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SCIENCE

# Fiber Is Good for You. Now Scientists May Know Why.

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A diet of fiber-rich foods, such as fruits and vegetables, reduces the risk of developing diabetes, heart disease and arthritis. Indeed, the evidence for fiber's benefits extends beyond any particular ailment: Eating more fiber seems to lower people's mortality rate, whatever the cause.

That's why experts are always saying how good dietary fiber is for us. But while the benefits are clear, it's not so clear *why* fiber is so great. "It's an easy question to ask and a hard one to really answer," said Fredrik Bäckhed, a biologist at the University of Gothenburg in Sweden.

He and other scientists are running experiments that are yielding some important new clues about fiber's role in human health. Their research indicates that fiber doesn't deliver many of its benefits directly to our bodies.

Instead, the fiber we eat feeds billions of bacteria in our guts. Keeping them happy means our intestines and immune systems remain in good working order.

In order to digest food, we need to bathe it in enzymes that break down its molecules. Those molecular fragments then pass through the gut wall and are absorbed in our intestines.

But our bodies make a limited range of enzymes, so that we cannot break down many of the tough compounds in plants. The term “dietary fiber” refers to those indigestible molecules.

But they are indigestible only to us. The gut is coated with a layer of mucus, atop which sits a carpet of hundreds of species of bacteria, part of the human microbiome. Some of these microbes carry the enzymes needed to break down various kinds of dietary fiber.

The ability of these bacteria to survive on fiber we can’t digest ourselves has led many experts to wonder if the microbes are somehow involved in the benefits of the fruits-and-vegetables diet. Two detailed studies published recently in the journal Cell Host and Microbe provide compelling evidence that the answer is yes.

In one experiment, Andrew T. Gewirtz of Georgia State University and his colleagues put mice on a low-fiber, high-fat diet. By examining fragments of bacterial DNA in the animals’ feces, the scientists were able to estimate the size of the gut bacterial population in each mouse.

On a low-fiber diet, they found, the population crashed, shrinking tenfold.

Dr. Bäckhed and his colleagues carried out a similar experiment, surveying the microbiome in mice as they were switched from fiber-rich food to a low-fiber diet. “It’s basically what you’d get at McDonald’s,” said Dr. Bäckhed said. “A lot of lard, a lot of sugar, and twenty percent protein.”

The scientists focused on the diversity of species that make up the mouse’s gut microbiome. Shifting the animals to a low-fiber diet had a dramatic effect, they found: Many common species became rare, and rare species became common.

Along with changes to the microbiome, both teams also observed rapid changes to the mice themselves. Their intestines got smaller, and its mucus layer thinner. As a result, bacteria wound up much closer to the intestinal wall, and that encroachment triggered an immune reaction.

After a few days on the low-fiber diet, mouse intestines developed chronic inflammation. After a few weeks, Dr. Gewirtz’s team observed that the mice began to change in other ways, putting on fat, for example, and developing higher blood sugar levels.

Dr. Bäckhed and his colleagues also fed another group of rodents the high-fat menu, along with a modest dose of a type of fiber called inulin. The mucus layer in their guts was

healthier than in mice that didn't get fiber, the scientists found, and intestinal bacteria were kept at a safer distance from their intestinal wall.

Dr. Gewirtz and his colleagues gave inulin to their mice as well, but at a much higher dose. The improvements were even more dramatic: Despite a high-fat diet, the mice had healthy populations of bacteria in their guts, their intestines were closer to normal, and they put on less weight.



Dr. Bäckhed and his colleagues ran one more interesting experiment. They spiked water given to mice on a high-fat diet with a species of fiber-feeding bacteria. The addition changed the mice for the better: Even on a high-fat diet, they produced more mucus in their guts, creating a healthy barrier to keep bacteria from the intestinal walls.

One way that fiber benefits health is by giving us, indirectly, another source of food, Dr. Gewirtz said. Once bacteria are done harvesting the energy in dietary fiber, they cast off the fragments as waste. That waste — in the form of short-chain fatty acids — is absorbed by intestinal cells, which use it as fuel.

But the gut's microbes do more than just make energy. They also send messages.

Intestinal cells rely on chemical signals from the bacteria to work properly, Dr. Gewirtz said. The cells respond to the signals by multiplying and making a healthy supply of mucus. They also release bacteria-killing molecules.

By generating these responses, gut bacteria help maintain a peaceful coexistence with the immune system. They rest atop the gut's mucus layer at a safe distance from the intestinal wall. Any bacteria that wind up too close get wiped out by antimicrobial poisons.

While some species of gut bacteria feed directly on dietary fiber, they probably support other species that feed on their waste. A number of species in this ecosystem — all of it built on fiber — may be talking to our guts.

Going on a low-fiber diet disturbs this peaceful relationship, the new studies suggest. The species that depend on dietary fiber starve, as do the other species that depend on them. Some species may switch to feeding on the host's own mucus.

With less fuel, intestinal cells grow more slowly. And without a steady stream of chemical signals from bacteria, the cells slow their production of mucus and bacteria-killing poisons.

As a result, bacteria edge closer to the intestinal wall, and the immune system kicks into high gear.

“The gut is always precariously balanced between trying to contain these organisms and not to overreact,” said Eric C. Martens, a microbiologist at the University of Michigan who was not involved in the new studies. “It could be a tipping point between health and disease.”

Inflammation can help fight infections, but if it becomes chronic, it can harm our bodies. Among other things, chronic inflammation may interfere with how the body uses the calories in food, storing more of it as fat rather than burning it for energy.

Justin L. Sonnenburg, a biologist at Stanford University who was not involved in the new studies, said that a low-fiber diet can cause low-level inflammation not only in the gut, but throughout the body.

His research suggests that when bacteria break down dietary fiber down into short-chain fatty acids, some of them pass into the bloodstream and travel to other organs, where they act as signals to quiet down the immune system.

“You can modulate what’s happening in your lung based on what you’re feeding your microbiome in your gut,” Dr. Sonnenburg said.

Hannah D. Holscher, a nutrition scientist at the University of Illinois who was not involved in the new studies, said that the results on mice need to be put to the test in humans. But it’s much harder to run such studies on people.

In her own lab, Dr. Holscher acts as a round-the-clock personal chef. She and her colleagues provide volunteers with all their meals for two weeks. She can then give some of her volunteers an extra source of fiber — such as walnuts — and look for changes in both their microbiome and their levels of inflammation.

Dr. Holscher and other researchers hope that they will learn enough about how fiber influences the microbiome to use it as a way to treat disorders. Lowering inflammation with fiber may also help in the treatment of immune disorders such as inflammatory bowel disease.

Fiber may also help reverse obesity. Last month in the American Journal of Clinical Nutrition, Dr. Holscher and her colleagues reviewed a number of trials in which fiber was used to treat obesity. They found that fiber supplements helped obese people to lose about five pounds, on average.

But for those who want to stay healthy, simply adding one kind of fiber to a typical Western diet won't be a panacea. Giving mice inulin in the new studies only partly restored them to health.

That's probably because we depend on a number of different kinds of dietary fiber we get from plants. It's possible that each type of fiber feeds a particular set of bacteria, which send their own important signals to our bodies.

"It points to the boring thing that we all know but no one does," Dr. Bäckhed said. "If you eat more green veggies and less fries and sweets, you'll probably be better off in the long term."

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