Industrial societies losing healthy gut microbes, finds study

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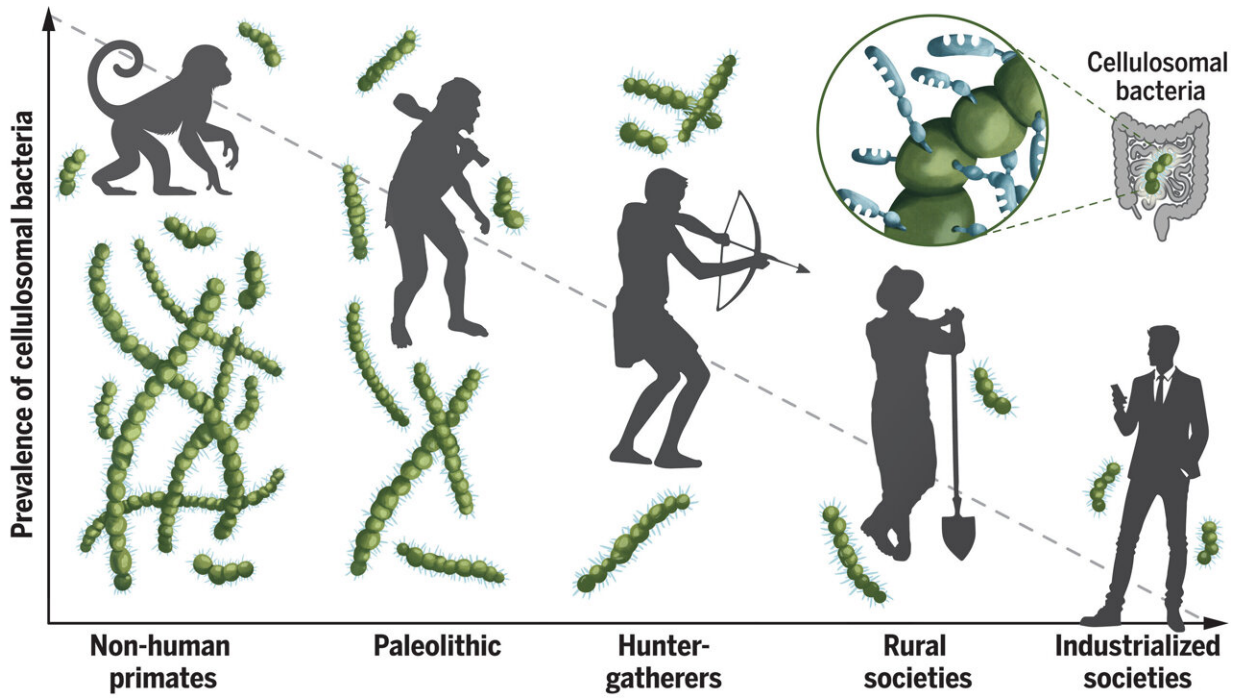

Cellulose degrading gut bacteria of hominids across evolutionary time. Previously unknown human gut cellulolytic ruminococcal species are highly prevalent in nonhuman primates, the great apes, ancient human populations, hunter-gatherer communities, and in rural populations but are rare in urbanized human populations. Credit: *Science* (2024). DOI: 10.1126/science.adj9223

Everyone knows that fiber is healthy and an important part of our daily diet. But what is fiber, and why is it healthy? Fiber is cellulose, the

stringy stuff that plants are made of. Leaves, stems, roots, stalks, and tree trunks (wood) are made of cellulose. The purest form of cellulose is the long, white fibers of cotton. Dietary fiber comes from vegetables or whole grain products.

Why is fiber healthy? Fiber helps to keep our intestinal flora (scientists call it our gut microbiome) happy and balanced. Fiber serves as the starting point of a natural food chain. It begins with bacteria that can digest cellulose, providing the rest of our microbiome with a balanced diet. But our eating habits in industrialized societies are far removed from those of ancient humans.

This is impacting our intestinal flora, it seems, as newly discovered cellulose-degrading bacteria are being lost from the human gut microbiome, especially in industrial societies, according to a new report published in *Science*.

The study comes from Prof. Itzhak Mizrahi's team at Ben-Gurion University (BGU) of the Negev in Israel, with support from the Weizmann Institute of Science in Rehovot and international collaborators in the US and Europe.

"Throughout human evolution, fiber has always been a mainstay of the human diet," explains lead investigator Sarah Moraïs from BGU, "It is also a main component in the diet of our primate ancestors. Fiber keeps our intestinal flora healthy."

Moraïs and team identified important new members of the human gut microbiome, cellulose-degrading bacteria named Ruminococcus. These bacteria degrade cellulose by producing large and highly specialized extracellular protein complexes called cellulosomes.

"It's no easy task to degrade cellulose; few bacteria can do it," explains

Prof. Edward Bayer, from the Weizmann Institute, a world leader in cellulosomes and co-author of the study. "Cellulose is difficult to digest because it is insoluble. Fiber in the gut is like a tree trunk in a swimming pool; it gets wet, but it does not dissolve."

Cellulosomes are engineered by bacteria to attach to cellulose fibers and peel them apart, like the individual threads in a piece of rope. The cellulosomal enzymes then break down the individual threads of fiber into shorter chains, which become soluble. They can be digested not only by Ruminococcus but also by many other members of the gut microbiome.

"Bottom line, cellulosomes turn fiber into sugars that feed an entire community, a formidable engineering feat," says Bayer.

The production of cellulosomes puts Ruminococcus at the top of the fiber-degradation cascade that feeds a healthy gut microbiome. But the evolutionary history of Ruminococcus is complicated, and Western culture is taking its toll on our microbiome, as the new study shows.

"These cellulosome-producing bacteria have been around for a long time; their ancestors are important members of the rumen microbiome in cows and sheep," explains Prof. Mizrahi from BGU, senior author of the study. The rumen is the special stomach organ of cows, sheep, and deer, where the grass they eat (fiber) is converted into useful food by cellulose-degrading microbes, including Ruminococcus.

"We were surprised to see that the cellulosome-producing bacteria of humans seem to have switched hosts during evolution because the strains from humans are more closely related to the strains from livestock than to the strains from our own primate ancestors."

That is, it looks like humans have acquired important components of a

healthy gut microbiome from livestock that they domesticated early in human evolution.

"It's a real possibility," says Mizrahi, an expert on rumen biology.

However, the story does not end there. Sampling of human cohorts revealed that Ruminococcus strains are indeed robust components of the human gut microbiome among human hunter-gatherer societies and among rural human societies but that they are sparse or missing in human samples from industrialized societies.

"Our ancestors in Africa 200,000 years ago did not pick up lunch from a drive-through or phone in a home-delivery for dinner," says Prof. William Martin at the Heinrich Heine University Düsseldorf in Germany, evolutionary biologist, and co-author of the study. In Western societies this does, however, happen on a large scale.

Diet is changing in industrialized societies, far removed from the farms where food is produced. The authors conclude that this shift away from a fiber-rich diet is an explanation for the loss of important cellulose -degrading microbes in our microbiome.

How can you counteract this evolutionary decline? It might help to do what doctors and dieticians have been saying for decades: Eat more fiber.

More information: Sarah Morais et al, Cryptic diversity of cellulose-degrading gut bacteria in industrialized humans, *Science* (2024). DOI: 10.1126/science.adj9223