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Gut Microbiota, Diet, and Chronic Inflammation: Emerging Targets for Disease Prevention

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ABSTRACT

Intestinal microbiota or gut microbiota is defined as the collection of microbes living in the gut and they are supposed to play a role in digestion immunity gut barrier, bile acids, and energy homeostasis. The association between the gut microbiota and inflammation show us that diet, microbes, and inflammatory disease are interconnected. This review article focuses on the effects of diet and microbiota on chronic disease development, with a focus on diet. Consumption of a plant-based diet rich in fiber allows increasing the production of beneficial compounds by the gut microbiota thus maintaining the gut health and good immune status. In contrast, overconsumption of heavily processed products alters the composition and functions of gut microbes. The ecosystem imbalance of the microbial community and breakdown of the intestinal barrier cause the formation of diseases like bowel disease obesity type 2 diabetes, non-alcoholic fatty liver disease and cardiovascular disease. The microbiome medicines consist of probiotics prebiotics synbiotics postbiotics fecal microbiota transplantation, bacteriophages, and therapies that target microbial products. There is a need for further research and development of preventive measures.

Keywords: *Gut microbiota; Diet–microbiota interaction; Chronic inflammation; Gut dysbiosis; Short-chain fatty acids (SCFAs); Microbial metabolites; Intestinal barrier integrity; Immune regulation; Dietary interventions; Probiotics and prebiotics; Metabolic disorders; Disease prevention.*

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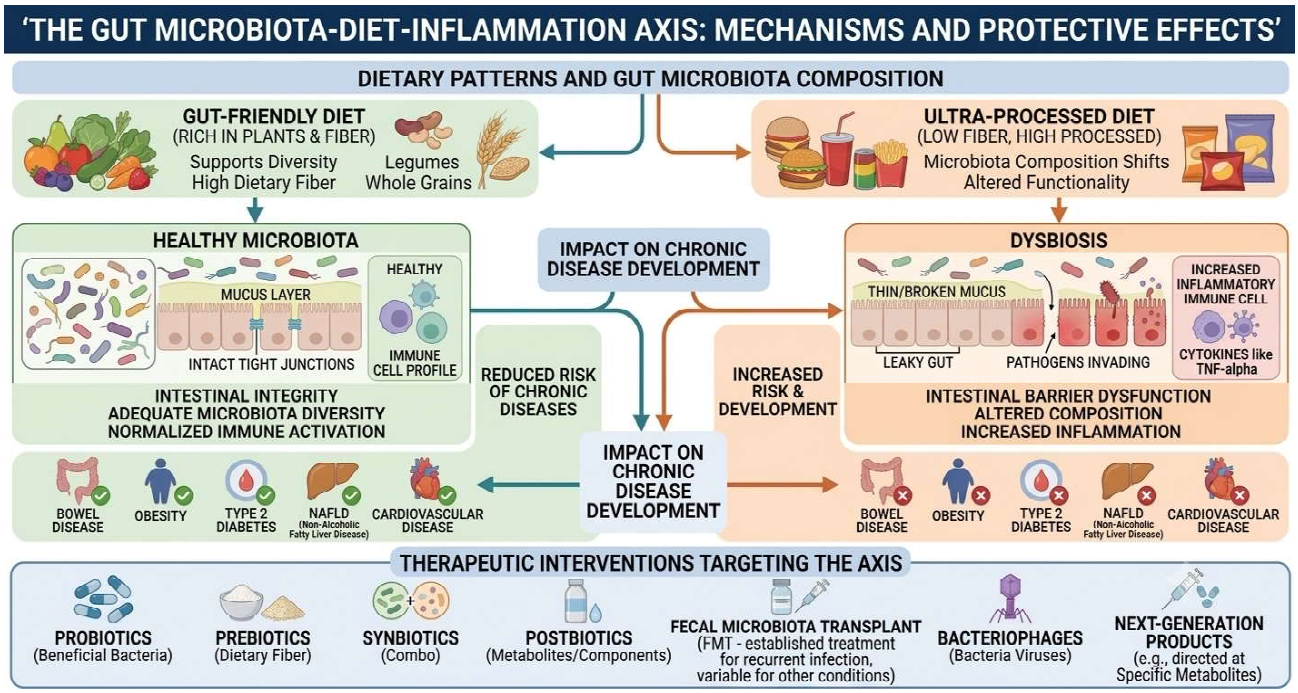

Graphical Abstract

INTRODUCTION

Chronic inflammation is a long?term, inflammation that stays in the body. It keeps going in every cell. Every part of the immune system. Because of inflammation the way tissues interact changes over time. It may cause tissue remodeling, insulin resistance, changes in vasculature, abnormalities in lipid metabolism, dysregulation of immune system etc. Chronic inflammation is linked to inflammatory bowel diseases obesity type 2 diabetes, cardiovascular disease, fatty liver disease and other immune and nervous system diseases (Wagenaar et al., 2021). There are many factors that may contribute to predispose a subject to inflammation. These things include genes, much belly fat poor sleep, a sedentary lifestyle, smoking, alcohol, infections, pollution, medications, mental stress, physical stress and food. The gut is a gateway between all these things and the rest of the body. The gut is not a tube for digestion; it is a big part of the immune system. The gut has a barrier made of mucus and cells defense peptides, lymph tissue and also a huge community of microbes (Gill et al., 2021). The word "microbiota" means the living things that live in that community. The phrase "gut microbiome" means those living things plus all of their genes. Most living things in the gut are bacteria. There are also archaea, fungi, viruses and bacteria that carry viruses. Current science is looking carefully at the functions that the community does the ways it stays strong and how it talks to the body instead of simply trying to call bacteria "good" or "bad". Food changes the gut microbiota faster than any factor. This can happen more quickly by focusing on the contents of a food like carbohydrates fibers proteins, fats polyphenols minerals emulsifiers alternative sugars etc that are available to the growing microbes. A diverse diet of a wide variety of plant foods will provide the microbes with fermentable carbohydrates and phytochemicals that promote the growth of a

diverse microbial population (He et al., 2022). A diet that is rich in carbs, high?energy foods, low fiber and lots of certain saturated fats can change what the microbes can do. That can weaken the gut barrier. Raise signals of inflammation in people who are already at risk. It is not about any food; it depends on the whole eating pattern and the effects of food combinations how much is eaten, a person's genes, medications and the starting microbiota. This review wants to show how gut microbiota, diet and chronic inflammation are all connected. It does not say that the microbiome alone causes disease. Where there is strong evidence, where there is misinformation and where changing diet seems doable it is a key difference that is worth pointing out. This is very important because microbiome science has promise but it can also be oversimplified or used in false commercial schemes (Yan et al., 2022).

GUT MICROBIOTA-DIET-INFLAMMATION AXIS

The axis of gut microbiota diet inflammation can be considered as multiple, interacting layers, that put together form a cascade. These comprise of our diet, the microbiota in our gut, the metabolic activity of said microbiota, gut barrier permeability, immune function, pathologies, and the end result of these (see Fig. 1).

The first is diet. What is eaten affects the quantity and diversity of substrates arriving in the colon. Most of the starch and sugars are broken down and absorbed in the small. Still, a few resistant starches, fiber, and different plant chemicals like polyphenols are transplanted to the colon and could be used and fermented by microbes. Some proteins also evade digestion, being further fermented by microbes. The composition of f. May alter. And so eventually affect microbial composition (Thomas et al., 2022). Secondly, in the ecological scale, the microbial compositions of the intestine change through competition, co-operation, cross-feeding. And microbiophage a type of virus that can infect bacteria, is involved. Host factors include bile acids, oxygen availability, transit rates, medication, and immune secretions. The effect of antibiotics was more exactly mentioned as the release of

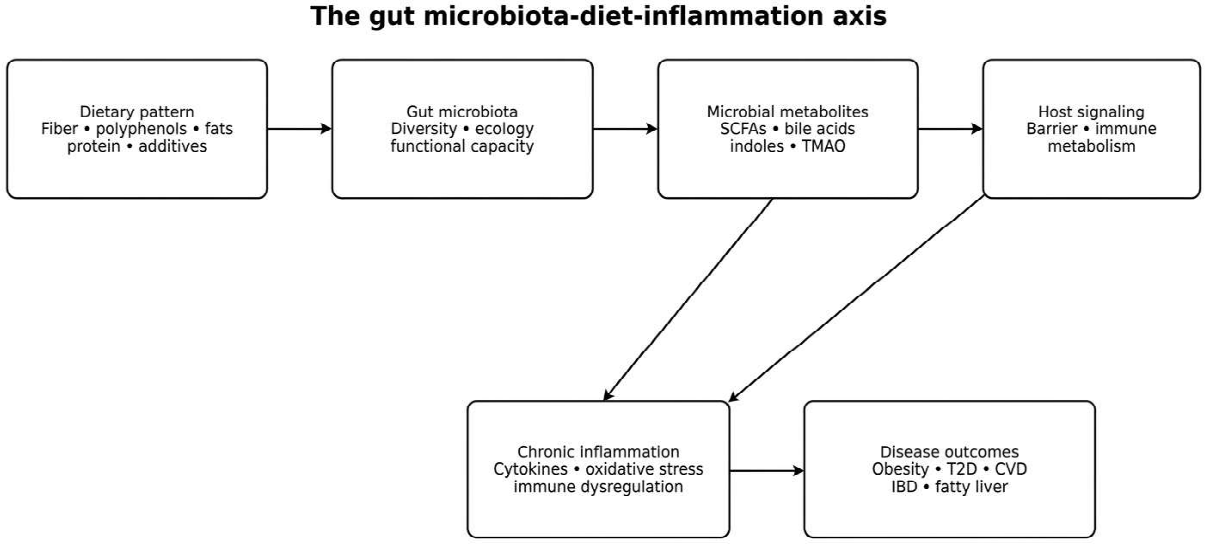

Fig. 1: Conceptual model of the gut microbiota–diet–inflammation axis

microbes from competition has drastic results. The author points out that, not all people's gut microbe populations change in the same way when diets are changed. Some people observe variation in microbe-produced metabolites while not an alteration in the microbial makeup. Others observe clear variation in species. This is an argument for Really a high diversity in microbiome should not be assumed to equate superior health. A diverse function may pass on same fitness as with a less diverse functionally stable community (Las et al., 2022).

Layer three is metabolism. Gut microbes convert the foods we consume into thousands of different molecules, several of which have been an area of interest. Many works have been done on the short chain fatty acids (SCFAs). Today, it is known that butyrate will nourish the epithelial cells of the colon. It supports the gallbladder lining and is helpful for managing our responses. Propionate and acetate are both found in the body and used as control centers for metabolic activities. They are also used as keystones for energy in other areas of the body. The microbiota can also modify other molecules such as bile acids, changing what signals the host receives. Tryptophan found in food stuffs can be changed by microbes to a group of molecules known as indoles. These molecules can influence a number of pathways through the aryl hydrocarbon receptor (AhR). A lot of other microbial derivatives are generated, some are positive, some beneficial, others not. It all depends on their location in the body and their amount with the hosts state of health (Adolph et al., 2022). The fourth level down is intestinal barrier function. An ideal barrier keeps nutrients in and other things out. The barrier is made up of mucus, intestinal epithelium with its tight junctions, antimicrobial proteins and peptides and the accompanying immune cells and microbes. With increasing inflammation some diets, infections, drugs, or metabolic stresses can result in a damaged barrier where bacterial products, mainly lipopolysaccharide (LPS) gain access to the intestinal tissue and systemic circulation. LPS and other delivery constituents up-regulate toll-receptor 4 (TLR4) and subsequent inflammatory cascades including NF-B. It is key to recognize that total exposure to microbes and their products is never absent, the immune system adapts from this constant state of expected exposure rather than seeking to completely remove it from the gut (Ross et al., 2024). Regulation the fifth layer. Between in an intimate microbial relationship with food antigens and beneficial microbes and some protect against pathogens. Microbial metabolites inhibit in cell cytokine production, regulate cell cytokine production, inhibit individual T-lymphocyte and T-helpercell function, inhibit macrophage function, inhibit dendritic cell function, inhibit innate lymphoid cell function. SCFAs effects on histone deacetylase activity and activate G-protine-coupledreceptor. Bile acids promote effects by using receptorsIndoles activate AhR related pathways (Christensen et al., 2024)

The sixth layer is physiology - a chronic low grade inflammation in the gut can affect tissues from the liver, muscle cells, blood vessels and the brain. For example obesity commonly presents with alterations in the gut microbiota increased gut permeability and may be tied to fat tissue inflammation and insulin resistance. Cardiovascular disease risk may also be mediated by compounds such as TMAO, SCFA's bile acids and others. In inflammatory bowel disease we see a clear causal relationship

because the disease takes place within the gut mucosa. Yet cause and effect is complex, disease can alter diet, medication use, gut motility and oxygen levels, which themselves alter the microbiome. So dysbiosis may be either a consequence or a cause of disease, or both (Hashhash et al., 2024). The whole axis becomes dynamic in the other direction too. Anything that causes inflammation in the body can alter mucus secretion, peptide release, access to nutrients, transit of gut and even oxygen tension in the gut liner. All these factors will in turn reshape the community. Due to this dynamic feedback loop, it may not be possible to introduce a strain and induce permanent means to the gut unless we coerce the environment to be change its hostile nature. Lasting alterations should be in the founding host state be it diet lifestyle drugs, and host biology itself rather than one microbe (Paudel et al., 2024).

Table 1: Major Dietary Determinants of Microbial Homeostasis and Inflammation

Dietary factor	*Microbial/ecological effect*	*Potential inflammatory relevance*	*Refferences*
Dietary fiber & resistant starch	Provides fermentable substrates; supports SCFA-producing networks and cross-feeding	May support epithelial barrier, regulatory immune pathways and metabolic homeostasis	(Gibson et al., 2024)
Fermented foods	Provides food-associated microbes and fermentation products	Potential effects on microbial exposure, barrier and immune signaling; effects are product specific	(Leeuwendaal et al., 2022)
Plant diversity & polyphenols	Increases substrate and phytochemical diversity; microbial transformation of polyphenols	Can promote bioactive metabolites and support a less inflammatory metabolic environment	(Yaskolka et al., 2021)
High saturated fat / excess energy	Can alter bile acids, microbial ecology and intestinal physiology	May contribute to metabolic inflammation in susceptible settings	(Heeren et al., 2021)
Unsaturated fats	Influences bile-acid pools and microbial ecology	Compatible with cardio metabolic patterns associated with lower inflammatory burden	(Harrison et al., 2022)
Adequate protein	Supplies amino acids; source and digestibility determine colonic substrate delivery	Supports lean mass; excessive proteolytic fermentation may alter metabolite profile	(Rizzoli et al., 2024)
Antibiotic exposure	Can markedly perturb community structure and function	May reduce colonization resistance and alter metabolite production	(Ucciferri et al., 2025)
Low-fiber dietary pattern	Reduces fermentable substrate diversity and may alter ecological stability	Associated with adverse metabolic and inflammatory profiles; individual additives vary	(Mann et al., 2024)

DIETARY DETERMINANTS OF MICROBIAL HOMEOSTASIS

Foods that cause bacteria to grow or shrink in the gut should be seen as tools to steer an ecosystem than as a collection of meals that can be described as "good" or "bad". The same meals can have effects on microbes depending mostly on the portion eaten the other meals eaten and the microbes that live in the gut. Fiber type matters too. Fiber can be soluble or insoluble. It must be broken down by microbes (Zhao et al., 2021). The shape and structure of fiber and how fast it breaks down are also important. Some microbes quickly turn fiber into chemicals in the part of the colon where plant material is digested while other fibers such as starch travel farther into the colon. Breaking down these fibers usually creates short?chain fatty acids. These acids lower substances in the gut and allow different microbes to work together. Because not all microbes can use all fibers one microbe may break down a sugar a little. Another microbe may then produce butyrate. By eating plants you may support a network of microbes working together of just adding more good microbes (Dunleavy et al., 2023). Resistant starch also reaches the gut. This starch is found in certain foods like beans lentils certain types of rice and potatoes that have been cooked and cooled. It is also a factor of how processing of the food, as well as the starch content, may alter the fermentation. A gentle build-up of carbs may be more tolerable. Polyphenols are another part of our diet. Polyphenols are found in fruit, vegetables, tea, coffee, cocoa, spices and herbs. Some polyphenols do not get absorbed in the gut. Instead reach the colon, where microbes break them down. The broken?down polyphenols can then have effects of just promoting growth. Polyphenols have also been shown to trigger responses from the microbial community. Plant-based foods provide microbes with both a cue and food (Li et al., 2021).

All fermented foods have microbes or substances from microbes. The effects are different according to the particular food and how the food has been prepared. Fermented foods like yogurt kefir pickled foods and numerous traditional fermented foods subject the gut to microbes. Can influence immune responses. However not all fermented foods contain probiotics that are proven to give a health benefit in an amount. Many fermented foods lack such evidence and the microbes they contain may not stay in the tract. The microbiome in the gut is partly influenced by the production of bile acids and the functioning of the gut. The amount and type of fat you eat affect both the bile acid system and the mix of microbes. Replacing some fats, such as saturated fats with types is good for heart health and may also change the gut. Still the goal of doing this should not be just to alter the microbiome (Xu et al., 2024). Protein is used by gut microbes. If a large amount of protein is digested and absorbed in the intestinal contents then only a small proportion of nitrogen reaches the colon. If excessive protein escapes digestion then microbes can ferment protein leading to the formation of many compounds such as branched chain fatty acids phenols indoles ammonia hydrogen sulphide, and others. That does not mean that eating protein is bad. The amount, type and digestibility of the protein the amount of dietary fiber and the overall diet matter more. Plant protein contains fiber and polyphenols which can influence how microbes break down protein. Additives in food are a growing Food additives are currently a hot research area.

Other research points to potential activity or gutlining effects of ingredients in processed foods, like, emulsifiers, and artificial sweeteners. However it is difficult to compare the amounts used in research with what people eat. Additives can have effects. The evidence for their impact is weaker than for factors like fiber intake and overall diet. It is better to suggest cutting processed foods instead of blaming a single additive, for chronic inflammation. Certain foods and a low?calorie diet can change the microbes in your bowel. The speed of weight loss can alter bile acids the number of microbes and what they produce. Eating little food or fiber may limit the nutrients you give to microbes so you might not be nourishing them. An anti?inflammatory diet can be healthy (Sanchez et al., 2022).

MICROBIOTA-DERIVED METABOLITES AND INFLAMMATORY SIGNALING

Some of the connections between diet and inflammation that derive from the microbiota are factors known as metabolites, which show what the microbes are actually doing. The primary categories of these metabolites are short-chain fatty acids, derivatives of bile acids, tryptophan by-products, methylamines such as TMA and their oxidized forms, as well as many phenolic and sulfur compounds. How these metabolites act depends greatly on the situation. Short chain fatty acids, mostly acetate, propionate, and butyrate are produced by the microbial fermentation of carbohydrates and other foods. Butyrate is most of all important for the colon because it offers the energy for colon cells, helps to keep gut barrier tight. They communicate with the body via receptors known as GPR 41 and GPR 43. These fatty acids can also upregulate enzymes that modify DNA and so influence cell behavior. So they have an impact on the gut cells and immune cells. I've seen studies in which SCFA signaling is linked to T-cell rapid growth, antimicrobial peptide release, mucus quality, and the regulation of inflammatory cytokines. But, their effects really depend on the amount of SCFAs present, the receptors on the cells, their location in the colon, and the way the host is eating. So WE think of SCFAs not as "anti-inflammatory chemicals" but as signaling substances (Tan et al., 2023). Tryptophan Depiction of the complex interplay between microbes and immune Tryptophan can be transformed by microbes in the gut into many different substances. Many of these substances activate the aryl hydrocarbon receptor, which is important for healthy gut barrier function and regulation of inflammatory signals. Scientists have examined variations in tryptophan metabolism in inflammatory bowel disease and other diseases that feature inflammation. Again the key factor is not the number of one type of bacteria but the community's ability to carry out chemical reactions.

TMAO has become popular in cardiovascular research. Certain bacteria in the gut make TMA from food sources that have choline, phosphatidylcholine, or carnitine. The TMA then goes to the liver and gets converted into TMAO. Human studies show people with high TMAO levels tend to have cardiovascular disease or metabolic issues. Animal studies show TMAO may influence fat metabolism, platelet function, blood vessel health, and inflammation it looks like TMAO levels depend on kidney function diet metabolic processing, and other factors. Microbial cell walls fragments and pattern are clues. LPS of Gram negatives may activate the Toll like receptor 4 when conditions are correct, although other signals,

like fragments flagellin DNA, activate other innate immune receptors. A normal sensibility of microbial signals is biological but excess exposure to normally non harmful doses, if intestinal bacterial barrier is compromised, may compound inflammatory condition. This concept of endotoxymia has been controversial, partly because of difficulty to define circulating LPS as well as to measure LPS in blood, which is a very sensitive measurement to technique used (Mohammad et al., 2021). Microbial metabolites also can alter the regulation of oxidation and reduction in the body. Some compounds can be helpful at levels but harmful when there is too much. Hydrogen sulfide is one example: it is normally produced by microbes and the body. May act as a signal. Still, when it is produced in high quantities under certain conditions it can also be a damaging signal to the gut lining. Phenols and indoles may also behave differently in the body based on the dose and how they are cleared.

GUT DYSBIOSIS IN CHRONIC DISEASES

Sometimes the term 'dysbiosis' is used to refer to alterations in the composition of microbes or in the function of the microbiota related to disease. This is useful but not precise. There is no healthy mix of microbes and no one type of dysbiosis that all long-term diseases share. A microbial feature can be good in one situation and not helpful or even bad in another. Dysbiosis linked to a disease can also happen because of medicines changes in eating habits, food changes in how food moves through the intestines being in the hospital or even because of inflammation itself. So dysbiosis should be seen as something that changes over time not a diagnosis. Inflammatory bowel disease is one of the examples. People with Crohns disease or ulcerative colitis often have fewer of bacteria that live without oxygen their ability to make short-chain fatty acids is different and some bacteria that can live with or without oxygen grow more under inflamed conditions. Inflammation changes the amount of oxygen and the nutrients in the gut making a place that can change the mix of microbes. This creates a cycle where inflammation changes the environment and changes in the environment can make inflammation worse. Some ways of eating have been studied to help with flares or keeping symptoms away. But no single diet works for everyone and the right diet must match the disease. Obesity is another area of study. Differences in the genes of microbes how they break things down how they handle bile acids and how the gut lets things through have been found in people with obesity and other problems with metabolism. Some experiments showed that microbes from animals could make germ-free animals fat, which supports that microbes play a role in animals. In people it's more complicated because diet, weight, exercise, medicines and money all change the microbes. The microbes might help with taking in energy. How the body makes inflammation but they are not the only reason for obesity. Keeping the balance of calories and how the body works is still very important (Lenska et al., 2023).

In type 2 diabetes changes in the mix of microbes and less of some pathways linked to short-chain fatty acids have been seen. The things microbes make can affect how the body controls sugar through the gut hormones bile acids, inflammation and how the body uses energy. Drugs used for diabetes can even change the microbes making it hard to know what is causing what. Metformin is an example of a drug that changes the mix of microbes in the gut and how bile acids work.

So the mix of microbes in a person with diabetes might partly show the treatment, not the disease. MASLD, which is linked with problems in how the body works is also connected to how the gut and liver talk to each other. The things microbes make and the things they break down go to the liver through the blood (Li et al., 2024). The liver makes bile acids that shape the mix of microbes in the gut. Things like leakage in the gut changes in how bile acids work microbes that make alcohol and things that cause inflammation have been studied as reasons for liver damage and fat in the liver. Weight, how the body uses insulin eating too much and not moving enough are still the main reasons for the disease. In all these cases there is a pattern that keeps happening: the strength of the gut the things microbes make the messages sent by the system and how the body uses energy are all connected. The microbes that change with disease are not always the thing to happen. To put it simply, it's a bit of both. How you eat and your body functions influence the microbes but in turn, the microbes alter the course of disease. Prevention should be for the things we know are dangerous and how the microbes can be altered as a form of assistance. This stops making the mistake of replacing proven treatments with thinking about the microbes (Hacioglu et al., 2026).

DIETARY STRATEGIES FOR RESTORING MICROBIAL BALANCE

broken down by the gut. Fiber recommendations change depending on the guidelines. What a person needs, but many adults could use more fiber from whole foods. Some fibers help make short-chain fatty acids while others help with moving waste through the gut. Foods like beans, vegetables, fruits, whole grains and foods with starch can help. For people who have gas or other gut issues the type and amount of fiber should be adjusted of just increasing it Diet is appealing as a way to change the microbiome because it can be done by lots of people it doesn't cost much. It can change the things that feed the microbes every day. However changing what you eat should be seen as making the environment better for the microbes of thinking of it as cleaning out or starting over with the gut (Zhang et al., 2024). The first idea is to have different plants. Plant foods like vegetables fruits beans grains, nuts, and seeds are all sources of various types of fiber and other plant chemicals. Different types of fiber keep different types of microbes alive and the plant chemicals give the microbes even more fuel choices. Starting out gradually may be easier on the body than consuming lots of fiber at once. The second idea is to have fiber that can be fast. The third idea is to focus on foods that are not heavily processed and to limit the amount of processed foods (Sharma et al., 2025). Processed foods are all different and the category alone doesn't show one clear problem. Still eating foods that are high in energy low in fiber and very refined can make the mix of food for microbes smaller and lead to eating too much. Changing some of those foods with lightly processed options is a good way to make the food better and help the gut. The fourth idea is to choose types of fat. Diets that use fats like those in nuts, seeds, fish and oils from plants can fit into ways of eating that're good for the heart (Safari et al., 2023). A lot of saturated fat and too many calories affect how the microbes live and how the body uses bile. A way to bring back a diet can be split into four parts: take out the main problems in the diet when needed add more plant foods make sure there is enough protein and vitamins

and check how the body is reacting and what happens. For long-term health issues this should be done with medical care (Slouha et al., 2023).

MICROBIOTA-TARGATED THERAPEUTIC APPROACHES

Microbiota therapies are changing. They are not causing changes in the environment anymore. Instead these therapies are getting more specific and accurate. They include things like changing what you eat making products and treatments that focus on the chemicals made by microbes. Probiotics are living things you take in to help your health. They can do this by stopping germs from making chemicals that affect the cells in your gut (Letchumanan et al., 2022). They can change the way your immune system works. The best proof that probiotics work is when they help treat illnesses with types. Probiotics don't always reduce swelling in the body. Also one type of Lactobacillus or Bifidobacterium is not the same as all the types in that group. Prebiotics are foods that have fiber and other things that help the microbes in your gut. They change the way your gut microbes act or what they do. The microbes themselves are not added. A prebiotic can work differently for people. For example the same prebiotic can act in ways depending on the mix of microbes in your gut. This shows how important it is to use treatments that work with your microbiome (Umirah et al., 2021).

Synbiotics use prebiotics along with microbes to help. In theory synbiotics look like they could be very useful. The right mix and the right condition to treat are very important. Some studies show that things like metabolism and inflammation get better. The results are not always clear. Postbiotics are parts of microbes that're not alive. They can be microbes, parts of microbes or chemicals they make (Xu et al., 2022). Benefits of postbiotics are that they are easy to make and last longer than microbes. Some important postbiotics include acids and other things that microbes make. A fecal microbiota transplant or FMT is when a group of microbes is moved from one person to another. FMT has been shown to work for a type of infection called c. Difficile. In the United States two products REBYOTA and VOWST have been approved to help lower the chance of this infection coming back in adults after treatment. Selected microbial consortia are groups of microbes that have jobs (Silva et al., 2022). Next-generation probiotics might use microbes that are chosen for their ability to change how the body works. These methods could be more reliable than products taken from donor stool. Viruses can be made to attack bacteria. They can stop some bacteria from working. They have problems like becoming resistant not working on all bacteria being hard to make tricky to use and causing problems. Bacteria can also be changed to sense signals in the gut and make things. Things, like safety, stability and rules stop these ideas from being used. Chemical-directed therapies operate on the chemicals that the microorganisms generate rather than the organisms themselves (Sanchez et al., 2022). Enzyme reduction and dietary changes may reduce the chemical levels within your body. Good chemicals can also be increased (see Fig. 2).

EVIDENCE GAPS AND TRANSLATIONAL CHALLENGES

Even with all of this progress many obstacles stand in the way for microbiome-related approaches to be normal ways of preventing and treating chronic inflammatory diseases. At

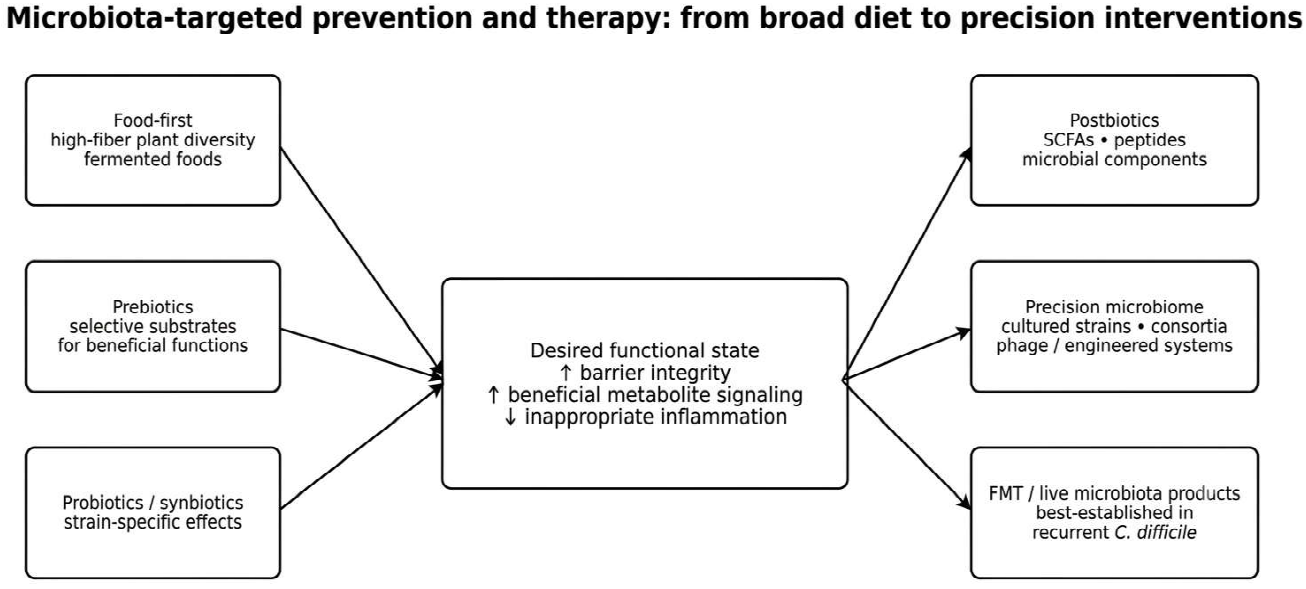

Fig. 2: Spectrum of microbiota-targeted strategies

first , the performance of the tests is different. The way the samples are collected and stored, the way the DNA is extracted and sequenced, the instruments used to analyze the data, and the databases used to compare the data affect the results (Koning et al., 2023). Stool samples can't detect all of the microbes on the inner gut lining, or what they are doing in specific parts of the gut. Secondly , it's not entirely known what a healthy microbiome is supposed to be. It's a term a study authors used inconsistently, and there are many ways to measure it, including microbial diversity, microbial count and products, whereas other measures like microbial gene content, microbial gene expression, and the host's response may be better (Jayachandran et al., 2023). The third link that is difficult to prove is that one thing causes another. Changes in microbes could be the cause of the disease, or they could be caused by the disease or its treatment. Data from observing people over time, well controlled experiments and lab models may help, but good human studies are still needed. Forth, People are different so treating them is hard. There are various factors like age sex genes, nutrition drugs workout, sleeping habits, riches, and childhood, which influence to the microbiome (Teo et al., 2024). A therapy may benefit one population but not any other. It's essential to contain lots of different people in research when it comes to medication, nutrition, and also various other therapies. Fifth, knowing what people eat is difficult. Food questionnaires and diaries are far from perfect. And, changing someone's diet during a study can alter their microbes. Combining reported diets with chemical markers of nutrition may help make research more reliable. Sixth, gains that clinics experience matter more than microbiome change. Giving people bacteria doesn't always mean fewer symptoms, less inflammation, fewer hospital visits, or even a more normal body response to food. Seventh, developing, and regulating microbiome products needs further effort (Biederman et al., 2024). The products have to confirm that the microbiome composition is sound and safe. Some probiotic substances require a careful screening of donors and the probiotic prebiotic

synbiotic and postbiotic products need to be defined and regulated. Eighth, Some microbiome test companies could give scientific not backed up recommendations or wrong health scores. Clear regulations are needed to differentiate tests that have been validated from those without proven effectiveness (Montrose et al., 2024). Ninth, testing long-term safety because changing the microbiome could have side effects that are unforeseen like on the immune system, microbes' resistance to medications, how medications work and microbial interactions. Finally choosing the best treatment for someone is a huge area of research. The initial condition of the microbes, what drugs they produce, a person's genes and what they eat, the drugs they take and how their body responds could all help identify who would benefit from which treatment (Limeketkai et al., 2024).

PUBLIC HEALTH IMPLICATIONS AND FUTURE DIRECTIONS

The public health importance of the microbiome partly comes from the chance to add microbiome?supporting habits to plans that stop chronic disease. The best ideas are ordinary. They match nutrition rules: eat many different plant foods get enough fiber pick foods that are not too processed keep a healthy weight eat the right amount of protein choose unsaturated fats cut down on refined foods and processed meats stop taking antibiotics unless needed move often sleep well and quit smoking (Nogal et al., 2021). A microbiome view gives reasons for these rules. Plant variety gives food for microbes; fiber is turned into short?chain fatty acids; polyphenols are changed by microbes; moving can change gut life and gut function;. Stopping needless antibiotics keeps the gut strong. These reasons may help explain why good diets already seem to help health. Public health messages should not say " Good bacteria versus bad bacteria" it should be microbiome is an ecosystem (Rauf et al., 2022). A microbe that helps in one setting can act differently when food, the body's defence or other microbes shift. Also just having microbes does not prove health. Messages should stress that the microbiome must work well and that the food must be good. Future studies should focus on long studies that include many different people and look at diet, microbiome, blood chemicals, body signals, medicines and health results. The microbiome changes over time many samples are needed (Cong et al., 2022). Using the rules for studies would make the data match better. Clinical studies should also look deeper. Of only asking if a probiotic works studies should say which strain, how much what the baseline microbiome is, what chemical changes are expected which body signals matter and what health goal they aim at. This can tell who will benefit and how a treatment works, whether by staying in the gut sending signals making chemicals or competing with microbes. Artificial intelligence and machine learning can help predict (Zhou et al., 2022). The models need lots of varied detailed data. If the model is a box doctors cannot understand the biology behind it. Combining DNA study of microbes with chemical study of the body and clinical pictures is more useful than looking at microbial numbers. The future may also use diet plans that fit the microbiome's real abilities. For example two people could get the fiber but one may make more short?chain fatty acids. One might need starch while the other may need foods rich in arabinoxylan or inulin. This idea is interesting. Should not be sold before trials show it works (Cintoni et al., 2023). Another big chance is stopping disease in people who're

at risk. People who are overweight have prediabetes have family history of heart or metabolic trouble or show inflammation may be in a window where diet and lifestyle can change the disease before damage is permanent.. Prevention programs must use proven risk signs, not unproven microbiome scores. In the end microbiome science should add to proven prevention not replace it. The best public health actions remain diet, moving, quitting smoking getting shots keeping infections in check staying at a healthy weight sleeping enough and using proven ways to treat high blood pressure, diabetes and high cholesterol. Microbiome?focused actions may become another layer of prevention as more evidence comes in (Adolph et al., 2022).

CONCLUSION

The gut microbiota diet axis is a system where the foods a person eats shape the gut microbiota, the immune system, energy metabolism and chronic inflammation. A diet that has a lot of fiber and includes different kinds of plant-based foods is important for making microbial metabolites like short-chain fatty acids, bile acid derivatives and tryptophan metabolites which are connected to keeping the body healthy. An unhealthy gut microbiota has been connected to a chance of getting some long-term diseases; however the proof that shows using microbiota focused treatments, like probiotics and microbiome-based scores is not strong. More research will need to be done to understand the role of each part of the microbiota and to create treatments that work for types of cells while making sure they are safe and work well. A healthy plant-based diet that fits with preferences and has a lot of fiber could affect many metabolic processes that help the body fight illness and lower the chance of getting long-term diseases (Oliver et al., 2024).

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