

Forum

Bridging data gaps: African reference genomes advancing inclusive microbiome research

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The need for African-specific microbiome reference genomes is critical as their absence limits research in health, agriculture, and sustainability. Current global guidelines often do not take into account the region's unique needs. This commentary advocates for Africa-focused microbiome initiatives and community-driven genome projects to better reflect the continent's ecological and demographic diversity, leading to more applicable outcomes.

The urgent need for African-specific microbiome reference genomes

The human microbiome plays a crucial role in maintaining overall health and managing diseases. However, most microbiome research is concentrated in high-income countries, leaving the vast microbial diversity of Africa largely unexplored. Reference genomes are essential for identifying microbial species and strains, providing insights into the dynamics of the microbiome [1,2]. Unfortunately, the lack of African-specific data limits the relevance of existing genomes for African populations. This gap distorts our understanding of global microbial diversity and hinders the development

of diagnostics and treatments tailored to local cultures and ecosystems [3].

Africa's unparalleled genetic and ecological diversity has a profound influence on microbiome composition, underscoring the need for reference genomes that reflect the unique characteristics of African communities. Without this knowledge, many key microbes may remain unidentified despite the notable advances made with reference-agnostic approaches.

The urgent need for African-specific microbiome reference genomes is evident, yet significant disparities exist across the continent. Sub-Saharan Africa has more research initiatives, while North Africa faces a critical data shortage. Therefore, immediate action is necessary to establish inclusive efforts that reflect Africa's microbial diversity and address variations among populations.

Prioritizing microbiome research in Africa and developing region-specific genomic resources are essential steps toward advancing global health equity. These efforts will ensure that the benefits of precision medicine extend to underserved populations, fostering inclusive and impactful healthcare solutions.

Breaking barriers to African genome reference projects

Efforts to establish microbiome reference genomes tailored to African populations face numerous challenges, resulting in critical gaps in our understanding of African microbiomes and their impact on health and disease. Key barriers include inadequate infrastructure, limited access to advanced technologies, a shortage of skilled bioinformaticians, insufficient funding, and data sovereignty concerns. Additionally, the remarkable genetic diversity within African populations adds another layer of complexity, making these efforts even more daunting.

A notable concern is the insufficient acknowledgment of African scientific

leadership. Research indicates that 79.8% of human microbiome studies in Africa were directed by researchers affiliated with non-African institutions [4]. Despite the gradual shift in recent years, this disparity remains a concern that is exacerbated by limited funding and outdated infrastructure, which impede African researchers from effectively addressing these issues [5]. Most funding for these initiatives originates from international sources, including the National Institutes of Health (NIH), the Bill and Melinda Gates Foundation, the European Union, the Wellcome Trust, and the Canadian Institutes of Health Research [4], while local funding remains inadequate, further deepening the resource gap.

Advances in genomic technology and declining costs offer hope for greater inclusion of African populations in global studies. Affordable sequencing technologies, such as the Oxford MinION, have the potential to revolutionize African genomic research. But the high cost of consumables and limited access to high-performance computing infrastructure in sub-Saharan Africa continue to restrict the full utilization of these technologies [5].

Africa's unique genetic diversity, shaped by a complex history of ancestries and admixture events, demands precise attention in microbiome research and reference genome creation [6]. Current genomic databases inadequately represent this diversity, limiting the applicability of global microbiome insights in African contexts [7]. Wu *et al.* [8] provided a perspective on the current state of phylogenetic diversity within publicly available microbial databases. Interestingly they highlighted both the comparatively lower levels of 'novelty' within human microbiome datasets as well as the fact that this may be compounded by the lack of suitable geographical diversity in these datasets.

Another critical challenge is data sovereignty. While national ownership of genetic

data can strengthen local research capacity, inconsistent data usage regulations across African countries often impede necessary cross-border collaborations [4]. Harmonizing these frameworks is essential to foster collaboration and advance African genomic research.

Addressing these challenges is essential to ensure that African populations are adequately represented in genomic research. Doing so will not only unlock transformative insights into health and disease across Africa but also contribute to the broader global scientific community.

The case for localized genome projects and data autonomy

While African genomic research faces significant challenges, data sovereignty offers a transformative opportunity to build local capacity and ensure long-term sustainability. Prioritizing national and regional ownership of genomic databases, alongside investing in training of local scientists, is crucial to advance the field effectively. For example, a decade-long initiative focused on establishing biorepositories successfully standardized protocols for sample collection, storage, and shipping while promoting ethical practices to produce high-quality African-origin samples [9]. Today, numerous biorepositories and biobanks across Africa provide secure storage for human samples, microbial cultures, and environmental specimens, simultaneously enhancing African scientists' expertise in sample collection, processing, and transportation (Figure 1).

In parallel, initiatives such as the African Human Microbiome Portal offer tailored metadata, specifically relevant to African populations [10]. By making critical studies more accessible, these resources pave the way for generating African-specific reference genomes, aligning microbiome research with the continent's unique health and agricultural needs.

The H3Africa initiative exemplifies the potential of African-led projects that prioritize local expertise, collaboration, and community engagement. This initiative has fostered regional partnerships, deepened understanding of health disparities, and empowered African scientists to shape research agendas (H3Africa Consortium, 2023). Experiences from projects like GenomeAsia 100K Consortium in Southeast Asia [11], further highlight the effectiveness of regional collaboration, data sovereignty, and localized focus in achieving significant genomic advancements.

Empowering African scientists through rigorous training and the provision of essential resources is crucial to addressing the continent's unique challenges. Initiatives like the Open Institute's 2022 workshops, which trained over 400 African scientists – 70% of whom were early-career researchers – and the Introduction to Bioinformatics Training (IBT) program (H3ABioNet), which has helped train hundreds of African bioinformaticians, demonstrate the transformative impact of investing in local scientific talent. The true impact of such initiatives lies not only in the training provided but in how these researchers apply their newly acquired skills to drive innovation. Furthermore, these workshops demonstrate the feasibility of implementing such frameworks across Africa, helping to address existing skill gaps and build sustainable pipelines for the future [12]. By continuing to develop infrastructure and cultivate skilled researchers, Africa is well-positioned to lead in creating genomic solutions that are both locally relevant and globally significant.

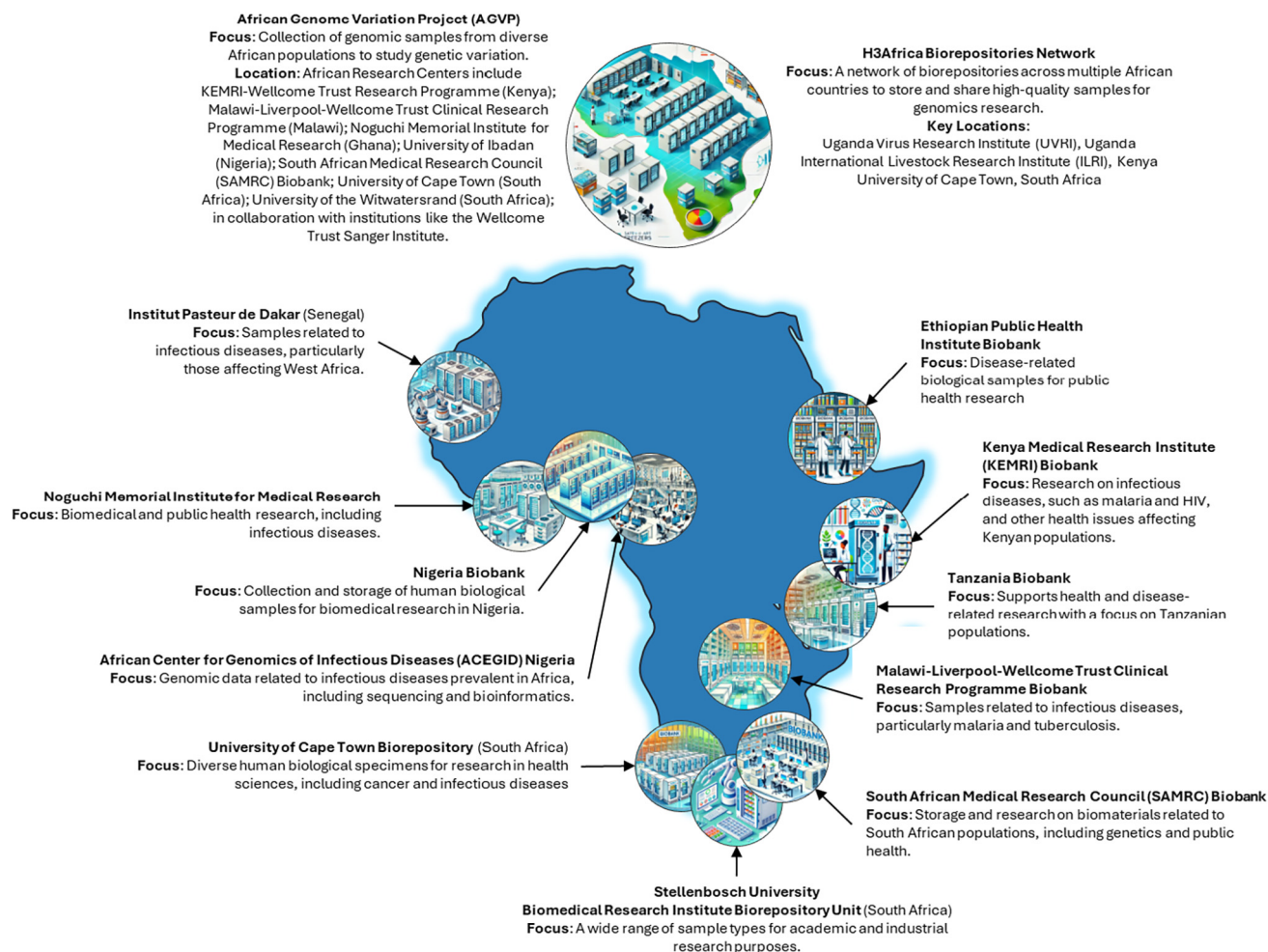
Critical gaps and oversights in global microbiome guidelines

Global microbiome guidelines aim to standardize research practices and foster international collaboration. However, they frequently overlook the unique challenges faced by researchers in resource-limited settings, particularly in Africa. These frameworks are predominantly informed by data

from high-income countries, reflecting dietary habits, healthcare systems, and environmental exposures specific to Western populations. Consequently, they fail to address the diverse genetic backgrounds, diets, and environmental conditions characteristic of African populations [13].

Current guidelines often assume access to advanced sequencing technologies, robust infrastructure, and well-established databases, which are scarce in many low- and middle-income countries (LMICs). The reliance on non-African reference genomes and the underrepresentation of African data in global microbiome databases compound these challenges. Notably, ethnolinguistic studies have identified over three million previously unknown host variants in African populations, and estimates suggest that an African genome could include 10% more DNA than current genome references [14]. These findings highlight the inadequacy of global datasets primarily reflecting populations from developed countries.

Moreover, global frameworks often underappreciate critical ethical and cultural dimensions, such as community concerns, societal taboos, and historical mistrust. This oversight complicates processes such as informed consent and sample collection. Challenges like language barriers and limited access to clear, culturally appropriate information hinder the ability to ensure that participants fully understand the implications of their involvement. This raises ethical concerns in research contexts. This oversight complicates processes like informed consent and sample collection. There is also limited emphasis on sustainability and capacity-building, which perpetuates dependence on external expertise, undermining the autonomy of local researchers. Issues of data sovereignty and equitable benefit-sharing, as previously mentioned [15], further marginalize African researchers, relegating them to secondary roles in research involving their own communities.



Trends in Microbiology

Figure 1. Biorepositories in Africa driving genomic and microbiome research. Numerous biorepositories and biobanks have been established across Africa, playing a pivotal role in advancing genomic, biomedical, and microbiome research. These facilities are crucial for preserving biological samples and driving research that accurately reflects the continent's diverse populations and environments. They empower genomic and microbiome studies specifically designed for Africa's unique diversity, support the creation of regionally relevant treatments and diagnostics, and ensure ethical practices for sample storage and data sharing under African governance.

Environmental factors, including geography, arid climates, diet, and pathogen exposure, also play a significant role in shaping African microbiomes. These factors are often overlooked in global guidelines, diminishing their applicability to African contexts. This omission not only limits the relevance of these frameworks but also hinders efforts to address health disparities and develop interventions tailored to African populations. Addressing these gaps is essential to creating inclusive and effective global microbiome research practices.

Call to action: centering African perspectives in global microbiome research

Addressing the underrepresentation of African microbiomes in global research is critical for advancing health equity and driving scientific innovation. Achieving our goals requires strategies focused on Africa, emphasizing local leadership, context-specific research, and sustainable funding. Empowering local researchers ensures that data collection and analysis reflect regional realities, leading to more relevant outcomes. To align African data sovereignty with

impactful results, collaboration with global pharmaceutical and R&D sectors is crucial. These partnerships can help convert microbiome datasets into practical solutions for the communities' contributing samples. African researchers must engage with global stakeholders to protect their data and foster innovations that extend beyond academic publications. By maintaining this balance, researchers can meet local needs while also advancing global health, resulting in benefits for both local communities and the wider world.

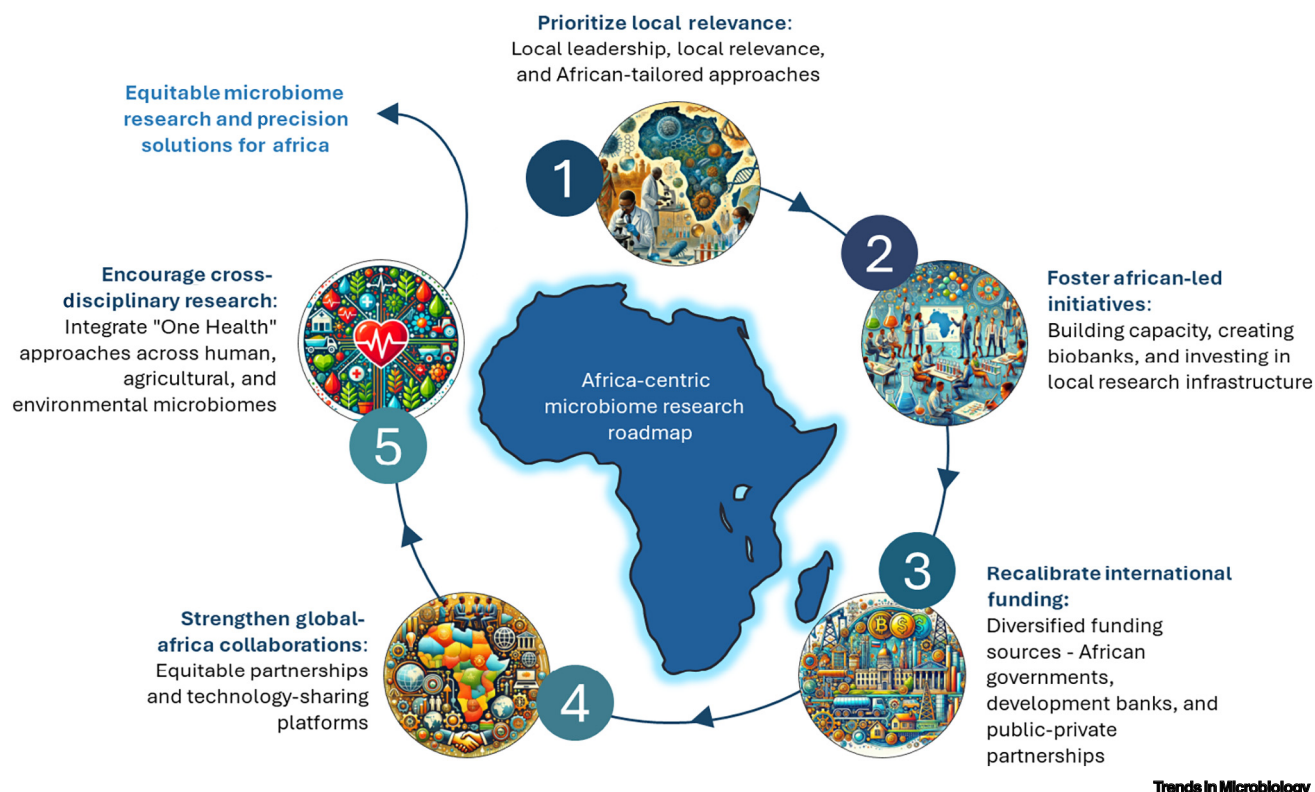


Figure 2. Accelerating African microbiome research through a strategic roadmap. A comprehensive roadmap to fast-track the advancement of African microbiome reference genomes and biomarker discovery is essential. This initiative hinges on five interrelated steps: (1) emphasizing the local relevance of research, (2) ensuring that initiatives are driven by African expertise, (3) recalibrating international funding through strategic public-private partnerships that involve African governments and development banks, (4) bolstering global collaborations with African partners, and (5) prioritizing cross-disciplinary research. Together, these steps will pave the way for equitable microbiome research and precision solutions tailored for Africa.

Collaborative networks such as the African Microbiome Special Interest Group (AMSIG), African Microbiome Institute, the vaginal microbiome research consortium for Africa (vmrc4africa), and H3Africa's Microbiome Task Force play an instrumental role in fostering knowledge exchange and addressing Africa's unique health, agricultural, and environmental challenges. Leveraging advanced sequencing technologies and developing African-specific reference genomes that reflect the continent's diverse ethnic and lifestyle contexts is essential for a comprehensive understanding of Africa's microbiomes.

Equitable global collaborations should emphasize shared benefits, resource sharing, and capacity-building to equip African

researchers with the tools and training needed to lead microbiome studies. A strategic roadmap, outlined in Figure 2, details five key strategies to accelerate the development of African microbiome reference genomes and biomarker discovery.

By implementing these targeted strategies, microbiome research can effectively address Africa's unique needs, enabling tailored public health interventions and positioning Africa as a global leader in microbiome science.

Declaration of interests

The authors declare no competing interests related to this commentary.

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