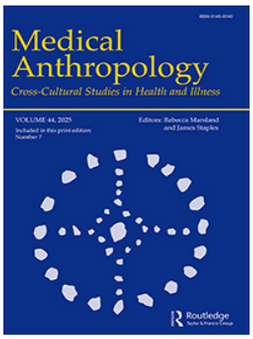

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Negotiated Categories: The Co-Construction of the Tunisian Population in Human Microbiome Science and Its Historical Entanglements

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ABSTRACT

The analysis of the intersection between race and microbiome science is a growing area in the social sciences, but little scholarly attention has been given to how population categories, that often have a racial subtext when applied to the Global South, are constructed, or how they intersect with or diverge from local conceptions of race. Drawing on research on an EU-funded human microbiome project involving Italian and Tunisian researchers, I argue that population categories in microbiome research are not merely imposed, but are continuously negotiated and co-constructed with local, homegrown racial categories.

KEYWORDS

Epigenetics; microbiome science; population categories; race; Tunisia

Horns honking, loud screams, noisy motorcycles: the Tunisian medina of the city I am living in is pandemonium. I skip over some holes in the street and run along the busy streets, avoiding the cars and taxis driving at full speed. I reach the large building in the lateral street with its impressive writing: *kulliat al ṭibb*[1] (Faculty of Medicine). The research lab I am visiting is part of the university, a state centralized system of research common to many North African countries. The scientists here are analyzing the DNA of soon-to-be-married couples to check for rare genetic diseases. Recently, however, their focus has shifted to studying the microbiome,[2] a diverse community of microorganisms, including bacteria, fungi and viruses, that reside on and within the human body. I follow them toward the doctors with whom they are collaborating, in a large square building hosting one of the most renowned hospitals in the area. I speak to Ines,[3] a woman in a white coat who describes the country's medical situation. Contrary to common perception, Tunisia shows high levels of medicalization and sanitization. All women give birth in the hospital and female health is highly subsidized by the state. Vaccination is mandatory: childhood vaccination is enforced in the homes, especially in the countryside. I recall talking the day before to some Italian scientists who are collaborating with them in an EU-funded microbiome research project; they were amazed to hear that the Tunisian hospital and university system is similar to those in Western[4] countries. Having worked for years in Tunisia, I know well that we often fall prey to misconceptions about this small country in North Africa.

My engagement with the Italian scientists, a dynamic and enthusiastic immunologist (Alessandro, the P.I.) and a postdoctoral researcher in microbiology (Fabio), was part of my field research on the aforementioned project involving a Tunisian university lab, a French research center,[5] and an Italian university team. I was conducting an in-depth ethnographic study on this scientific collaboration (henceforth the Project). My informal involvement in the Project, as an anthropologist, stems from my interest in conducting an ethnographic inquiry into how microbiome science is shifting our understanding of the human, with a specific focus on Africa. I proactively connected with the Italian

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microbiology team, whom I knew were already collaborating with a Tunisian university lab. Given my decade of experience working on issues of race in Tunisia, I chose to follow this collaboration's activities to expand my understanding how microbiome science is developing in Africa. The Italian team, already receptive to interdisciplinary work (they had worked with philosophers before), was highly collaborative. The Project's objectives comprised a capacity-building program in metagenomics for the Tunisian researchers and, in the background, the analysis and comparison of human microbiome data in patients with non-communicable diseases (henceforth NCDs) in the Tunisian and Italian population. My research explores how Italian scientists conceptualized the notion of population within the Tunisian context and integrates this analysis with the point of view of Tunisian researchers. While the Project's background aim – to compare Italian and Tunisian microbiomes – did not yield actual results due to the scarcity of collected and analyzed data, the data I collected through interviews with the researchers offer valuable insights into how scientific categorizations are mobilized within microbiome science.

This article is situated within the social science literature that foregrounds race in the study of science (Ferreira da Silva 2007; Reardon 2009), focusing on a specific angle – namely, population categories within microbiome science.[6] Population categories are socially constructed classifications of individuals, based on demographic or national characteristics, that researchers often employ to define study cohorts, analyze variations, and generalize findings (see Wiley 2021). Indeed, social science research across both genomics[7] (M'charek 2005; Reardon 2001; TallBear 2013) and microbiome science (De Wolfe et al. 2021; Núñez Casal 2024) has consistently shown how categories like "nationality" or "population" often operate as proxies for race, especially when applied to Global South[8] populations.

The Project's case study contributes to the existing literature on the intersection between race and microbiome science, that unveils patterns of racialization of Black and brown bodies (Benezra et al. 2012; Benezra 2020; De Wolfe et al. 2021; Maroney 2017; Nieves Delgado and Baedke 2021:2024; Núñez Casal 2024; Raffaetà 2022; Rawson 2024; Zimmer 2019). While this stream of literature is gaining hold, there is a notable gap in understanding how supposedly universal scientific racial categories in microbiome science intersect with or diverge from local understandings of race. To maintain this dual focus, I address population categories in Tunisia as contextual, historically sedimented (Ahmed 2015) phenomena. I deploy anthropological literature on race in Tunisia and North Africa (Davis 2022; Pouessel 2012; Scaglioni 2020) and answer the social sciences' call to analyze the historicity behind the use of racial differences in science (Meloni et al. 2022; Prasad 2023). As such, I challenge a simplistic dichotomy that scholars often draw between Western, modern scientific typological thinking – which they see as deterministic-and pre-modern, local conceptions of race – which they assume to be fluid and changeable. By dissecting the various layers of the researchers' understandings of population cohorts in the Project, I demonstrate that population categories are not simply imposed; instead, they are continually negotiated and co-constructed with local, homegrown racial categories.

Before proceeding, it is necessary to clarify the dialogue between the categories used by local actors, those employed in the Project framework, and my own analytical categories. In Tunisia, scientists primarily use the term "population" rather than "race," both because there is no direct Arabic translation of the word (Hall 2011:10) and because they conceptualize their cohort in terms of national membership and shared cultural-environmental characteristics at the country's level. Ideas of race in Tunisia are constructed differently than in Euro-American contexts, intertwining genealogical, physical, religious, and socio-economic factors. North African ideas of race, for example, rely heavily on religious status, in contrast to the Western modern attachment to the division between race and religion (Davis 2022). Moreover, my previous analysis among slave descendants in Tunisia (Scaglioni 2020) has foregrounded descent and genealogy in the construction of local ideas of race. Scientists navigate these different layers of race, which I tend to think of as "assemblages," and which are constructed by ideas referring to the more flexible realm of faith, to biological characteristics, and to Western scientific taxonomies.

I begin by introducing the Project and briefly tracing the history of microbiology in Tunisia, which historically served an imperialist agenda in the French colonies. Subsequently, drawing from interviews with the Project's scientists, I will explore how population categories are employed to produce knowledge and the main conceptual challenges behind their application in Tunisia. Within this analysis, I will incorporate homegrown notions of race in Tunisia, giving voice to the Tunisian scientists. By bringing together these exogenous population categories and local understandings of race, I will delve into how population categories in contemporary microbiome science operate within the epigenetic paradigm, which examines how socio-cultural and environmental factors can change gene expression without altering the DNA sequence. When I refer to "the epigenetic paradigm," I am pointing to a broader epistemic shift in biology over the past few decades that encompasses diverse but related movements.[9] Here, what matters is that microbiome research participates in this broader shift toward emphasizing environmental influences on biology, representing a departure from purely genetic explanations of human biological variation. Epigenetics has also transformed our understanding of race by attributing patterns of human difference to shared environments and experiences (Meloni et al. 2022). Within the Project's underlying population concept, Tunisians are lumped together not only by virtue of common genes or ancestry, but of exposure to common experiences and environment, framed as "lifestyle."

This article is based on an ethnography conducted through participant observation and in-depth interviews with Tunisian scientists and their Italian collaborators involved in the Project. My fieldwork included remote participation in their online meetings, separate in-depth interviews, and a two-month residency at the Tunisian lab, resulting in 30 formal interviews and numerous informal conversations. Given my year-long research experience in Tunisia, I was able to carry out interviews in French and to use my strong understanding of Tunisian Arabic to follow the everyday life at the lab. Interviews with the Italian scientists were carried out in Italian, my native language. In addition, I examined secondary literature about the Pasteur Institute in Tunis and visited the institute and its library. While at the Tunisian lab, my positionality was ambivalent: on the one hand, I actively participated in the Project, contributing to funding applications and supporting grant writing and proposing. On the other hand, I was carrying out ethnographic research, observing and analyzing the lab's activities and interviewing its scientists. In so doing, I also participated in the construction of a "Tunisian microbiota"; my complicit role provided me with useful insights into the making and constructing of ideas of population and lifestyle. My complicity was only partial, though: in helping them to analyze and disseminate their data, I encouraged them to assume a more critical standpoint. My ethnographic stay was also favored by my gender identity as a female: the Project's Tunisian scientists are almost all women, reflecting a national trend (Jaziri 2013). While high numbers of female scientists in Tunisia might appear progressive, this phenomenon exists within a broader patriarchal system where pre-tenure scientific positions are often not considered "proper jobs" and are thus avoided by men, who face social pressure to secure stable employment and housing by their thirties to achieve full masculinity, particularly through marriage. Overall, being a female, young, European researcher has been a propitious standpoint to get in touch with them and to join their activities, both in the lab and outside it. Navigating precarity and uncertain career trajectories was something that brought me and the Tunisian scientists together; we shared experiences, expectations, and fears for the future. This shared vulnerability allowed me to conduct ethnography through "emotional resonance" (Wikan 1992).

The Project's genesis and the first steps of microbiome research in Tunisia

The recent rise of computational approaches[10] to studying the human microbiome has triggered what anthropologists Heather Paxson and Helmreich (2014) have termed a microbial turn; that is, the integration of microbes as rightful components of our bodies and not just "pathogens." Advances in research methods, such as metagenomics and computational analysis,[11] have revolutionized the field by enabling the study of a microbial community's DNA composition without the need for cultivation in a petri dish (Benezra et al. 2012).

These techniques have facilitated exploration of the microbiome's role in host metabolic, immune, and neuroendocrine functions, positioning microbes as critical contributors to human health and diseases.

The Project, spanning from 2020 to 2023, fostered a collaboration between a Tunisian university lab, an Italian university lab, and a French research center to advance human microbiome science in Tunisia and to study its role in connection to three NCDs (diabetes, colorectal cancer (CRC), and obesity) (for an overview, see Shivani et al. 2021). The project was designed to transfer knowledge and capacity in metagenomic analysis to the Tunisian laboratory, enabling the establishment of a center for human microbiota analysis. According to Italian researcher Fabio, the limited expertise and capacity with metagenomic software and analysis is the main obstacle to the emergence of microbiome research in Tunisia. This perspective motivated the Italian team's humanitarian efforts to build capacities with the aim of fostering a more equitable microbiome science, a call that is increasingly gaining momentum in the field (Bader et al. 2023; Greenhough et al. 2020; Ishaq et al. 2019, 2021; Mangola et al. 2022). In addition to this goal, the Project was a good opportunity to compare "Tunisian" and "Italian" gut microbiota in patients with similar NCDs.

Patients with NCDs and healthy patients (the control samples) were enrolled, and stool samples were collected from them at a hospital in the Tunisian city. Their data were analyzed by Tunisian scientists with the help of online training on metagenomic techniques provided by European partners. In the words of Khaoula, microbiologist and Postdoctoral researcher at the Tunisian lab, the Project is one of the first attempts to map the Tunisian gut microbiome,[12] although some preliminary analyses have been conducted by the Pasteur Institute in Tunis. In Tunisia, the importance of the microbiome for human health is not widely recognized among scientists, let alone lay people: there is no "every day of the microbiome."[13] Therefore, the Project envisaged a work package specifically aimed at communicating and disseminating information about the microbiome, comprising a teaching unit for the Master of Medicine course at the University. According to Marwa, the PI of the Tunisian lab and a dynamic, resourceful scientist with a background in genetics, histology, and biotechnology, the microbiome is also a new topic at the university level.

Accustomed to targeted sequencing of human cells (through 16S technologies), the Project's team required capacity-building to transition to shotgun sequencing.[14] Marwa proposed the possibility of undergoing training in metagenomics to the Italian partners. To date, the Project's results remain limited, as do the collected samples. Alessandro considers the project to be mainly bioinformatic methodological training. This is in line with many North-South scientific collaborations that have capacity building at their core: the agenda is to put "donors" in contact with a "beneficiary" in the Global South in an asymmetric way (Binka 2005; Shivakoti and Milner 2022). Capacity building is often not enough to overcome consistent asymmetries in funding, leading institutions, and authorship that have been detected in the emergence of microbiome science in Africa (see Allali et al. 2021). Critical development scholars have identified capacity building as a buzzword (Eade 2007) or as a new development fetish (Clarke 2010) that, like other forms of neoliberal ideology, practice, and policy, focuses on individuals and individual agency while dismissing structural constraints and structural histories.[15] The Project entails in fact some obstacles: similarly to what has been shown by political scientist Bradley (2008), the partnership of co-creation between Italy and Tunisia has indeed augmented individual research skills among the Tunisian research group, but has yielded limited results in terms of joint publications and data analysis, including the comparison of data in the two cohorts.

As I will demonstrate, this asymmetry extends to how population categories are formed within the Project's research agenda and in the scientists' discourses, shaping how knowledge is produced and what kinds of knowledge are prioritized. To unveil the asymmetries inherent in these practices, I first need to unravel the colonial genealogies (Prasad 2023) of population categories in Tunisia.

Population categories in colonial Tunisia: The historical construction of difference at the Pasteur Institute

While microbiome research has only recently attracted interest in Tunisia, microbiology is a well-established discipline; it can be dated back to the establishment of the Pasteur Institute[16] in Tunis in 1893.[17] In Tunisia, the emergence of microbiology – including bacteriology, virology, and epidemiology – occurred within the French colonial framework; it was a response to what anthropologist Fassin (2001) analyzes as a specific form of biopolitics, which equates *clean* with *good* when considering non-French bodies. These disciplines had a civilizing mission (*mission civilisatrice*) to keep the colonies free from diseases; they were configured as a tool of imperialism from the outset. Their practices were implemented, tested, and eventually standardized in the colonies before being accepted in the European capitals (Lock and Nguyen 2018).

When taking biopolitical control of the Tunisian colony, racial construction was an integral part of the agenda. Colonial science created and categorized its objects of study through racial taxonomies (Seth 2009). In the Tunisian case, handling racialized bodies was possible through a classification in subpopulation categories, as the French were "obsessed with classifying spaces, races, species" (Tolan-Szkilnik 2023:166). French colonial scientists employed vocabularies of race to construct populations and microbes – and their related diseases – as scientific objects: during the years of the French Protectorate in Tunisia (1881–1956), the Pasteur Institute relied on censuses of the population to track mortality rates, for example during the cholera epidemic in 1911 (Conseil 1970). The French colonial construction of racial categories in Tunisia operated through ethnic and religious markers, disregarding local constructions based on genealogy, descent, tribal affiliation, regional origin, and socio-economic status, that would have given these colonial categories a more granular and contextually grounded character. By contrast, some pre-colonial racial terms in Tunisia differentiated (and still differentiate) racial membership through Arabic terms like *qabila* (tribe), *'irq* (lineage, stock), *nasab* (patrilinear descent).

The French categories employed for epidemiological purposes included *musulmans* (Muslims), *israélites* (Jews), *français* (French), *italiens* (Italians), and *maltais* (Maltese), alongside the overarching division between *européens* (Europeans) and *indigènes* (Indigenous). This last classification system collapsed religious identity, national origin, and presumed racial characteristics into singular categories for scientific administration. The category *indigènes*, in particular, served as a racialized catchall that erased internal Tunisian diversity, regardless of their actual social or regional diversity (Loir 1898). For example, cholera was rare among the Tunisian bourgeoisie but was readily associated with the "Indigenous" category. Similarly, the 1930 plague, also linked to *les indigènes*, notably spread from Douiret, a poor rural village in the South (Moulin 2020).

Mainstream scholars in the West typically view race as a byproduct of modernity, originating from a Western intellectual tradition, specifically the Enlightenment and the rise of modern nation-states (Holt 2002; Smedley 2007; Winant 2004). For instance, scholars analyzing Africa often consider racial distinctions to have been solely imported by colonialism (Garuba 2008; Mamdani 2018; Pierre 2013). However, this perspective overlooks the presence of homegrown pre-modern and pre-colonial ideas; in Tunisia, for example, notions around an embodied connection between physical appearance, blood, and moral qualities predate the colonial encounter (Pouessel 2012; Scaglioni 2020). Historical literature shows how, in Islamic areas in Africa, racial ideas entailed both inborn factors (such as the predominance of genealogy in shaping a person physically and morally) (El Hamel 2013) and environmentally deterministic assumptions (like the importance of socio-religious status for racial identities) (Glassman 2011; Hall 2011).

French clinicians assumed the importance of religion, using it to divide the Indigenous cohort into subpopulations, specifically distinguishing Jews, Christians, and Muslims. This internally attentive racial categorization had a performative nature.[18] For instance, the low morbidity rate of leishmaniasis within the Indigenous Muslim population led French clinicians to conjecture that parasites were transmitted via dogs. This hypothesis was based on the French clinicians' understanding that Muslims

consider dogs impure, carefully avoided, and certainly not kept in homes (Moulin 2020). In essence, during colonial Tunisia, population and subpopulation differentiations for epidemiological purposes were the result of the mind-set of French scientists but mapped onto preexisting local categorizations. These differentiations were then further reinforced by being framed within a microbiological explanatory framework. Through this process, French colonial science crystallized population categories, with French anthropology complicit through its anthropometrical analyses. René Collignon, both a military doctor and an anthropologist, differentiated *races* (in French) within the Tunisian population through anthropometric measurements, incorporating religious, geographical, lifestyle (e.g., "nomads," "Berbers," "sedentary"), and phenotypical (*Nègres*, *sic*) factors (Collignon 1886, 1887).

The historicity of population categories in colonial Tunisia helps us complicate the steadfast distinction between fixed, imposed race categories and new, environmentally-driven, epigenetic racial categorizations (Meloni 2016; Rawson 2024; Seth 2018). Clearly, French colonial clinicians had no epigenetic awareness; nevertheless, they recognized that socio-religious factors significantly influenced local biologies. Looking closely at how population categories have been conceptualized by the Project's scientists, the next paragraph will unravel the admixture between biological and environmental determinism, and exogenous and homegrown notions of race and population.

Constructing a Tunisian microbial signature

Within the Project, comparing Italian and Tunisian patients with similar NCDs did not yield significant results in either the analysis or publications. This was primarily due to the project's focus on capacity building, contingent constraints like COVID travel restrictions, and the limited number of samples actually analyzed. However, within the Project, Italian and Tunisian scientists, along with myself, discussed the characteristics of the Tunisian sampled population, which allowed me to understand their framing of Tunisians not only by demographic factors and common ancestry, but also by exposure to shared experiences and environments, conceptualized as "lifestyle." This aligns with how anthropology conceptualizes biosocial race and population, relying on dynamic processes, including biology, genes, and culture (Hartigan 2013). This concept positions itself within an emerging paradigm that studies body and environment together, based on assumptions of emergent shared ontologies across the sciences.[19] Adding to the discussions about the samples, we also brainstormed ideas for a potential project to propose to international donors, primarily the European Union. These discussions demonstrate how project writing, a central activity in contemporary research, can be legitimately considered an epistemic practice, actively engaging scientists in knowledge production processes.

Italian scientists aimed to compare the two populations to understand the mechanisms connecting CRC and gut microbiome compositions. Their university is located in a region with high CRC rates, and their research hypothesizes that diet, especially the high consumption of red meat, is among the causes. During our first meeting in May 2023, Alessandro explained their logic: "We want to compare our cohort with somewhere where people live completely different. We want to understand the age of onset [of CRC] better, matching patients with similar characteristics [mainly age and health status]." When I asked what they were expecting to find as differences, he pointed to a less industrialized diet, that they considered to be "at the furthest" from a meat-based one. This perceived difference is epitomized by the concept of "rurality" – a term I heard in my conversations with the Italian team, for example:

> There [in Tunisia] it is easier to find people who live in a rural setting, because here in the [Italian] cities it is difficult to find someone who has lived in the countryside for all his/her life. (Alessandro)

Microbiome scientists have built an entrenched tradition of sampling human microbes in rural habitats on a civilizational logic – the assumption that microbial diversity decreases as human societies transition from foraging and rural farming to urban and industrialized Western lifestyles (Nieves Delgado and Baedke 2021). Microbiome researchers particularly seek microbial data from populations

they consider to be "at the furthest" from Western lifestyles, as the overresearch of the community of the Hadzabe, a hunter-gatherer community in Tanzania, shows (Mangola et al. 2022; Rawson 2024). As geographer Ariel Rawson (2024) argues, comparative frameworks are deeply embedded in the structure of microbiome research itself, particularly in projects spanning the Global North and South. When microbiome researchers compare "rural" environments to industrialized ones, they assume that rural environments harbor "good" microbes (Ruiz-Calderon et al. 2016), which would have been disrupted by contact with modernity.[20] Regarding Global South populations, this approach reveals what anthropologist Fabian (1983) terms a "denial of coevalness" – treating research subjects as existing in a different, usually earlier, historical time period.

These comparisons construct populations through microbiome-based racial differences (Nieves Delgado and Abigail 2024) – running the risk of reproducing colonial patterns of racialization. A closer look reveals that the reality of the sampled area in Tunisia contradicts the assumption of rurality. The hospital's surrounding area is far from rural; it is a heavily industrialized and polluted city with high levels of medicalization. Moreover, practices like antibiotic abuse are widespread (Mansour 2018). Given the strong negative impact on human microbes, antibiotic abuse can consistently curb microbial diversity and thus alter the final scientific results. As the Project's Tunisian team member and medical doctor Ines told me:

> For antibiotics, as a doctor, I see that here there is no control. On the prescription of antibiotics. You go to the pharmacist. The only thing you can't have without prescription is neuroleptics. So, my mom, if she goes to a doctor and she doesn't give her a list like that [indicates a long list with her hands] of medicines, then she's not a good doctor.

Regarding diet, biomedical research is increasingly concerned with the consumption of ultra-processed food, particularly among Tunisian children (Dogui et al. 2022). By archetypally representing Tunisians – who are geographically the closest to Europe among African populations – Italian scientists reproduce colonial knowledge patterns, maintaining the West as the standard. This epistemological pattern is so deeply embedded that it forms a constituent part of modern science (Ingold 2018).

On their side, the Tunisian lab is a diverse team, bringing together expertise from immunology, medical practice (especially pediatrics), microbiology, biotechnology, and genetics. The team's goal is threefold: to acquire capacity and expertise in metagenomic analysis; to discover biomarkers for existing diseases through microbiome analysis; and to generate knowledge about a "Tunisian microbiome," which they believe is unjustly under-researched and unmapped. When asked about the presumed rurality of the Tunisian population, they countered with data, numbers, and facts. Ines explained to me the mechanisms behind antibiotic abuse (the ability to buy them without prescription, poor adherence to administration periods, and distrust of alternative methods among both patients and doctors), high rates of hospital births and Cesarean sections (which limit infant exposure to maternal vaginal microbiota, see Dominguez-Bello et al. 2010), and low neonatal and infant mortality rates compared to the region.

The negotiation of what constituted a "Tunisian microbiome" unfolded across multiple settings over several months. In May 2023, I observed the team preparing for a consortium meeting with their European partners. Shortly before, we had brainstormed ideas for new projects to be submitted to the European Union. We spent an afternoon going through upcoming calls and funding schemes, identifying which priorities aligned with their research capabilities. The exercise became a lesson in strategic positioning – we discussed possible connections between specific socio-cultural factors in Tunisia and the gut microbiome, always with an eye toward what would appeal to EU reviewers. We looked for specific characteristics that would yield innovative results, such as understudied connections, and that would show the profound knowledge and competence of the context. Marwa referred to the characteristics of a Tunisian microbiome as a "unique signature." A microbiome signature, in this context, refers to a reproducible pattern of microbial life (bacteria, fungi, viruses, etc.) associated with a specific host state, environmental condition, or intervention (Pendergrass 2024). Microbiome

scientists usually consider these "fingerprints" to be shared across individuals who are exposed to the same environmental, cultural, or socio-economic influences. This reveals how population membership is understood also through common experiences, moving typological thinking beyond classic genetic determinism to encompass the realm of cultural determinism.

According to the P.I. Marwa and to Ragheb, a male microbiologist involved in the Project, diet is one of the most impactful factors influencing the Tunisian microbiome. They frequently cite the consumption of *legmi*, a fermented beverage derived from palm trees and consumed widely in Tunisia, especially in the South, and its connection to human microbial diversity as a possible unexplored research question. While microbiome researchers have well-explored the correlation between fermented beverages and human microbial diversity (Debbarma et al. 2025), the specific research question about *legmi*'s correlation with a Tunisian microbiome signature remains an open discussion among them.

Yet, population categories among Tunisian scientists are also framed as groups sharing a local specific genetic and ancestral background, underlying homegrown notions of racial membership. This became particularly evident during our brainstorming session in May 2023, when the topic of consanguinity emerged as a potential research question. As Ragheb raised, Tunisian scholars have been studying high rates of consanguinity and geographical endogamy for years in genetics (see for example Chaabouni-Bouhamed 2008; Romdhane et al. 2014), especially relating them to infertility or children's malformations, but the question whether it could influence the microbiome remains open. Ragheb's attention to ancestry is not only a strategic response to what EU funding schemes find appealing, but is also linked to local conceptions of race, where genealogy often overrides other factors, such as phenotype, in describing racial communities (Pouessel 2012; Scaglioni 2020). Furthermore, Khaoula intervened by adding that we could integrate this conception with epigenetic notions: she explained how she wanted to switch to the analysis of how cohabitation patterns influence horizontal microbiome transmission, and how these patterns are linked to consanguinity.

In addition, during our brainstorming sessions, and in dialogue with Italian scientists, the Tunisian lab expressed interest in understanding how Ramadan fasting patterns and eating habits during the holy month impact the human microbiome. This research question focused on a specific cohort of Muslim and religiously observing Tunisians. Alessandro and Fabio enthusiastically welcomed this suggestion, as researchers had previously studied the correlation between Ramadan fasting and human microbial composition (Saglam et al. 2023), and they wanted to deepen the topic. Framing the research questions in these terms resonated with the Italian scientists' interest in understanding the relationship between human microbiota and chronotypes, meaning variation in microbial composition based on individual activity levels in the morning or in the evening (Fabio).

These ideas about the Tunisian population category rely on how microbiome scientists cluster microorganisms into a microbial "signature" and attribute them to "ethnoracial" differences (Abu El-Haj 2007). Tunisian scientists mobilize them because they actively negotiate essentialist frameworks, viewing them not merely as imposed categories but as strategic tools for advancing their research agendas (Kurzwelly et al. 2020). Essentialism, in this context, pertains to how the Project's research questions aim to determine a unique microbial signature for an entire country, integrating both biological and cultural factors. During brainstorming sessions, this became explicit through the repeatedly asked questions on "how is a Tunisian microbiome different," and "what do we have that they don't?" and through the answers about how this signature consisted of combined biological factors (consanguinity rates, genetic background) and cultural practices (Ramadan fasting, *legmi* consumption, traditional diet). As Khaoula put it: "It's how we live that makes us unique." This approach reflects how scholars and scientists have shifted their thinking about difference from "a fixed quality, an inherent essence, or a unique causal mechanism" – which prevailed during the genomic era – to viewing difference "as a process, one that offers no certain line by which either 'biology' or 'society' can be starkly delineated" (Hartigan 2013:194).

Another angle from which to frame the Tunisian scientists' participation and agency in defining the Project's research questions pertains to the global scientific arena in which they operate. This raises the

fundamental question of what constitutes "local science." The Project's Tunisian scientists are socialized and trained within Western biomedical science, which the Tunisian state enforced since the 1960s and 1970s as part of the country's post-independence modernist agenda (Siino 2013). Yet their practice cannot be simply dismissed as merely "imported" Western biomedical science. When I first met Ragheb, he claimed proudly: "Je suis Pasteurien" (I'm Pastorian). This did not only mean that Ragheb studied at the Pasteur Institute in Tunis, but also that he belonged to an "imagined community," which scholarly analysis explains in terms of a sacred order or cult (Perrey 2005), or to a post-colonial scientific arena where circulation of knowledge speaks the French *lingua franca*. This challenges a common, unexamined assumption – namely, that biomedicine was and is "made" in the "West" and then exported to the "rest," where it can be applied everywhere without modification (Lock and Nguyen 2018). Western biomedical practices were rather implemented and standardized in colonial settings before being transported back to Europe. The Project's scientists' work thus challenges a distinction between "local" (responding to Tunisia's specific health contexts and priorities) and "modern" (participating in global knowledge production and epistemologies).

The construction of a "Tunisian microbiome" within this global arena operates across multiple, sometimes contradictory scales. On the one hand, this essentialization process encompasses the whole population, constructed through shared experiences and environment. On the other, however, microbiome science, with its focus on understanding the individual's unique microbial landscape based on factors like diet, habits, and religious practices, introduces an individualized approach to personalized health, carrying with it the risk of reducing complex community identity and political engagement to mere individual consumer choices (De Lima Hutchison and Núñez Casal 2023). This tension became evident when I naively asked Khaoula whether every Tunisian had the same microbiome. She said: "Well, no. It varies person to person – your diet, your stress level, whether you fast during Ramadan, whether you exercise. Even in the same family, microbiomes are different." On this note, researchers and medical practitioners have hailed personalized medicine – the analysis of individual human microbiota to offer highly specific medical interventions – as an innovation but it entails the risks of exacerbating socio-economic and health inequities, as well as deepening the gap between the Global North and the Global South in the access to health and treatments (Raffaetà and Ferrari 2025).

Below, I will delve into the asymmetries in how the Italian and the Tunisian population categories are constructed and compared within the Project, as it can shed further light on how knowledge production continues to exist within a dominated framework, setting the West as the norm.

The challenges of asymmetrical representation in population categories

Social scientists have warned against the risk that biosocial conceptions of race and population might reproduce racial hierarchies (Meloni et al. 2022; Rawson 2024), but they have also highlighted the potential for these conceptions to deconstruct racist narratives (Blackman 2016) and to dethrone Eurocentric views (Braidotti 2013; Frost 2016; Rawson 2024). Some scholars also consider that comparisons between racial constructs entail the potential to decenter Eurocentric perspectives on race (Shih 2008). Within the Project, however, the comparisons between the Italian and the Tunisian microbiomes entailed the risk of reproducing hierarchies as they were assigned *a priori* and without an informed knowledge of the context. Moreover, they fall into what I call "the asymmetry problem," that refers to the unequal levels of specificity and nuance applied when categorizing different populations. Not only are categories applied to Global South populations often poorly informed by local contexts, but the categories themselves are structured with fundamentally different levels of granularity – with Global North populations receiving broad, homogeneous classifications while Global South populations are subject to fine-grained subdivisions.

Comparative thinking is central to scientific practices (Candea 2019), and very common in microbiome science, where large-scale projects often operate at national or regional levels – for instance, the American Gut Project's mapping of inter- and intra-national microbiome diversity

(McDonald et al. 2018) and population-level studies comparing microbiome compositions across geographical regions (Deschasaux et al. 2018; He et al. 2018). Within the Project, the Italian cohort was defined regionally, while the Tunisian cohort was framed nationally. This asymmetrical categorization mirrors broader patterns in which OMICs researchers studying Africa often employ detailed characterizations of cohorts in the Global North but use broad population categories like "Sub-Saharan African" or "Greater Middle Eastern," revealing the privilege of the Global North to define itself. Clearly, comparing single nation states with political and economic "consortium" of nations is unequal and problematic (Núñez Casal 2024).

In anthropological terms, the comparison proposed between the Italian and Tunisian samples in the Project exemplifies a "frontal comparison," where an unfamiliar entity is contrasted with a supposedly familiar background (Candea 2016). Anthropologists have criticized frontal comparisons for their inherent risks of asymmetry, oversimplification, and essentialization, and for their strong post-colonial and hierarchical implications (Candea 2016, 2019). On an epistemological level, such comparisons may prove neither empirically valid nor representationally accurate (Candea 2019). To yield significant results, we need to frame research questions within a "lateral comparison" (Candea 2016), where "populations" are laid out side by side to form a series, moving beyond an "us-them" dichotomy.

It is necessary here to emphasize that scientists *need* categories to produce knowledge, as Alessandro and Fabio have often repeated to me. Population categories are in fact operational, and science relies on them as forms of representing reality (Raffaetà 2022). Also, we need to distinguish between the single researchers and the way race is (mis)used in science. Scientists, in fact, rely on genealogies of science, that reify racial categories and notions and make them seem real by constant use – especially when supported by previous scientists with authority (Graves and Goodman 2023). In explaining to me the rationale for approaching Tunisians as a "rural reservoir of microbes," Alessandro mentions studies on "uncontacted" Amazonian populations, which should show "unprecedented levels of bacterial diversity":

I have seen many projects where they go to the Amazonian forest and look for these populations who have never come in touch with civilization. (Alessandro)

The project to which Alessandro is referring is *The microbiome of uncontacted Amerindians* (Clemente et al. 2015). The sampled population is far from being "uncontacted" (Maroney 2017; Raffaetà 2022), but the study has remained entrenched in the scientific genealogy and in the scientists' mind-set. Scientists thus navigate a complex terrain where racial thinking persists, even as they attempt to move beyond racial categories toward more precise biological and environmental variables.

Conclusions

The study of the Project, an EU-funded human microbiome project mainly pivoting around a capacity building program involving a Tunisian university lab an Italian university research center, has provided evidence to reflect on the asymmetrical structures behind North-South scientific collaborations. While microbiome researchers themselves are paying increasing attention to fundings, infrastructure, ethical concerns, and authorship, especially when the discipline moves within the Global South, the construction and mobilization of population categories still remains understudied. And yet, race, underpinning these categories, is a crucial lens to look at contemporary science.

Social scientists have warned against the imposition of Western scientific categories onto non-Western contexts within microbiome research, and yet, this article refers to the study of how Western science has historically accompanied older and local forms of knowledge, instead of replacing them. In Tunisia, microbiology gave birth to co-constructed ideas about what factors lump people together in a (intra-)national or racial membership. This sheds light on how race is not only a byproduct of Western modernity and helps us decenter our gaze toward contexts which have remained at the margins of scholarly inquiry. Then, a closer look at population categories can shed light on how systematic classifications, sorting, discrimination and ordering – activities that practically shape race

and racism – imply epistemological consequences, and how they are never neutral activities, but rather respond to broader geo-political patterns (Bowker and Susan 1999). Analyzing population categories within the Project, I also refer to how race is constitutive in the modern global word, and ineluctable (Ferreira da Silva 2007). Even "biosocial" views that emphasize the "plasticity" of biology – the idea that bodies and genes respond to social and environmental conditions – remain integral to colonial formations of race and their aftermaths (Meloni 2016; Seth 2018). These approaches may appear to move beyond genetic determinism, yet they can reproduce colonial logics by attributing racial difference to "lifestyle," environment, and cultural practices rather than challenging the fundamental project of racial categorization itself.

If scientists use population categories to produce knowledge, then the construction and deployment of these categories requires critical reflexivity at every stage. Life scientists have begun to recognize these challenges, recently proposing guidelines that emphasize consulting with groups being categorized and avoiding attributing unexplained variance to racial or ethnic differences (*Using Population Descriptors in Genetics and Genomics Research 2023; Why Nature Is Updating Its Advice to Authors* 2023). However, the challenge goes beyond gathering more granular data about established population categories. Instead, researchers must critically examine how they construct and employ these categories, ensuring they meaningfully align with their specific research questions while remaining attentive to the colonial genealogies embedded in their frameworks (Raffaetà 2022). Researchers must ask: Whose knowledge counts in defining a population? What assumptions underlie comparisons between cohorts? How do funding structures and theoretical frameworks shape what becomes scientifically visible? Racism is produced at the interstices of science and popular knowledge (Reardon 2009), with scientific concepts percolating to the popular level – making it imperative that scientists critically examine the categories they employ rather than simply refining them.

To conclude, I suggest an interdisciplinary effort-one that life sciences themselves have called for (Nature 2015) – that introduces social sciences at the initial agenda-setting stages of research, not as external critique but as constitutive of research design itself. Only through such collaboration can we work toward more rigorous, equitable, and reflexive science.

Notes

1. Arabic words have been transliterated according to the IJMES system: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cambridge.org/core/services/aop-file-manager/file/57d83390f6ea5a022234b400/transchart.pdf.
2. The term "human microbiome" usually refers to the collective genome of human microorganisms, which are termed "microbiota." However, microbiome also scientifically refers to the microbial community and to their activities, see Eisen (2015).
3. The names of the project and the researchers, as well as the funding scheme, have been anonymized. Specific diseases have not been mentioned in order to protect the identity of the patients involved; the city and the hospital have also been anonymized.
4. Even as I am aware of the colonial, ethnocentric nature of categories such as "Western," I use it as a geographical convention to delimit primarily Western Europe, North America, and Australia (thus including Italy). Also, I use it in an epistemological sense, referring to the dominant, often Eurocentric, frameworks and methodologies of modern science. As decolonial science literature emphasizes (Prasad 2023), "Western science" is not merely a geographical label; it represents a specific mode of knowledge production that gained hegemony through historical processes of coloniality, often marginalizing or discrediting other forms of knowing.
5. The interactions with French scientists were consistently limited by some restructuring taking place in the research center during the development of the project. Thus, their perspective has been left at the margins of this inquiry.
6. Another angle exploring the intersection between race and microbiome science examines how racial discrimination and racism impact microbiome diversity; this is an emerging area within the microbiome literature itself (Amato et al. 2021; see also the work of the Ishaq Lab at the University of Maine: Ishaq et al. 2019, 2021, 2022).
7. The suffix "omics" refers to various disciplines in biology such as genomics, proteomics, metabolomics, and microbiomics. These fields collectively aim to characterize and quantify pools of biological molecules that translate into the structure, function, and dynamics of organisms. Genomics is the branch of molecular biology concerned with the structure, function, evolution, and mapping of genomes. The suffix -ome signifies "totality,"

suggesting that these disciplines study the collective of the units in an organism. For the genealogy of the suffix, see Lederberg and McCray (2001).

8. While the distinction between Global North and Global South is far from rigid (Comaroff and Comaroff 2012), I use this denomination primarily because EU funding schemes explicitly categorize Tunisia as belonging to the Global South. Additionally, I employ it as a loose convention referring to geopolitical and economic realities, encompassing countries that have historically experienced colonialism and are largely located in the Southern Hemisphere. It is crucial to note that "Global South" and "non-Western" are not interchangeable. "non-Western" in science refers to diverse epistemological traditions and knowledge systems that exist outside the hegemonic structures of science. Consequently, not all scientific practices or knowledge systems originating from the Global South are inherently "non-Western" in their epistemological foundations, as exemplified by many researchers within the Global South, such as the Project's Tunisian scientists, who are trained and operate within Western biomedical scientific paradigms.
9. For example, developmental systems theory (DST), niche-construction, evolutionary developmental biology (evo-devo), and ecological developmental biology (eco-devo) (see Meloni 2016).
10. The emergence of microbiome research can be traced back to the launch of the Human Microbiome Project in 2007 (Turnbaugh et al. 2007).
11. Metagenomics is a molecular technique that involves directly studying genetic material (DNA or RNA) recovered from environmental samples containing multiple organisms or microorganisms. This method allows researchers to analyze the collective genome of all organisms present in a given sample, rather than having to isolate and culture individual species.
12. A few microbiome studies have been conducted in Tunisia, e.g. studies on the microbiome's association with heart and coronary diseases (Bouzid et al. 2022; Gtif et al. 2021) and with newborns' health (Hanachi et al. 2022).
13. This expression has been borrowed from anthropologist Michelle Pentecost's "the everyday of the epigenetics" (Pentecost 2016).
14. The shotgun method sequences the genetic material in samples without selecting it. It thus allows the sequencing of enormous quantities of microbial DNA. For a description of microbiome science technologies and the difference between targeted sequencing (16S) and shotgun techniques, see Raffaetà (2022):71–75).
15. For an history of the concept, see West (2016).
16. French microbiologist Louis Pasteur discovered the bacteriological identity of infectious diseases, triggering a revolutionary shift in biomedicine. See Latour (1993).
17. http://www.pasteur.tn/. The Institut's foundation was the idea of Louis Pasteur's nephew, Adrien Loir; it is one of the most renowned and most ancient Pasteur institutes in the world.
18. For the performativity of categorization in science, see Bowker and Susan (1999).
19. See for example the concepts of local biologies (Niewöhner and Lock 2018), biosocialities (Rabinow 2022), naturecultures (Haraway 2003), and entanglement (Barad 2007).
20. See for example microbiologist Martin Blaser's work (Blaser 2014). This assumption has come under criticism by social sciences: see for example Benezra et al. (2012); Maroney (2017); Benezra (2020); De Wolfe et al. (2021); Raffaetà (2022); Rawson (2024); Núñez Casal (2024).

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Media teaser

How do European scientists construct racial categories when studying human microbiomes in the Global South, revealing both colonial legacies and local agency in knowledge production?

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