Anthropology of microbes

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We describe the need to further integrate the fields of human microbial ecology and anthropology and outline some of the potential goals and benefits of this collaborative work.

food | human microbiome | integration of natural and social sciences | subfields of anthropology

Issues of global health and the dynamics of human relationships connect the concerns of biological and social scientists. The development of new methods for understanding the microbial world provides an opportunity to reevaluate the way we view our human biological and cultural diversity. We believe that negotiating the distinct and sometimes divergent methods, vocabularies, and conceptual categories that exist between anthropology and human microbial ecology is a timely and worthwhile challenge. These considerations frame our call for these two fields to join together to cosponsor studies of the "anthropology of microbes."

Analyses of the microbial communities that live on and in our human bodies have progressed at a spectacular rate over the past 5 years. This progress is due in large part to the application of "metagenomic" methods: a series of experimental and computational approaches that allow a microbial community's composition to be defined by DNA sequencing without having to culture its members. This work has yielded catalogs of microbial species, many previously unknown and belonging to all three domains of life, as well as lists of millions of microbial genes collectively known as our "microbiome." The results of these studies have provided insights about the intra- and interpersonal variation of these species and gene assemblages as a function of body habitat, age, physiologic status, and family relationships. One goal of these efforts is to understand the genomic and metabolic foundations of the symbiosis that exists between microbes and humans, and to gain a more thorough comprehension of how this coexistence contributes to our health, biological differences, and predispositions to various diseases.

Studies of the human microbiome are helping us to evolve our sense of personal identity. We are seeing ourselves with increasing definition as a "supraorganism" composed of microbial and human cells, as well as human and microbial genes, with the number of microbial components vastly exceeding the number of human (*Homo sapiens*) components (1). This expanded understanding emphasizes our uniqueness: Even though our *H. sapiens* genomes are >99% identical, and we all have approximately the same human cellular composition, we differ from one another substantially in terms of the microbial species and microbial genes that we harbor, even in the case of monozygotic twins (2–5). Our microbial communities provide snapshots of those with whom we have lived, the diversity of our daily habits, as well as the impact of our changing lifestyles. For example, our guts are homes to our largest collection of microbes, where the number of microbial cells is measured in terms of tens of trillions. Gut microbial communities in humans are shared among family members and underscore the long-lasting impact of our interpersonal relationships. Common as well as distinct features in gut communities are being documented among populations representing varied "cultural traditions" and geographical locations (6–8). The breathtaking rate of change in food availability and preparation methods, the expansive movement of human populations, the rapid proliferation of technology, and the ubiquitous use of antibiotics emphasize the importance of studying the microbiological heritage of humans, just as we study our genetic, linguistic, and cultural heritages (9, 10).

Anthropology attempts to make up a holistic science of humanity by studying the material history of humans and our biological diversity, combined with analyses of the variability of cultures and cultural practices. Fundamental questions of relatedness, selfhood, and social transformation have long been, and still remain, central to anthropological study. Incorporating anthropological analyses into the design and interpretation of studies of human microbial ecology can provide scientists with crucial information about the specific social, dietary, and political–economic factors that shape human microbiomes. Investigating microbes from an ethnographic perspective should provide anthropologists with new perspectives about how human biology and social practices are inextricable. Reshaping our understanding of individuals as microbiological entities will allow anthropologists to further develop the concept of the "biological-social self." Human microbiome projects can contribute to the pervasive debate about the relationship between anthropology and ontology (see refs. 11–13).

Many subfields of anthropology, outlined in Fig. 1, are positioned to be, or already are invested cosponsors of work on the anthropology of microbes. From its beginning as a subfield in the early 1960s, medical anthropology has emphasized empirical research and collaboration with health practitioners and medical scientists to link social analysis to the development of medical knowledge (14–16). Principally concerned with the interaction of human populations with their environments, as well as the impact of political economy and history on the transmission and treatment of disease, much of the empirical research in medical anthropology is motivated by a desire to obtain a more comprehensive view of health and illness, the dynamics of context-specific health transitions, and illness beliefs or practices. Many medical anthropologists have a longstanding interest in how microbes affect human social, political, and economic life, with the primary focus being on infectious diseases [e.g., studying how the rise of antibiotic resistance affects transmission and treatment of tuberculosis (17, 18)]. The anthropology of microbes can expand ethnographic analyses to include investigations of how our "indigenous" microbial populations (microbiota) are shaping human health and how they could impact clinical practice.

Biological anthropology refers to the study of the evolution and biological development of the human species, incorpo-

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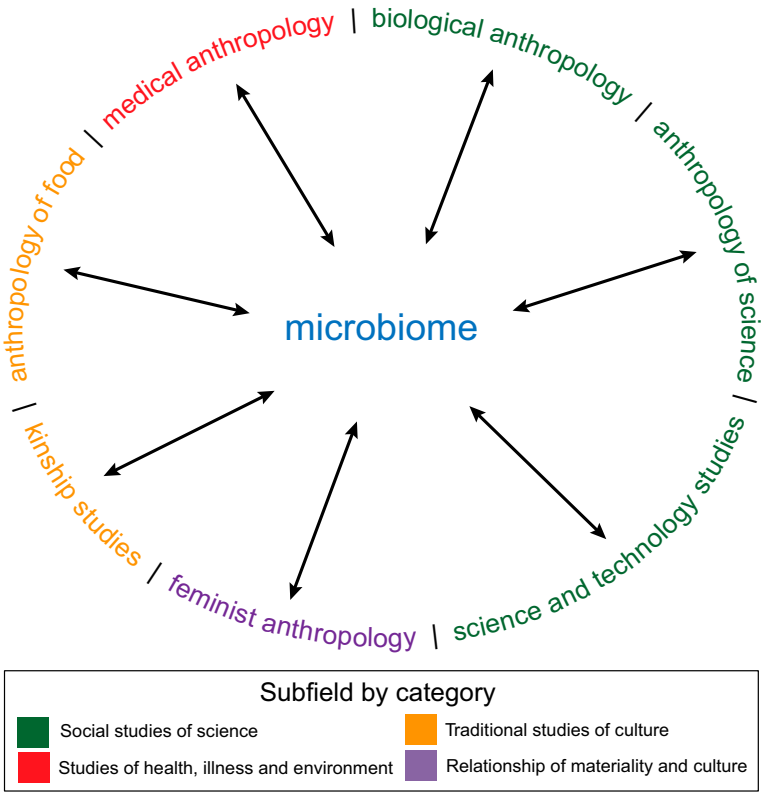

Fig. 1. Envisioned connections between subfields of anthropology and studies of the human microbiome. The color code is one view of a categorization of subfields within anthropology. These subfields can be defined as follows: *medical anthropology*, the study of the development of systems of medical knowledge and practice within and across different contexts, as well as the interaction of social, environmental, and biological factors with understandings of health and illness; *biological anthropology*, the study of the evolution and biological development of the human species in comparison with nonhuman primates (incorporates biocultural studies of human diversity, ancestry, and the comparative anatomy, behavior, history, and ecology of primates); *anthropology of science*, the application of anthropological perspectives and ethnographic methods to scientific fields (examines laboratory and social practices, and contingencies in the production of scientific knowledge); *science and technology studies*, the examination of how social, political, and cultural values affect scientific research and technological innovation, and how these in turn affect society, politics, and culture; *feminist anthropology*, founded in reaction to the paucity of ethnographic data about the experiences of women, this subfield has evolved to using gender as an important analytic tool that reframes history, material relations, social institutions, and cultural meanings; *kinship studies*, the study of the social and biological associations between people that constitute relatedness, and the cultural specificity and fluidity of form and meaning of these relations; *anthropology of food*, the exploration of how food has been used as an organizing principle in societies and the various and complex ways that food shapes human and nonhuman relationships. Other potential interacting subfields that are discussed in this perspective but not shown in the figure include the following: *applied anthropology*, the application of the method and theory of anthropology to the analysis and solution of practical problems, such as work with nongovernmental organizations or organizations in international development; *development anthropology*, the application of anthropological perspectives to the study of the social and economic issues in developing countries (taking development as an object of study, this work often critiques, analyzes, and contributes to development issues); *postcolonial studies*, the interdisciplinary study and critique of the legacy of colonialism on cultural and national identity; *cultural materialism*, the investigation of how material realities such as technological, economic, and demographic factors mold and influence culture; and *political economy*, the analysis of how political institutions and economic systems influence each other within a specific time and place.

rating studies of human diversity, ancestry, and the comparative anatomy, behavior, and ecology of primates. Biological anthropology can help our understanding of how human migration patterns, agricultural histories, and gene–culture interactions have impacted human–microbial relationships (19, 20). Sociocultural anthropologists and human microbial ecologists alike will benefit from a partnership with biological anthropologists.

Collaborative work between anthropologists and human microbial ecologists on the human microbiome can incorporate topics of traditional anthropological research in new ways. Anthropologists have long studied kinship systems based on shared bodily substance, direct descent, concrete networks of relationships, and forms of reproduction such as in vitro fertilization (21–24). As a core anthropological subfield, kinship studies (the investigation of the social and biological associations between people that constitute relatedness, and the cultural specificity and fluidity of form and meaning of these relations) can be used as an analytic to examine how knowledge of the microbiome is altering our perceptions of biological and social relatedness between humans. The gut microbial communities of monozygotic cotwins are not more similar to one another than those of dizygotic twins, whereas the patterns of microbial colonization of infants delivered vaginally differ from those delivered by cesarean section (2, 25). These latter two observations emphasize the important role of our early environmental exposures in shaping our microbial community structures. This is an important observation for anthropologists studying the scales of biological and social relatedness between humans. For microbiome scientists, this perspective would emphasize that there are social relationships between people (beyond biological kinships) that need to be considered in designing and interpreting observational and interventional studies that target the microbiome.

Closely tied to biological anthropology and kinship studies, feminist anthropology uses gender as an important analytic tool to reframe history, material relations, social institutions, and cultural meanings (26, 27). Feminist anthropology will play an important role in helping to define how microbial ecology characterizes the boundaries of "body," "family," and "community" (28, 29). Gender already figures into studies of human microbial communities (30), but feminist anthropology may provide a deeper description of how gender and its corresponding cultural, economic, and familial roles impact the microbiome.

Food occupies a unique role in human lives, intersecting social with biological needs. Diet affects the structure and function of the gut microbiome, whereas the microbiome in turn impacts the nutritional value of food and food ingredients (10, 31–36). Although sociocultural anthropology has an extensive tradition of examining religious, familial, and political practices that are identified through food, little has been done to integrate biological—including microbial—perspectives into this analysis (37). Similarly, biological anthropology and nutritional anthropology (how different factors affect the nutritional status of individuals and populations) tend to focus on agriculture, food security, micronutrient deficiencies, and political and economic conditions without equally considering social

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Table 1. Examples of conceptual and methodological approaches to studying the anthropology of microbes

Concepts
Investigating concepts of the self and ownership of microbes in specific social contexts
Studying human microbial heritage—of isolated populations and groups—as a complement to cultural, political, and ethnic heritages
Comparing how humans and nonhuman primates and their microbes adapt to different physical and social environments
Understanding how changing lifestyles such as modernization, globalization, food distribution, and migration from rural to urban areas are impacting health and the human microbiome
Analyzing how prenatal and neonatal care is shaped by cultural traditions, and how this affects intergenerational transmission of microbes
Examining the types of relations and networks that are formed within microbiome research: between humans (scientists, anthropologists, and study subjects), between humans and microbes, and between microbes
Methods
Anthropologists joining scientists who study human microbial ecology and the expressed functions of the human microbiome in the laboratory, sharing and learning methods and concepts—creating a collaborative space, and changing the culture of engagement between the disciplines
Anthropologists working at scientific field sites, conducting ethnographic research at the community level with human microbiome study participants
Scientists and anthropologists designing fieldwork and laboratory experiments, starting the collaborative process upstream, rather than retrospectively
Meaningful consideration of ethnographic data when interpreting scientific result

practices of eating (38). The anthropology of food, which has conventionally only addressed the sociocultural, behavioral, and economic factors related to food and nutrition, could be reframed to consider important biological factors, including microbes. This has the potential to provide a deeper understanding of how the nutritive, energetic, social, and ethical values of food are defined. An anthropology of food in turn can help inform metagenomic studies of the impact of diet on the composition of gut microbiomes and their metabolic activities (39–43) with studies of human social lives (44).

The need for such interdisciplinary collaboration is critically important, considering that our human population may increase to 9 billion in the next several decades, requiring new and effective ways to increase the quantity, quality, and nutritional value of foods produced. Distributing food to populations living in distinct and changing cultural contexts, and ensuring that the most vulnerable—infants and young children—are provided with the micro- and macronutrients they need during critical phases of their human and microbial cellular development will be vital to global human health. A number of other areas of anthropology are also essential to addressing these latter challenges, particularly in the developing world [e.g., the role of international aid and development (applied anthropology, development anthropology), the legacy of colonialism on national identity, economy, and culture (postcolonial studies), how "material realities" such as technology and economy affect culture (cultural materialism), and how political institutions and economic systems influence each other (political economy)].

The interdisciplinary field of science and technology studies (STS) examines how society, politics, and culture affect science and technology, and how scientific and technological innovations in turn affect society, politics, and culture (45, 46). One focus of STS is the anthropology of science: the application of anthropological perspectives and ethnographic methods to scientific fields (47). Primarily concerned with the intersection between science and society, STS will be an important component in the domain we have defined as the "anthropology of microbes." Integrating anthropology into the design and interpretation of microbiome studies has the potential to take several forms: (*i*) to ethnographically investigate the impact of enrollment in microbiome studies on participants (how microbial terms and concepts are introduced; how these concepts are taken up in local, cultural, religious, and political contexts; and how they affect fundamental conceptions of the individual, family, and community), (*ii*) to study the impact of human microbiome studies on the investigators themselves, and (*iii*) to understand the transformative dynamic evolving from cross-disciplinary work (between biologists studying the microbiome and engaging with anthropology, and anthropologists engaging with human microbial ecology).

Microbes are the dominant life form on the planet. Studying them in the context of their human hosts using metagenomic methods is changing the way we view microbial and human diversity, evolution, and biology. Reconfiguring ideas about human health, diet, and kinship will serve to connect the concerns of anthropologists and scientists who are studying the human microbiome. Considering the study of microbes through the lens of anthropology links many of the discipline's subfields in novel ways (48–50). Bringing anthropology and human microbial ecology into a meaningful dialogue allows for new modes of collaborative research. It should create a symbiosis that enables both fields to codevelop in ways that encourage a more profound view of our "humanness"—transforming our categories of "community," "individual," and "life," and in the process helping to address major global health inequities.

Taking the challenges of this work seriously, both the anthropologist and the biomedical scientist embarking on this type of collaboration must begin from a place of methodological accord. Although the concepts and practices of data collection and analysis are very different for ethnography and human microbial ecology, collaborators must be willing to acknowledge these divergences and bring them into conversation with one another. Table 1 provides some examples of conceptual and methodological approaches that could be used to start this work.

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