

Commentary

Why We Should Speak of the Microbiota–Gut–Brain–Mind Axis: Beyond Reductionisms

Massimo Agnoletti¹

1. Humanitas University, Rozzano, Italy

Recent discoveries regarding the interactions between the microbiota, intestinal barrier, and nervous system have popularized the concept of the microbiota–gut–brain axis. However, this formulation still risks underestimating the bidirectional causal role played by psychological and sociocultural processes in human health and disease. This paper proposes extending the traditional microbiota–gut–brain axis into a microbiota–gut–brain–mind (M.G.B.M.) axis, to better represent the integrated bio-psycho-social nature of the human holobiont and to avoid reductionistic interpretations that equate psychological phenomena exclusively with neural activity.

The M.G.B.M. axis further reinforces the need for a PNEI-oriented interpretation of the microbiota–gut–brain–mind axis, highlighting the reciprocal interactions among psychological states, neural regulation, endocrine responses, immune activity, intestinal permeability, and microbial ecology. The proposed framework may provide a more comprehensive theoretical basis for future microbiota research and for the development of integrative clinical approaches to health and disease.

Correspondence: papers@team.qeios.com — Qeios will forward to the authors

Over the past two decades, research on the microbiota–gut–brain axis has profoundly transformed our understanding of the biological mechanisms underlying human health and disease.

The microbiota can be defined as the collection of microbial communities that stably or transiently colonize a given organism, interacting both with one another and with the host cells through complex ecological, metabolic, immunological, and neuroendocrine processes^{[1][2][3][4][5][6][7][8][9][10]}.

A growing body of evidence has demonstrated that bidirectional communication between the intestinal microbiota, the gastrointestinal tract, the immune system, the endocrine system, and the nervous system

plays a crucial role in regulating physiological and psychological processes.

These discoveries have contributed to the emergence of a more integrated perspective of health, moving beyond reductionist models that interpret psychological phenomena solely through neural activity or isolated biological mechanisms.

Despite these advances, the traditional microbiota–gut–brain (M.G.B.) axis remains primarily focused on biological interactions and does not fully capture the complexity of human functioning as a holobiont biopsychosocial phenomenon^[11].

Psychological processes, individual meaning-making, behavioral patterns, social relationships, and environmental influences are increasingly recognized as active determinants of physiological regulation.

Likewise, biological processes occurring within the gut ecosystem can influence cognition, emotion, motivation, and behavior through multiple bottom-up pathways. Consequently, a more comprehensive conceptual framework is required to integrate these bidirectional interactions within a unified model of human health.

This paper proposes the adoption of the Microbiota–Gut–Brain–Mind (M.G.B.M.) axis as an evolution of the traditional M.G.B. framework. The inclusion of the construct of *mind* is intended to acknowledge the scientific relevance of psychological and sociocultural processes as integral components of human regulation rather than as secondary deterministic outcomes of neural functioning.

Within this conceptual framework, we propose the inclusion of the term “mind” when referring to the human context, as mental phenomena cannot be fully reduced to neural processes alone.

For example, the placebo effect is a clear demonstration of the causal power of positive expectations, and therefore of psychological and social factors, over biological dynamics^[12].

Mind is the domain of subjective experience and meaning attribution through which the human bio-psycho-social holobiont interprets reality and regulates behavior across biological, psychological, and social levels of organization.

The proposed Microbiota–Gut–Brain–Mind (M.G.B.M.) axis is conceptually embedded within the broader Bio-Psycho-Social Holobiont Model of Health^[11].

According to this framework, human beings should not be understood as isolated biological organisms but rather as bio-psycho-social holobionts, whose functioning is shaped by the continuous interactions

among human biological systems, microbial ecosystems, psychological processes, and sociocultural environments.

Within this perspective, health cannot be adequately explained through purely biological mechanisms, nor through exclusively psychological or social determinants.

Instead, it reflects the degree of dynamic coherence achieved among the multiple levels of organization that constitute the human holobiont.

The M.G.B.M. axis represents one of the principal regulatory pathways through which these interactions occur, linking microbial activity, gastrointestinal physiology, neural regulation, subjective experience, and social adaptation.

Consequently, the inclusion of the concept of mind within the traditional microbiota–gut–brain framework is consistent with a holobiont bio–psycho–social conception of health, in which biological, psychological, and social dimensions are viewed as reciprocally interacting components of a single integrated system.

Furthermore, the M.G.B.M. axis reinforces the relevance of a psychoneuroendocrinoimmunological (PNEI) approach by emphasizing the reciprocal relationships among psychological states, neural regulation, endocrine activity, immune responses, intestinal permeability, and microbiota ecology^[13]. By integrating these dimensions into a single theoretical framework, the proposed model aims to provide a more comprehensive understanding of health and disease and to support the development of more effective interdisciplinary research and clinical interventions.

The clarification of using the term M.G.B.M. axis instead of M.G.B. axis is not merely terminological or philosophical in nature. Rather, it carries important conceptual implications that influence both the interpretation of the rapidly expanding microbiota literature and the development of clinical and preventive interventions aimed at promoting human health. The way in which the components of this axis are conceptualized inevitably shapes the questions researchers ask, the explanatory models they adopt, and the therapeutic strategies they design.

Before proceeding further, it is important to emphasize that any discussion of human health must be situated within a holobiont bio–psycho–social framework in order to avoid reductionist interpretations of health and well-being^{[14][15][11][16]}.

Human beings cannot be adequately understood through biological variables alone, as psychological processes and social contexts actively participate in shaping human and extra-human physiological

regulation, behavior, adaptation, and health outcomes^[17].

Consequently, the microbiota–gut–brain–mind axis should be interpreted within a broader bio-psycho-social perspective that acknowledges the human and extra-human dynamic interactions among biological, psychological, and social dimensions of human functioning^[11].

The complexity of psychological phenomena, as well as that of sociocultural systems, cannot be fully reduced to the neural processes. Although the underlying level constitutes a necessary (*sine qua non*) condition for its existence, it does not exhaustively explain its properties, and therefore the higher level cannot be fully reduced to it.

Although neural activity constitutes a *sine qua non* condition for the existence of mental phenomena, it is not sufficient to account for the full range of dynamics that characterize psychological functioning.

This perspective is consistent with the view advanced by numerous scientists and philosophers who have emphasized the relative autonomy of different levels of complexity^{[18][19][20][21][22][23][24]}. According to this framework, each level of organization is grounded in lower-level processes and remains dependent upon them for its existence, yet possesses properties, principles, and dynamics that cannot be fully derived from or reduced to those underlying processes alone.

Consequently, the relationship between different levels of complexity should be understood as one of mutual interaction and reciprocal influence rather than simple hierarchical unidirectional causation. Higher-order phenomena are grounded in lower-order structures, but they also exhibit peculiar characteristics that require their own level of description and analysis. As a result, a comprehensive understanding of biological, psychological, and sociocultural processes requires explanatory models capable of integrating multiple levels of organization without reducing one level entirely to another.

Although mental activity is undeniably associated with neural dynamics, mental phenomena cannot be entirely derived from, or reduced to, the physicochemical causal processes occurring within the brain.

Cognitive representations, intentionality, meaning attribution, decision-making, and symbolic communication are connected to neural activity but cannot be completely explained by reference to neural mechanisms alone.

Consequently, any attempt to understand human functioning exclusively through neural or molecular explanations risks neglecting the psychological dimensions that are indispensable for a comprehensive account of human behavior and health.

A review of the scientific literature on the *microbiota–gut–brain axis* reveals that the concept of stress — more precisely, *negative psychosocial stress*— is one of the most frequently cited factors influencing both gut microbiota composition and intestinal permeability. The pervasive use of this concept within microbiota research often creates the implicit impression that stress can be fully explained as a neurophysiological and biochemical phenomenon originating within the central nervous system.

This implicit assumption reflects the persistence of a biomedical paradigm that, despite important scientific advances, remains largely influenced by a reductionist view of human functioning.

Rather than adopting a fully integrated bio-psycho-social perspective, many interpretations continue to rely, either explicitly or implicitly, on a framework in which mental and social phenomena are ultimately reduced to their underlying biological substrates.

Therefore, psychological and social processes are frequently treated as secondary manifestations of neural activity rather than as explanatory levels possessing their own causal relevance.

The limitations of this perspective become evident when attempting to explain how phenomena such as psychological stress, emotions, beliefs, expectations, linguistic interactions, social relationships, and cultural meanings influence biological regulation.

These phenomena cannot be adequately described solely in physicochemical terms, yet abundant evidence indicates that they exert measurable effects on neuroendocrine, immune, gastrointestinal, and microbial processes.

Consequently, an exclusively reductionist interpretation risks obscuring the mechanisms through which higher-order psychological and social processes become biologically embedded and ultimately shape physiological functioning.

Recognizing these interactions requires a broader conceptual framework capable of integrating human and extra-human biological, psychological, and social levels of analysis^[11].

Such an approach does not deny the biological basis of human experience but rather acknowledges that causality in complex living systems operates across multiple levels of organization, each contributing to the emergence and regulation of health and disease.

The contemporary scientific literature has provided substantial evidence supporting the integrated and holistic nature of human beings, highlighting the dynamic interplay among biological, psychological, and social dimensions of health and functioning^{[14][25][15][26][27][28][29][30]}.

These developments have revealed that health and disease cannot be adequately understood solely through genetic or physiological determinants but must also be viewed as the outcome of continuous interactions among environmental, human and extra-human bio-psycho-social factors.

In light of these considerations, the continued use of the term *microbiota–gut–brain axis* appears increasingly limited when applied to the human context.

Although this formulation has been highly valuable in advancing scientific understanding, it risks underestimating the distinctive contribution of psychological and social processes, which exert measurable effects on neural regulation, gastrointestinal functioning, immune activity, and microbiota composition.

Consequently, a broader conceptual framework such as the microbiota–gut–brain–mind axis may provide a more comprehensive representation of the multidirectional interactions that characterize human health and adaptation^[31].

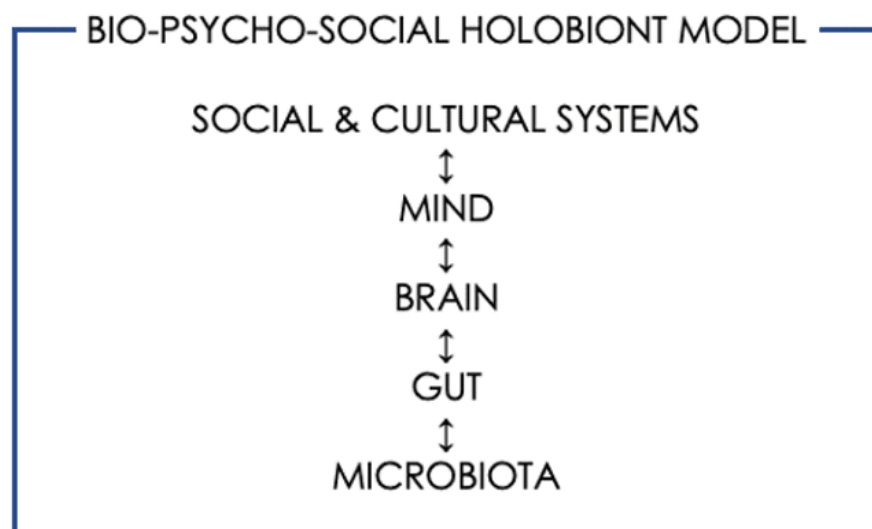


Figure 1.

One particularly important consideration concerns the role of psychosocial stress, which has become a pervasive feature of contemporary societies and represents a major determinant of human health and well-being.

Failing to adequately recognize this dimension, and instead reducing it exclusively to its neural correlates, risks overlooking one of the defining characteristics of the human condition.

Human beings do not merely respond to objective environmental stimuli; rather, they continuously interpret, evaluate, and assign meaning to their experiences, and these processes substantially influence physiological regulation.

A notable characteristic of psychosocial stress is its inherently subjective nature.

The same stressor may be perceived and experienced in profoundly different ways by different individuals, resulting in markedly distinct neurophysiological, endocrine, immunological, and behavioral responses. This variability poses a challenge to conceptualizations of the traditional microbiota–gut–brain (M.G.B.) axis, within which subjective experience has no explicit theoretical status and is typically subsumed under neural activity alone.

To overcome this conceptual limitation, we propose extending the traditional framework by introducing a fourth component—mind—thereby adopting the concept of the microbiota–gut–brain–mind (M.G.B.M.) axis.

The inclusion of mind acknowledges the existence of psychological processes that both influence and are influenced by biological systems operating throughout the axis.

From a top-down perspective, psychological states such as anxiety, depression, chronic worry, or perceived stress can contribute to changes in neural activation patterns, endocrine responses, immune functioning, intestinal permeability, gastrointestinal physiology, and microbiota composition.

Conversely, from a bottom-up perspective, alterations in gut physiology, microbial ecology, immune signaling, and inflammatory processes can influence cognition, emotional regulation, motivation, and subjective experience.

For example, accumulating evidence suggests that intestinal inflammation and microbiota-related dysregulation may contribute to the emergence of anxiety and depressive symptoms through complex neuroimmune and neuroendocrine pathways.

Within this framework, the concept of mind serves not as an alternative to biological explanations but as a complementary level of analysis that allows subjective experience to be incorporated into a more comprehensive and scientifically coherent model of human health. Such an approach is particularly consistent with a bio-psycho-social understanding of the human organism and provides a broader

theoretical foundation for interpreting the multidirectional interactions that characterize health and disease.

The inclusion of the psychological dimension within the traditional microbiota–gut–brain framework enables the investigation not only of biological processes but also of experiential and sociocultural dynamics.

This shift expands the focus from a purely objective description of human functioning toward a more comprehensive perspective that acknowledges the subjective, phenomenological, and highly heterogeneous nature of human experience.

Within the context of the human person conceived as a holobiont bio-psycho-social unit, intentionality, decision-making, and voluntary behavior are more adequately described at the level of mind than at the level of neural activity alone.

The importance of adopting a microbiota–gut–brain–mind perspective becomes evident when considering how psychological and biological processes continuously influence one another.

For example, receiving the traumatic news that a loved one has died in a car accident can rapidly trigger profound changes in neural activity, endocrine regulation, immune function, and cellular processes, with potential downstream effects on the composition and functioning of the gut microbiota.

Recent findings by Chang and colleagues^[17] identified an important mechanism through which psychological stress can induce both intestinal dysbiosis and systemic inflammation through vagal modulation of Brunner's glands, providing further evidence for the causal influence of psychological processes on gut physiology and microbiota regulation.

Only by distinguishing between mental and neural levels of analysis can we understand the causal role of the anxious experience on brain dynamics and therefore on the vagus nerve, the intestines, and the microbiota.

Conversely, growing evidence suggests that certain forms of anxiety and depression may arise, at least in part, from intestinal inflammatory processes and alterations of the gut ecosystem, even in the absence of a primarily psychological etiology^[32].

Only by distinguishing between mental and neural levels of analysis can we understand how brain mechanisms designed to prevent neuroinflammation may contribute to the emergence of mental states such as anxiety and depression.

Recognizing the multidirectional nature of these interactions has important implications for both research and clinical practice.

Professionals involved in the promotion of health should ideally possess a more integrative understanding of human functioning, encompassing biological, psychological, social, neural, metabolic, and immunological dimensions.

Such an approach may help reduce the risk of iatrogenic errors resulting from excessively narrow explanatory models.

For instance, clinicians may unsuccessfully search for traumatic or psychosocial causes underlying specific forms of anxiety or depression when inflammatory or microbiota-related mechanisms represent significant contributing factors.

Conversely, healthcare professionals may underestimate the role of psychological experience, stress appraisal, and social context in shaping physiological regulation and disease progression.

From this perspective, interventions that focus exclusively on a single level of analysis appear increasingly inadequate.

Attempting to treat anxiety disorders solely through psychological means while assuming an exclusively psychological etiology or addressing gastrointestinal conditions such as peptic ulcer disease or irritable bowel syndrome exclusively through pharmacological or physiological interventions while neglecting psychosocial influences, risks overlooking critical determinants of health. Such reductionist approaches may not only limit therapeutic effectiveness but may also compromise the overall well-being of the individual.

The complexity of human health therefore requires a framework capable of integrating the biological, psychological, and social dimensions of human existence.

Acknowledging the central role of psychosocial factors alongside physiological and microbiota processes is essential for avoiding further reductionist interpretations and for promoting a more comprehensive understanding of health, disease, and clinical care within the context of the human bio-psycho-social holobiont.

A key advantage of adopting the Microbiota–Gut–Brain–Mind (M.G.B.M.) framework lies in its ability to address several conceptual limitations of the traditional Microbiota–Gut–Brain (M.G.B.) model.

While the M.G.B. axis has been highly successful in describing the biological interactions among microbial, gastrointestinal, neural, endocrine, and immune processes, it does not explicitly account for

the role of subjective experience, meaning attribution, intentionality, stress appraisal, and other psychological and sociocultural factors that influence human physiology and behavior.

By incorporating the concept of mind, the M.G.B.M. framework provides a more comprehensive account of how subjective and social experiences become biologically embedded and reciprocally interact with microbial and physiological processes.

The M.G.B.M. framework may offer a more comprehensive epistemological account of human functioning than the traditional M.G.B. formulation. Moreover, it may reduce the risk of both dualistic and reductionistic interpretations of the mind–body relationship.

Furthermore, this perspective generates novel research hypotheses concerning the mechanisms through which beliefs, expectations, social relationships, cultural meanings, and psychological interventions may influence microbiota composition, intestinal permeability, immune regulation, and health outcomes.

Such hypotheses may contribute to the development of more integrative and multidimensional models of human health within the broader bio–psycho–social holobiont framework.

The adoption of the Microbiota–Gut–Brain–Mind (M.G.B.M.) framework may open new avenues for interdisciplinary research by providing a more comprehensive conceptual model of human health and disease.

Future investigations could examine how subjective experience, meaning attribution, stress appraisal, beliefs, and sociocultural factors interact with neural, endocrine, immune, gastrointestinal, and microbial processes across multiple levels of organization.

Such an approach may facilitate the development of more sophisticated experimental designs capable of investigating both top–down and bottom–up pathways within the human bio–psycho–social holobiont.

Furthermore, the M.G.B.M. framework may contribute to overcoming persistent reductionist tendencies in microbiota research by encouraging the integration of biological, psychological, and social variables within a single explanatory model.

Ultimately, this perspective may support the emergence of more effective preventive, diagnostic, and therapeutic strategies that better reflect the multidimensional nature of human health and adaptation.

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