frontiers FOR YOUNG MINDS

HUMAN HEALTH
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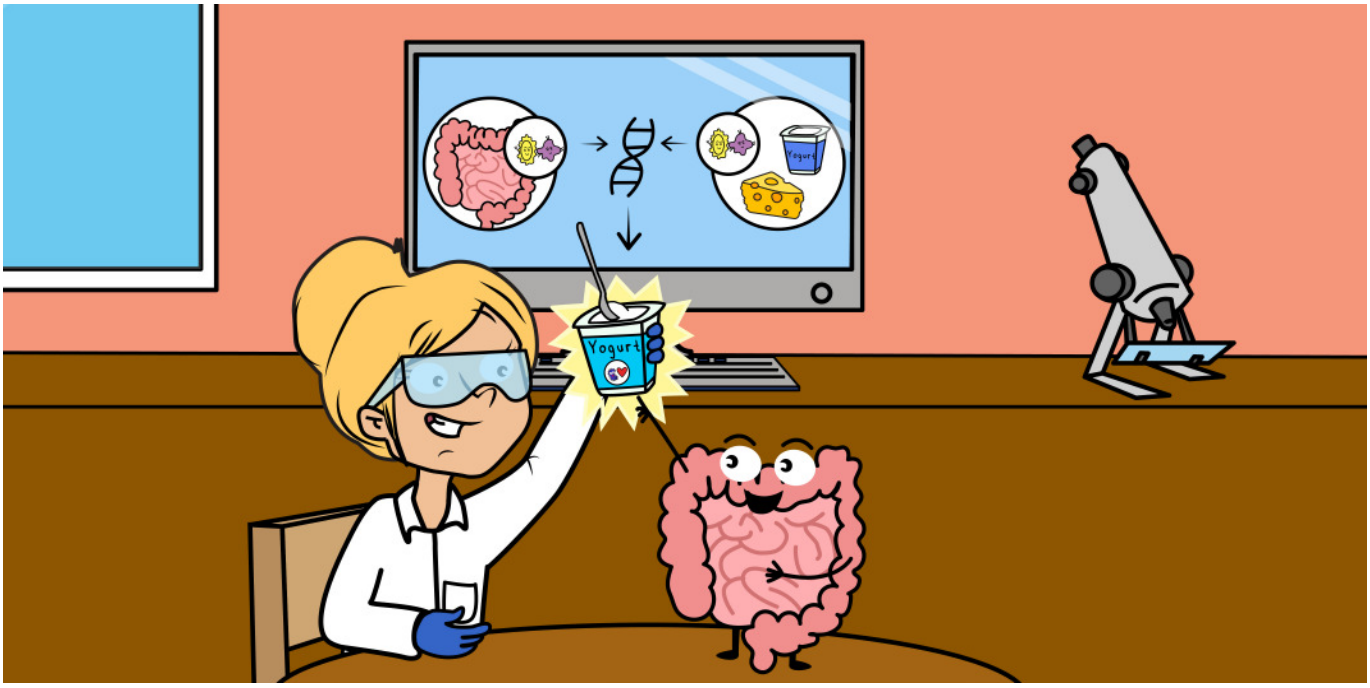

CAN EATING BACTERIA IN DAIRY PRODUCTS SUPPORT YOUR HEALTH?

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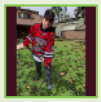
Huge numbers of bacteria live in the human gut. We know those bacteria are important to our health, so we need to treat them well. We wanted to know whether it was possible to design new yogurts that can introduce special bacteria into the gut, to improve our well-being. We studied hundreds of types of bacteria isolated from cheese and yogurt and found that 24 of these bacterial species can perform most of the important bacterial functions that happen in the human gut. Therefore, there is exciting potential for designing new, gut-healthy yogurts.

YOUNG REVIEWERS:


CAMERON
AGE: 10


ELLIOT
AGE: 11


EVE
AGE: 11

SPECIES

A group of organisms, like bacteria, that behave similarly and have very similar genomes.

BACTERIA KEEP US HEALTHY

Bacteria were among the first life forms to appear on Earth. They are extremely small organisms, consisting of a single cell. There are many **species** (major types) of bacteria that can be incredibly different from

each other: some prosper deep below the ocean, at temperatures higher than that of boiling water, while others live happily in Antarctic ice. Bacteria populate the entire surface of Earth. So, it is not surprising that some bacterial species live with humans—a vast number of bacteria live in and on our bodies. Unfortunately, humans commonly think of bacteria as bad, because some types of bacteria can make us sick. Yes, there are bad guys—but there are also good guys! In fact, most bacterial species do *not* make us sick, and some even help us stay healthy [1, 2]. Most of the bacteria that live inside humans are found in the gut. These good bacteria protect us against disease-causing bacteria, help us digest food, and produce vitamins that our bodies need but cannot produce on their own [1]. Recently, researchers found that gut bacteria can even influence mental health [1]. Together, this collection of gut bacteria is known as the **gut microbiome**.

GUT MICROBIOME

All the bacteria that live in the human gut.

WHAT MAKES A HEALTHY GUT MICROBIOME?

How can we nurture good gut bacteria without strengthening the bad ones? One way is to feed our good gut bacteria their favorite foods. Fast foods, for example, even though they are very tasty, are good neither for us nor for our gut bacteria. Fast foods are full of sugar and low in vitamins and fiber. Most good gut bacteria prefer to be fed fiber, and if there is not enough, they can starve! It is important for the gut microbiome to contain many different types of bacteria, because a high **diversity** in the gut microbiome makes us more resistant to infections and to the effects of the occasional fast-food treat. Why might that be?

DIVERSITY

The variety of living things in a particular habitat. The more species, the higher the diversity.

Suppose the bacteria in the gut are very diverse. Some like to eat sugar, some fat, some fiber, and some protein. In that case, when there is no sugar around, only the sugar-eating bacteria become weak—the others are fine, which means that, as a whole, the community is still strong. However, if most bacteria only ate sugar, the microbiome would become weak in the absence of sugar, making it much easier for bad bacteria to conquer the gut and cause illness. This is one reason why a balanced diet is important.

There is another reason why a lack of diversity in the gut microbiome may be bad. When gut bacteria are diverse, multiple types of bacteria can perform the same job in the bacterial community, like digesting milk sugar or vitamin production. If one species of bacteria is lost, another might be able to take its place. In a less diverse gut microbiome, this might not be possible, and the gut microbiome may be weakened. One strategy for strengthening the gut microbiome, and thus human health, could be ensuring that there are several different bacterial species that can perform the same functions. We can achieve this by supplementing those bacteria through our diets.

CAN YOGURT OR CHEESE SUPPORT THE GUT MICROBIOME?

Bacteria can be found in many foods, particularly in dairy products like cheese or yogurt, which have been consumed for ages. Ten thousand years ago, when most people still lived as hunter-gatherers, all humans were lactose intolerant, which means they could drink milk when they were young, but if they did so as adults, they would feel bloated and sick. When humans started farming sheep, cows, and other milk-producing animals, they discovered ways to process milk so that it tasted different, lasted longer, and, most importantly, could be digested without making them feel sick [3]. We call this process **fermentation**, and it led to the production of the first yogurts and cheeses. What these early communities did not know was that bacteria were responsible for fermentation. Specific species of bacteria live and grow in milk, changing its taste, texture, and composition. After fermentation, a cup of yogurt (200 g) contains more bacteria (at least 20 billion) than there are humans on Earth (8 billion)!

FERMENTATION

The production of foods such as yogurt, cheese, bread, kimchi, beer, and wine with the help of yeast or bacteria.

Early yogurts contained many distinct species of bacteria, and every yogurt was different. In contrast, most modern yogurts only contain two species of bacteria, selected for fast and reliable mass production. Could we make yogurt from a different cocktail of bacteria, optimized not just for mass production but also to help the gut microbiome and improve human health (Figure 1)?

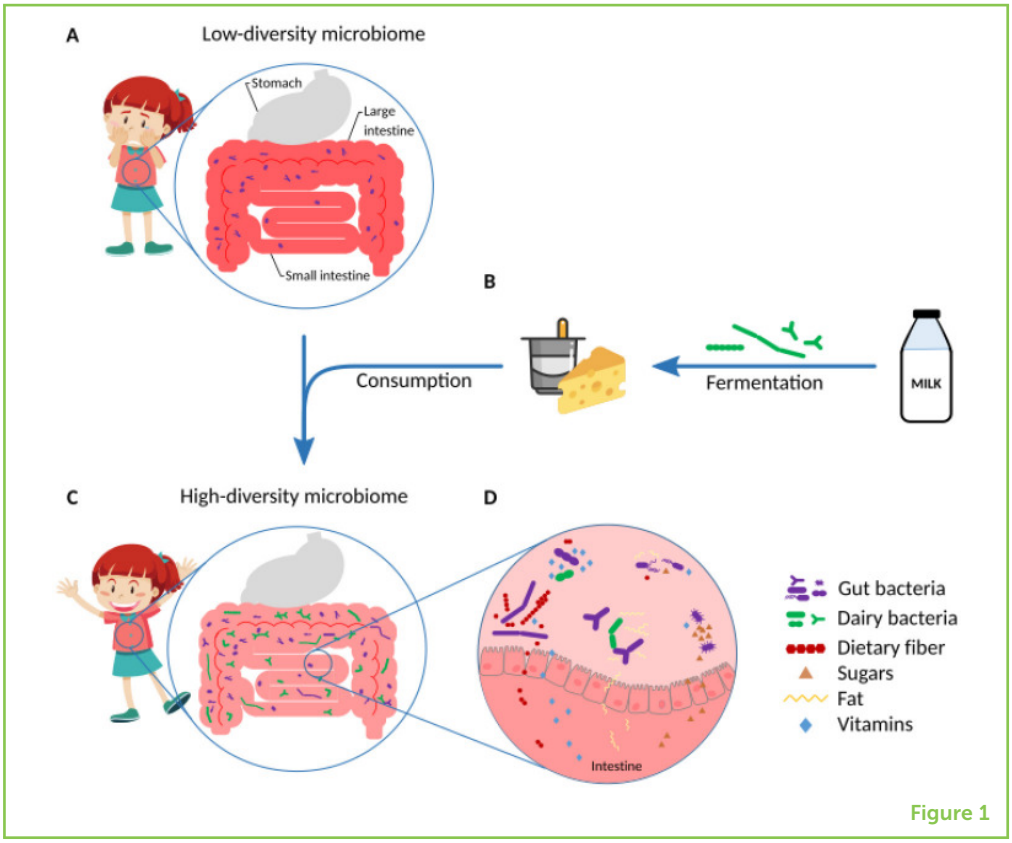


Figure 1

Figure 1

Can yogurt or cheese support the gut microbiome? **(A)** Unbalanced diets can lower the diversity of the gut microbiome, meaning that some species are present in very low numbers or even extinct. This can reduce the strength of the gut microbiome. **(B,C)** We are trying to find out if a dairy product fermented with selected bacteria can support or restore the functions of a healthy gut microbiome. **(D)** These functions include providing us with useful vitamins, sugars, and fats, and helping us to digest fiber from fruits and vegetables.

THE QUEST FOR THE RIGHT BACTERIA

Where could we get suitable bacteria for making gut-healthy yogurt? Switzerland has a proud tradition of cheese and yogurt making. Agroscope, the Swiss center of excellence for agricultural research, collects, stores, and investigates the bacteria found in yogurt and cheese. So far, Agroscope has collected over 10,000 different bacteria from dozens of species!

With such a large bacterial bank, how do we decide which are the best for a healthy yogurt? Conveniently, scientists at Agroscope have studied the DNA of close to 1,000 of the bacteria they have collected, using a process called **sequencing**, to see which **genes** the bacteria have. Genes are short segments of DNA that code for functions that allow bacteria to survive. For example, certain genes enable bacteria to split into two, and others give them the ability to swim around.

SEQUENCING

The process of studying the DNA composition of an organism.

GENE

A segment of DNA that determines a specific characteristic, capability, or function of a life form.

SUPPLEMENTING THE GUT MICROBIOME

Our idea was to see if yogurt bacteria could support gut bacteria in their work, and possibly even increase the diversity of the gut microbiome. We used DNA sequences from four human microbiomes, which contained a mix of genes from many different gut bacteria. Then, we used a computer program to determine the functions of these genes, using the same method we used for the dairy bacteria (Figure 2).

When we compared the dairy bacteria to bacteria from the human microbiome, we were surprised: each individual bacterial species from the milk could perform about half of the functions of the human gut microbiome, even though dairy bacteria are from a completely different environment and are rarely found in the human gut. Combined, our 24 species of dairy bacteria covered 89% of the functions of the human gut microbiome [4]! We also noticed that some human microbiomes lack certain functions compared to other human microbiomes. Some of those functions are present in dairy bacteria, meaning we may be able to develop a yogurt that can supplement missing or lost functions in a human microbiome, making it more resilient and thus helping people to be healthier.

WHAT IS NEXT?

Our study shows that bacteria from cheese or yogurt have similar functions to those of human gut bacteria. We think this knowledge will be very useful. For example, people with certain diseases, like obesity, lack specific types of gut bacteria. So, in future studies, we could recruit study participants with a known disease who lack the gut bacteria

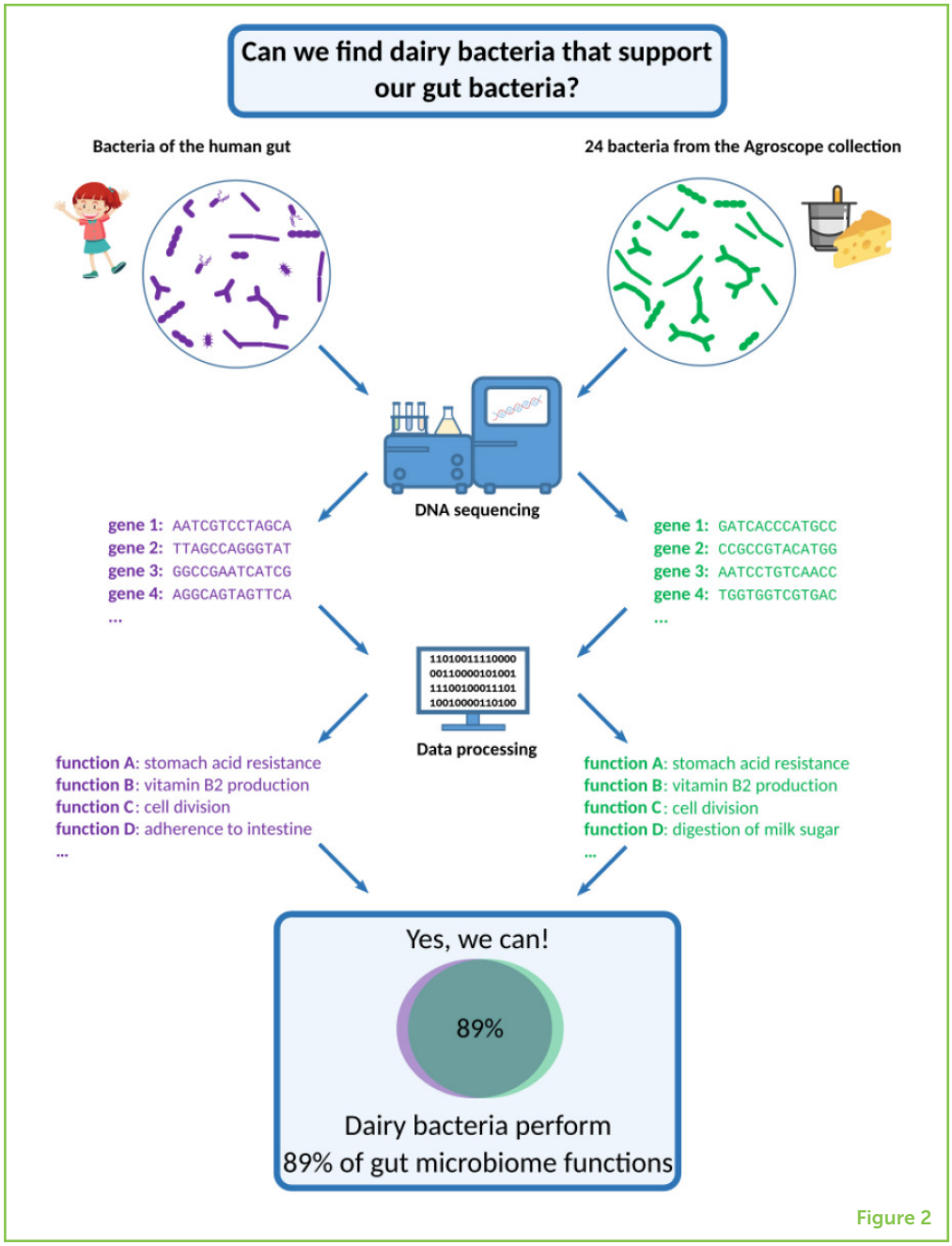


Figure 2

The quest for the right bacteria. Using DNA sequencing followed by computer analysis of the data, we found that 24 dairy bacteria from Agroscope's bacteria bank (right) can perform most of the functions of the human gut microbiome (left). This finding may help us to design a yogurt that supports the functions of the gut microbiome, making it more resilient and thus promoting human health.

that perform certain functions. Then we could search Agroscope's collection for milk bacteria that have the missing functions and produce a special yogurt with them. Next, we could feed this yogurt to the participants and evaluate the effects on their health.

Humans have been raising cattle and eating fermented foods for millennia, but only recently have we gained the understanding and the tools to develop health-promoting dairy foods based on scientific data. This process is long, but worthwhile! If scientists continue to explore the potential of bacteria to improve human health, we may eventually be able to help many people with diseases like

obesity and diabetes by feeding those people foods that contain helpful bacteria.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

CAMERON, AGE: 10

I am 10 years old, I like to play sports, especially hockey. I like to read and play video games in my spare time. In the summer I like going to my cottage to swim and play baseball with my friends.

ELLIOT, AGE: 11

Elliot loves to read, play soccer and camp with his boy scout troop. He also has a blast going on adventures with his friend, Eve. Together, they like to rock climb, complete high ropes courses and downhill ski. Basically, they like to play hard and laugh hard!

EVE, AGE: 11

Eve loves to read, play softball and hang out with her friends. She also has a blast going on adventures with her friend, Elliot. Together, they like to rock climb, complete high ropes courses and downhill ski. Basically, they like to play hard and laugh hard!

AUTHORS

THOMAS RODER

Thomas is a Ph.D. student in bioinformatics at the university of Bern, Switzerland. He is trying to design new yogurts by combining various bacteria. At the same time, he is developing a website that makes comparing bacterial genomes easier. He works on these projects using computers, but prior to this project, he studied the interaction between plants and root-eating larvae in the lab. *thomas.roder@bioinformatics.unibe.ch

GRÉGORY PIMENTEL

Grégory is a researcher at the Functional Nutritional Biology Group at Agroscope. He specializes in the analysis of dairy products and other biological fluids (blood or urine) using a technique called metabolomics, which allows the detection of thousands of small compounds present in a sample. Metabolomics can help scientists better understand the chemical reactions happening in milk during fermentation, and it can be used to investigate the health effects of eating fermented dairy products. Grégory holds master's degrees in food science, engineering, and nutrition, and his Ph.D. is from the University of Lausanne in Switzerland, in cardiovascular biology and metabolism.

CORNELIA BÄR

Cornelia is a scientist in the Biochemistry of Milk and Microorganisms group at Agroscope, Switzerland. She was always driven by the desire to put scientific knowledge into practice and she earned her Ph.D. studying fortified foods. A postdoc studying food composition followed, which sparked her interest in how bacterial metabolism changes the composition of food. Trained in microbiology, immunobiology, and protein biochemistry, Cornelia is particularly interested

in which bacteria and proteins are responsible for food transformation, how bacteria interact in food, and how the consumption of these foods affects human health.

UELI VON AH

The combination of technology and biology has always been of great interest to Dr. Ueli von Ah. After studying food sciences, he earned a Ph.D. in food biotechnology. His work focuses on the use of lactic acid bacteria in food applications. In addition to finding the optimal growth conditions for these bacteria, he is also interested in understanding how genome information relates to the functions of bacteria in food. Ueli von Ah is now head of the Biotechnology research group at Agroscope, and he teaches a class in food biotechnology at a Swiss university of applied sciences.

RÉMY BRUGGMANN

Rémy is the head of the Bioinformatics Unit and director of studies of the master's of science program called Bioinformatics and Computational Biology at the University of Bern. A molecular biologist by training, he has always been interested in computer science, and in bioinformatics he found the ideal combination of his two passions. He has sequenced hundreds of genomes from bacteria and higher organisms and wants to better understand how genomic information is translated into a functioning organism.

GUY VERGÈRES

During the last three decades, Dr. Guy Vergères conducted research in several scientific disciplines, including chemistry, biochemistry, molecular biology, physical chemistry, pharmaceutical sciences, and microbiology—always with the aim of linking important molecules to their impact on human health. This combination naturally led him to conduct nutritional research on fermented foods. Guy Vergères is now heading the Functional Nutritional Biology research group at Agroscope and teaching the science of nutrigenomics (modern nutrition research) at Swiss universities.