 CUP	3.7	3.1	0.6
Cherries	1 CUP	3.3	2.3	1
Cherries, maraschino	1 CUP	1.4	1	0.4
Chervil (dried)	1 TSP	0.1	0	0
Chestnuts	1 CUP	16.7	13.2	3.5
Chinese cabbage, Pak-choi, cooked	1 CUP	2.7	1.7	1
Chinese cabbage, Pak-choi, raw	1 CUP	0.7	0.4	0.3
Chinese cabbage, Pe-tsai, cooked	1 CUP	3.2	1.5	1.7
Chinese cabbage, Pe-tsai, raw	1 CUP	2.4	1.9	0.5
Chinese vegetables, canned	1 CUP	1.4	0.9	0.5
Chives, raw	1 TBSP	0.07	0.05	0
Coconut unsweetened	1 CUP	13	11.9	1.1

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Coconut, fresh	1 MEDIUM	35.7	31.8	3.9
Collards, cooked	1 CUP	5.3	2.1	3.2
Collards, raw	1 CUP	1.3	0.5	0.8
Coriander, leaf, fresh or dried	1 TBSP	0.1	0.03	0.1
Cranberries	1 CUP	4	3	1
Cranberries, dried (Craisins)	1 CUP	6	4.4	1.6
Cucumber, raw, with or without peel	1 CUP	0.8	0.6	0.2
Dark chocolate	1 OZ	1.7	1.6	0.1
Dates	1 CUP	13.4	11.2	2.2
Eggplant, cooked	1 CUP	2.5	1.8	0.7
Elderberries	1 CUP	10.2	8.3	1.9
Endive (curly), cooked	1 CUP	5.2	3.7	1.5
Endive (curly), raw	1 CUP	0.9	0.6	0.3
Fennel bulb, raw	1 CUP	2.7	1.7	1
Fennel seed	1 TSP	0.7	0	0
Fenugreek seed	1 TSP	0.9	0	0
Figs	1 CUP	5.8	2.8	3
Figs, dried, uncooked	1 CUP	24.3	16.3	8
Filberts or hazelnuts	1 CUP	8.2	4.8	3.4
Flax Seed	1 CUP	25.5	11.7	13.8

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Garlic powder	1 TSP	0.3	0.1	0.2
Garlic, fresh	1 TSP	0.06	0	0.1
Ginger (ground)	1 TSP	0.2	0	0
Ginger root, raw	1 CUP	1.9	0	0
Golden Flax	1 CUP	12.9	9.4	3.5
Gooseberries	1 CUP	6.5	5.1	1.4
Gooseberries, canned	1 CUP	6	4	2
Grapefruit, canned, water pack	1 CUP	2.8	0.5	2.3
Grapefruit, white, pink or red	1 MEDIUM	2.8	0.5	2.3
Grapes	1 CUP	1.6	1	0.6
Guava	1 CUP	8.9	7.4	1.5
Hearts of palm, canned	1 CUP	3.5	0	0
Honeydew melon	1 CUP	1	0.7	0.3
Jicama or yambean, cooked	1 CUP	2.6	1.5	1.1
Jicama or yambean, raw	1 CUP	6.4	3.1	3.3
Kale, cooked	1 CUP	2.6	1.2	1.4
Kiwi	1 MEDIUM	2.6	2	0.6
Kohlrabi, cooked	1 CUP	1.8	0.6	1.2
Kohlrabi, raw	1 CUP	4.9	1.5	3.4
Kumquat	1 MEDIUM	1.3	0.8	0.5
Lemon	1 MEDIUM	1.6	0.6	1

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Lettuce, iceberg	1 CUP	0.8	0.7	0.1
Lettuce, romaine or cos	1 CUP	0.9	0.6	0.3
Loganberries	1 CUP	7.2	6.5	0.7
Macadamia nuts	1 CUP	12.5	9.9	2.6
Mandarin orange	1 CUP	4.5	2.7	1.8
Mango	1 MEDIUM	3.7	2.2	1.5
Mushrooms, canned	1 CUP	3.7	3.4	0.3
Mushrooms, cooked fresh	1 CUP	3.4	3.1	0.3
Mushrooms, raw	1 CUP	0.8	0.7	0.1
Nectarine	1 MEDIUM	2.2	1.4	0.8
Okra, cooked	1 CUP	5.1	3.1	2
Olives, black	1 MEDIUM	0.2	0.1	0.1
Olives, green	1 MEDIUM	0.1	0.1	0
Olives, stuffed	1 MEDIUM	0.1	0.1	0
Onion, white, yellow, or red, cooked	1 CUP	2.9	0.8	2.1
Onion, white, yellow, or red, raw	1 CUP	2.9	1.1	1.8
Orange	1 MEDIUM	3.1	1.3	1.8
Orange juice	1 CUP	0.5	0.3	0.2
Papaya	1 CUP	2.5	1.3	1.2
Parsley, fresh	1 TBSP	0.1	0	0.1

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Parsnip, cooked	1 CUP	6.2	2.6	3.6
Passion fruit	1 MEDIUM	1.9	0.5	1.4
Peach	1 MEDIUM	2	1.2	0.8
Peach, canned, water pack	1 CUP	3.2	2	1.2
Peach, dried	1 CUP	13.1	7	6.1
Peach, dried, cooked, unsweetened	1 CUP	7	3.8	3.2
Pear	1 MEDIUM	4	1.8	2.2
Pecans	1 CUP	8.2	6.6	1.6
Peppers, green – sweet, cooked	1 CUP	2.2	0.7	1.5
Peppers, green – sweet, raw	1 CUP	2.7	1.6	1.1
Peppers, hot chili, green, canned	1 CUP	2.4	0.8	1.6
Peppers, hot chili, green, cooked fresh	1 CUP	2	0.7	1.3
Peppers, hot chili, green, raw	1 CUP	2.3	1.4	0.9
Peppers, hot chili, red, canned	1 CUP	1.8	0.6	1.2
Peppers, hot chili, red, cooked fresh	1 CUP	2.1	1.3	0.8
Peppers, hot chili, red, raw	1 CUP	2.3	1.4	0.9
Peppers, hot chili, sun-dried	1 CUP	10.6	0	0
Peppers, jalapeno, canned	1 CUP	3.5	1.2	2.3
Peppers, jalapeno, cooked fresh	1 CUP	3.9	2.4	1.5

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Peppers, jalapeno, raw	1 CUP	2.5	1.5	1
Peppers, red – sweet, cooked	1 CUP	2.2	0.9	1.3
Peppers, red – sweet, raw	1 CUP	3	1.9	1.1
Peppers, yellow – sweet, cooked	1 CUP	1.7	1.1	0.6
Peppers, yellow – sweet, raw	1 CUP	1.3	0.8	0.5
Persimmon	1 MEDIUM	6.1	5.3	0.8
Pickles, dill	1 CUP	1.7	1.4	0.3
Pimento	1 TBSP	0.2	0.1	0.1
Pine nuts – pignolias	1 CUP	14.6	13.1	1.5
Pine nuts – pinyon	1 CUP	13.9	12.5	1.4
Pineapple	1 CUP	1.9	1.7	0.2
Pineapple, canned, juice pack	1 CUP	2	1.5	0.5
Pistachio nuts	1 CUP	13.8	10.4	3.4
Plaintains, boiled or baked	1 CUP	3.5	2.8	0.7
Plum	1 MEDIUM	2.5	1.2	1.3
Pomegranate	1 MEDIUM	1	0.8	0.2
Potato, baked, with skin	1 CUP	2.9	1.7	1.2
Potato, baked, without skin	1 CUP	1.9	0.6	1.3
Potato, boiled, with skin	1 CUP	3	1.8	1.2
Potato, boiled, without skin	1 CUP	2.8	1.2	1.6
Potato, canned	1 CUP	4.5	1	3.5

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Prune	1 CUP	12.1	5.6	6.5
Prune, cooked, unsweetened	1 CUP	16.4	12.2	4.2
Pumpkin or squash seeds	1 CUP	8.8	6.4	2.4
Pumpkin, canned	1 CUP	7.1	6.1	1
Radicchio, raw	1 CUP	0.4	0.2	0.2
Radish, raw	1 CUP	1.9	1.4	0.5
Raisins	1 CUP	6.2	4.5	1.7
Raspberries	1 CUP	8.4	7.5	0.9
Raspberries, frozen, sweetened	1 CUP	11	9.8	1.2
Rhubarb, cooked, unsweetened	1 CUP	3.4	2.2	1.2
Rutabaga, cooked	1 CUP	3.1	2.6	0.5
Sapodilla	1 MEDIUM	13.9	9	4.9
Sauerkraut	1 CUP	5.9	3.9	2
Scallions or spring onions, cooked	1 CUP	5.5	2.6	2.9
Scallions or spring onions, raw	1 CUP	2.6	1	1.6
Sesame seeds	1 CUP	11.7	8.8	2.9
Spinach, canned	1 CUP	5.1	3.8	1.3
Spinach, cooked fresh	1 CUP	5.4	4.3	1.1
Spinach, cooked frozen	1 CUP	6.1	4.9	1.2
Spinach, raw	1 CUP	0.8	0.6	0.2
Sprouts, acorn, cooked	1 CUP	10.8	4.6	6.2

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Sprouts, mung bean, canned	1 CUP	1	0.5	0.5
Sprouts, mung bean, cooked fresh	1 CUP	1	0.4	0.6
Squash, butternut, cooked	1 CUP	3.3	1.9	1.4
Squash, chayote, cooked	1 CUP	4.5	3.5	1
Squash, hubbard, cooked	1 CUP	6.6	2.8	3.8
Squash, spaghetti, cooked	1 CUP	2.2	1	1.2
Squash, summer (green or yellow) cooked	1 CUP	2.5	2	0.5
Squash, summer (green or yellow) raw	1 CUP	1.5	1.2	0.3
Squash, winter (dark green or orange), cooked	1 CUP	6.7	2.9	3.8
Squash, zucchini, cooked	1 CUP	2.5	1.4	1.1
Squash, zucchini, raw	1 CUP	1.4	0.8	0.6
Strawberries	1 CUP	3.3	2.4	0.9
Sunflower butter	1 TBSP	1.3	0.8	0.5
Sunflower seeds	1 CUP	13.4	10.7	2.7
Sweet potato, canned, vacuum packed	1 CUP	3.6	2.2	1.4
Sweet potato, cooked	1 CUP	7.6	4.8	2.8
Tahini (sesame butter)	1 TBSP	1.4	1.1	0.3
Tapioca	1 CUP	1.4	1.2	0.2

PRODUCE NAME	SERVING SIZE	TOTAL FIBER g/100g (Dry Weight)	SOLUBLE FIBER g/100g (Dry Weight)	INSOLUBLE FIBER g/100g (Dry Weight)
Tomatillo, raw	1 CUP	2.5	2.3	0.2
Tomato paste	1 CUP	10.7	8.6	2.1
Tomato puree	1 CUP	5	3	2
Tomato, canned	1 CUP	2.4	1.4	1
Tomato, green, raw	1 CUP	2	1.8	0.2
Tomato, orange, raw	1 CUP	1.4	1.3	0.1
Tomato, raw	1 CUP	2	1.8	0.2
Tomato, sun-dried, dry pack	1 CUP	6.6	6	0.6
Tomato, sun-dried, oil pack	1 CUP	6.4	5.8	0.6
Tomato, yellow, raw	1 CUP	1	0.9	0.1
Turnip greens, canned	1 CUP	3.1	1.8	1.3
Turnip greens, cooked	1 CUP	5	2.8	2.2
Turnip, cooked	1 CUP	3.1	2	1.1
Walnuts	1 CUP	5.8	4	1.8
Water chestnuts, canned	1 CUP	3.1	1.8	1.3
Watercress, raw	1 CUP	0.5	0.2	0.3
Watermelon	1 CUP	1.4	0.8	0.6
Yams, canned, vacuum-packed	1 CUP	3.6	2.2	1.4
Yams, cooked	1 CUP	7.6	4.8	2.8

RECIPES

DIY BASIC VINAIGRETTE

3 tablespoons oil, such as extra-virgin olive oil, avocado oil, walnut oil, or macadamia nut oil
2 tablespoons acidic liquid, such as fresh lemon juice, fresh lime juice, apple cider vinegar, balsamic vinegar, coconut water vinegar, or white or red wine vinegar
Pinch of salt

1. Combine the ingredients in a jar and shake before serving.

BRAISED GREENS

2 tablespoons cooking fat
4 to 12 cups chopped greens (less for substantial greens and more for tender greens)
1 tablespoon to 2 cups water or other braising liquid (see suggestions above)
Salt, to taste

1. Heat the fat in a large skillet or wok over medium-high heat. Add the greens and 1 to 3 tablespoons of the liquid, adding less for tender greens and more for tougher greens. Stir relatively frequently. If the liquid evaporates before the greens are fully cooked, add a little more. For tender greens, you probably won't have to add more liquid. For tougher greens, you may need to add liquid several times during cooking.
2. When the greens are done to your liking, taste and season with salt if desired, then serve. Ideally, the greens will be done just as the liquid fully evaporates. Otherwise, you can serve the greens with tongs or a slotted spoon and leave the liquid in the pan.

STEAMED VEGETABLES

Vegetable of choice

1. Fill a saucepot with enough water that it just barely reaches the bottom of a steamer insert or steamer basket.
2. Bring the water to a boil over high heat. Add the vegetables to the steamer insert or basket and cover with a loose-fitting lid. If using an insert, you can position the lid so that one side hangs over the insert just enough to let the steam escape.
3. Cook until the desired tenderness is reached, using the cooking times on the next page as a guide.

VEGETABLE STEAMING TIMES

VEGETABLE	STEAMING TIMES
Artichokes	35 to 40 minutes for whole artichokes, 20 minutes for baby artichokes, 10 minutes for artichoke hearts
Asparagus	4 minutes for thin spears; add an extra minute or two for thicker spears
Beets	30 to 40 minutes for medium-sized whole beets or wedges of larger beets
Broccoli	5 minutes for florets; add an extra minute or two if the florets are large
Brussels sprouts	10 to 12 minutes for whole, 7 to 8 minutes if cut in half
Cabbage	20 to 23 minutes for quartered, 8 to 10 minutes for shredded
Carrots	8 minutes for 1/4-inch-thick rounds
Cauliflower	6 to 8 minutes for medium florets
Kohlrabi	30 to 35 minutes for wedges
Leafy greens	3 to 5 minutes, just until wilted
Turnips	15 minutes for 1/4-inch-thick slices
Winter squash	5 to 10 minutes for 1-inch pieces
Zucchini & other summer squash	8 to 10 minutes for 1/4-inch-thick slices, 15 to 20 minutes for whole pattypan squash

ROASTED ROOTS

2 pounds root vegetables such as sweet potatoes, carrots, parsnips, and green plantain; peeled and cut into ½-inch-thick circles, semicircles or chunks
3 tablespoons extra-virgin coconut oil, lard, or duck fat, melted

1. Preheat the oven to 375˚F.
2. Place the root veggies in a large bowl. Toss with the coconut oil and salt until evenly coated. Arrange the slices in a single layer on the prepared baking sheet.
3. Bake for 15-20 minutes, then remove from the oven and toss.
4. Bake for another 15 minutes. Toss and check for doneness. If needed, cook an additional 10 minutes. Enjoy!

KALE CHIPS

8 loosely packed cups kale (or other dense green), torn into 1-1 1/2" pieces, tough stems removed
2 tablespoons extra virgin coconut oil, melted and still warm (or avocado oil)
1/4 teaspoon salt, to taste

1. Preheat the oven to 275˚F.
2. Wash and thoroughly dry the kale, using a salad spinner, tea towels, or paper towels to remove all the water. Place in a plastic container or large bowl.
3. Pour the coconut oil over the kale. Mix with your hands to thoroughly coat each leaf (if you put it in a container with a lid, you can also close the lid and shake the container vigorously to coat).
4. Spread out on a large baking sheet. Sprinkle with the salt.
5. Bake for 40 to 60 minutes, depending on the variety of kale you are using, until crispy. Enjoy!

CAULIFLOWER GRAVY

½ head cauliflower, cut into florets
1½ cups Bone Broth (chicken or beef)
1 clove garlic
Salt, to taste

1. Place the cauliflower in a saucepot with the broth and garlic. Bring to a boil, then reduce the heat to maintain a simmer. Simmer for 15 to 20 minutes, until the cauliflower is overcooked.
2. Pour the mixture into a high-speed blender. Blend for 1 minute, until completely smooth. Taste and season with salt if desired. If too thick, thin with additional broth or water.

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