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ROLE OF THE GUT MICROBIOME IN HEALTH AND NUTRITION

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ABSTRACT

The way that polyphenols, polysaccharides, and gut bacteria interact to provide health benefits has emerged as a key area for focused dietary intervention techniques and fundamental biomedical research. Dietary polyphenols and polysaccharides both have biological properties that control bodily functions. Because to their intrinsic structure and physicochemical characteristics, single components have a low bioavailability and cannot produce their best benefits. By enhancing their functional characteristics, the compound structure created by the interaction of polyphenols and polysaccharides can more successfully promote health benefits and prevent diseases. The functions of polyphenols and polysaccharides in controlling glucose and lipid metabolism, their enhancement of these processes via the gut microbial pathway, and the ways in which they interact to control these processes are the main topics of this article. The regulating effects of plant polyphenols and polysaccharides on glucose and lipid metabolism have been validated by a significant quantity of early research. There are currently very few investigations on the mechanisms and combined effects of these two elements. The purpose of this review is to serve as a guide for future investigations into their interactions and modifications to their functional characteristics.

KEYWORDS: Gut microbiota, lipid metabolism, metabolic homeostasis, immune response, prebiotic & probiotic.

INTRODUCTION

The human body can be viewed as a complex ecosystem that hosts trillions of microorganisms, including bacteria, viruses, archaea, phage, fungi, and unicellular eukaryotes"[1] Both inside and outside the human body, microorganisms have preferred habitats. They can be found externally on the skin, eyes, nails, and around the mouth, nose, and urogenital areas. They may also get in through skin wounds. They reside in parts of the body such as the kidneys, bladder, gut, lungs, and vagina. One of nature's most intricate ecosystems is the gut microbiome. They contains huge numbers of bacteria living in the intestines and colon—about 100 to 1,000 billion microorganisms in just one gram of

intestinal content. Most of these bacteria (about 95%) are anaerobes, meaning they live without oxygen.[2] "This group of microorganisms shares a pool of genes called the metagenome, which contains DNA from many different species.

It's packed with enzymes that help produce a variety of chemicals, nutrients, and even some substances made by the host's body". The human body's microbiome is made up of microbial communities, their core genes, and the chemicals they share with the host."This relationship is a two-way street that benefits both the microbes and the host. This connection keeps vital bodily processes including inflammation, the immune system, the gut lining, and digestion stable when everything is in balance and healthy. Additionally, it may affect changes in energy levels, weight, gastrointestinal health issues, and even behaviour.[3,4] Cirrhosis, Parkinson's disease, hepatocellular carcinoma, alcoholic liver disease (ALD), depression, inflammatory bowel disease (IBD), metabolic dysfunction-associated steatotic liver disease (MASLD), immunological disorders, chronic kidney diseases (CKDs), and cardiovascular diseases (CVDs) have all been linked to additional effects of the gut microbiota.[5,6,7,8,9,10] This review will present an updated understanding of the role of the gut microbiome in health, including a partial list of diseases associated with changes in the density and diversity of the microbiome.[11]

DEFINITION OF GUT MICROBIOME

The gut microbiome refers to the vast and diverse population of microorganisms, including bacteria, viruses, fungus, protozoa, and archaea, that inhabit the human gastrointestinal system. The collective genetic material of these microbes, which have millions of genes much more than human genes is referred to as the metagenome.[12] Because it supports several physiological processes, including as immune system control, nutrition absorption and digestion, vitamin production, and defence against harmful pathogens, this complex ecosystem is essential to human health. The gut microbiota not only affects gut function locally, but it also produces a wide range of metabolites and signalling molecules that impact systemic processes as metabolism, inflammation, and even brain function through the gut-brain axis. The makeup and function of the gut microbiome are influenced by a wide range of factors, including age, genetics, environment, usage of drugs (including antibiotics), food, and overall health.[13,14] Maintaining homeostasis requires a normal microbiome, while dysbiosis—disruptions or imbalances—has been linked to a variety of ailments, including as obesity, metabolic disorders, neurological disorders, and inflammatory bowel diseases.[15]

Importance of gut microbiome in human health: Sustaining human health depends primarily on the gut microbiome, which is made up of trillions of microorganisms such as bacteria, viruses, fungi, and archaea. Since it affects many physiological systems, it is a major area of study for contemporary science and medicine.

Gut Microbiota Functions

- Impacts on Immune maturation as well as homeostasis.
- Proliferation of host cells.
- Vascularization.
- Signalling in the nervous system.
- Burden of pathogens.
- Endocrine functions of the stomach.
- Density of bones.
- Biogenesis of energy.

The process of biosynthesis

- Vitamins.
- Hormone steroids.
- Neurotransmitters.

Metabolism

Aromatic and branching-chain amino acids.

Dietary elements

Salts of bile.[16]

FUNCTIONS

The gut microbiota is necessary for the fermentation of dietary fiber, which includes oligosaccharides, polysaccharides, pectin, lignin, and resistant starches. Short-chain fatty acids (SCFAs), particularly propionate, butyrate, and acetate, are produced in greater quantities as a result. SCFA is mostly produced by the bacterial phyla Firmicutes and Bacteroidetes.[17,18] SCFAs, a crucial source of energy for host cells, are absorbed via the gastrointestinal tract (GIT). Controlling gene expression, apoptosis, chemotaxis, gluconeogenesis, and maybe regulating hunger or maintaining the integrity of the GIT gut are just a few of the many additional functions that SCFAs have. IgA is necessary for both warding off dangerous bacteria and tolerating gut microorganisms, and its synthesis by intestinal B-cells has been connected to acetate.

Trimethylamine (TMA) is created when gut bacteria break down lecithin, choline, and L-carnitine. Trimethylamine-N-oxide (TMAO), a chemical with proatherogenic qualities, is produced when TMA is oxidized in the liver. Most TMA is produced by the phyla Proteobacteria, Actinobacteria, and Firmicutes.[19] Important vitamins including vitamin K and other B-group vitamins, including folate, which is necessary for DNA synthesis and repair, are also produced by gut bacteria. Bifidobacteria are the primary producers of folate. Furthermore, primary bile acids can be changed by gut bacteria into secondary bile acids that are reabsorbed. The gut microbiome is also connected to polyphenol activation. After activation, polyphenols are absorbed in the portal system.

Research has indicated a connection between gut bacteria and the brain. The gut–brain axis is a two-way communication network that links the hypothalamus pituitary-adrenal system to the central, autonomic, and enteric nervous systems. This axis is believed to influence mood, behaviour, and several bodily functions, including satiety and digestion. Numerous neurological, endocrine, and immunological connections connect the gut and brain. The ENS and vagus nerve mediate the neuronal circuit. The Meissner's plexus in the intestinal submucosa and the Auerbach's plexus in the intestinal muscle layer make up the ENS. In addition to being linked by many nerve fibers, the ENS and gut-associated lymphoid tissue (GALT) have a strong relationship. Numerous substances, including as dopamine, acetylcholine, serotonin, and gamma-aminobutyric acid (GABA), are produced by gut bacteria in endocrine pathways. One aspect of the immune system's role in the gut–brain axis is the toxic effects of pro-inflammatory cytokines on the central nervous system (CNS). Lipopolysaccharide (LPS), a structural element of Gram-negative bacteria, has the ability to initiate the synthesis of pro-inflammatory cytokines.[20]

Important Functions of a Healthy Gut Microbiota in Preserving Human Health

In a healthy person, the gut microbiota maintains a symbiotic interaction with the gut mucosa and contributes significantly to metabolic, immunological, and gut protective activities. With a broad spectrum of metabolic capabilities and considerable functional flexibility, the gut microbiota is an organ unto itself. It sheds epithelial cells and obtains its nutrition from the host's food.

Kinds of dietary polyphenols found in different foods and the kinds of microbes that cause their breakdown[29]

Polyphenolic compounds	Classes involved	Foods containing polyphenols	Gut bacteria
Flavanols	Kaempferol, Quercetin, Myricetin	Onions, capers, apples, broccoli, grapes and plums	Bacteroides distasonis, Bacteroides uniformis, Enterococcus casseliflavus and Eubacterium ramulus
Flavanones	Hesperetin, Naringenin	Citrus fruits and tomatoes	Bifidobacterium infantis and Clostridium coccides
Flavan-3-ols	Catechin, Epicatechin, Gallocatechin	Greentea, cocoa, kola,banana, pomegranate	Bifidobacterium infantis and Clostridium coccides
Anthocyanidins	Cyanidin, Pelagonidin, Malvidin	Bilberries and all red, blue and purple fruits (especially berries)	Lactobacillus plantarum, L. casei, L. acidophilus and Bifidobacterium longum
Isoflavones	Daidzein, Geinstein, Formononentin	Soy, beans, lentils, chickpea (Fabaceae family)	Lactobacillus and Bifidobacterium
Flavones	Luteolin, Apigenin	Cereals, parsley, thyme, celery and citrus fruits	C.orbiscinden, Enterococcus avium
Tannins	Gallo tannins, Ellagitannins	Raseberries, cranberries, strawberries, walnuts, grapes and pomegranate	Butyrivibriosps
Lignins	Secoisolariciesinol, metaresinol, pinoresinol, larciresinol, isolarciresinol, syringiresinol	Flax seeds, cereals, strawberries, and apricots	Species of Bacteroides, Clostridium, Peptostreptococcus and Eubacterium
Chlorogenic acids	Caffeic acid, feruic acid	Peach, plums and coffee	E.coli, Bifidobacterium sps and L. gasseri

Function in nutrition and digestion

The Fermentation of Dietary Fiber

Gut microbes degrade indigestible food fibers to create short-chain fatty acids (SCFAs), including butyrate, propionate, and acetate. SCFAs, which release energy, regulate immunological responses, and maintain the integrity of the gut barrier, are absorbed by coloocytes.Producing Essential Nutrients.The microbiota produces vitamins such as riboflavin, biotin, folate, vitamin K, and vitamin B12.Cellular activity, metabolism, and overall health all depend on these vitamins.

Bile Acid and Xenobiotic Metabolism

Signalling cascades and lipid absorption are altered when gut bacteria convert primary bile acids into secondary bile acids.Additionally, they metabolise xenobiotics, or foreign substances, which affects the toxicity and effectiveness of medications.

Improving the Absorption of Minerals

Microbial activity and SCFAs aid in the absorption of iron, calcium, and magnesium.

Energy Harvest Modification

By controlling appetite, fat storage, and the transformation of food into usable energy, gut microbiota have an impact on energy balance.

The Development of the Immune System

Although it is not directly nutritional, microbial contact with the gut-associated lymphoid tissue (GALT) enhances immunological tolerance and food absorption.

Breakdown of complex nutrients

The human gastrointestinal tract contains a complex and dynamic microbial community called the gut microbiome, which has a major influence on host digestion, nutrition metabolism, and energy homeostasis. Even though the host contains endogenous enzymes that can hydrolyse basic nutrients in the upper gastrointestinal tract, a sizable amount of food—especially complex carbs, proteins, and fats—enters the colon largely undigested. The gut flora compensates for this limitation through a variety of enzymatic activities and is essential for nutrient salvage and metabolic integration.

Degradation of Complex Carbohydrates (Polysaccharides and Oligosaccharides) The primary microbially mediated digestive activity is the fermentation of complex polysaccharides, such as resistant starches, non-starch polysaccharides, and plant cell wall fibers (cellulose, hemicellulose, and pectin). These substrates are hydrolysed by microbial glycoside hydrolases, polysaccharide lyases, and other enzymes that are not encoded in the human DNA.

Production of Short-Chain Fatty Acids (SCFA): During fermentation, butyrate, propionate, and acetate are created and taken up by colonocytes. They serve a number of physiological purposes.Butyrate: The primary energy source for coloocytes it has anti-inflammatory and intestinal barrier-improving effects.Propionate: Through gut-brain axis signalling, it regulates appetite and hepatic gluconeogenesis. Acetate: Promotes lipid biosynthesis and microbial metabolic cross-feeding by acting systemically. One important degrader of resistant starch is Ruminococcusbromii.A significant butyrate producer with anti-inflammatory qualities is Faecali bacterium prausnitzii.

Protein Fermentation and Amino Acid Metabolism Short-chain fatty acids, ammonia, branched-chain fatty acids, and bioactive metabolites such as hydrogen sulfide, phenols, and indoles are produced by microbial proteolysis in the colon from proteinaceous substrates that cannot be broken down in the upper gastrointestinal track Functional Consequences: Some by-products, like p-cresol and H_2S, may contribute to colonic cytotoxicity, especially when consumed in high-protein, low-fiber diets, while others, like indole-3-propionic acid, have neuroprotective or anti-inflammatory qualities. Microbial amino acid metabolism links gut microbial activity to host neurophysiology by facilitating the synthesis of neuroactive chemicals (e.g., GABA and serotonin precursors). Proteolytic activity depend on the bacteria genera Bacteroides, Peptostreptococcus, and Clostridium spp.

Short-chain fatty acid production

SCFAs are produced by the gut bacteria fermenting carbohydrates and other nonabsorbable substances. The most common SCFAs are acetate (C2), propionate (C3), and butyrate (C4); they are present in a 3:1:1 ratio and make up 90–95% of all SCFAs produced in the colon.

The host may use the SCFAs produced as a source of nutrition, or downstream bacterial species may use them for cross-feeding.

Although colonocytes rely on butyrate (C4) for about 70% of their energy, it can also be absorbed by the lumen and enter peripheral circulation to support metabolic balance in general. It was widely reported that butyrate, one of the three SCFAs, also plays a role in ion transport, intestinal barrier function, cell growth, and immuneregulation.

Insoluble fibre supplementation may lead to increased butyrate production, which is closely linked to the makeup of a person's gut microbiome. The production of butyrate involves two primary processes: polysaccharide degradation and butyrate synthesis.

In order to create mono and di-oligosaccharides that secondary producers can further ferment into butyrate, primary degraders target specific polymer bonds. These two processes can differ between strains, as can the metabolites produced in them could provide one another with food through a complicated metabolic process. However, these reaction efficiencies need to be balanced in order for the polysaccharide degrader to consume the majority of the available carbon and energy.

Human gut produces butyrate primarily through the species Eubacterium rectale and Faecalibacteriumprausnitzii, while other species, like Ruminococcus and Bifdobacterium, are resistant to starch degradation. A deeper comprehension of individual supplementation regimens is necessary because the butyrate production efficiencies vary among individuals with different dietary, genetic, health, and geographic backgrounds.[21]

Production of minerals

The bioavailability and absorption of vital minerals like calcium, magnesium, iron, phosphorus, and zinc are greatly improved by the gut microbiota. Although these inorganic elements are not synthesised by microbes, they use a variety of methods to enhance their absorption in the gastrointestinal tract and release them from dietary sources.

Microbial Phytases Degrading Phytate

Phytic acid, found in a lot of plant-based foods, binds minerals and lowers their bioavailability. Certain gut bacteria produce phytase enzymes, which hydrolyze phytic acid and release bound minerals like calcium, magnesium, iron, and phosphorus, enhancing their absorption.

Short-chainfattyacid Manufacturing

The fermentation of dietary fibers by gut microorganisms produces SCFAs like acetate, propionate, and butyrate. By lowering the pH of the intestinal tract, these acids make minerals more soluble and make absorption easier. Furthermore, SCFAs increase intestinal surface area and stimulate the production of calcium-binding proteins, which facilitates mineral absorption even more. The intestinal absorptive surface area is increased by microbial metabolites, which also promote enterocyte proliferation and villus height. This morphological improvement increases mineral absorption efficiency.

Alteration in Mineral Transporter

The intestinal epithelium's mineral transporter expression can be increased by some probiotics. For example, Enterococcus fecium has been demonstrated to improve phosphorus absorption by upregulating the expression of sodium-dependent phosphate transporters.

Impact on the metabolism of iron

Iron absorption can be impacted by gut microbes in a number of ways. The production of siderophores by certain bacteria aids in the uptake of iron by binding and transporting it. Furthermore, through fermentation processes, lactic acid bacteria such as Lactobacillus plantarum can transform iron into forms that are easier to absorb.

Effect on the Bioavailability of Zinc

The processes by which the gut microbiota affects zinc absorption are intricate. Certain probiotic strains may improve zinc uptake, according to some research, while microbial activity may decrease zinc bioaccessibility by binding it in the colon, according to other studies.

Prebiotics and Symbiotics importance

Beneficial gut bacteria use prebiotics such as galactose oligosaccharides (GOS) and fructose oligosaccharides (FOS) as substrates to grow and function. By fermenting, these prebiotics boost the synthesis of SCFAs and enhance their absorption and mineral solubility. When probiotics and prebiotics are combined, symbiotics can have a synergistic effect on mineral bioavailability.[22]

Role of the Gut Microbiome in Health and Nutrition

Effects on the Immune System

The GI microbiome, which is made up of billions of bacteria, viruses, and fungi that live in the intestines, is essential to human health because it supports the immune system and nutrition. In order to produce short-chain fatty acids that promote gut health and lower inflammation, these microorganisms aid in the digestion of complex carbs and fibers that the body is unable to break down on its own.

They also synthesize essential vitamins like B and K, influencing nutrient absorption and metabolic health. The gut contains around 70% of immune cells, and the microbiota there works closely with the immune system to teach it to distinguish between dangerous and benign substances while controlling inflammation. Dysbiosis, or disturbances in this microbial balance, has been connected to a number of illnesses, such as infections, metabolic diseases, and autoimmune disorders.The Gut Microbiome's Function in Nutrition and Health. The composition of the gut microbiome is greatly influenced by a number of factors, including lifestyle choices, antibiotic use, food, and birth type. Microbial variety is promoted by diets high in fiber and fermented foods, whereas stress and processed meals can decrease good bacteria. Maintaining a balanced gut microbiome through healthy eating and lifestyle choices is essential for digestion, immunity, and overall well-being.[23]

Modulation of immune response

The gut microbiota regulates immune response by acting as a dynamic interface between the external environment and the body's internal defence systems. The gut, which contains trillions of microbes, acts as an important training ground for the immune system, with microbial exposure shaping immune cell growth and function beginning in infancy. In order to preserve immunological tolerance and avoid excessive inflammatory reactions, commensal bacteria encourage the growth of immune cells like regulatory T cells. Both innate and adaptive immunity are impacted by the cytokine and antimicrobial peptide production that these microbes regulate. The microbial fermentation of dietary fibers produces short-chain fatty acids (SCFAs), which are vital metabolites that improve immunological homeostasis by strengthening the intestinal barrier and having anti-inflammatory qualities. Additionally, the gut microbiota reduces the

risk of allergies, autoimmune diseases, and chronic inflammation by teaching immune cells to distinguish between dangerous bacteria and benign antigens.

An imbalance in gut microbial populations, known as dysbiosis, can interfere with immune regulation and cause aberrant immune responses, which can lead to inflammatory bowel disease, asthma, and even systemic conditions like type 1 diabetes and rheumatoid arthritis.Diet, antibiotic use, stress, and illnesses can all affect microbial diversity, with low-fiber diets and excessive drug exposure upsetting beneficial bacterial populations the most. Restoring microbial equilibrium through prebiotics, probiotics, and a fiber-rich diet can improve immune function and resilience against disease. As studies go on, it becomes more evident that keeping a balanced and healthy gut microbiota is crucial for both digestion and immune response regulation, underscoring its vital role in disease prevention and the creation of future immune-targeted treatments.[24,27]

Manufacturing of anti-inflammatory substances

The production of anti-inflammatory molecules, which are necessary for immunological homeostasis and defense against chronic inflammation and related diseases, is greatly aided by the gut microbiota. Short-chain fatty acids (SCFAs), primarily butyrate, propionate, and acetate, are among the most significant of these compounds. They are produced when intestinal bacteria break down refractory starches and dietary fibers. In addition to feeding colonocytes and fortifying the intestinal barrier, these SCFAs also modulate the immune system by controlling the activity of immune cells like regulatory T cells (Tregs), which are crucial for reducing inflammatory reactions.

Butyrate has powerful anti-inflammatory effects by inhibiting the activity of NF-κB a critical protein implicated in generating inflammation, and increasing the expression of anti-inflammatory cytokines like interleukin-10 (IL-10).

Beyond SCFAs, the microbiome also produces other beneficial metabolites such as **indole derivatives** from tryptophan metabolism, which activate receptors like the aryl hydrocarbon receptor (AhR) in immune cells, helping to maintain mucosal homeostasis and reduce gut inflammation. Furthermore, specific gut microorganisms help convert dietary polyphenols and flavonoids into bioactive forms with anti-inflammatory properties, which contributes to overall health advantages. These anti-inflammatory substances not only act locally in the stomach, but also travel through the bloodstream and influence inflammation in distant regions such as the brain, lungs, and joints. This systemic activity could help prevent or manage disorders such as inflammatory bowel disease (IBD), metabolic syndrome, type 2 diabetes, cardiovascular disease, and even neurodegenerative ailments like Alzheimer's disease. The therapeutic potential of these microbiota-derived compounds is increasingly recognised in medical research, with growing interest in using prebiotics (fiber-rich foods that nourish beneficial bacteria), probiotics (live beneficial microbes), and postbiotics (beneficial byproducts such as SCFAs) to support health. Clinical and experimental studies have shown that enhancing SCFA production through diet or supplementation can reduce markers of inflammation, improve insulin sensitivity, lower blood pressure, and strengthen gut barrier integrity. Furthermore, breakthroughs in microbiome-based therapeutics are investigating tailored probiotics capable of delivering specific anti-inflammatory chemicals directly to the gut. However, the effectiveness of these interventions is strongly reliant on the diversity and composition of an individual's microbiome, which can be altered by factors such as food, age, antibiotic use, and overall lifestyle. In summary, the gut microbiome functions as a biochemical factory, creating a diverse range of anti-inflammatory chemicals required for immunological homeostasis and protection against chronic illnesses. These substances not only

protect the gut lining against inflammatory assaults, but they also have a wide range of health advantages, making microbiome-targeted methods a promising path for both prevention and treatment.[25-27]

Barrier function against pathogens

Additionally, the gut microbiota preserves the barrier function of the gastrointestinal tract, serving as the first line of defence against invasive pathogens and fostering overall immunological protection. Mucus, epithelial cells, immunological components, and tight junction proteins make up the intricate, multilayered intestinal barrier, which keeps poisons and dangerous microbes out of the bloodstream. The barrier is strengthened by a diversified and healthy gut flora in a number of ways. Commensal (good) bacteria first prevent colonization by competing with pathogenic organisms for resources and attachment sites on the intestinal lining (a process known as colonization resistance).

Furthermore, these microorganisms encourage the creation of mucins (glycoproteins that comprise the mucus layer), which serve as a physical barrier between microbes and epithelial cells. They also increase the expression and integrity of tight junction proteins such as occludin and claudin, which seal the crevices between intestinal cells, preventing pathogens and antigens from entering the body. Beneficial microorganisms improve immune responses by increasing secretory IgA activity and encouraging the release of antimicrobial peptides including defensins and RegIIIγ, which target and neutralise pathogenic microbes. One of the key microbial products involved in strengthening barrier function is **butyrate**, a short-chain fatty acid produced by the fermentation of dietary fiber. Butyrate serves as the primary energy source for colonocytes and promotes anti-inflammatory responses, helping maintain a stable and resilient intestinal lining. An imbalance in the gut microbiota, known as dysbiosis, can undermine these defences and result in increased intestinal permeability, or "leaky gut," which lets toxins, pathogens, and undigested food particles enter the bloodstream. This causes inflammation and contributes to a number of illnesses, such as autoimmune conditions, allergies, and inflammatory bowel disease (IBD). The gut microbiome and barrier integrity can be weakened by a number of factors, including infections, stress, poor diet (particularly low fibre and rich in processed foods), and abuse of antibiotics. The intestinal barrier can be strengthened by re-establishing microbial balance through the ingestion of probiotics (good bacteria), prebiotics (fibres that nourish them), and postbiotics (their advantageous metabolic byproducts). For example, strains like *Lactobacillus* and *Bifidobacterium* are known to enhance mucin production and tight junction strength, while also reducing pathogen-induced damage. Maintaining a strong gut barrier not only prevents local infections and inflammation but also plays a critical role in protecting distant organs by reducing systemic inflammation and immune activation. As such, the gut microbiome is not only essential for digestive health but is also a key player in preserving the body's frontline defense system, making it a major target for strategies aiming to prevent and manage a wide spectrum of diseases linked to barrier dysfunction.[26,28]

Regulation of glucose and lipid metabolism: By controlling the digestion, absorption, storage, and secretion of dietary lipids, the microbiome can function as a regulator of lipid metabolism in the intestine. As a result, the gut microbiota can aid in increasing the quantity of energy derived from food; a host's energy balance may be impacted by the control of signalingpathways.When the intestinal epithelium's fasting-induced adipocyte protein factor (Fiaf) is suppressed by microbes, the circulating lipoprotein lipase (LPL), an inhibitor and essential protein for triglyceride metabolism, is decreased. Adipocytes' LPL activity is also elevated, and fat cells' capacity to store liver-derived triacylglycerols is improved. In white adipose tissue (WAT), intestinal microorganisms promote lipid accumulation while suppressing the

expression of the fiaf gene. In comparison to conventional mice, GF mice exhibited higher expression of WAT fiaf, an inhibitor of LPL action, in the small intestine.[81]

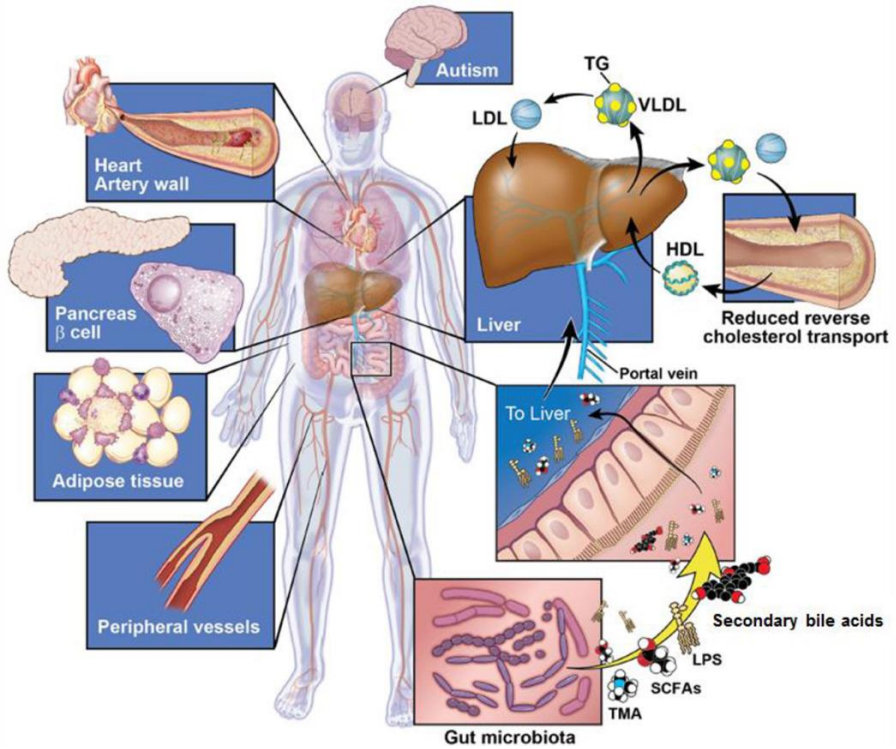

Figure No. 1: Schematic illustration of organ systems and tissues that can be affected by the gut microbiota.

Association with obesity and metabolic disorders: Numerous lines of evidence point to the involvement of altered gut bacteria composition or activity in the development of peripheral and coronary artery disease, obesity and associated metabolic abnormalities (such as type 2 diabetes), and even neurobehavioral disorders like autism.[30] Gut microorganisms may play a part in altering human lipid metabolism, as evidenced by recent findings of strong correlations between the proportions of several intestine bacterial taxa and lipid levels. The effects of gut microbes can be controlled by a variety of methods, such as the production of lipopolysaccharide (LPS) or other bioactive metabolites that function essentially as hormones since they can move throughout the body and act at different locations.[31] Two such instances that have been demonstrated to impact lipid levels and other metabolic characteristics are the generation of short chain fatty acids (SCFAs) by gut microbes and secondary bile acids. Research indicates that certain dietary nutrients can also be converted by gut bacteria into intermediate precursors (like trimethylamine), which the host can subsequently further metabolize to produce physiologically active products (like trimethylamine N-oxide). These products can then directly affect lipid metabolism and aid in the onset or progression of disease. Reverse cholesterol transport, hepatic cholesterol and sterol metabolism, intestinal lipid transport, bile acid composition and pool size, glucose and insulin metabolism, energy harvest/expenditure, and other biological systems can all be influenced by gut microbial metabolites.[32]

Modulation by Diet and Lifestyle: Diet and lifestyle play a crucial role in modulating the gut microbiome, influencing its composition, diversity, and function, which in turn impacts overall health. A balanced diet rich in fiber and prebiotic foods can promote a diverse and healthy gut microbiota, while unbalanced diets and lifestyle factors like stress can disrupt the microbiome and potentially lead to health issues.

Prebiotics: Dietary substrates known as prebiotics specifically encourage the growth and/or activity of "beneficial" bacteria that are naturally present in the colon. Since its initial publication in 1995 by Gibson and Roberfroid,[33] the idea has undergone multiple iterations and revisions. According to the current definition, prebiotics are "selectively fermented ingredients that result in specific changes, in the composition and/or activity in the GI microbiota, thus conferring benefit(s) upon host health".[35]

Probiotics: Live microorganisms which when administered in adequate amounts confer a health benefit on the host" is how probiotics are defined. Probiotics are continuously used to preserve intestinal health in humans by enhancing the equilibrium of the internal microbiota.[38] Probiotics have garnered public attention in recent years due to their ability to support intestinal health in humans, and it has also been suggested that prebiotics be added to probiotics as synbiotics.

As a result, the probiotics market has expanded quickly worldwide, making probiotics a meal as well as a supplement.[39] Remarkably, probiotics have been demonstrated to enhance the management and prognosis of such illnesses.[41] Further research is required to determine how probiotics affect the human gut microbiota after intake, even though the genetic. It has been proposed that taking probiotics can improve immunity and general health.

It is now known that metabolic illnesses like obesity, diabetes, and inflammatory bowel disease may be influenced by t he human gut microbiota.[40] It's interesting to note that probiotics have been demonstrated the idea, purpose, and connection between gut microbiome-associated disorders and probiotics are briefly summarized in this article.[42]

Dietary fiber: Dietary fiber is a type of carbohydrate found in plant foods that have dominated human diets for millions of years, including whole grains, vegetables, fruit, and legumes. Over 100 g of different digestible and indigestible dietary fiber from plants were consumed daily by the ancient people from the Paleolithic era, when hunter-gatherers mostly devoured fruit and wild grains, to the agricultural era, when crops were first planted.[43,44] Through the digestion of lactose and cellulose, the breakdown of toxins, and the biosynthesis of vitamins, signal molecules, and other necessary compounds, the human gut microbiota has been providing crucial nutritional services for millions of years.[45]

The gut microbiota drives the colon's fermentation of fiber, and the intestinal flora's nutritional substrate can alter the microbiome's variety and structure. Regarding the connection between dietary fiber consumption and the beta diversity of gut microbiota, the findings are consistent. It has been repeatedly observed that the microbial community structure of people following fiber-rich diets (vegetarian, Mediterranean, or rural/unindustrialized diets) differs significantly from that of those in developed regions.[46,47,48]

A recent study of a Chinese adult cohort found a substantial relationship between changes in the gut microbiome's beta diversity and the amount of vegetables and whole grains consumed in a regular diet [49]. The majority of intervention trials that administered high-fiber meals consistently showed similar changes in bacterial composition.[50,51,52,53,54,55,56]

Dietary fibers are categorized based on a number of factors, such as their main source of nutrition, chemical makeup, viscosity and water solubility, and fermentability. Dietary fibers can be classified as either insoluble and soluble forms or as polysaccharides (resistant starch [RS], resistant oligosaccharides [ROs], and non-starch polysaccharides [NSPs]).[57]

Polyphenols: The most prevalent antioxidants in our daily lives are most likely polyphenols, which are defined as secondary metabolites of plants. Fruits, vegetables, cereals, green tea, coffee, and other foods are the primary dietary sources of these chemicals.[58] An adult's daily intake of dietary polyphenols can reach up to 1 g, which is roughly ten times higher than their intake of vitamin C and even 100 times higher than their intake of vitamin E and carotenoids.[59]

The health benefits of polyphenols, such as their anti-inflammatory, antibacterial, anti-adipogenic, antioxidant, and neuro-protective properties, have been the subject of an enormous amount of research in recent decades.[60,61]

According to reports, the majority of dietary polyphenol intake is not absorbed in the small intestine, but the gut bacteria may substantially metabolize the unabsorbed portions in the large intestine. As a result, gut bacteria are crucial for the biotransformation and conversion of the original polyphenolic structures into easily absorbed, low-molecular-weight metabolites that support host health. However, little is now understood about the potential relationship between gut bacteria, host health, and dietary polyphenols.[62]

Effects of antibiotics and other drugs: The human gut microbiome, which is composed of billions of microbes, forms a complex ecology that is vital to maintaining h ost health. Antibiotics have a major impact on the delicate balance of the gut microbiota, even though they are necessary for treating bacterial infections.[63]

Effects of antibiotics during pregnancy and lactation: Pregnant women are frequently prescribed β-lactam antibacterials, sulphonamides/trimethoprim, and macrolides/lincosamides/streptogramins to treat infections such respiratory tract infections, urinary tract infections, and bacterial vaginosis.[64] Intrapartum antibiotic prophylaxis (IAP), which aims to reduce infection rates and halt the spread of Group B streptococcus, also uses antibiotics during labor. The development of an infant's microbiota may be impacted by IAP's potential to alter the diversity of microbes in the infant's gut.[65]

Antibiotic impact on neonates and infants: Antibiotics are frequently administered to newborns, especially premature infants, because of their increased vulnerability to infections. Amoxicillin, co-amoxiclav, benzylpenicillin, cephalosporins, gentamicin, vancomycin, clindamycin, and azithromycin are examples of common antibiotics However, antibiotic treatment significantly alters bacterial populations, including Bifidobacterium, and reduces the diversity of the infant's gut microbiota. Long-term consequences of antibiotic exposure during infancy include changes in metabolic processes, microbial composition, and the development of allergies, asthma, and obesity.[66]

Impact on adults: Antibiotic use in adults will eventually have long-term effects on the microbiological makeup of a healthy state. Antibiotic-resistant bacteria grew and the microbial composition altered for up to 12 weeks after therapy ended, according to studies on healthy persons treated with cefprozil, ciprofloxacin, and amoxicillin. For two years following treatment, the bacterial community was significantly disrupted by antibiotics with short half-lives, such as Clindamycin.[67]

Differences in antibiotic types, such as bacteriostatic and bactericidal, also have an impact on gut microbiota. Increased genes that produce lipopolysaccharides and the growth of Gram-negative bacteria have been linked to bacteriostatic medications. However, cidal drugs have been associated with a rise in Gram-positive bacteria and an overrepresentation of genes involved in endospore production. Even when given systemically, antibiotics can still affect the stomach.

Antibiotics can increase the number of oral resistant strains, raise minimal inhibitory doses, and eradicate non-pathogenic strains, all of which can lead to systemic infections and inflammation when used in dental procedures.[68-69]

CONCLUSION

An overview of the importance of the gut microbiota in nutrition and health: The bacterial community in our stomachs was mainly disregarded for a long time. However, new data makes it abundantly evident that our microbial symbionts are essential for preserving normal metabolic balance in a number of ways. These findings have wide-ranging consequences for understanding pathophysiological processes mediated by bacteria that modify lipid metabolism and other associated metabolic characteristics.

Prospective avenues for investigation and implementation: Clinically speaking, this recently identified endocrine organ system can be targeted for therapeutic benefit or the prevention of risk factors and cardiometabolic illnesses. Though recent rapid advancements in gut microbiome studies illustrate the possibility and promise of targeting intestinal microorganisms for therapeutic advantage, the ability to modify the gut microbiome for better health and illness prevention is still in its early stages of development.

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