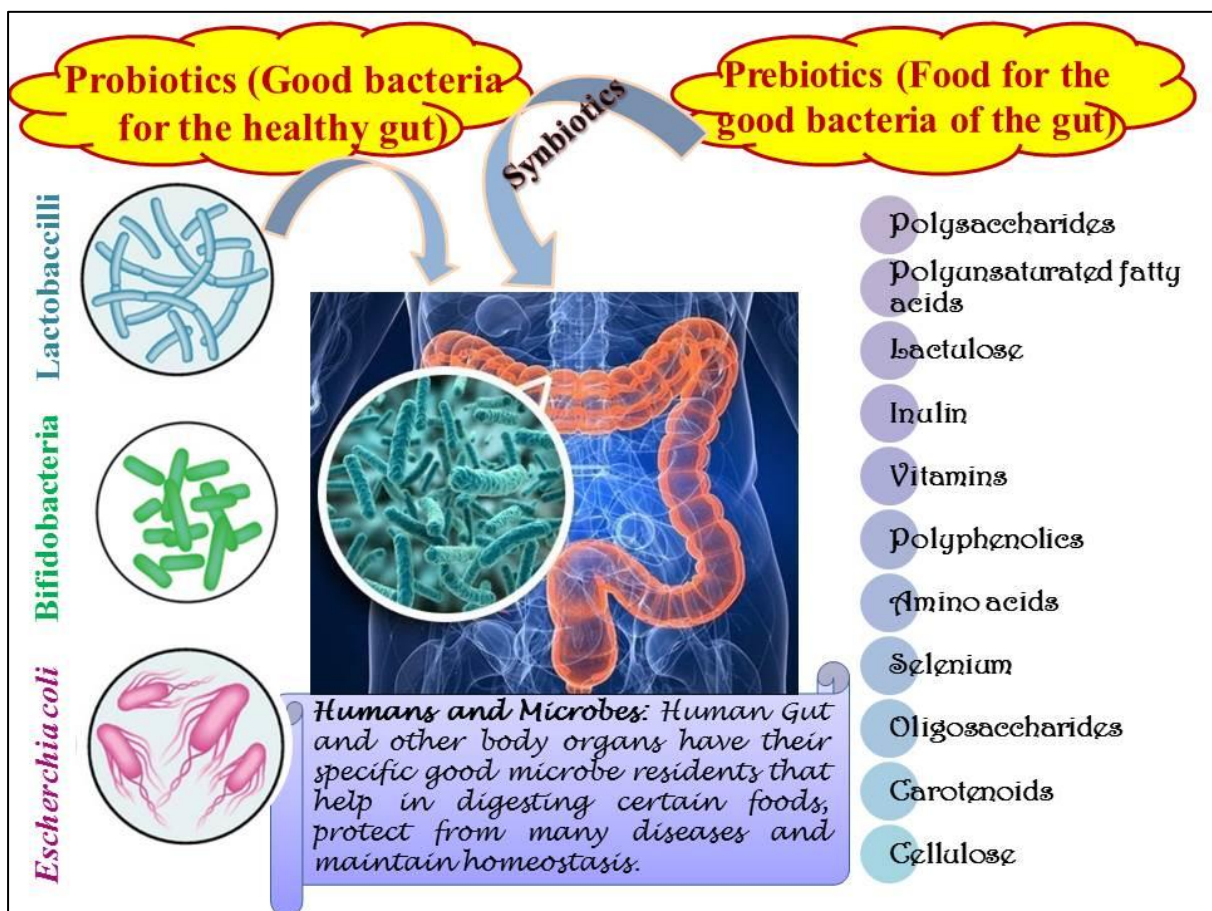


Pre-, Pro- and Syn-biotics

Sir: Why are not-so-tasty fermented foods, like curd, kimchi and kombucha better than the very tasty foods burgers, pizza and pasta?



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Pre-, Pro- and Syn-biotics

Storyline

Microbes are everywhere inside and outside us. While most of them are harmless and do their respective jobs without disturbing anybody, some of them become notorious. These naughty ones can cause diseases, for which we turn to medicines for a cure. But, wait a minute.....there are some soldiers in this microbial community, and they can help us fight against the naughty ones!!! Let's dive into the details of these good bacteria.

Probiotics are live bacteria that have been shown to provide health benefits and they come in various combinations. When probiotics are consumed, they enter our digestive tract, where trillions of other microbes already live. This collection of microbes is called the gut microbiota or microbiome, and like a fingerprint, no two gut microbiotas are the same. This unique collection of microbes greatly impacts overall health through immune function, metabolism, and nutrition.

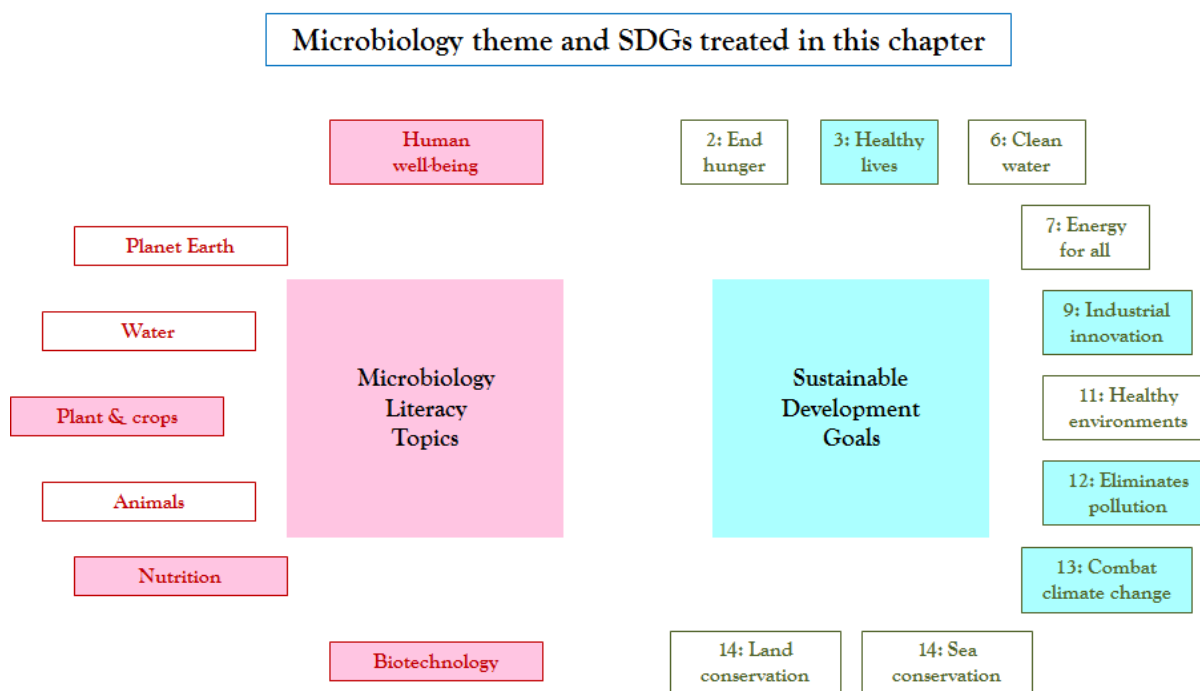
Our resident microbes, many a time, protect us from harmful microbes that we may encounter and fall sick from. So it becomes very important for us to encourage these helpful microbes that call our bodies their home. Prebiotics helps! Most prebiotics are a type of dietary fibre, along with some micro- and macronutrients, that are used by the beneficial microbes residing in our intestine. In other words, prebiotics are food for the beneficial bacteria inside our gut: including *Lactobacillus*, *Bifidobacterium* and other resident microbes. When a single formulation provides us the benefit of both prebiotics and probiotics, it is called a synbiotic. Inclusion of prebiotics, probiotics and/or synbiotics in routine diets is favourable for the overall human health.

The Microbiological and Societal Context

The Microbiology: Microbes in the human gut, the general composition of the gut microbiome, the health implications of a balanced gut microbiome, disease conditions caused by imbalance, and the role of pre- and probiotics in supporting beneficial gut bacteria.

The Societal Context: A healthy gut with beneficial bacteria leads to the overall well-being of individuals, which in turn reduces the burden on healthcare. Healthy people perform better at work, and eventually, the economy benefits at large.

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Pre-, Pro- and Syn-biotics: The Microbiology

1. Gut health by virtue of microbes:

It has been believed since time immemorial that good health is the most precious of all. For maintaining good health, we know the importance of consuming nutritious food, but the lesser-known aspect is the role of microbes that help keep us healthy and their nutritional requirements. For this aspect of health, certain food items are categorized as prebiotics and probiotics.

These two words may sound similar; some people may even think that “prebiotic” is a misspelling of “probiotic,” but they are quite different and play distinct roles in our gut. Our gut is home to tens of billions of bacteria, which are key players in maintaining a healthy gut, strong immunity, optimal brain function, and overall well-being. There is a delicate balance between good and bad bacteria in our gut that supports good health. However, this balance can sometimes be disrupted due to factors such as poor dietary habits, antibiotic use, and/or exposure to disease-causing microbes.

This imbalance can manifest as various health conditions, some of which may be detrimental. Probiotics have been developed to restore the balance of beneficial gut microbes by introducing a fresh population of them. However, this is somewhat like adding a drop of microbes into an

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ocean of microbes, and they may eventually pass through the system, as they are often unable to colonize the gut due to a non-conducive environment.

The solution to this problem lies in plant fibres, which constitute most prebiotics. These fibres serve as food for beneficial bacteria and support their growth over harmful bacteria, thereby helping to restore balance. Pre- and probiotics are functional or health-promoting foods with diverse benefits.

Important facts:

- *The human gut by virtue of its beneficial bacteria, acts as a training centre for our immune system. It teaches the immune system that not everything is harmful, thus, maintaining a proper balance between reaction and tolerance. Otherwise, every time you eat new food or visit a new place, your immune system would overreact.*
- *The human body harbours about 3.5 lbs. of bacteria, which is much greater than the weight of our brain. Additionally, the gut functions as a “second brain” with a comparable number of neural connections. So, next time, it may be worth trusting your gut feeling!!!*

2. Concept of Probiotics:

The word probiotic is derived from two Greek words— pro meaning “in favour of” and bios meaning “life.” It can thus be simply described as substances that are beneficial for life and the health of the host. The term “probiotic” was first coined by Ferdinand Vergin in 1954 to describe substances beneficial for gut health that help gut flora flourish. Later, Lilly and Stillwell (1965) defined it as “substances produced by some microorganisms that aid the growth of other microorganisms.” Fuller subsequently defined probiotics as “certain non-pathogenic microbes which, when ingested, exert a positive effect on the host’s health and overall physiology.” The widely accepted definition today, as given by the World Health Organization (WHO), Food and Agriculture Organization (FAO), and European Food Safety Authority (EFSA), is: “live microorganisms which, when ingested in adequate amounts, confer a health benefit on the host.”

Probiotics are live beneficial bacteria naturally present in many fermented foods such as curd, yogurt, kimchi, sauerkraut, kefir, kombucha, pickles, tempeh, miso, certain cheeses, sourdough bread, natto, etc. (Figure 1). They are also available as pills, capsules, and other formulations, or added as ingredients in yogurt and various health drinks.

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Figure 1. Natural sources of probiotics, A. Curd; B. Yogurt; C. Kimchi; D. Sauerkraut; E. Kefir; F. Kombucha; G. Pickles; H. Tempeh; I. Miso; J. Fermented cheese; K. Sourdough bread; L. Nattō . These are represented by the photographs.

3. Old and common probiotics from lactic acid fermentation:

Early interest in lactic acid fermentation dates back to the beginning of the 20th century, notably by the Russian scientist and immunologist Élie Metchnikoff, who was awarded the Nobel Prize in 1907. In his book *Studies on Optimism*, he stated that “with various foods undergoing lactic acid fermentation and consumed raw (sour milk, kefir, sauerkraut, pickles), humans introduce large amounts of proliferating lactic acid bacteria into their alimentary tracts.”

4. Probiotics come in a variety and provide different benefits:

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There are many probiotic products and supplements available, but not all may be equally beneficial for every individual. They differ in composition, as different products contain different probiotic microorganisms with specific characteristics and health benefits. One key difference among probiotics lies in their outer structures, which can stimulate different responses from our digestive and immune systems.

Scientists classify probiotics in the same way as other living organisms—by genus and species. For example, common probiotic genera include *Lactobacillus* and *Bifidobacterium*. Probiotics are further identified by their strain. Just as different breeds of cats can vary greatly, different strains within the same genus and species can have significant differences. A specific strain may support immune function, while another may not produce the same effect.

Another important distinction among probiotics is the level of scientific evidence supporting their claimed benefits. Some are backed by strong research studies, while others are less well understood. Scientists are still working to fully determine how different probiotics function. Therefore, it is best to choose a probiotic that has been specifically studied for the benefit you are seeking.

Probiotic products may also vary in the number of strains they contain and in the quantity of live microorganisms, measured as colony-forming units (CFU). These can range from 100 million to 50 billion or more per dose. However, a higher dose or more strains does not necessarily mean greater effectiveness. The dosage should align with levels supported by scientific research. It is important to carefully evaluate these differences and make an informed decision about which probiotic product is most suitable for your needs.

5. Identity of microbes contained in probiotics:

The microorganisms used in probiotics include certain *Lactobacillus* spp., *Escherichia coli*, *Enterococcus* spp., *Saccharomyces* spp., *Streptococcus* spp., and *Bacillus coagulans*. Most probiotic formulations primarily contain *Lactobacillus*, *Bifidobacterium*, and *E. coli*. These microbes are added to foods—especially fermented milk products—either individually or in combination. Ongoing research continues to identify and validate new strains for probiotic use. Let's discuss some common ones in more detail.

Lactic acid bacteria (LAB): *Lactobacillus* belongs to Gram-positive, anaerobic lactic acid bacteria and plays a major role in fermented foods such as yogurt. There are thousands of strains, each with distinct effects. They are particularly beneficial for individuals who have difficulty digesting

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milk sugar (lactose) and also provide general health benefits. *Lactobacillus* species have been widely used as probiotics since ancient times.

Bifidobacterium: This group of bacteria is among the early colonizers of the human gut. They play a key role in digestion, inhibit the growth of harmful microbes in the intestines, help prevent constipation, and support the immune system. Some studies suggest they may also reduce the levels of carcinogenic enzymes in the colon. While they are present in certain dairy products, they are more commonly added as probiotic formulations. *Bifidobacterium* species are also known to help alleviate symptoms of irritable bowel syndrome (IBS).

Escherichia coli: This is a common and prominent resident of the gut, belonging to the family Enterobacteriaceae. Beneficial strains of *E. coli* play an important role in digestion, overall health, and the production of vitamin K. They also help prevent the formation of harmful bacterial biofilms. Studies have shown that the probiotic strain *Escherichia coli* Nissle 1917 (EcN) can outcompete biofilm formation by pathogens such as enterohemorrhagic *E. coli* (EHEC), *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Staphylococcus epidermidis*.

You may now wonder how these bacteria (or certain yeasts) are incorporated into probiotic drinks, pills, capsules, powders, or functional foods.

6. There is an extensive list of health benefits conferred by probiotics:

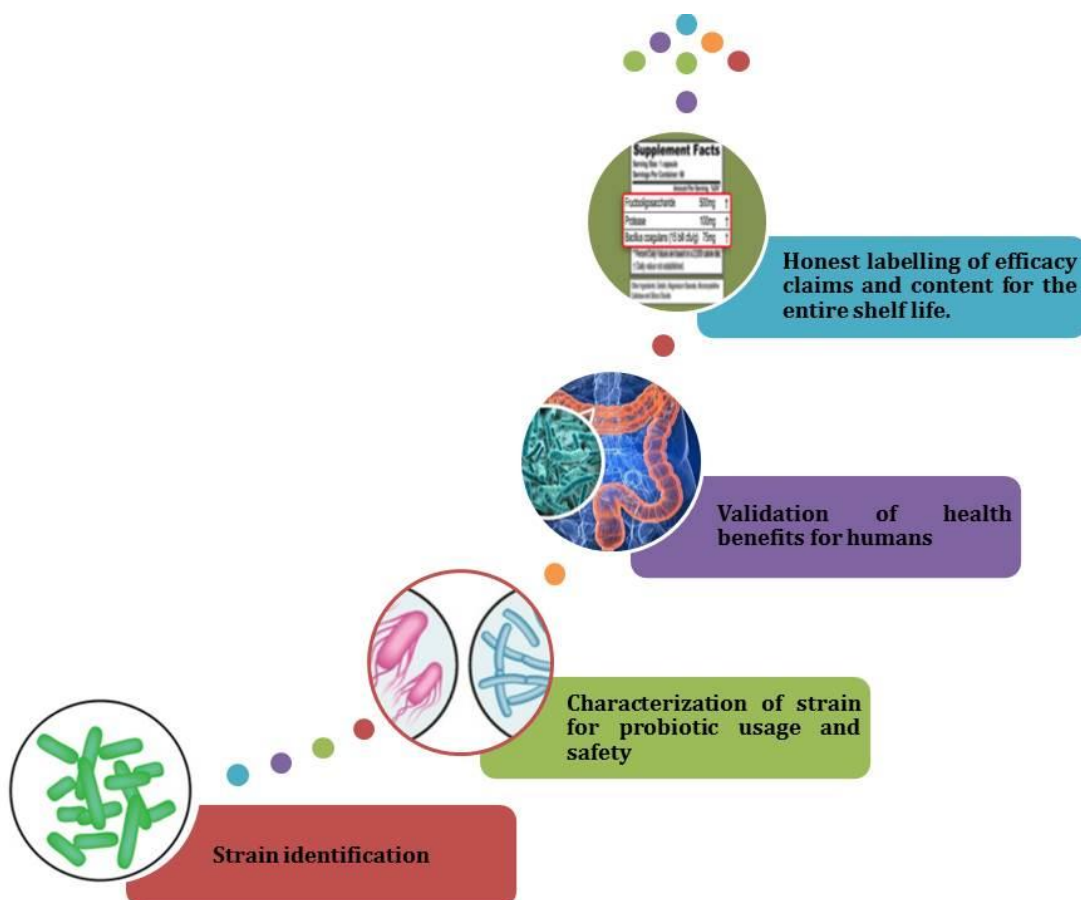
- Commonly associated with improved digestive and immune health.
- Help relieve everyday digestive symptoms such as occasional constipation, diarrhoea, and bloating.
- Keep harmful microorganisms in check, aid in lactose digestion, and help reduce antibiotic-associated diarrhoea.
- Used to replenish gut microbiota lost due to antibiotic use. For this reason, clinicians often recommend probiotics, vitamins, and folate supplements alongside antibiotics to help maintain beneficial gut flora and prevent opportunistic infections.
- Help combat gastrointestinal side effects of medications, which might otherwise lead to yeast infections due to harmful microbial overgrowth.
- May help reduce the recurrence of vaginal infections.

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- May improve heart health by helping to lower cholesterol levels.
- Infants may experience specific benefits from probiotics. Beneficial bacteria may help reduce crying time in colicky babies, prevent eczema, treat acute paediatric diarrhoea, and reduce the risk of necrotizing enterocolitis in preterm infants.
- Preliminary studies suggest that some probiotics may improve psychological symptoms such as anxiety and depression, possibly through the gut-brain connection. However, research in this area is still in early stages.

7. Commercial production:

Commercially produced probiotics are strictly regulated and have recommended properties: Probiotic products are regulated according to guidelines set by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) to ensure their quality and efficacy (Figure 2). The properties of probiotics may vary depending on the specific health benefit they are intended to provide to the host. Some of these properties are illustrated in Figure 3.



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Figure 2. Activities necessary as per the guidelines set by the FAO and WHO for the development of probiotics.

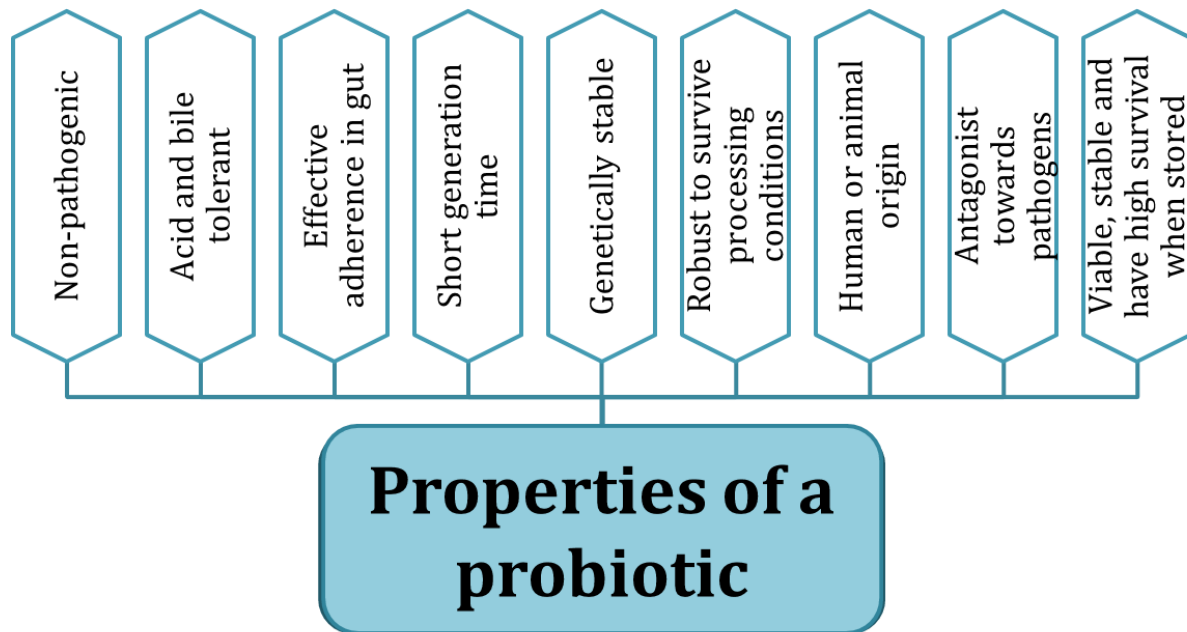


Figure 3. Properties governing the selection of a microbe or a consortium of microbes as probiotics for human use.

Interesting fact:

The good bacteria can be consumed through probiotic foods, but this is like adding a drop into a bucket of bacteria; they may pass through the gut without effectively colonizing it. In contrast, consuming prebiotic foods is more advantageous, as they nourish and support growth of beneficial gut microbes

8. Concept of Prebiotics (food for our good gut bacteria):

Prebiotics are the non-digestible food ingredients that provide beneficial effects on the consumer's health by selectively stimulating the growth and/or activity of specific beneficial gut bacteria. They help control the colonization of harmful bacteria, thus, maintaining overall balance of the gut microflora. Naturally, prebiotics are found in plant fibres such as leeks, bananas, barely, beet, onion, garlic, asparagus, apples (with skin), soybean, oats, seaweeds etc. (Figure 4).

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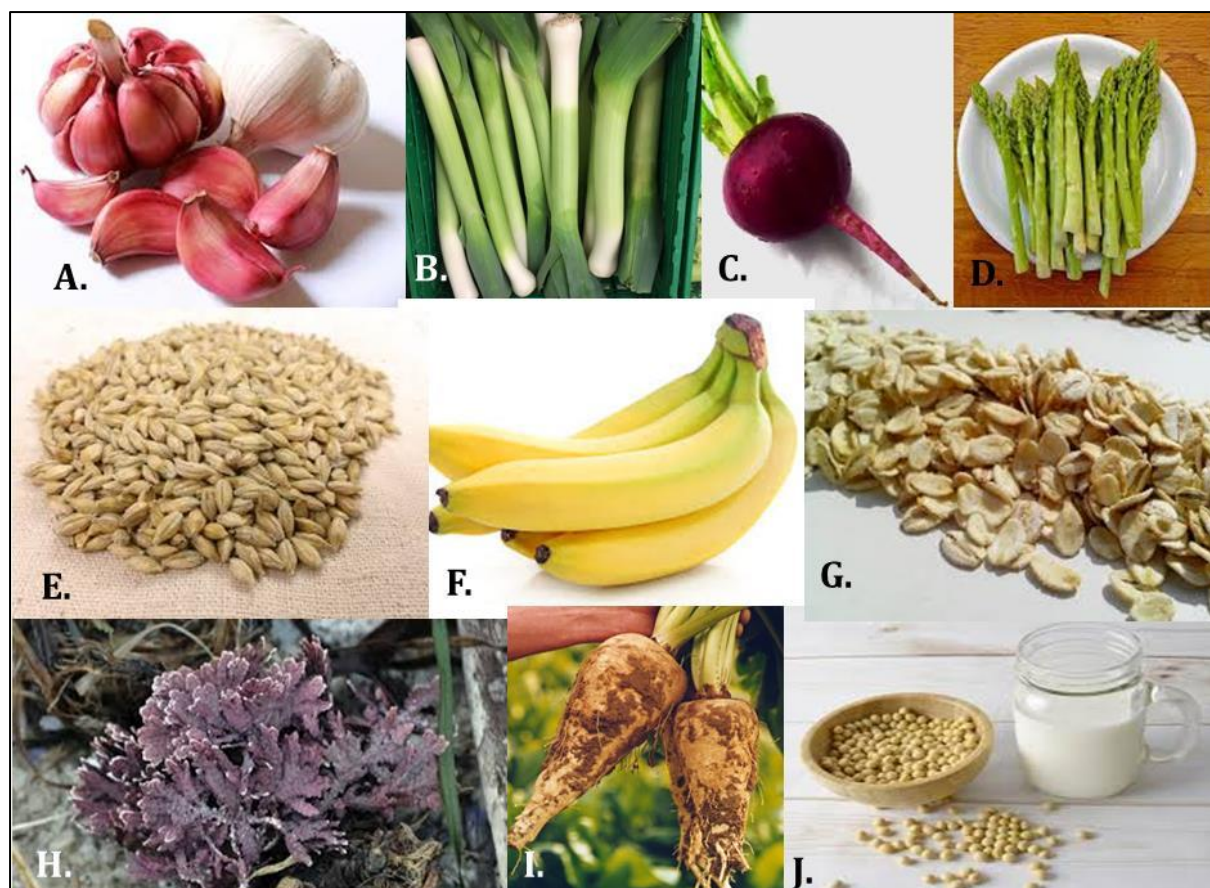


Figure 4. Natural sources of prebiotics, A. Garlic; B. Leeks; C. Beet; D. Asparagus; E. Barley; F. Bananas; G. Oats; H. Seaweeds; I. Chicory root; and J. Soybean. These are represented by the photographs.

Additionally, prebiotics are produced from raw materials such as lactose, sucrose, xylan, plant sources, and starch using different methods. They are then classified into different categories based on their origin, including lactose-derived, sucrose-derived, xylan-derived, starch-derived and soybean-derived prebiotics.

Table 1. Selected prebiotics along with their corresponding source compounds, from which they are derived using various methods.

Source	Prebiotic component derived
Lactose	Lactulose, Lactosucrose, Fructooligosaccharides (FOS)
Sucrose	Fructooligosaccharides (FOS) and Isomaltulose
Starch	Malto-oligosaccharides, Isomaltotriose, isomalto-oligosaccharides (IMO) and enzyme-resistant dextrin
Xylan	Arabinoxyloligosaccharides (AXOS) and Xyloligosaccharides (XOS)
Soybean	Soybean oligosaccharides (SOS),

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9. The benefits of prebiotics :

Some benefits have already been demonstrated, while many others are actively being investigated actively. A detail list of benefits is provided below:

- **Brain health:** Improves general cognition, decreases risk of dementia, enhances memory and recall, increases learning ability, uplifts mood, supports nervous system development in infants, shows positive effects in individuals with autism, and aids in treatment of hepatic encephalopathy.
- **Heart health:** Decreases lipogenesis, reduces low density lipopolysaccharides (LDL) levels, lowers cholesterol levels
- **Bone health:** Increases calcium absorption
- **Integument (skin) health:** Reduces the risk of atopic dermatitis, decreases erythema, improves water and keratin retention, and enhances collagen formation
- **Immune system:** Increases antibody response to viral vaccines, improves overall immune activity by modulating immune components (natural killer cells, dendritic cells, T-cells, toll-like receptors, interleukins, C-reactive protein *etc.*)
- **Gut health:** Modulates gut microbiota, reduces the risk of colorectal cancer, irritable bowel syndrome, and Crohn's disease.

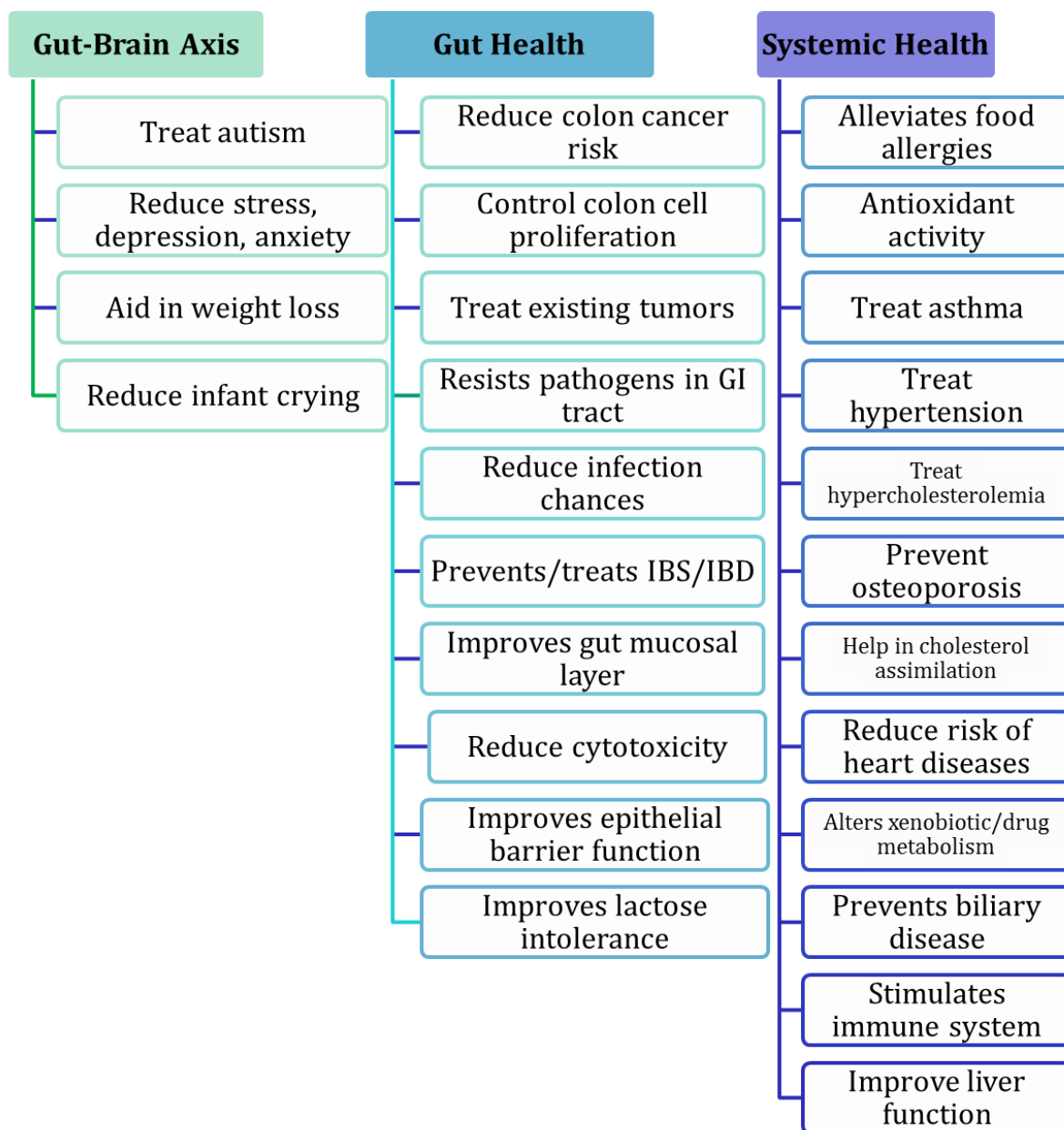
The benefits of prebiotics on overall human health are significant. This makes them very promising agents for naturally combating common illnesses such as cancer, cardiovascular diseases, mental disorders, obesity *etc.*, while also improving quality of life. Consequently, this potential has attracted considerable attention from biotech firms, with scientists worldwide working on the development of effective prebiotic formulations. In summary, the gut microbiota, considered a major functional “organ”, can be fed properly with prebiotics to enhance its composition and activity, thereby positively influencing overall health.

10. Synbiotics: Concept, Sources and Benefits:

The concept of prebiotics was first proposed by Glenn Gibson and Marcel Roberfrid in 1995, they also envisioned that prebiotics and probiotics to be combined to produce *synbiotics*. There are two main categories of synbiotics: **complementary symbiotics** and **synergistic symbiotics**. Complementary synbiotics consist of a probiotic and a prebiotic that does not necessarily serve as a preferential substrate for the probiotic strain. Instead the prebiotic component supports the growth and activity of other beneficial gut microorganisms. Therefore, the effectiveness of complementary symbiotic depends on the presence of native gut microbiota capable of utilizing

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the prebiotic component. Synergistic synbiotics are designed such that the prebiotic substrate specifically supports the growth and activity of the included probiotic microbial strain. There is no essential requirement of presence of a gut microbe capable to utilize prebiotic component of the synergistic synbiotic. However, developing effective synbiotic formulations presents practical challenges. Identifying a prebiotic that selectively promotes the targeted probiotic strain is difficult. In practice, formulation decisions are often influenced by factors such as shelf life, cost, industrial feasibility, availability, and marketing considerations. Additionally, results observed under controlled (*in vitro*) conditions may not always translate to similar outcomes *in vivo*, as the probiotic strain must compete with a diverse and complex gut microbiota for the utilization of the prebiotic substrate.



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Figure 5. Health claims associated with synbiotics for human populations. The listed benefits relate to gut health, systemic health and gut-brain axis. Abbreviations: GI-Gastrointestinal, IBS-Irritable Bowel Syndrome, IBD-Inflammatory Bowel Disease.

Synbiotics are usually administrated as dietary supplements formulated to target specific health benefits. They combined the functional advantages of both prebiotics and probiotics. Therefore, their health effects generally reflect the benefits of previously described for prebiotics and probiotics.

Table 2. Selected synbiotics tested in various hosts for the activity of their prebiotic and probiotic components. References describing these synbiotics and their study outcomes are is cited alongside the host column .

Prebiotic component	Probiotic component	Host (tested in)	Reference
Transgalactosylated oligosaccharide	<i>Bifidobacterium breve</i> 4006	Human adults	Tanaka <i>et al.</i> 1983
Amylomaize	<i>Bifidobacterium lafti</i> TM 8B	Mice	Wang <i>et al.</i> 1999
Oligofructose-enriched inulin	<i>Lactobacillus rhamnosus</i> LGG [®] & <i>B. lactis</i> Bb12	Rats	Femia <i>et al.</i> 2002
Dextran	<i>L. casei</i> subsp. <i>casei</i> JCM 1134 TM	Mice	Ogawa <i>et al.</i> 2005, 2006
Galactooligosaccharide	<i>B. adolescentis</i> IVS-1	Rats	Krumbeck <i>et al.</i> 2015
Fructooligosaccharide and Inulin	<i>L. sporogenes</i> , <i>L. casei</i> , <i>L. rhamnosus</i> , <i>Streptococcus thermophilus</i> , <i>B. longum</i> , <i>L. bulgaricus</i>	Overweight or obese patients	Fernandes <i>et al.</i> 2016
Galactooligosaccharide	<i>B. breve</i>	Patients with ulcerative colitis	Ghouri <i>et al.</i> 2014, Saez-Lara <i>et al.</i> 2015
Synergy inulin (inulin & oligofructose mix)	<i>B. longum</i>	Patients with Crohn's disease	Ghouri <i>et al.</i> 2014, Saez-Lara <i>et al.</i> 2015

Relevance to Sustainable Development Goals and Grand Challenges

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The production and use of prebiotic and probiotic-rich foods, involving beneficial microbial populations, have certain implications for the SDGs, particularly:

Goal 3: Ensure healthy lives and promote well-being for all at all ages

The use of prebiotics and probiotics contributes to overall human health and well-being. These functional foods help maintain a balanced gut microbiota, which positively influences gastrointestinal health, the gut-brain axis, and systemic physiological functions. As a result, they may reduce the occurrence of diseases, particularly lifestyle-related disorders, thereby lowering the burden on healthcare systems. This can ultimately lead to reduced reliance on medical interventions and associated healthcare costs.

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

Industries focused on plant-based product processing are generally more sustainable and environmentally friendly. The production of fermented plant-based foods represents a sustainable approach with significant potential for innovation. Such industries can be established locally, creating opportunities for farmers who often do not receive a fair share of profits. Advancements in biotechnology can further enhance innovation in this sector, leading to broader societal and economic benefits while minimizing environmental impact.

Goal 12: Ensure sustainable consumption and production patterns

A shift toward reduced consumption of animal products promotes more sustainable consumption patterns. Many prebiotic- and probiotic-rich foods are plant-based and require fewer resources—such as soil, water, and energy—compared to animal-based food production. Additionally, microbial fermentation helps reduce food waste by improving preservation and shelf life. Increased consumption of plant-based foods can encourage practices such as crop rotation, which benefits soil health and enhances agricultural biodiversity. Preference for locally produced agricultural products further supports sustainability by reducing transportation-related environmental costs.

Goal 13: Take urgent action to combat climate change and its impacts

Reducing the consumption of animal-derived foods decreases the demand for large-scale animal farming, processing, and distribution systems, which are major sources of greenhouse gas emissions and environmental pollutants. These systems are also associated with the use of antibiotics and the spread of pathogens, some of which may lead to epidemics. Transitioning to

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locally sourced, plant-based foods can significantly reduce these impacts and contribute to climate change mitigation. Furthermore, improved public health resulting from better nutrition may reduce dependence on pharmaceuticals and healthcare resources, thereby decreasing the environmental burden associated with medical production and waste.

Potential Implications for Decisions

Individual

- a. Adults have the freedom to choose their diets, and their decisions also influence children. Therefore, they should make healthy food choices that include a higher intake of plant-based foods such as fruits and vegetables (sources of prebiotics), fermented foods like yogurt and kimchi (sources of probiotics), and locally produced agricultural products.
- b. Individuals should aim to reduce or avoid processed and packaged foods, as these often contain preservatives and additives that may negatively affect health. Additionally, their large-scale production can have adverse environmental impacts.
- c. Food choices should not be driven solely by taste; individuals should also consider the nutritional benefits and potential health risks of what they consume.
- d. Supporting local agriculture is encouraged, as it promotes sustainability and strengthens local economies.
- e. Individuals should raise awareness by informing friends and family about the benefits of consuming natural prebiotic- and probiotic-rich foods.

Community

- a. Food sellers should be monitored by the community to ensure that, in addition to imported and processed products, locally produced farm goods are adequately represented in community stores.
- b. Consumers should be provided with choices and encouraged to prefer fresh, healthy foods over preserved and processed items.

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- c. Communities should promote engagement in agricultural activities so that individuals better understand the origin of their food. Workshops can be organized to share knowledge of local foods and traditional fermentation practices.
- d. Schools and colleges can incorporate visits to local farms and fermentation facilities into their programs and encourage students to appreciate and consume locally produced foods.

National

- a. Guidelines related to food security should be strict and rigorously enforced.
- b. Farmers form the backbone of the economy; therefore, they should be directly involved in agricultural policymaking.
- c. National campaigns should be promoted to raise awareness about the health benefits of prebiotics and probiotics, similar to existing initiatives on iodine and folic acid intake. In some countries, food fortification programs are also implemented to ensure adequate intake of micronutrients such as vitamin D.
- d. Governments should ensure that animal rights are protected and not violated.
- e. National-level regulations on environmental standards and sustainability in food production (including agriculture and fisheries) should be effectively implemented and enforced.

Pupil Participation

1. Class Discussion

- a. Health benefits of consuming natural prebiotic- and probiotic-rich foods.
- b. The global rise in diseases associated with unhealthy dietary habits.

2. Pupil stakeholder awareness

- a. Prepare two separate lists of processed and fermented food items, and compare their respective benefits and potential health impacts.
- b. Examine the environmental impact of processed foods, including the role of large-scale industries in their production.

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c. Evaluate how fermented foods contribute positively to both human health and environmental sustainability.

3. Exercise

Listing the prebiotic and probiotic foods.

Through this activity, students can assess whether their diet includes a balance of prebiotic and probiotic components, identify gaps in their daily nutrition and explore ways to address these gaps

Requirements: A list of food items consumed by students eat at their respective homes.

Procedure:

- Students are asked to prepare a list of food items they consume over a period of 10 days.
- Each student then categorizes the listed items to identify foods that are potential sources of prebiotics and/or probiotics (e.g., curd, yogurt). The instructor may assist in this classification.
- Students analyze their lists to identify nutritional gaps in their diets.
- Instructors guide students by recommending suitable, commonly available food items to help fill these gaps.

Learning

Students learn to make informed and deliberate food choices that are enjoyable, healthy, nutritious, and beneficial

Outcome:

4. Class Experiment

Can missing microbes be replenished?

Learning objectives:

- Learn how antibiotics use reduces gut microbiome diversity
- Explore the role of prebiotics and probiotics in restoring balance in the gut microbiome

Requirements:

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Color beads (14 types), lentils (3 types), trays (3)

Procedure:

1. Distribute coloured beads across three trays to represent the gut microbiomes of vegetarian, non-vegetarian, and vegan individuals. Use six different bead colours in each tray, with two colours overlapping between trays (see Fig. 6).
2. Simulate the effect of antibiotic treatment by removing one or more bead types from each tray to represent the loss of beneficial microbes.
3. This simulation demonstrates how antibiotics can negatively select certain microbial populations, creating vacant niches within the gut environment.
4. Such imbalance may allow pathogenic microbes to colonize and proliferate in the gut.
5. Next, simulate prebiotic and/or probiotic treatment. This step restores microbial balance to some extent—prebiotics support the growth and activity of beneficial microbes, while probiotics reintroduce lost microbial species into the gut.

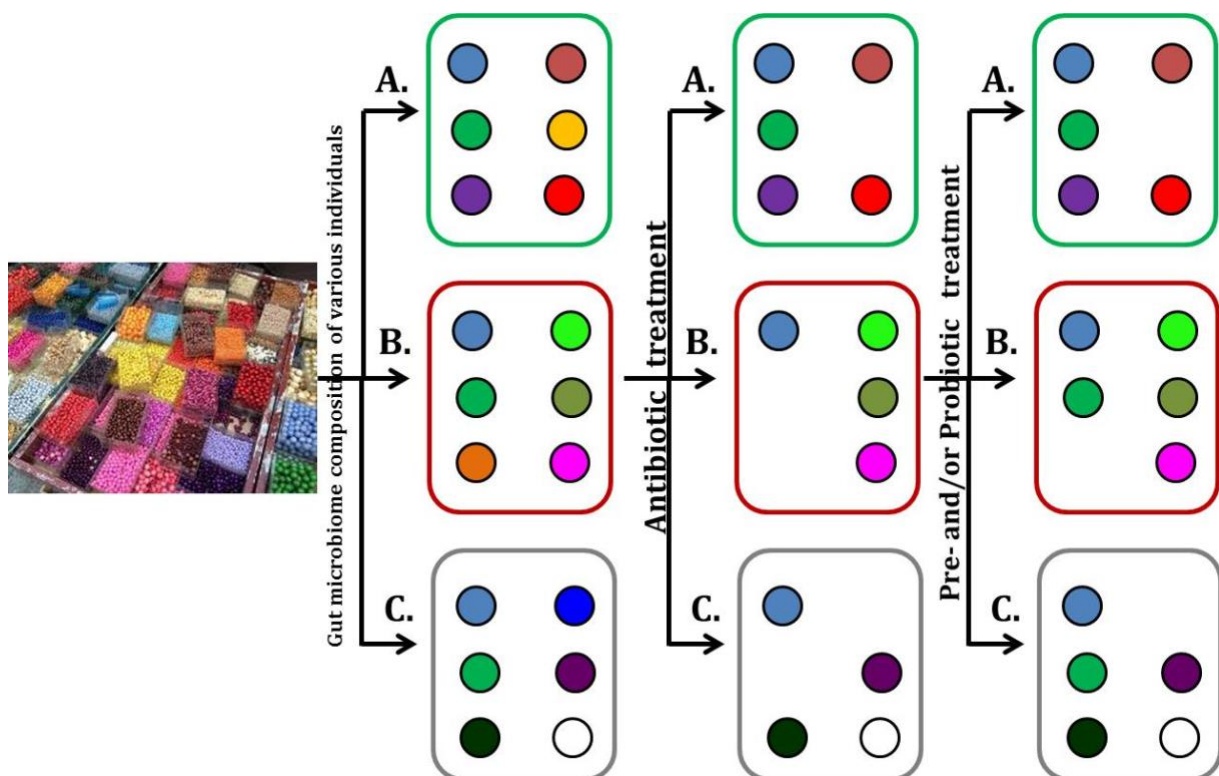


Figure 6. Simulation experiment illustrating the effect of antibiotics on the gut microbiome and restoration of microbial balance through prebiotic and/or probiotic treatment. Three trays represent individuals with different dietary patterns: (A) vegetarian, (B) non-vegetarian, and (C) vegan. Based on dietary habits, the gut microbial composition of the three individuals differs significantly; however, two microbial groups (blue and light green) are common to all. In the next step, antibiotic treatment is simulated, resulting in the loss of certain beneficial microbes. This

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creates an imbalance in the gut microbiome and leaves vacant niches that may be colonized by pathogenic organisms. If this imbalance persists over time, it may lead to mild to moderate illness. Subsequently, prebiotic and/or probiotic treatment is simulated. These interventions help restore microbial balance—prebiotics promote the growth and activity of beneficial microbes, while probiotics reintroduce lost microbial species. Over time, and with appropriate dietary support, the gut microbiome can be further replenished. Notably, the reappearance of the light green microbe across all three microbiomes illustrates the role of probiotics in restoring beneficial microbial populations.

Conclusion: Prebiotic and probiotics interventions can aid in restoring gut microbial balance, although their effects are limited.

The Evidence Base, Further Reading and Teaching Aids

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External Links

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4. https://www.youtube.com/watch?v=xjxYauok94Q&feature=emb_logo

Glossary

Functional Food: Foods that provide additional health benefits beyond basic nutrition, often targeting specific health functions. Examples include fortified dairy products, juices, and cereals.

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Gut Health: A state characterized by the absence of gastrointestinal illness and a balanced community of gut microorganisms that support digestion, nutrient production and absorption, and immune system regulation.

Health: A state of complete physical, mental, and social well-being, not merely the absence of disease, injury, or infirmity.

Immunomodulation: The process of regulating or modifying the immune response to achieve a desired effect, such as controlling pathogens in the gut through beneficial microbes.

Prebiotic: Non-digestible food components that promote the growth and activity of beneficial microbes in the colon. These are typically plant fibres that pass undigested through the small intestine. Examples include onions, garlic, oats, whole wheat (with bran), leeks, asparagus, barley, apples (with skin), and various fruits and vegetables.

Probiotic: Live microorganisms (bacteria or yeasts) that, when consumed in adequate amounts, confer health benefits. They are commonly found in fermented foods or available as supplements (e.g., capsules, powders).

Synbiotic: A combination of prebiotics and probiotics in a single formulation that provides synergistic health benefits. Examples include formulations containing *Bifidobacterium* and *Lactobacillus* along with prebiotic components such as oligofructose-enriched inulin.